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Abstracts of Award Winning and Honorable Mention Essays for 2016

Award Essays

First Award – **A Frame-Dependent Gravitational Effective Action Mimics a Cosmological Constant, but Modifies the Black Hole Horizon** by Stephen L. Adler; Institute for Advanced Study, Einstein Drive, Princeton, NJ 08540; e-mail: adler@ias.edu

Abstract – A frame dependent effective action motivated by the postulates of three-space general coordinate invariance and Weyl scaling invariance exactly mimics a cosmological constant in Robertson-Walker spacetimes. However, in a static spherically symmetric Schwarzschild-like geometry it modifies the black hole horizon structure within microscopic distances of the nominal horizon in such a way that g_{00} never vanishes. This could have important implications for the black hole "information paradox".

Second Award – **New Insights into Quantum Gravity from Gauge/Gravity Duality** by Netta Engelhardt and Gary T. Horowitz; Department of Physics, University of California, Santa Barbara, CA 93106; e-mail: engeln@physics.ucsb.edu, gary@physics.ucsb.edu

Abstract – Using gauge/gravity duality, we deduce several nontrivial consequences of quantum gravity from simple properties of the dual field theory. These include: (1) a version of cosmic censorship, (2) restrictions on evolution through black hole singularities, and (3) the exclusion of certain cosmological bounces. In the classical limit, the latter implies a new singularity theorem.

Third Award – **Spontaneous Dimensional Reduction in Quantum Gravity** by S. Carlip; Department of Physics, University of California, Davis, CA 95616;
e-mail: carlip@physics.ucdavis.edu

Abstract – Hints from a number of different approaches to quantum gravity point to a phenomenon of "spontaneous dimensional reduction" to two space-time dimensions near the Planck scale. I examine the physical meaning of the term "dimension" in this context, summarize the evidence for dimensional reduction, and discuss possible physical explanations.

Fourth Award – **Quadratic Gravity: from Weak to Strong** by Bob Holdom and Jing Ren; Department of Physics, University of Toronto, Toronto, Ontario, Canada M5S1A7; e-mail: bob.holdom@utoronto.ca, jren@physics.utoronto.ca

Abstract – More than three decades ago quadratic gravity was found to present a perturbative, renormalizable and asymptotically free theory of quantum gravity. Unfortunately the theory appeared to have problems with a spin-2 ghost. In this essay we revisit quadratic gravity in a different light by considering the case that the asymptotically free interaction flows to a strongly interacting regime. This occurs when the coefficient of the Einstein-Hilbert term is smaller than the scale Λ_{QG} where the quadratic couplings grow strong. Here QCD provides some useful insights. By pushing the analogy with QCD, we conjecture that the nonperturbative effects can remove the naive spin-2 ghost and lead to the emergence of general relativity in the IR.

Fifth Award – **Axion Experiments to Algebraic Geometry — Testing Quantum Gravity via the Weak Gravity Conjecture** by Ben Heidenreich, Matthew Reece, and Tom Rudelius; Department of Physics, Harvard University, Jefferson Laboratory, 17 Oxford St., Cambridge, MA 02138; e-mail: bjheiden@physics.harvard.edu, mreece@physics.harvard.edu, rudelius@physics.harvard.edu

Abstract – Common features of known quantum gravity theories may hint at the general nature of quantum gravity. The absence of continuous global symmetries is one such feature. This inspired the Weak Gravity Conjecture, which bounds masses of charged particles. We propose the Lattice Weak Gravity Conjecture, which further requires the existence of an infinite tower of particles of all possible charges under both abelian and nonabelian gauge groups and directly implies a cutoff for quantum field theory. It holds in a wide variety of string theory examples and has testable consequences for the real world and for pure mathematics. We sketch some implications of these ideas for models of inflation, for the QCD axion (and LIGO), for conformal field theory, and for algebraic geometry.

Honorable Mention Awards **(Alphabetical Order)**

1. **Stringent Theoretical and Experimental Bounds on Graviton Mass** by Ahmed Farag Ali[1] and Saurya Das[2]; [1]Department of Physics, Faculty of Science, Benha University, Benha 13518, Egypt, [2]Theoretical Physics Group, Department of Physics and Astronomy, University of Lethbridge, 4401 University Drive, Lethbridge, Alberta, Canada T1K 3M4; e-mail: ahmed.ali@fsu.edu.eg, saurya.das@uleth.ca

Abstract – We show from theoretical considerations, that if the graviton is massive, its mass is constrained to be about 10^{-32} eV/c^2. This estimate is consistent with those obtained from experiments, including the recent gravitational wave detection in advanced LIGO.

