GRAVITY RESEARCH FOUNDATION

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Abstracts of Award Winning and Honorable Mention Essays for 2008

Award Essays

First Award – Gravity: The Inside Story – by T. Padmanabhan; IUCAA, Post Bag 4, Ganeshkhind, Pune – 411 007, India; email: paddy@iucaa.ernet.in.

Abstract – It is well known that one could determine the *kinematics* of gravity by using the Principle of Equivalence and local inertial frames. I describe now how the *dynamics* of gravity can be similarly understood by suitable thought experiments in a local Rindler frame. This approach puts in proper context several unexplained features of gravity and describes the dynamics of spacetime in a broader setting than in Einstein's theory.

Second Award – Noncommutative Gravity, a "No Strings Attached" Quantum - Classical Duality, and the Cosmological Constant Puzzle – by T.P. Singh; Tata Institute of Fundamental Research, Homi Bhabha Road, Mumbai 400 005, India; email: tpsingh@tifr.res.in.

Abstract – There ought to exist a reformulation of quantum mechanics which does not refer to an external classical spacetime manifold. Such a reformulation can be achieved using the language of noncommutative differential geometry. A consequence which follows is that the "weakly quantum, strongly gravitational" dynamics of a relativistic particle whose mass is much greater than Planck mass is dual to the "strongly quantum, weakly gravitational" dynamics of another particle whose mass is much less than Planck mass. The masses of the two particles are inversely related to each other, and the product of their masses is equal to the square of Planck mass. This duality explains the observed value of the cosmological constant, and also why this value is nonzero but extremely small in Planck units.

Third Award – On the Physical Interpretation of Asymptotically Flat Gravitational Fields – by Carlos Kozameh[1], Ezra T. Newman[2], and Gilberto Silva-Ortigoza[3]; [1]FaMaF, University of Cordoba, Cordoba, Argentina; email: kozameh@famaf.unc.edu.ar, [2]Department of Physics and Astronomy, University of Pittsburgh, Pittsburgh, PA 15260; email: newman@pitt.edu, [3]Facultad de Ciencias Físico Matemáticas de la Universidad Autónoma de Puebla, Apartado Postal 1152, 72001, Puebla, Pue., México; email: gsilva@fcfm.buap.mx.

Abstract – A problem in general relativity is how to extract physical information from solutions to the Einstein equations. Most often information is found from special conditions, e.g., special vector fields, symmetries or approximate symmetries. Our concern is with asymptotically flat space-times with approximate symmetry: the BMS group. For these spaces the Bondi four-momentum vector and its evolution, found at infinity, describes the total energy-momentum and the energy-momentum radiated. By generalizing the simple idea of the transformation of (electromagnetic) dipoles under a translation, we define (analogous to center of charge) the center of mass for asymptotically flat Einstein-Maxwell fields. This gives kinematical meaning to the Bondi four-momentum, i.e., the four-momentum and its evolution is described in terms of a center of mass position vector, its velocity and spin-vector. From dynamical arguments, a unique (for our approximation) total angular momentum and evolution equation in the form of a conservation law is found.

Fourth Award – Quantum Field Theory in Curved Spacetime, the Operator Product expansion, and Dark Energy – by Stefan Hollands[1] and Robert M. Wald[2]; [1]School of Mathematics, Cardiff University, Cardiff, Wales, CF10 3XQ, UK; email: HollandsS@cardiff.ac.uk, [2]Enrico Fermi Institute and Department of Physics, University of Chicago, Chicago, IL 60637; email: rmwa@uchicago.edu.

Abstract – To make sense of quantum filed theory in an arbitrary (globally hyperbolic) curved spacetime, the theory must be formulated in a local and covariant manner in terms of locally measurable field observables. Since a generic curved spacetime does not possess symmetries or a unique notion of a vacuum state, the theory also must be formulated in a manner that does not require symmetries or a preferred notion of a "vacuum state" and "particles." We propose such a formulation of quantum field theory, wherein the operator product expansion (OPE) of the quantum fields is elevated to a fundamental status, and the quantum field theory is viewed as being defined by its OPE. Since the OPE coefficients may be better behaved than any quantities having to do with states, we suggest that it may be possible to perturbatively construct the OPE coefficients – and, thus, the quantum field theory. By contrast, ground/vacuum states – in spacetimes, such as Minkowski spacetime, where they may be defined – cannot vary analytically with the parameters of the theory. We argue that this implies that composite fields may acquire nonvanishing vacuum state expectation values due to nonperturbative effects. We speculate that this could account for the existence of a nonvanishing vacuum expectation value of the stress-energy tensor of a quantum field occurring at a scale much smaller than the natural scales of the theory.

