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Abstracts of Award Winning and Honorable Mention Essays for 2007

Award Essays

First Award – Symmetries, Horizons, and Black Hole Entropy – by S. Carlip; Department of Physics, University of California, Davis, CA 95616; email: carlip@physics.ucdavis.edu

Abstract – Black holes behave as thermodynamic systems and a central task of any quantum theory of gravity is to explain these thermal properties. A statistical mechanical description of black hole entropy once seemed remote, but today we suffer an embarrassment of riches: despite counting very different states, many inequivalent approaches to quantum gravity obtain identical results. Such "universality" may reflect an underlying two-dimensional conformal symmetry near the horizon, which can be powerful enough to control the thermal characteristics independent of other details of the theory. This picture suggests an elegant description of the relevant degrees of freedom as Goldstone-boson-like excitations arising from symmetry breaking by the conformal anomaly.

Second Award – How Black Holes Form in High Energy Collisions – by Nemanja Kaloper[1] and John Terning[2]; Department of Physics, University of California, Davis, CA 95616; email: [1]kaloper@physics.ucdavis.edu, [2]terning@physics.ucdavis.edu

Abstract – We elucidate how black holes form in trans-Planckian collisions. In the rest frame of one of the incident particles, the gravitational field of the other, which is rapidly moving, looks like a gravitational shock wave. The shock wave focuses the target particle down to a much smaller impact parameter. In turn, the gravitational field of the target particle captures the projectile when the resultant impact parameter is smaller than its own Schwarzschild radius, forming a black hole. One can deduce this by referring to the original argument of escape velocities exceeding the speed of light, which Michell and Laplace used to discover the existence of black holes.

Third Award – Heavy Ion Collisions and Black Hole Dynamics – by Steven S. Gubser; Joseph Henry Laboratories, Princeton University, Princeton, NJ 08544; email: ssgubser@princeton.edu

Abstract – Relativistic heavy ion collisions create a strongly coupled quark-gluon plasma. Some of the plasma's properties can be approximately understood in terms of a dual black hole. These properties include shear viscosity, thermalization time, and drag force on heavy quarks. They are hard to calculate from first principles in QCD. Extracting predictions about quark-gluon plasmas from dual black holes mostly involves solving Einstein's equations and classical string equations of motion. AdS/CFT provides a translation from gravitational calculations to gauge theory predictions. The gauge theory to which the predictions apply is $\mathcal{N} = 4$ super-Yang-Mills theory. QCD is different in many respects from super-Yang-Mills, but it seems that its high temperature properties are similar enough to make some meaningful comparisons.

Fourth Award – How Many Black Holes Fit on the Head of a Pin? – by Frederik Denef[1] and Gregory W. Moore[2]; [1]Instituut voor Theoretische Fysica, KU Leuven, Celestijnenlaan 200D, B-3001 Leuven, Belgium; [2]NHETC and Department of Physics and Astronomy, Rutgers University, Piscataway, NJ 08855-0849; email: [1]frederik.denef@fys.kuleuven.be, [2]gmoore@physics.rutgers.edu

Abstract – The Bekenstein-Hawking entropy of certain black holes can be computed microscopically in string theory by mapping the elusive problem of counting microstates of a strongly gravitating black hole to the tractable problem of counting microstates of a weakly coupled D-brane system, which has no event horizon, and indeed comfortably fits on the head of a pin. We show here that, contrary to widely held beliefs, the entropy of spherically symmetric black holes can easily be dwarfed by that of stationary multi-black-hole "molecules" of the same total charge and energy. Thus, the corresponding pin-sized D-brane systems do not even approximately count the microstates of a single black hole, but rather those of a zoo of entropically dominant multicentered configurations.