2. **Quantum Nonlocality, and the End of Classical Spacetime** by Shreya Banerjee, Sayantani Bera, and Tejinder P. Singh; Tata Institute of Fundamental Research, Homi Bhabha Road, Mumbai 400005, India; e-mail: shreya.banerjee@tifr.res.in, sayantani.bera@tifr.res.in, tpsingh@tifr.res.in

Abstract – Quantum non-local correlations and the acausal, spooky action at a distance suggest a discord between quantum theory and special relativity. We propose a resolution for this discord by first observing that there is a problem of time in quantum theory. There should exist a reformulation of quantum theory which does not refer to classical time. Such a reformulation is obtained by suggesting that space-time is fundamentally non-commutative. Quantum theory without classical time is the equilibrium statistical thermodynamics of the underlying non-commutative relativity. Stochastic fluctuations about equilibrium give rise to the classical limit and ordinary space-time geometry. However, measurement on an entangled state can be correctly described only in the underlying non-commutative spacetime, where there is no causality violation, nor a spooky action at a distance.

3. **Reconstructing Spacetime from the Hologram, even in the Classical Limit, Requires Physics beyond the Planck Scale** by David Berenstein and Alexandra Miller; Department of Physics, University of California, Santa Barbara, CA 93106; e-mail: dberens@physics.ucsb.edu, apmiller@physics.ucsb.edu

Abstract – We argue in this essay that for classical configurations of gravity in the AdS/CFT setup, it is in general impossible to reconstruct the bulk geometry from the leading asymptotic behavior of the classical fields in gravity alone. This is possible sufficiently near the vacuum, but not more generally. We argue this by using a counterexample that utilizes the supersymmetric geometries constructed by Lin, Lunin, and Maldacena. In the dual quantum field theory, the additional data required to complete the geometry is encoded in modes that near the vacuum geometry lie beyond the Planck scale.

4. **A Microscopic Description of Black Hole Evaporation via Holography** by Evan Berkowitz[1], Masanori Hanada[2,3,4], and Jonathan Maltz[2,5]; [1]Nuclear and Chemical Sciences Division, Lawrence Livermore National Laboratory, Livermore CA 94550, [2]Stanford Institute for Theoretical Physics, Stanford University, Stanford, CA 94305, [3]Yukawa Institute for Theoretical Physics, Kyoto University, Kitashirakawa Oiwakecho, Sakyo-ku, Kyoto 606-8502, Japan, [4]The Hakubi Center for Advanced Research, Kyoto University, Yoshida Ushinomiyacho, Sakyo-ku, Kyoto 606-8501, Japan, [5]Berkeley Center for Theoretical Physics, University of California at Berkeley, Berkeley, CA 94720; e-mail: berkowitz2@llnl.gov, hanada@yukawa.kyoto-u.ac.jp, jdmaltz@berkeley.edu, jdmaltz@alumni.stanford.edu

Abstract – We propose a description of how a large, cold black hole (black zero-brane) in type IIA superstring theory evaporates into freely propagating D0-branes, by solving the dual gauge theory quantitatively. The energy spectrum of emitted D0-branes is parametrically close to thermal when the black hole is large. The black hole, while initially cold, gradually becomes an extremely hot and stringy object as it evaporates. As it emits D0-branes, its emission rate speeds up and it evaporates completely without leaving any remnant. Hence this system provides us with a concrete holographic description of black hole evaporation without information loss.

5. **Horizon Shells: Classical Structure at the Horizon of a Black Hole** by Matthias Blau[1], and Martin O'Loughlin[2]; [1]Albert Einstein Center for Fundamental Physics, Institute for Theoretical Physics, University of Bern, Sidlerstrasse 5, 3012 Bern, Switzerland, [2]University of Nova Gorica, Vipavska 13, 5000 Nova Gorica, Slovenia; e-mail: blau@itp.unibe.ch, martin.oloughlin@ung.si

Abstract – We address the question of the uniqueness of the Schwarzschild black hole by considering the following question: How many meaningful solutions of the Einstein equations exist that agree with the Schwarzschild solution (with a fixed mass m) everywhere except maybe on a codimension one hypersurface? The perhaps surprising answer is that the solution is unique (and uniquely the Schwarzschild solution everywhere in spacetime) *unless* the hypersurface is the event horizon of the Schwarzschild black hole, in which case there are actually an infinite number of distinct solutions. We explain this result and comment on some of the possible implications for black hole physics.