Fifth Award – The Delocalized Effective Degrees of Freedom of a Black Hole at Low Frequencies – by Barak Kol; Racah Institute of Physics, Hebrew University, Jerusalem, 91904, Israel; email: barak_kol@phys.huju.ac.il.

Abstract – Identifying the fundamental degrees of freedom of a black hole poses a long-standing puzzle. Recently Goldberger and Rothstein forwarded within the effective field theory approach a theory of the low frequency degrees of freedom, where they are relevancy-ordered but of unclear physical origin. Here these degrees of freedom are identified with near-horizon but non-compact gravitational perturbations which are decomposed into de-localized multipoles. Their world-line (kinetic) action is determined within the classical effective field theory (CLEFT) approach and their interactions are discussed. The case of the long-wavelength scattering of a scalar wave off a Schwarzschild black hole is treated in some detail, interpreting within the CLEFT approach the equality of the leading absorption cross section with the area.

1. Subtleties in the Quasi-Classical Calculation of Hawking Radiation – by Emil T. Akhmedov[1], Terry Pilling[2], and Douglas Singleton[3]; [1]Moscow, B. Cheremushkinskaya, 25, ITEP, Russia 117218; email: akhemdov@itep.ru, [2]Department of Physics, North Dakota State University, Fargo, ND 58105; email: terry.pilling@ndsu.edu, [3]Physics Department, CSU Fresno, Fresno, CA 93740-8031; email: dougs@csufresno.edu.

Abstract – The quasi-classical method of deriving Hawking radiation is investigated. In order to recover the original Hawking temperature one must take into account a previously ignored contribution coming from the temporal part of the action. This contribution plus a contribution coming from the spatial part of the action gives the correct temperature.

2. Is Physics Asking for a New Kinematics? – by R. Aldrovandi[1] and J. G. Pereira[2]; Instituto de Física Teórica, Universidade Estadual Paulista, Rua Panplona 145, 01405-900 São Paulo, Brazil; email: [1]ra@ift.unesp.br, [2]jpereira@ift.unesp.br.

Abstract – It is discussed whether some of the consistency problems of present-day phyisics could be solved by replacing special relativity, whose underlying kinematics is ruled by the Poincaré group, by de Sitter relativity, with underlying kinematics ruled by the de Sitter group. In contrast to ordinary special relativity, which seems to fail at the Planck scale, this new relativity is "universal" in the sense that it holds at all energy scales.

3. The Self-Organized de Sitter Universe – by J. Ambjørn[1,3], J. Jurkiewicz[2], and R. Loll[3]; [1]The Niels Bohr Institute, Copenhagen University, Blegdamsvej 17, DK-2100 Copenhangen Ø, Denmark; email: ambjorn@nbi.dk, [2]Institute of Physics, Jagellonian University, Reymonta 4, PL 30-059 Krakow, Poland; email: jurkiewicz@th.if.uj.edu.pl, [3]Institute for Theoretical Physics, Utrecht University, Leuvenlaan 4, NL-3584 CE Utrecht, The Netherlands; email: loll@phys.uu.nl.

Abstract – We propose a theory of quantum gravity which formulates the quantum theory as a nonperturbative path integral, where each spacetime history appears with the weight exp (iS^{EH}), with S^{EH} the Einstein-Hilbert action of the corresponding causal geometry. The path integral is diffeomorphism-invariant (only geometries appear) and background-independent. The theory can be investigated by computer simulations, which show that a *de Sitter Universe* emerges on large scales. This emergence is of an entropic, self-organizing nature, with the weight of the Einstein-Hilbert action playing a minor role. Also the quantum fluctuations around this de Sitter universe can be studied quantitatively and remain small until one gets close to the Planck scale. The structures found to describe Planck-scale gravity are reminiscent of certain aspects of condensed-matter systems.