Fifth Award – The Return of a Static Universe and the End of Cosmology – by Lawrence M. Krauss[1,2] and Robert J. Scherrer[2]; [1]Department of Physics, Case Western Reserve University, Cleveland, OH 44106; [2]Department of Physics and Astronomy, Vanderbilt University, Nashville, TN 37235; email: [1]krauss@cwru.edu, [2]robert.scherrer@vanderbilt.edu

Abstract – We demonstrate that, as we extrapolate the current ΛCDM universe forward in time, all evidence of the Hubble expansion will disappear, so that observers in our "island universe" will be fundamentally incapable of determining the true nature of the universe, including the existence of the highly dominant vacuum energy, the existence of the CMB, and the primordial origin of light elements. With these pillars of the modern Big Bang gone, this epoch will mark the end of cosmology and the return of a static universe. In this sense, the coordinate system appropriate for future observers will perhaps fittingly resemble the static coordinate system in which the de Sitter universe was first presented.

Honorable Mention Awards (Alphabetical Order)

1. The Role of Planck Scale in Black Hole Radiance – by Iván Agulló[1], José Navarro-Salas[2], Gonzalo J. Olmo[3], and Leonard Parker[4]; [1,2]Departamento de Física Teórica and IFIC, Universidad de Valencia-CSIC, Facultad de Física, Burjassot-46100, Valencia, Spain; email: [1]ivan.agullo@uv.es; [2]jnavarro@ific.uv.es; [3,4]Physics Department, University of Wisconsin-Milwaukee, P.O. Box 413, Milwaukee, WI 53201; email: [3]olmoalba@uwm.edu; [4]leonard@uwm.edu

Abstract – Lorentz invariance plays a pivotal role in the derivation of the Hawking effect, which crucially requires an integration in arbitrarily small distances, or equivalently, in unbounded energies. New physics at the Planck scale could, therefore, potentially modify the emission spectrum. We show, however, that the kinematic invariance can be deformed in such a way that the thermal spectrum remains insensitive to trans-Planckian physics.

2. Possible Polarisation and Spin Dependent Aspects of Quantum Gravity – by D.V. Ahluwalia-Khalilova, N.G. Gresnigt, Alex B. Nielsen, D. Schritt, and T.F. Watson; Department of Physics and Astronomy, Rutherford Building, University of Canterbury, Private Bag 4800, Christchurch 8020, New Zealand; email: dharamvir.ahluwalia-khalilova@canterbury.ac.nz

Abstract – We argue that quantum gravity theories that carry a Lie algebraic modification of the Poincaré and Heisenberg algebras inevitably provide inhomogeneities that may serve as seeds for cosmological structure formation. Furthermore, in this class of theories one must expect a strong polarisation and spin dependence of various quantum-gravity effects.

3. A Curvature Principle for the Interaction between Universes – by Orfeu Bertolami; Instituto Superior Técnico, Departamento de Física, Av. Rovisco Pais, 1049-001 Lisboa, Portugal and Centro de Física dos Plasmas, Instituto Superior Técnico, Lisbon, Portugal; email: orfeu@cosmos.ist.utl.pt

Abstract – We propose a Curvature Principle to describe the dynamics of interacting universes in a multi-universe scenario and show, in the context of a simplified model, how interaction drives the cosmological constant of one of the universes toward a vanishingly small value. We also conjecture on how the proposed Curvature Principle suggests a solution for the entropy paradox of a universe where the cosmological constant vanishes.

4. The Return of the Membrane Paradigm? Black Holes and Strings in the Water Tap – by Vitor Cardoso[1,2], Óscar J.C. Dias[3] and Leonardo Gualtieri[4]; [1]Department of Physics and Astronomy, The University of Mississippi, University, MS 38677-1848; email: vcardoso@phy.olemiss.edu, [2]Centro de Física Computacional, Universidade de Coimbra, P-3004-516 Coimbra, Portugal; [3]Departament de Física Fonamental, Universitat de Barcelona, Diagonal 647, E-08028 Barcelona, Spain; email: odias@ub.edu, [4]Dipartimento di Fisica Università di Roma “La Sapienza”, Piazzale Aldo Moro 2, 00185 Rome, Italy; email: gualtieri@roma1.infn.it