6. **Symmetries of Space-Time** by Martin Bojowald; Institute for Gravitation and the Cosmos, The Pennsylvania State University, 104 Davey Lab, University Park, PA 16802; e-mail: bojowald@gravity.psu.edu

Abstract – The equations of Hamiltonian gravity are often considered ugly cousins of the elegant and manifestly covariant versions found in the Lagrangian theory. However, both formulations are fundamental in their own rights because they make different statements about the nature of space-time and its symmetries. These implications, along with the history of their derivation and an introduction of recent mathematical support, are the topic of this essay.

7. **Torsion or not Torsion, That Is the Question** by Yuri Bonder; Instituto de Ciencias Nucleares, Universidad Nacional Autónoma de México, Apartado Postal 70-543, Coyoacán, 04510 D. F., México; e-mail: bonder@nucleares.unam.mx

Abstract – A hypothesis of general relativity is that spacetime torsion vanishes identically. This assumption has no empirical support; in fact, a non-vanishing torsion is compatible with all the experimental tests of general relativity. The first part of this essay studies the framework that is suitable to test the vanishing-torsion hypothesis, and an interesting relation with the gravitational degrees of freedom is suggested. In the second part, some original empirical tests are proposed based on the observation that torsion induces new interactions between different spin-polarized particles.

8. **Quantum Leaps of Black Holes: Magnifying Glasses of Quantum Gravity** by Sumanta Chakraborty and Kinjalk Lochan; IUCAA, Post Bag 4, Ganeshkhind, Pune University Campus, Pune 411 007, India; e-mail: sumanta@iucaa.in, sumantac.physics@gmail.com, kinjalk@iucaa.in, kinjalk.lochan@gmail.co.in

Abstract – We show using simple arguments, that the conceptual triad of a *classical* black hole, semi-classical Hawking emission and geometry quantization is inherently, mutually incompatible. Presence of any two explicitly violates the third. We argue that geometry quantization, if realized in nature, magnifies the quantum gravity features hugely to catapult them into the realm of observational possibilities. We also explore a quantum route towards extremality of the black holes.

9. **Observable Effects of Quantum Gravity** by Lay Nam Chang, Djordje Minic, Chen Sun, and Tatsu Takeuchi; Center for Neutrino Physics, Department of Physics, Virginia Tech, Blacksburg, VA 24061; e-mail: laynam@vt.edu, dminic@vt.edu, sunchen@vt.edu, takeuchi@vt.edu

Abstract – We discuss the generic phenomenology of quantum gravity and, in particular, argue that the observable effects of quantum gravity, associated with new, extended, non-local, non-particle-like quanta, and accompanied by a dynamical energy-momentum space, are not necessarily Planckian and that they could be observed at much lower and experimentally accessible energy scales.

10. **Leading Gravitational Corrections and a Unified Universe** by Alessandro Codello and Rajeev Kumar Jain; CP^3-Origins, Centre for Cosmology and Particle Physics Phenomenology, University of Southern Denmark, Campusvej 55, 5230 Odense M, Denmark; e-mail: codello@cp3-origins.net, jain@cp3.sdu.dk

Abstract – Leading order gravitational corrections to the Einstein-Hilbert action can lead to a consistent picture of the universe by unifying the epochs of inflation and dark energy in a single framework. While the leading local correction induces an inflationary phase in the early universe, the leading non-local term leads to an accelerated expansion of the universe at the present epoch. We argue that both the leading UV and IR terms can be obtained within the framework of a covariant effective field theory of gravity. The perturbative gravitational corrections therefore provide a fundamental basis for understanding a possible connection between the two epochs.