4. Covariant Anomalies, Horizons and Hawking Radiation – by Rabin Banerjee; S.N. Bose National Centre for Basic Sciences, Block JD, Sector III, Salt Lake, Kolkata – 700098, India; email: rabin@bose.res.in.

Abstract – Hawking radiation is obtained from anomalies resulting from a breaking of diffeomorphism symmetry near the event horizon of a black hole. Such anomalies, manifested as a nonconservation of the energy momentum tensor, occur in two different forms – covariant and consistent. The crucial role of covariant anomalies near the horizon is revealed since this is the *only* input required to obtain the Hawking flux, thereby highlighting the universality of this effect. A brief description to apply this method to obtain thermodynamic entities like entropy or temperature is provided.

5. The Quantum Theory 4 Dimensional de Sitter Space – by T. Banks; Department of Physics and SCIPP, University of California, Santa Cruz, CA 95064 and Department of Physics and NHETC, Rutgers University, Piscataway, NJ 08540; email: banks@scipp.ucsc.edu.

Abstract – I discuss a proposal for a quantum theory of four dimensional de Sitter (dS) space, and its implications for particle physics and supersymmetry.

6. Gravity-Aided Magnetic Survival – by John D. Barrow[1] and Christos G. Tsagas[2]; [1]DAMTP, University of Cambridge, Wilberforce Road, Cambridge CB3 0WA, UK; email: J.D.Barrow@damtp.cam.ac.uk, [2]Section of Astrophysics, Astronomy and Mechanics, Department of Physics, Aristotle University of Thessaloniki 54124, Greece; email: tsagas@astro.auth.gr.

Abstract – Spacetime curvature and general relativity can change the evolution of cosmological magnetic fields in an unexpected way. The decay of large-scale magnetic fields in marginally open universes is slowed down to such an extent that fields of primordial origin can successfully seed galactic dynamos and explain the magnetic fields observed in the Universe today.

7. Emergence of a Cyclic Universe from the Hagedorn Soup – by Tirthabir Biswas; Department of Physics, Institute for Gravitation and the Cosmos, The Pennsylvania State University, 104 Davey Lab, University Park, PA 16802; email: tbiswas@gravity.psu.edu.

Abstract – One of the challenges of constructing a successful cyclic universe scenario is to be able to incorporate the second law of thermodynamics which typically leads to Tolman's problem of ever shrinking cycles. In this paper we construct a non-singular toy model where as the cycles shrink in the past they also spend more and more time in the entropy conserving Hagedorn phase. Thus in such a scenario the entropy asymptotes to a finite non-zero constant in the infinite past. The universe "emerges" from a small (string size) geodesically complete quasi-periodic space-time. The paradigm also naturally addresses some of the classic puzzles of Big Bang cosmology, such as the largeness, horizon and flatness problems.

8. Entanglement and Thermodynamics of Black Hole Entropy – by R. Brout; Perimeter Institute for Theoretical Physics Waterloo, Ontario N2L 2Y5, Canada; Departments of Applied Mathematics and Physics University of Waterloo, Waterloo, Ontario N2L 3G1, Canada; and Service de Physique Théorique, Université Libre de Bruxelles The International Solvay Institutes, B1050 Bruxelles, Belgium; email: robert.brout@ulb.ac.be.

Abstract – Using simple conditions drawn from the stability of the cosmos in terms of vacuum energy density, the cut-off momentum of entanglement is related to the planckian mass. In so doing the black hole entropy is shown to be independent of the number of field species that contribute to vacuum fluctuations. And this in spite of the fact that the number of field species is a linear multiplicand of the entanglement entropy when this latter is expressed in terms of the fundamental momentum cut-off of all fields.