Abstract – Several general arguments indicate that the event horizon behaves as a stretched membrane. We propose using this relation to understand gravity and dynamics of black objects in higher dimensions. We provide evidence that (i) the gravitational Gregory-Laflamme instability has a classical counterpart in the Rayleigh-Plateau instability of fluids. Each known feature of the gravitational instability can be accounted for in the fluid model. These features include threshold mode, dispersion relation, time evolution and critical dimension of certain phase transitions. Thus, we argue that black strings break in much the same way as water from a faucet breaks up into small droplets (ii) General rotating black holes can also be understood with this analogy. In particular, instability and bifurcation diagrams for black objects can easily be inferred. This correspondence can and should be used as a guiding tool to understand and explore physics of gravity in higher dimensions.

5. Origin of Matter out of Pure Curvature – by Naresh Dadhich[1] and Hideki Maeda[2,3,4,5]; [1]Inter-University Centre for Astronomy & Astrophysics, Post Bag 4, Pune 411 007, India; email: nkd@iucaa.ernet.in; [2]Centro de Estudios Científicos (CECS), Casilla 1469 Valdivia, Chile; [3]Graduate School of Science and Engineering, Waseda University, Tokyo 169-8555, Japan; [4]Department of Physics, Rikkyo University, Tokyo 171-8501, Japan; [5]Department of Physics, International Christian University, 3-10-2 Osawa, Mitaka-shi, Tokyo 181-8585, Japan; email: hideki@gravity.phys.waseda.ac.jp

Abstract – We propose a mechanism for origin of matter in the universe in the framework of Einstein-Gauss-Bonnet gravity in higher dimensions. The recently discovered new static black hole solution by the authors with the Kaluza-Klein split up of spacetime as a product of the usual $\mathcal{M}^4$ with a space of negative constant curvature is indeed a pure gravitational creation of a black hole which is also endowed with a Maxwell-like *gravitational charge* in four-dimensional vacuum spacetime. Further it could be envisioned as being formed from anti-de Sitter spacetime by collapse of radially inflowing charged null dust. It thus establishes the remarkable reciprocity between matter and gravity – as matter produces gravity (curvature), gravity too produces matter.

6. The Inequality between Mass and Angular Momentum for Axially Symmetric Black Holes – by Sergio Dain; Facultad de Matemática, Astronomía y Física, Universidad Nacional de Córdoba, Ciudad Universitaria, 5000 Córdoba, Argentina; Max Planck Institute for Gravitational Physics (Albert Einstein Institute) Am Mühlenberg 1, D-14476 Potsdam, Germany; email: dain@famaf.unc.edu.ar

Abstract – In this essay I first discuss the physical relevance of the inequality $m \geq \sqrt{|J|}$ for axially symmetric (non-stationary) black holes, where m is the mass and J the angular momentum of the spacetime. Then, I present a proof of this inequality for the case of one spinning black hole. The proof involves a remarkable characterization of the extreme Kerr black hole as an absolute minimum of the total mass. Finally, I conjecture on the physical implications of this characterization for the non linear stability problem for black holes.

7. Symmetries, Singularities and the De-emergence of Space – by Thibault Damour[1] and Hermann Nicolai[2]; [1]Institut des Hautes Etudes Scientifiques, 35 Route de Chartres, F-91440 Bures-sur-Yvette, France; email: damour@ihes.fr; [2]Max-Planck-Institut für Gravitationsphysik, Albert-Einstein-Institut, Mühlenberg 1, D-14476 Potsdam, Germany; email: nicolai@aei.mpg.de

Abstract – Recent work has revealed intriguing connections between a Belinsky-Khalatnikov-Lifshitz-type analysis of spacelike singularities in General Relativity and certain infinite dimensional Lie algebras, and in particular the 'maximally extended' hyperbolic Kac-Moody algebra E_{10}. In this essay we argue that these results may lead to an entirely new understanding of the (quantum) nature of speed (-time) at the Planck scale, and hence – via an effective 'de-emergence' of space near a singularity – to a novel mechanism for achieving background independence in quantum gravity.