11. **Bulk Supertranslation Memories: a Concept Reshaping the Vacua and Black Holes of General Relativity** by Geoffrey Compère; Université Libre de Bruxelles and International Solvay Institutes, CP 231, B-1050 Brussels, Belgium; e-mail: gcompere@ulb.ac.be

Abstract – The memory effect is a prediction of general relativity on the same footing as the existence of gravitational waves. The memory effect is understood at future null infinity as a transition induced by null radiation from a Poincaré vacuum to another vacuum. Those are related by a supertranslation, which is a fundamental symmetry of asymptotically flat spacetimes. In this essay, I argue that supertranslation diffeomorphisms should be extended into the bulk spacetime consistently with canonical charge conservation. It then leads to fascinating geometrical features of gravitational Poincaré vacua. I then argue that in the process of black hole merger or gravitational collapse, dramatic but computable memory effects occur. They lead to a final stationary metric which qualitatively deviates from the Schwarzschild metric.

12. **The Power of Weak-Field GR Gravity** by F. I. Cooperstock; Department of Physics and Astronomy, University of Victoria, P.O. Box 3055, Victoria, B.C. V8W 3P6 Canada; e-mail: cooperst@uvic.ca

Abstract – We discuss the limitations of the long-held belief in the idea of the "Newtonian-limit" of general relativity (GR). Examples are given in which there is no Newtonian-limit for well-known phenomena in general relativity. A particularly simple new example of the stark difference that Newtonian gravity and weak-field general relativity exhibit is presented for a modified van-Stockum source, which speaks to the galactic rotation problem. We witness the power of weak-field general relativity in guiding us to our successful prediction of the size of our Milky-Way, in mapping galactic mass distributions and in modifying our picture of the galactic masses required to yield observed flat rotation curves. Freeing ourselves of the Newtonian-limit bias opens the way for more progress in the application of weak-field general relativity.

13. **Black Hole Fusion Made Easy** by Roberto Emparan[1,2] and Marina Martínez[2]; [1]Institució Catalana de Recerca i Estudis Avançats (ICREA), Passeig Lluís Companys 23, E-08010 Barcelona, Spain, [2]Departament de Física Fonamental, Institut de Ciències del Cosmos, Universitat de Barcelona, Martí i Franquès 1, E-08028 Barcelona, Spain; e-mail: emparan@ub.edu, marinamartinez@ub.edu

Abstract – The fusion of two black holes – a signature phenomenon of General Relativity – is usually regarded as a process so complex that nothing short of a supercomputer simulation can accurately capture it. In this essay we explain how the event horizon of the merger can be found in an exact analytic way in the limit where one of the black holes is much smaller than the other. Remarkably, the ideas and techniques involved are elementary: the equivalence principle, null geodesics in the Schwarzschild solution, and the notion of event horizon itself. With these, one can identify features such as the line of caustics at which light rays enter the horizon, and find indications of universal critical behavior when the two black holes touch.

14. **Physical Effects of the Gravitational Θ-Term** by Willy Fischler[1] and Sandipan Kundu[2]; [1]Theory Group, Department of Physics, University of Texas, Austin, TX 78712 and Texas Cosmology Center, University of Texas, Austin, TX 78712, [2]Department of Physics, Cornell University, Ithaca, New York, 14853; e-mail: fischler@physics.utexas.edu, kundu@cornell.edu

Abstract – We describe the effect of the gravitational Θ-term on the behavior of the stretched horizon of a black hole in (3 + 1)-dimensions. The gravitational Θ-term is a total derivative; however, it affects the transport properties of the horizon. In particular, the horizon acquires a third order parity violating, dimensionless transport coefficient which affects the way localized perturbations scramble on the horizon. In the context of the gauge/gravity duality, the Θ-term induces a non-trivial contact term in the energy-momentum tensor of a (2+1)–dimensional large-N gauge theory, which admits a dual gravity description. As a consequence, the dual gauge theory in the presence of the Θ-term acquires the same third order parity violating transport coefficient.

15. **Observational Strong Gravity and Quantum Black Hole Structure** by Steven B. Giddings; Department of Physics, University of California, Santa Barbara, CA 93106; e-mail: giddings@physics.ucsb.edu

Abstract – Quantum considerations have led many theorists to believe that classical black hole physics is modified not just deep inside black holes but at *horizon scales*, or even further outward. The near-horizon regime has just begun to be observationally probed for astrophysical black holes – both by LIGO, and by the Event Horizon Telescope. This suggests exciting prospects for observational constraints on or discovery of new quantum black hole structure.