9. Nonlinear Resonance in the Very Early Universe: Sounds of the Primordial Music – by H.P. de Oliveira[1]; I Damião Soares[2] and E.V. Tonini[3]; [1]Instituto de Física, Universidade do Estado do Rio de Janeiro, CEP 20550-013 Rio de Janeiro, RJ, Brazil; email: oliveira@dft.if.uerj.br, [2]Centro Brasileiro de Pesquisas Físicas, Rua Dr. Xavier Sigaud 150, Urca, Rio de Janeiro CEP 22290-180-RJ, Brazil; email: ivano@cbpf.br, [3]Centro Federal de Educação Tecnológica do Espírito Santo Avenida Vitória, 1729, Jucutuquara, Vitória CEP 29040-780-ES, Brazil; email: tonini@cefetes.br.

Abstract – Nonlinear resonance is ubiquitous in nature. Resonance is relevant to understand phenomena in quite distinct areas such as music, cellular structure, astrophysics, and in the very early Universe. In order to see the crucial role played by resonance in Cosmology, we assume that closed FRW universes with a massive inflation field evolve according to the field equations that contain additional terms arising from high energy corrections to cosmological scenarios. As a consequence, nonsingular bounces in the early evolution of the universe are produced. We have shown that in narrow windows of the parameter space of the models, nonlinear resonance phenomena of KAM tori occur and leading to the destruction of those tori that trap the inflaton, resulting in the escape of the universe into inflation. These resonance windows labeled by an integer $n \geq 2$, where n is related to the ratio of the frequencies in the scale factor/scalar field degrees of freedom.

10. Quantum Cosmic Censor: Gravitation Makes Reality Undecidable – by Rodolfo Gambini[1] and Jorge Pullin[2]; [1]Instituto de Física, Facultad de Ciencias, Universidad de la República, Iguá 4225, CP 11400 Montevideo, Uruguay; email: rgambini@fisica.edu.uy, [2]Department of Physics and Astronomy, Louisiana State University, Baton Rouge, LA 70803-4001; email: pullin@lsu.edu.

Abstract – When one takes into account gravitation, the measurement of space and time cannot be carried out with infinite accuracy. When quantum mechanics is reformulated taking into account this lack of accuracy, the reolution of the measurement problem can be implemented via decoherence without the usual pitfalls. The resulting theory has the same physical predictions of quantum mechanics with a reduction postulate, but is radically different, with the quantum states evolving unitarily in terms of the underlying variables. Gravitation therefore makes this worrisome situation, potentially leading to two completely different views of reality, irrelevant from an empirical point of view. It may however be highly relevant from a philosophical point of view.

11. Why Supersymmetry Should Be Restored at the TeV Scale – by M. Gasperini; Dipartimento di Fisica, Università di Bari, Via G. Amendola 173, 70126 Bari, Italy and Instituto Nazionale di Fisica Nucleare, Sezione di Bari, Bari, Italy; email: gasperini@ba.infn.it.

Abstract – It is explained why the curvature associated to the vacuum energy density arising from SUSY breaking cannot be completely transferred to the extra spatial dimensions of a bulk space-time manifold, and it is shown – without using hierarchy arguments but only the results of current large-scale observations – why the TeV scale should correspond to the maximal allowed SUSY-breaking scale.

12. Colorful Horizons with Charge in Anti-de Sitter Space – by Steven S. Gubser; Joseph Henry Laboratories, Princeton University, Princeton, NJ 08544; email: ssgubser@Princeton.EDU.

Abstract – An abelian gauge symmetry can be spontaneously broken near a black hole horizon in anti-de Sitter space using a condensate of non-abelian gauge fields. There is a second order phase transition between Reissner-Nordstrom-anti-de Sitter solutions, which are preferred at high temperatures, and symmetry breaking solutions, which are preferred at low temperatures. Analogies with superconductors are briefly considered.

13. A Covariant Entropy Bound Conjecture on the Dynamical Horizon – by Song He[1] and Hongbao Zhang[2]; [1]School of Physics, Peking University, Beijing, 100871, China; email: hesong@pku.edu.cn, [2]Perimeter Institute for Theoretical Physics, Waterloo, Ontario, N2L 2Y5, Canada; Department of Astronomy, Beijing Normal University, Beijing, 100875, China; email: hzhang@perimeterinstitute.ca.