8. Gravitational Anomalies: A Recipe for Hawking Radiation – by Saurya Das[1], Sean P. Robinson[2], and Elias C. Vagenas[3,4]; [1]Department of Physics, University of Lethbridge, 4401 University Drive, Lethbridge, Alberta – T1K 3M4, Canada; email: saurya.da@uleth.ca; [2]Department of Physics, Massachusetts Institute of Technology, Cambridge, Massachusetts 02139; email: spatrick@mit.edu; [3]Nuclear and Particle Physics Section, Physics Department, University of Athens, GR-15771, Athens, Greece; email: evagenas@phys.uoa.gr; [4]Research Center for Astronomy & Applied Mathematics, Academy of Athens, Soranou Efessiou 4, GR-11527, Athens, Greece.

Abstract – We explore the method of Robinson and Wilczek for deriving the Hawking temperature of a black hole. In this method, the Hawking radiation restores general covariance in an effective theory of near-horizon physics which otherwise exhibits a gravitational anomaly at the quantum level. The method has been shown to work for broad classes of black holes in arbitrary spacetime dimensions. These include static black holes, accreting or evaporating black holes, charged black holes, and rotating black holes. In the charged and rotating cases, the expected super-radiant current is also reproduced.

9. Black Hole Nonextensive Entropy: Formation Processes Signalized by Gravitational Wave Emission – by H.P. de Oliveira[1] and I. Damião Soares[2]; [1]Universidade do Estado do Rio de Janeiro, Instituto de Física, Departamento de Física Teórica, CEP 20550-013, Rio de Janeiro, RJ Brazil; email: oliveira@dft.if.uerj.br; [2]Centro Brasileiro de Pesquisas Físicas/MCT, R. Dr. Xavier Sigaud, 150, CEP 22290-180 Rio de Janeiro, RJ, Brazil; email: ivano@cbpf.br

Abstract – We show that gravitational wave emission, both in the linear approximation and in the full nonlinear regime of General Relativity, gives a hint of black hole thermodynamic processes by which a black hole evolves emitting part of its perturbation in the form of gravitational waves and absorbing the remaining of it, reaching a final configuration with a larger entropy. The partition of energy in this process is constrained by the maximum entropy principle, and the final entropy obtained numerically is given as a distribution function of the efficiency of the process. The distribution function is in the realm of nonextensive thermostatistics with entropic index $q \cong 1/2$, a result that is validated analytically by the linear approximation.

10. The Holographic Interpretation of Hawking Radiation – by Alessandro Fabbri[1] and Giovanni Paolo Procopio[2]; [1]Departamento de Físico Teórica and IFIC, Universidad de Valencia-CSIC, C. Dr. Moliner 50, Burjassot-46100, Valencia, Spain; email: afabbri@ific.uv.es; [2]D.A.M.T.P., Centre for Mathematical Sciences, University of Cambridge, Wilberforce Road, Cambridge CB3 0WA, U.K.; email: g.p.procopio@damtp.cam.ac.uk

Abstract – Holography gives us a tool to view the Hawking effect from a new, classical perspective. In the context of Randall-Sundrum braneworld models, we show that the basic features of four-dimensional evaporating solutions are nicely translated into classical five-dimensional language. This includes the dual bulk description of particles tunneling through the horizon.

11. Holography from Loop Quantum Gravity – by Rodolfo Gambini[1] and Jorge Pullin[2]; [1]Instituto de Física, Facultad de Ciencias, Iguá 4225, esq. Mataojo, Montevideo, Uraguay; email: rgambini@fisica.edu.uy; [2]Department of Physics and Astronomy, Louisiana State University, Baton Rouge, LA 70803-4001; email: pullin@lsu.edu

Abstract – We show that holography follows directly from the basic structure of spherically symmetric loop quantum gravity. The result is not dependent on detailed assumptions about the dynamics of the theory being considered. It ties strongly the amount of information contained in a region of space to the tight mathematical underpinnings of loop quantum gravity.

