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Abstracts of Award Winning and Honorable Mention Essays for 2006

Award Essays

First Award – Information Recovery from Black Holes – by Vijay Balasubramanian*, Donald Marolf[+], and Moshe Rozali[#]; *David Rittenhouse Laboratories, University of Pennsylvania, Philadelphia, PA 19104; [+]Physics Department, UCSB, Santa Barbara, CA 93106; [#]Physics Department, University of British Columbia, Vancouver, BC V6T1Z1, Canada.

Abstract – The authors argue that if black hole entropy arises from a finite number of underlying quantum states, then any particular such state can be identified from infinity. The finite density of states implies a discrete energy spectrum, and, in general, such spectra are non-degenerate except as determined by symmetries. Therefore, knowledge of the precise energy, and of other commuting conserved charges, determines the quantum state. In a gravitating theory, all conserved charges including the energy are given by boundary terms that can be measured at infinity. Thus, within any theory of quantum gravity, no information can be lost in black holes with a finite number of states. However, identifying the state of a black hole from infinity requires measurements with Planck scale precision. Hence observers with insufficient resolution will experience information loss.

Second Award – Towers of Gravitational Theories – by Walter D. Goldberger* and Ira Z. Rothstein[+]; *Department of Physics, Yale University, New Haven, CT 06520; [+]Department of Physics, Carnegie Mellon University, Pittsburgh, PA 15213.

Abstract – In this essay, the authors introduce a theoretical framework designed to describe black hole dynamics. The difficulties in understanding such dynamics stems from the proliferation of scales involved when one attempts to simultaneously describe all of the relevant dynamical degrees of freedom. These range from the modes that describe the black hole horizon, which are responsible for dissipative effects, to the long wavelength gravitational radiation that drains mechanical energy from macroscopic black hole bound states. The authors approach the problem from a Wilsonian point of view, by building a tower of theories of gravity each of which is valid at different scales. The methodology leads to multiple new results in diverse topics including phase transitions of Kaluza-Klein black holes and the interactions of spinning black holes in non-relativistic orbits. Moreover, the methods tie together speculative ideas regarding dualities for black hole horizons to real physical measurements in gravitational wave detectors.

Third Award – Gravity's Immunity from Vacuum: The Holographic Structure of Semiclassical Action – by T. Padmanabhan; IUCAA, Pune University Campus, Ganeshkhind, Pune- 411 007, India.

Abstract – Principle of equivalence, general covariance and the demand that the variation of the action functional should be well defined, lead to a generic Lagrangian for semiclassical gravity of the form $L = Q_a^{\ bcd}R^a_{\ bcd}$ with $\nabla_b Q_a^{\ bcd} = 0$. The expansion of $Q_a^{\ bcd}$ in terms of the derivatives of the metric tensor determines the structure of the theory uniquely. The zeroth order term gives the Einstein-Hilbert action and the first order correction is given by the Gauss-Bonnet action. Remarkably, any such Lagrangian can be decomposed into surface and bulk terms which are related holographically. The equations of motion can be obtained purely from a surface term in the gravity sector and hence gravity does not respond to the changes in the bulk vacuum energy density.

Fourth Award – The "Dark Side" of Gravitational Experiments – by Dr. Charles D. Hoyle, Jr.; University of Washington, CENPA Laboratory, Campus Box 354290, Seattle, WA 98195-4290.

Abstract – Theoretical speculations about the quantum nature of the gravitational interaction have motivated many recent experiments. But perhaps the most profound and puzzling questions that these investigations address surround the observed cosmic acceleration, or Dark Energy. This mysterious substance comprises roughly 2/3 of the energy density of the universe. Current gravitational experiments may soon have the sensitivity to detect subtle clues that will reveal the mechanism behind the cosmic acceleration. On the laboratory scale, short-range tests of the Newtonian inverse-square law provide the most sensitive measurements of gravity at the Dark Energy length scale, $\lambda_d = (\hbar c/\rho_d)^{1/4} \approx 85\ \mu m$, where $\rho_d \approx 3.8\ keV/cm^3$ is the observed Dark Energy density. This length scale may also have fundamental significance that could be related to the "size" of the graviton. At the University of Washington, scientists are conducting the world's most sensitive, short-range test of the Newtonian inverse-square law.

Fifth Award – Null Infinity, H-space and Equations of Motion – by Carlos Kozameh*, Ezra T. Newman[+], and Gilberto Silva-Ortigoza[#]; *FaMaF, University of Cordoba, Cordoba, Argentina; [+]Department of Physics and Astronomy, University of Pittsburgh, Pittsburgh, PA 15260; [#]Facultad de Ciencias Físico Matemáticas de la Universidad Autónomade Puebla, Apartado Postal 1152, Puebla, Pue., Mexico.

Abstract – The authors discuss the existence, arising by analogy to that in algebraically special space-times, of a unique asymptotically shear-free congruence in any asymptotically flat space-time. Associated with it is a unique complex analytic curve in H-space. The surprising potential physical significance of this curve is discussed.