16. **Gravity-Assisted Emergent Higgs Mechanism in the Post-Inflationary Epoch** by Eduardo Guendelman[1], Emil Nissimov[2], and Svetlana Pacheva[2]; [1]Department of Physics, Ben-Gurion University of the Negev, Beer-Sheva 84105, Israel, [2]Institute for Nuclear Research and Nuclear Energy, Bulgarian Academy of Sciences, Sofia 1784, Bulgaria; e-mail: guendel@bgu.ac.il, nissimov@inrne.bas.bg, svetlana@inrne.bas.bg

Abstract – We consider a non-standard model of gravity coupled to a neutral scalar “inflaton” as well as to $SU(2) \times U(1)$ iso-doublet scalar with positive mass squared and without self-interaction, and to $SU(2) \times U(1)$ gauge fields. The principal new ingredient is employing two alternative non-Riemannian space-time volume-forms (covariant integration measure densities) independent of the metric. The latter have a remarkable impact – although not introducing any additional propagating degrees of freedom, their dynamics triggers a series of important features: appearance of infinitely large flat regions of the effective “inflaton” potential as well as dynamical generation of Higgs-like spontaneous symmetry breaking effective potential for the $SU(2) \times U(1)$ iso-doublet scalar.

17. **Quantum Gravity Effects around Sagittarius A*** by Hal M. Haggard[1] and Carlo Rovelli[2]; [1]Physics Program, Bard College, 30 Campus Rd, Annandale-on-Hudson, NY 12504, [2]CPT, Aix-Marseille Université, Université de Toulon, CNRS, Case 907, F-13288 Marseille, France and Samy Maroun Research Center for Time, Space and the Quantum; e-mail: haggard@bard.edu, rovelli@cpt.univ-mrs.fr

Abstract – Recent VLBI observations have resolved Sagittarius A* at horizon scales. The Event Horizon Telescope is expected to provide increasingly good images of the region around the Schwarzschild radius r_S of Sgr A* soon. A number of authors have recently pointed out the possibility that non-perturbative quantum gravitational phenomena could affect the space surrounding a black hole. Here we point out that the existence of a region around $7r_S/6$ where these effects should be maximal.

18. **The Quantum Bound on the Thermodynamic Description of Gravity** by Shahar Hod; The Ruppin Academic Center, Emeq Hefer 40250, Israel and The Hadassah Institute, Jerusalem 91010, Israel; e-mail: shaharhod@gmail.com

Abstract – The seminal works of Bekenstein and Hawking have revealed that black holes have a well-defined thermodynamic description. In particular, it is often stated in the physical literature that black holes, like mundane physical systems, obey the first law of thermodynamics: $\Delta S = \Delta E/T_{\mathrm{BH}}$, where T_{BH} is the Bekenstein-Hawking temperature of the black hole. In this essay we test the regime of validity of this thermodynamic description of gravity. In particular, we provide compelling evidence that, due to quantum effects, the first law of thermodynamics breaks down in the low-temperature regime $T_{\mathrm{BH}} \times r_{\mathrm{H}} \lesssim (\hbar/r_{\mathrm{H}})^2$ of near-extremal black holes (here r_{H} is the radius of the black-hole horizon).

19. **Graviton Laser** by A. Landry and M. B. Paranjape; Groupe de physique des particules, Département de physique, Université de Montréal, C.P. 6128, succ. centre-ville, Montréal, Québec, Canada, H3C 3J7; e-mail: alexandre.landry.1@umontreal.ca, paranj@lps.umontreal.ca

Abstract – We consider the possibility of creating a graviton laser. The lasing medium would be a system of contained, ultra cold neutrons. Ultra cold neutrons are a quantum mechanical system that interacts with gravitational fields and with the phonons of the container walls. It is possible to create a population inversion by pumping the system using the phonons. We compute the rate of spontaneous emission of gravitons and the rate of the subsequent stimulated emission of gravitons. The gain obtainable is directly proportional to the density of the lasing medium and the fraction of the population inversion. The applications of a graviton laser would be interesting.

20. **Conformal Invariance and the Metrication of the Fundamental Forces** by Philip D. Mannheim; Department of Physics, University of Connecticut, Storrs, CT 06269; e-mail: philip.mannheim@uconn.edu

Abstract – We revisit Weyl's metrication (geometrization) of electromagnetism. We show that by making Weyl's proposed geometric connection be pure imaginary, not only are we able to metricate electromagnetism, an underlying local conformal invariance makes the geometry be strictly Riemannian and prevents observational gravity from being complex. Via torsion we achieve an analogous metrication for axial-vector fields. We generalize our procedure to Yang-Mills theories, and achieve a metrication of all the fundamental forces. Only in the gravity sector does our approach differ from the standard picture of fundamental forces, with our approach requiring that standard Einstein gravity be replaced by conformal gravity. We show that quantum conformal gravity is a consistent and unitary quantum gravitational theory, one that, unlike string theory, only requires four spacetime dimensions.