12. Black Holes, Information, and Locality – by Steven B. Giddings; Department of Physics, University of California, Santa Barbara, CA 93106-9530; email: giddings@physics.ucsb.edu

Abstract – Thirty years of a deepening information paradox suggest the need to revise our basic physical framework. Multiple indicators point toward reassessment of the principle of locality: lack of a precise definition in quantum gravity, behavior of high-energy scattering, hints from strings and AdS/CFT, conundrums of quantum cosmology, and finally lack of good alternative resolutions of the paradox. A plausible conjecture states that the non-perturbative dynamics of gravity is unitary but nonlocal. String theory may directly address these issues but so far important aspects remain elusive. If this viewpoint is correct, critical questions are to understand the "correspondence" limit where nonlocal physics reduces to local quantum field theory, and beyond, to unveil principles of an underlying nonlocal theory.

13. Child Universes UV Regularization? – by E.I. Guendelman; Physics Department, Ben-Gurion University of the Negev, Beer-Sheva 84105, Israel; email: guendel@bgu.ac.il

Abstract – It is argued that high energy density excitations, responsible for UV divergences in quantum field theories, including quantum gravity, are likely to be the source of child universes which carry them out of the original space time. This decoupling prevents these high UV excitations from having any influence on physical amplitudes. Child universe production could therefore be responsible for UV regularization in quantum field theories which take into account gravitational effects. Finally child universe production in the last stages of black hole evaporation, the prediction of absence of transplanckian primordial perturbations, connection to the minimum length hypothesis and in particular the connection to the maximal curvature hypothesis are discussed.

14. The Israel Theorem: What is Nature Trying to Tell Us? – by L. Herrera; Escuela de Física, Facultad de Ciencias, Universidad Central de Venezuela, Caracas, Venezuela; email: laherrera@cantv.net.ve

Abstract – We explore the possible physical consequences derived from the fact that the only static and asymptotically-flat vacuum space-time possessing a regular horizon is the Schwarzschild solution (Israel Theorem). If small deviations from the Schwarzschild metric are described by means of exact solutions to Einstein equations (as it should be), then for very compact configurations, at the time scale at which radiatable multipole moments are radiated away, important physical phenomena should occur, as illustrated by some results on different solutions belonging to the Weyl class of static axially-symmetric solutions to the Einstein equations.

15. Black Holes Have a Good Temper(ature) – by Shahar Hod; The Hadassah Institute, Jerusalem 91010, Israel; email: shaharhod@gmail.com

Abstract – It is well known that black holes are the most extreme objects in nature: they have the maximal energy and entropy capacities allowed by the laws of physics. In this essay we reveal another extreme property of these fascinating objects: black holes have the fastest relaxation dynamics allowed by a quantum theory of gravity. From information theory and thermodynamic considerations a universal bound on the relaxation time τ of a perturbed physical system is inferred, $\tau \geq \hbar/\pi T$, where T is the system's temperature. We then show that black holes actually attain this fundamental bound, which makes them the fastest relaxing objects in the universe.

16. A New Spin on Quantum Gravity– by Craig J. Hogan[1] and Mark G. Jackson[2]; [1]Departments of Physics and Astronomy, University of Washington, Seattle, Seattle, Washington 98195; email: hogan@u.washington.edu; [2]Particle Astrophysics Center, Fermi National Accelerator Laboratory, Batavia, Illinois 60510; email: markj@fnal.gov

Abstract – We suggest that the (small but nonvanishing) cosmological constant, and the holographic properties of gravitational entropy, may both reflect unconventional quantum spin-statistics at a fundamental level. This conjecture is motivated by the nonlocality of quantum gravity and the fact that spin is an inherent property of spacetime. As an illustration we consider the 'quon' model which interpolates between fermi and bose statistics, and show that this can naturally lead to an arbitrarily small cosmological constant. In addition to laboratory tests, we briefly discuss the possible observable imprint on cosmological fluctuations from inflation.