Abstract – As a compelling pattern for the holographic principle, our covariant entropy bound conjecture is proposed for more general dynamical horizons. Then we apply our conjecture to ΛCDM cosmological models, where we find it imposes a novel upper bound 10^{-90} on the cosmological constant for our own universe by taking into account the dominant entropy contribution from super-massive black holes, which thus provides an alternative macroscopic perspective to understand the longstanding cosmological constant problem. As an intriguing implication of this conjecture, we also discuss the possible profound relation between the present cosmological constant, the origin of mass, and the anthropic principle.

14. Possible Way Out of the Hawking Paradox: Erasing the Information at the Horizon – by L. Herrera; Escuela de Física, Facultad de Ciencias, Universidad Central de Venezuela, Caracas, Venezuela; email: laherrera@cantv.net.ve.

Abstract – We show that small deviations from spherical symmetry, described by means of exact solutions to Einstein equations, provide a mechanism to "bleach" the information about the collapsing body as it falls through the apparent horizon, thereby resolving the information loss paradox. The resulting picture appears to be consistent with Landauer's principle in the presence of a gravitational field.

15. The Fluid-Gravity Correspondence: The Membrane at the End of the Universe – by Veronika E. Hubeny[1], Shiraz Minwalla[2], Mukund Rangamani[1], and Mark Van Raamsdonk[3]; [1]Centre for Particle Theory & Department of Mathematical Sciences, Science Laboratories, South Road, Durham DH1 3LE, United Kingdom; email: veronika.hubeny@durham.ac.uk; mukund.rangamani@durham.ac.uk; [2]Department of Theoretical Physics, Tata Institute of Fundamental Research, Homi Bhabha Rd, Mumbai 400005, India; email: minwalla@theory.tifr.res.in; [3]Department of Physics and Astronomy, University of British Columbia, 6224 Agricultural Road, Vancouver, B.C., V6T 1W9, Canada; email: mav@phas.ubc.ca.

Abstract – We establish an explicit connection between the evolution of generic inhomogeneous black brane solutions in asymptotically AdS spacetimes and the evolution of relativistic conformal fluids in one lower dimension. Specifically, given any solution to a particular set of fluid dynamical equations, one can construct an inhomogeneous black brane solution with regular event horizon. This connection is reminiscent of the membrane paradigm for black holes; in our case the dynamics of the entire spacetime is encoded in a fluid living at the boundary. This fluid-gravity correspondence leads to interesting implications for both gravitational physics and fluid dynamics.

16. Transient Astrophysical Pulses and Quantum Gravity – by Michael Kavic, Djordje Minic, and John Simonetti; Institute for Particle, Nuclear and Astronomical Sciences, Department of Physics, Virginia Tech, Blacksburg, VA 24061; email: kavic@vt.edu; dminic@vt.edu; jhs@vt.edu.

Abstract – Searches for transient astrophysical pulses could open an exciting new window into the fundamental physics of quantum gravity. In particular, an evaporating primordial black hole in the presence of an extra dimension can produce a detectable transient pulse. Observation of such a phenomenon can in principle explore the electroweak energy scale, indicating that astrophysical probes of quantum gravity can successfully complement the exciting new physics expected to be discovered in the near future at the Large Hadron Collider.

17. Cosmological Particle Creation: Fluctuation and an Ensemble Picture – by Ali Kaya, Boğaziçi University, Department of Physics, 34342, Bebek, İstanbul, Turkey and Feza Gürsey Institute, Emek Mah. No: 68, Çengelköy, İstanbul, Turkey; email: ali.kaya@boun.edu.tr.

Abstract – We point out that in the context of quantum fields in time dependent classical backgrounds, the number of created particles with a given momentum largely deviates about its mean value. Since the corresponding Fourier modes are nonlocal, this deviation shows that the expectation value of the number operator can only make sense in an ensemble of spacetimes. Using a complete orthonormal family of localized wave packets, we show how an ensemble interpretation can be given to cosmological particle creation in local terms. The reheating process following inflation is reexamined in the light of this construction.