21. **What Prevents Gravitational Collapse in String Theory?** by Samir D. Mathur; Department of Physics, The Ohio State University, Columbus, OH 43210; e-mail: mathur.16@osu.edu

Abstract – It is conventionally believed that if a ball of matter of mass M has a radius close to $2GM$ then it must collapse to a black hole. But string theory microstates (fuzzballs) have no horizon or singularity, and they do *not* collapse. We consider two simple examples from classical gravity to illustrate how this violation of our intuition happens. In each case the 'matter' arises from an extra compact dimension, but the topology of this extra dimension is not trivial. The pressure and density of this matter diverge at various points, but this is only an artifact of dimensional reduction; thus we bypass results like Buchdahl's theorem. Such microstates give the entropy of black holes, so these topologically nontrivial constructions dominate the state space of quantum gravity.

22. **Cosmic Information Determines the Cosmological Constant: What You (Can) See Is What You Get!** by T. Padmanabhan[1] and Hamsa Padmanabhan[2]; [1]IUCAA, Post Bag 4, Ganeshkhind, Pune - 411 007, India, [2]ETH Zurich, Switzerland; e-mail: paddy@iucaa.in, hamsa@phys.ethz.ch

Abstract – A non-zero cosmological constant blocks out the information about some regions of the universe from a given observer, however long she waits. That is, the amount of cosmic information (I_c) accessible to an eternal observer (which is infinite if $\Lambda = 0$) becomes finite when $\Lambda \neq 0$. One can relate this information content to the number of modes which were pushed out of the Hubble radius during the inflationary phase, thereby relating Λ to I_c. These modes were sub-Planckian at the early stages of inflation and carry one unit of quantum gravitational information, $I_{QG} = 4\pi$. Equating $I_c = I_{QG}$ allows us to determine the numerical value of Λ, thereby relating the cosmic information to the non-zero value of the cosmological constant.

23. **Are Most Particles Gravitons?** by Don N. Page; Theoretical Physics Institute, Department of Physics, 4-183 CCIS, University of Alberta, Edmonton, Alberta T6G 2E1, Canada; e-mail: profdonpage@gmail.com

Abstract – The number of baryons in the observable universe is of the order of 10^{80}, as is the number of electrons. The number of photons is about nine orders of magnitude greater, 10^{89}, as is the estimated number of neutrinos. However, the number of gravitons could be more than twenty orders of magnitude larger yet, of the order of $10^{113}\, r$, where r is the tensor-to-scalar ratio for quantum fluctuations produced by inflation, which could be as high as 0.1.

24. **Prospects for Primordial Gravitational Waves in String Inflation** by Susha L. Parameswaran[1] and Ivonne Zavala[2]; [1]Department of Mathematical Sciences, University of Liverpool, Liverpool, L69 7ZL, UK, [2]Department of Physics, Swansea University, Swansea, SA2 8PP, UK; e-mail: Susha.Parameswaran@liverpool.ac.uk, e.i.zavalacarrasco@swansea.ac.uk

Abstract – Assuming that the early universe had (i) an epoch of slow-roll inflation (ii) a description using perturbative string theory and its field theory limit, we derive a conservative upper bound on the amplitude of primordial gravitational waves, $r \lesssim 0.2$. Restricting to the classes of compactifications typically used in string cosmology, where for instance moduli stabilisation is well under control, the bound becomes much stronger $r \lesssim 10^{-9}$. Therefore, any detection of inflationary gravitational waves would present an interesting but difficult challenge for inflation in string theory.

25. **The Quantum Interaction of Macroscopic Objects and Gravitons and the Secret Quantum Life of a Boeing 747** by Tsvi Piran; The Racah Institute of Physics, The Hebrew University, Jerusalem, 91904, Israel; e-mail: tsvi.piran@mail.huji.ac.il

Abstract – It is commonly believed that we generate gravitational radiation when we wave our hands. However, the quantum nature of gravitons suppresses gravitational waves emission from objects whose kinetic energy is less than the Planck energy. Most humans don't emit even a single graviton during their whole life time. This quantum suppression affects even larger and faster objects (e.g. a 747 at flight speed) that behave quantum mechanically when considering gravitational waves emission. While it is impossible to check experimentally this quantum gravitational effect it might be possible to carry out analogous electromagnetic experiments that will shed light on this macroscopic quantum mechanical behavior.