17. Quiescent Cosmology and the Final State of the Universe – by Philipp A. Höhn[1] and Susan M. Scott[2]; Centre for Gravitational Physics, Department of Physics, College of Science, The Australian National University, Canberra ACT 0200, Australia; email: [1]hoephil@gmail.com; [2]susan.scott@anu.edu.au

Abstract – It has long been a primary objective of cosmology to understand the apparent isotropy in our universe and to provide a mathematical formulation for its evolution. A promising school of thought for its explanation is *quiescent cosmology* which already possesses a mathematical framework, namely the definition of an *isotropic singularity*, but only for the initial stage of the universe. A complementary framework is therefore necessary to also describe possible final states of the universe. Our new definitions of an *anisotropic future endless universe* and an *anisotropic future singularity*, whose structure and properties differ significantly from those of the *isotropic singularity*, offer a promising realisation for this framework. The combination of the three definitions together then provides the first complete formalisation of the *quiescent cosmology* concept.

18. Non-Local Inflation Around a Local Maximum – by James E. Lidsey; Astronomy Unit, School of Mathematical Sciences, Queen Mary, University of London, Mile End Road, London, E1 4NS, U.K.; email: J.E.Lidsey@qmul.ac.uk

Abstract – It is shown that non-local, higher-derivative operators, which arise generically in a string field theory, can act as additional sources of friction on the inflation field as it rolls away from a maximum in its potential. Moreover, the cosmic dynamics can be quantified in terms of a local field theory, where the curvature of an effective potential has been suppressed. A prolonged phase of quasi-exponential expansion can therefore be realised with steep potentials that typically arise in particle physics models. We illustrate this effect within the context of *p*-adic string theory.

19. Falling into a Black Hole – by Samir D. Mathur; Department of Physics, The Ohio State University, Columbus, OH 43210; email: mathur@mps.ohio-state.edu

Abstract – String theory tells us that quantum gravity has a dual description as a field theory (without gravity). We use the field theory dual to ask what happens to an object as it falls into the simplest black hole: the 2-charge extremal hole. In the field theory description the wavefunction of a particle is spread over a large number of 'loops', and the particle has a well-defined position in space only if it has the same 'position' on each loop. For the infalling particle we find one definition of 'same position' on each loop, but there is a different definition for outgoing particles and no canonical definition in general in the horizon region. Thus the meaning of 'position' becomes ill-defined inside the horizon.

20. Gravity as an Emergent Phenomenon – by T. Padmanabhan; IUCAA, Post Bag 4, Ganeshkhind, Pune – 411 007, India; email: paddy@iucaa.ernet.in

Abstract – There are strong reasons to believe that the gravitational interaction – described in terms of a metric on a smooth spacetime – is an emergent, long wavelength phenomenon, like elasticity. I describe a concrete framework for realizing this paradigm in the backdrop of several recent results. In this perspective, quantum fluctuations of the microscopic degrees of freedom of the spacetime lead to residual random displacements of any null surface. The latter can be described in terms of an effective theory using an action associated with the normal displacements of the null surfaces. Extremizing this action leads to an equation *determining the background geometry*. The resulting theory is Einstein gravity at the lowest order with the Lanczos-Lovelock type quantum corrections. The metric is *not* a dynamical variable in this approach and gravity arises as a coarse grained statistical feature of an underlying microscopic theory.