18. Halos of Modified Gravity – by Kirill Krasnov[1] and Yuri Shtanov[2]; [1]School of Mathematical Sciences, University of Nottingham, Nottingham, NG7 2RD, UK; email: kirill.krasnov@nottinham.ac.uk; [2]Bogolyubov Institute for Theoretical Physics, Kiev 03680, Ukraine; email: shtanov@bitp.kiev.ua.

Abstract – We describe how a certain simple modification of general relativity, in which the local cosmological constant is allowed to depend on the space-time curvature, predicts the existence of halos of modified gravity surrounding spherically-symmetric objects. We show that the gravitational mass of an object weighed together with its halo can be much larger than its gravitational mass as seen from inside the halo. This effect could provide an alternative explanation of the dark-matter phenomenon in galaxies. In this case, the local cosmological constant in the solar system must be some six orders of magnitude larger than its cosmic value obtained in the supernovae type Ia experiments. This is well within the current experimental bounds, but may be directly observable in the future high-precision experiments.

19. Late Time Decay of the False Vacuum, Measurement, and Quantum Cosmology – by Lawrence M. Krauss[1], James Dent[2], and Glenn D. Starkman[1]; [1]CERCA, Department of Physics, Case Western Reserve University, Cleveland, OH 44106; [2]Department of Physics & Astronomy, Vanderbilt University, Nashville, TN 37235; email: krauss@cwru.edu, james.b.dent@vanderbilt.edu, gds6@cwru.edu.

Abstract – The recent suggestion that late time quantum dynamics may be important for resolving cosmological issues associated with our observed universe requires a consideration of several subtle issues associated with quantum cosmology, as we describe here. The resolution of these issues will be important if we are able to properly ascribe probability measures associated with eternal inflation, and a string landscape.

20. A New Paradigm in Cosmology? – by G. Lessner; Universität Paderborn, Department Physik, 33098 Paderborn, Germany; email: lessner@phys.uni-paderborn.de.

Abstract – An alternative approach in cosmology is outlined: An open, over-oscillating universe without cold dark matter and with a negative cosmological constant. It comes out of a spontaneous symmetry breaking in Minkowski space. Matter and radiation are created in this universe from the gravitational energy due to the space-time curvature over an extremely long period of about 30 billion years.

21. General Relativistic Spin-Orbit Precession and Evidence for a New Type of Gravitational Collapse – by Tsvi Piran and Nir J. Shaviv; Racah Institute of Physics, Hebrew University of Jerusalem, Jerusalem 91904, Israel; email: tsvi@phys.huji.ac.il, Shaviv@phys.huji.ac.il.

Abstract – G is small and c is large. General Relativistic effects are, therefore, hardly ever seen and even more rarely have direct implications on astronomical phenomenon. Neutron stars are believed to form in core collapse accompanied by a supernova. Kinematic properties of the double pulsar system J0737-3039 have led us to suggest that the younger neutron star this system formed from a $\sim 1.45\ M_\odot$ progenitor with no mass ejection. Our associated prediction that the system has a low proper motion has recently been verified. We show here that the lack of a relativistic spin-orbit precession in J0737-3039 confirms this proposition. This new previously unseen type of gravitational collapse has wide implications on stellar evolution on pulsars birth rates and the rate of neutron star mergers.

22. The Effect of Structure Formation on the Expansion of the Universe – by Syksy Räsänen; Université de Genève, Département de Physique Théorique, 24 quai Ernest-Ansermet, CH-1211 Genève 4, Switzerland; email: syksy.rasanen@iki.fi.

Abstract – Observations of the expansion rate of the universe at late times disagree by a factor of 1.5-2 with the prediction of homogeneous and isotropic models based on ordinary matter and gravity. We discuss how the departure from linearly perturbed homogeneity and isotropy due to structure formation could explain this discrepancy. We evaluate the expansion rate in a dust universe which contains non-linear structures with a statistically homogeneous and isotropic distribution. The expansion rate is found to increase relative to the exactly homogeneous and isotropic case by a factor of 1.1-1.3 at some tens of billion of years. The timescale follows from the cold dark matter transfer function and the amplitude of primordial perturbations without additional free parameters.