26. **Residual Diffeomorphisms and Symplectic Hair on Black Holes** by M. M. Sheikh-Jabbari; School of Physics, Institute for Research in Fundamental Sciences (IPM), P.O.Box 19395-5531, Tehran, Iran; e-mail: jabbari@theory.ipm.ac.ir

Abstract – General covariance is the cornerstone of Einstein's General Relativity (GR) and implies that any two metrics which are related by diffeomorphisms are physically equivalent. There are, however, many examples pointing to the fact that this strict statement of general covariance needs refinement. There are a very special (measure-zero) subset of diffeomorphisms, *the residual diffeomorphisms*, to which one can associate well-defined conserved charges. We discuss that these symmetries may be appropriately called "symplectic symmetries". This would hence render these diffeomorphic geometries physically distinct. Existence of residual diffeomorphisms and symplectic symmetries can be a quite general feature and not limited to the examples discussed so far in the literature. We propose that, in the context of black holes, these diffeomorphic, but distinct, geometries may be viewed as "symplectic hair" on black holes. We comment on how this may remedy black hole microstate problem and possibly the information paradox.

27. **Global versus Local – Mach's Principle versus the Equivalence Principle** by Douglas Singleton[1] and Steve Wilburn[2]; [1]Physics Department, CSU Fresno, Fresno, CA 93740, [2]Twin Prime Inc., Redwood City, CA 94063; e-mail: dougs@csufresno.edu, stevejwilburn@gmail.com

Abstract – The equivalence principle is the conceptual basis for general relativity. In contrast Mach's principle, although said to have been influential on Einstein in his formulation of general relativity, has not been shown to be central to the structure of general relativity. In this essay we suggest that the quantum effects of Hawking and Unruh radiation are a manifestation of a *thermal* Mach's principle, where the local thermodynamic properties of the system are determined by the non-local structure of the quantum fields which determine the vacuum of a given spacetime. By comparing Hawking and Unruh temperatures for the same local acceleration we find a violation of the Einstein elevator version of the equivalence principle, which vanishes in the limit that the horizon is approached.

28. **End of a Dark Age?** by W. M. Stuckey[1], Timothy McDevitt[2], and Michael Silberstein[3]; [1]Department of Physics, Elizabethtown College, Elizabethtown, PA 17022, [2]Department of Mathematical Sciences, Elizabethtown College, Elizabethtown, PA 17022, [3]Department of Philosophy and Foundations of Physics, Committee for Philosophy and the Sciences, University of Maryland, College Park, MD 20742; e-mail: stuckeym@etown.edu, mcdevittt@etown.edu, msilbers@umd.edu

Abstract – We argue that dark matter and dark energy phenomena associated with galactic rotation curves, X-ray cluster mass profiles, and type Ia supernova data can be accounted for via small corrections to idealized general relativistic spacetime geometries due to disordered locality. Accordingly, we fit THINGS data rivaling MOND, ROSAT/ASCA data rivaling metric-skew-tensor gravity, and Union2 Compilation data rivaling ΛCDM without non-baryonic dark matter or a cosmological constant. In the case of dark matter, we geometrically modify proper mass interior to the Schwarzschild solution. In the case of dark energy, we modify proper distance in Einstein-deSitter cosmology. Therefore, the phenomena of dark matter and dark energy may be chimeras created by an errant belief that spacetime is a differentiable manifold rather than a disordered graph.

29. **Gravitational Waves, Gamma Ray Bursts, and Black Stars** by Tanmay Vachaspati; Physics Department, Arizona State University, Tempe, AZ 85287; e-mail: tvachasp@asu.edu

Abstract – Stars that are collapsing toward forming a black hole but appear frozen near their Schwarzschild horizon are termed “black stars”. The collision of two black stars leads to gravitational radiation during the merging phase followed by a delayed gamma ray burst during coalescence. The recent observation of gravitational waves by LIGO, followed by a possible gamma ray counterpart by Fermi, suggests that the source may have been a merger of two black stars with profound implications for quantum gravity and the nature of black holes.