21. A Covariant Road to Spatial Averaging in Cosmology: Scalar Corrections to the Cosmological Equations – by Aseem Paranjape; Tata Institute of Fundamental Research, Homi Bhabha Road, Mumbai 400 005, India; email: aseem@tifr.res.in

Abstract – A consistent approach to Cosmology requires an explicit averaging of the Einstein equations, to describe a homogeneous and isotropic geometry. Such an averaging will in general modify the Einstein equations. The averaging procedure due to Buchert has attracted considerable attention recently since it offers the tantalizing hope of explaining the phenomenon of dark energy through such corrections. This approach has been criticized, however, on the grounds that its effects may be gauge artifacts. We apply the fully covariant formalism of Zalaletdinov's Macroscopic Gravity and show that, after making some essential gauge choices, the Cosmological equations receive *spacetime scalar* corrections which are therefore observable in principle, and further, that the broad structure of these corrections is *identical* to those derived by Buchert.

22. Think Positive – by Andrew Randono; Center for Relativity, Department of Physics, University of Texas at Austin, Austin, TX 78712; email: arandono@physics.utexas.edu

Abstract – Most simple extensions of the Standard Model to include neutrino mass utilize both the Dirac and Majorana fermionic inner products. It is natural then to assume that the universal symmetry group which preserves both these inner products may be the spacetime symmetry group underlying the gravitational interaction. We show that the largest subgroup of the four dimensional general linear group that preserves both these inner products is, in fact, locally isomorphic to the de Sitter group. This mechanism therefore gives a natural explanation for the existence and positivity of the bare cosmological constant. We then show that there are simple extensions of the Macdowell-Mansouri formalism where gravity is a gauge theory of the de Sitter group that retains exact local de Sitter symmetry.

23. Quantum Condensates in Extreme Gravity: Implications for Cold Stars and Dark Matter – by M.P. Silverman; Department of Physics, Trinity College, Hartford, CT 06070; email: mark.silverman@trincoll.edu

Abstract – Stable end-point stars currently fall into two distinct classes – white dwarfs and neutron stars – differing enormously in central density and radial size. No stable cold dead stars are thought to span the intervening densities nor have masses beyond ~2-3 solar masses. I show, however, that the general relativistic condition of hydrostatic equilibrium augmented by the equation of state of a neutron condensate generates stable sequences of cold stars that span the density gap and can have masses well beyond prevailing limits. The radial sizes and mass limit of each sequence are determined by the mass and scattering length of the composite bosons. Solutions for hypothetical bosons of ultra-small mass and large scattering length yield huge self-gravitating systems of low density, resembling galactic dark matter halos.

24. The Inevitable Nonlinearity of Quantum Gravity Falsifies the Many-Worlds Interpretation of Quantum Mechanics – by T.P. Singh; Tata Institute of Fundamental Research; Homi Bhabha Road, Mumbai 400 005, India; email: tpsingh@tifr.res.in

Abstract – There are fundamental reasons as to why there should exist a reformulation of quantum mechanics which does not refer to a classical spacetime manifold. It follows as a consequence that quantum mechanics as we know it is a limiting case of a more general nonlinear quantum theory, with the nonlinearity becoming significant at the Planck mass/energy scale. This nonlinearity is responsible for a dynamically induced collapse of the wave-function, during a quantum measurement, and it hence falsifies the many-worlds interpretation of quantum mechanics. We illustrate this conclusion using a mathematical model based on a generalized Doebner-Goldin equation. The non-Hermitian part of the Hamiltonian in the norm-preserving, nonlinear, Schrödinger equation dominates during a quantum measurement, and leads to a breakdown of linear superposition.