23. OJ 287: New Testing Ground for General Relativity and Beyond – by C Sivaram; Indian Institute of Astrophysics, Bangalore.

Abstract – The supermassive short period black hole binary OJ287 is discussed as a new precision testing ground for general relativity and alternate gravity theories. Like in the case of binary pulsars, the relativistic gravity effects are considerably larger than in the solar system. For instance the observed orbital precession is forty degrees per period. The gravitational radiation energy losses are comparable to typical blazar electromagnetic radiation emission and it is about ten orders larger than that of the binary pulsar with significant orbit shrinking already apparent in the light curves. This already tests Einstein gravity to a few percent for objects at cosmological distances. Constraints on alternate gravity theories as well as possible detection of long term effects of dark matter and dark energy on this system are described.

24. Exotic Statistics for Ordinary Particles in Quantum Gravity – by John Swain; Department of Physics, Northeastern University, Boston, MA 02115; email: john.swain@cern.ch.

Abstract – Objects exhibiting statistics other than the familiar Bose and Fermi ones are natural in theories with topologically nontrivial objects including geons, strings, and black holes. It is argued here from several viewpoints that the statistics of *ordinary* particles with which we are already familiar are likely to be modified due to quantum gravity effects. In particular, such modifications are argued to be present in loop quantum gravity and in any theory which represents spacetime in a fundamentally piecewise-linear fashion. The appearance of unusual statistics may be a *generic* feature (such as the deformed position-momentum uncertainty relations and the appearance of the fundamental length scale) which are to be expected in any theory of quantum gravity, and which could be testable.

25. Low Energy Quantum Gravity, the Cosmological Constant and Gauge Coupling Constants – by David J Toms; School of Mathematics and Statistics, Newcastle University, Newcastle upon Tyne, U.K. NE1 7RU; email: d.j.toms@newcastle.ac.uk.

Abstract – Robinson and Wilczek have suggested that loop corrections in quantum gravity can alter the running gauge coupling constants from the behaviour found in the absence of gravity. Although their original calculation is not correct, the basic idea behind their paper has been re-examined recently for quantized Einstein-Maxwell theory with a cosmological constant. In this essay I discuss some of the issues surrounding the calculation and mention some of the implications. I argue that it is possible for a theory that is not conventionally asymptotically free to become so in the presence of gravity, and for gravity to lead to a new ultraviolet fixed point. This establishes a provocative link between the microscopic and macroscopic realms.

26. Strong in Small and Weak at Large: Thoughts and Bounds on Higher Dimensional 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 – Gravity in a higher dimensional scenario is one of the most topical of research subjects due to the possibility of decisive results from experiments. The field exhibits duality of various kinds. On the one hand the weakness of gravity and the hierarchy issues are dealt with some success as one cascades from a larger number of small dimensions with strong gravity to smaller number of dimensions of larger space with weaker effective gravity. On the experimental front, the highest energy accelerator and the weakest energy mechanical oscillators available to use today are simultaneously focused at the TeV scale to address new features in gravity physics. This intriguing scenario and its conceptual and phenomenological aspects are examined here with new results from considerations of hitherto unexplored higher-dimensional gravitomagnetic effects at the atomic scale.

27. Cosmology with Decaying Dark Energy and Cosmological 'Constant' – by P.S. Wesson[1,4], B Mashhoon[2,4] and J.M. Overduin[3,4]; [1]Department of Physics and Astronomy, University of Waterloo, Waterloo, Ontario N2L 3GI, Canada, [2]Department of Physics and Astronomy, University of Missouri, Columbia, MO 65211, [3]Gravity-Probe B, Hansen Physics Labs., Stanford University, Stanford, CA 94305, [4]Space-Time-Matter Consortium, http://astrp.uwaterloo.ca/~wesson; email: wesson@astro.uwaterloo.ca.

Abstract – We outline an improved cosmology which uses a higher-dimensional space of the type implied by unification, where the cosmological 'constant' decays from an unbounded value at the big bang to an acceptable value today. This model leads to a better understanding of inflation and is in good agreement with observations of galaxies.