25. Celestial Optical Interferometry: A New Tool for Ultra-High Precision Studies in Gravity – by C.S. Unnikrishnan[1] and G.T. Gillies[2]; [1]Gravitation Group, Tata Institute of Fundamental Research, Homi Bhabha Road, Mumbai – 400 005, India; email: unni@tifr.res.in; [2]School of Engineering and Applied Science, University of Virginia, Charlottesville, VA 22904-4746; email:gtg@virginia.edu

Abstract – The tremendous progress in the science and technology of timing devices and laser sources has reached a stage where their stability and coherence are sufficient to implement unbalanced interferometers over a length scale exceeding the Earth-Moon distance. This opens up the possibility of optical homodyne interferometry over such distances, either to the moon, or to artificial satellites that are at large distances from the earth. The precision of the measurement of changes in the orbital distance would increase by a factor of 10^4 or more, enabling new ultra-high precision tests of the equivalence principle, study of gravitomagnetism, and of subtle gravitational phenomena including the constancy of the gravitational constant and possible gravitational expansion of space. It will enable geodesy and tide studies with unprecedented precision. Such interferometers are also useful for the detection and study of low frequency gravitational waves.

26. Resummed Quantum Gravity – by B.F.L. Ward; Department of Physics, Baylor University, Waco, Texas 76798-7316; email: BFL_Ward@baylor.edu

Abstract – We present the current status of the new approach to quantum general relativity based on the exact resummation of its perturbative series as that series was formulated by Feynman. We show that the resummed theory is UV finite and we present some phenomenological applications as well.

27. A New Look at the Big Bang – by Paul S. Wesson; Department of Physics, University of Waterloo, Waterloo, Ontario N2L 3G1, Canada.

Abstract – We give a mathematically exact and physically faithful embedding of curved 4D cosmology in a flat 5D space, thereby enabling us to visualize the big bang in a new and informative way. In fact, in unified theories of fields and particles with real extra dimensions, it is possible to dispense with the initial singularity.

28. Gravitational Energy and Cosmic Acceleration – by David L. Wiltshire; Department of Physics and Astronomy, University of Canterbury, Private Bag 4800, Christchurch 8140, New Zealand; email: David.Wiltshire@canterbury.ac.nz

Abstract – Cosmic acceleration is explained quantitatively as an apparent effect due to gravitational energy differences that arise in the decoupling of bound systems from the global expansion of the universe. “Dark Energy” is a misidentification of those aspects of gravitational energy which by virtue of the equivalence principle cannot be localised, namely gradients in the energy due to the expansion of space and spatial curvature variations in an inhomogeneous universe. A new scheme for cosmological averaging is proposed which solves the Sandage-de Vaucouleurs paradox. Concordance parameters fit supernovae luminosity distances, the angular scale of the sound horizon in the CMB anisotropies, and the effective comoving baryon acoustic oscillation scale seen in galaxy clustering statistics. Key observational anomalies are potentially resolved, and unique predictions made, including a quantifiable variance in the Hubble flow below the scale of apparent homogeneity.

29. Space Gravitational Wave Detectors Can Determine the Thermal History of the Early Universe – by Jun’ichi Yokoyama; Research Center for the Early Universe (RESCEU), Graduate School of Science, The University of Tokyo, Tokyo 113-0033, Japan; email: yokoyama@resceu.s.u-tokyo.ac.jp

Abstract – It is shown that space-based gravitational wave detectors such as DECIGO and/or Big Bang Observer (BBO) will provide us with invaluable information on the reheating process after inflation and they will be able to determine the thermal history of the early Universe between inflation and primordial nucleosynthesis. Therefore it is strongly desired that they will be put into practice as soon as possible.

30. Dark Energy: A Unifying View – by Winfried Zimdahl; Departamento de Física, Universidade Federal do Espírito Santo, CEP29060-900 Vitória, Espírito Santo, Brazil; email: zimdahl@thp.uni-koeln.de

Abstract – Different models of the cosmic substratum which pretend to describe the present stage of accelerated expansion of the Universe, like the ΛCDM model or a Chaplygin gas, can be seen as special realizations of a holographic dark energy cosmology if the option of an interaction between pressureless dark matter and dark energy is taken seriously. The corresponding interaction strength parameter plays the role of a cosmological constant. Differences occur at the perturbative level. In particular, the pressure perturbations are intrinsically non-adiabatic.