Honorable Mention Awards (Alphabetical Order)

1. Is the Equivalence Principle Doomed Forever to Dante's Inferno on Account of Quantum Mechanics? – by Antonio Accioly*[+], Ruben Aldrovandi[+], and Ricardo Paszko[+]; *Centro Brasileiro de Pesquisas Físicas – CBPF, Rua Dr. Xavier Sigaud 150, 22290-180, Rio de Janeiro, RJ, Brazil; [+]Instituto de Física Teórica, UNESP – São Paulo State University, Rua Pamplona 145, 01405-000 São Paulo, SP, Brazil.

Abstract – It is commonly assumed that the equivalence principle can coexist without conflict with quantum mechanics. The authors argue here that, contrary to popular belief, this principle does not hold in quantum mechanics. They illustrate this point by computing the second-order correction for the scattering of a massive scalar boson by a weak gravitational field, treated as an external field. The resulting cross section turns out to be mass-dependent. A way out of this dilemma would be, perhaps, to consider gravitation without the equivalence principle. At first sight, this seems to be a too much drastic attitude towards general relativity. Fortunately, the teleparallel version of general relativity – a description of the gravitational interaction by a force similar to the Lorentz force of electromagnetism and that, of course, dispenses with the equivalence principle – is completely equivalent to general relativity, thus providing a consistent theory for gravitation in the absence of the aforementioned principle.

2. Relativistic Effects in Extrasolar Planetary Systems – by Fred C. Adams* and Gregory Laughlin[+]; *Michigan Center for Theoretical Physics, Physics Department, University of Michigan, Ann Arbor, MI 48109, and Astronomy Department, University of Michigan, Ann Arbor, MI 48109; [+]Lick Observatory, University of California, Santa Cruz, CA 95064.

Abstract – This paper considers general relativistic effects in currently observed extrasolar planetary systems. Although general relativistic corrections are small, they can compete with secular interactions in these systems and thereby play an important role. Specifically, some of the observed multiple planet systems are close to secular resonance, where the dynamics is extremely sensitive to general relativistic corrections, and these systems can be used as laboratories to test general relativity. For the three-planet solar system Upsilon Andromedae, secular interaction theory implies an 80% probability of finding the system with its observed orbital elements if general relativity is correct, compared with only a 2% probability in the absence of general relativity. In the future, tighter constraints can be obtained with increased temporal coverage.

3. Dark Matter and its Darkness – by D.V. Ahluwalia-Khalilova; Ashram for the Studies of the Glass Bead Game, Apartado Postal C-600, Department of Mathematics, University of Zacatecas, Zacatecas 98060, Mexico.

Abstract – Assuming the validity of the general relativistic description of gravitation on astrophysical and cosmological length scales, the author analytically infers that the Friedmann-Robertson-Walker cosmology with Einsteinian cosmological constant, and a vanishing spatial curvature constant, unambiguously requires a significant amount of dark matter. This requirement is consistent with other indications, such as non-Keplerian galactic rotational curves, for dark matter. The same spacetime symmetries that underlie the freely falling frames of Einsteinian gravity also provide symmetries (Poincaré), which for the spin one half representation space, furnish a novel construct that carries extremely limited interactions with respect to the terrestrial detectors made of the standard model material. Both the 'luminous' and 'dark' matter turn out to be residents of the same representation space but they derive their respective 'luminosity' and 'darkness' from either belonging to the sector with $(CPT)^2 = +\mathbb{1}$, or to the sector with $(CPT)^2 = -\mathbb{1}$.

4. Killing Horizons Kill Horizon Degrees – by L. Bergamin* and D. Grumiller+; *ESA Advanced Concepts Team (EUI-ACT), ESTEC, Keplerlaan 1, NL-2201 AZ Noordwijk, The Netherlands; +Institute for Theoretical Physics, University of Leipzig, Augustusplatz 10-11, D-04109 Leipzig, Germany.

Abstract – Frequently it is argued that the microstates responsible for the Bekenstein-Hawking entropy should arise from some physical degrees of freedom located near or on the black hole horizon. In this essay, the authors elucidate that instead entropy may emerge from the conversion of physical degrees of freedom, attached to a generic boundary, into unobservable gauge degrees of freedom attached to the horizon. By constructing the reduced phase space it can be demonstrated that such a transmutation indeed takes place for a large class of black holes, including Schwarzschild.

5. Supermassive Black Holes or Boson Stars? Hair Counting with Gravitational Wave Detectors – by Emanuele Berti* and Vitor Cardoso+; *McDonnell Center for the Space Sciences, Department of Physics, Washington University, St. Louis, MO 63130; #Department of Physics and Astronomy, The University of Mississippi, University, MS 38677-1848.

Abstract – The evidence for supermassive Kerr black holes in galactic centers is strong and growing, but only the detection of gravitational waves will convincingly rule out other possibilities to explain the observations. The Kerr spacetime is completely specified by the first two multipole moments: mass and angular momentum. This is usually referred to as the "no-hair theorem", but it is really a "two-hair" theorem. If general relativity is the correct theory of gravity, the most plausible alternative to a supermassive Kerr black hole is a rotating boson star. Numerical calculations indicate that the spacetime of rotating boson stars is determined by the first *three* multipole moments ("three-hair theorem"). The Laser Interferometer Space Antenna (LISA) could accurately measure the oscillation frequencies of these supermassive objects. The authors propose to use these measurements to "count their hair", unambiguously determining their nature and properties.

6. A Graceful Exit for Old Inflation and a Solution to the Hierarchy Problem – by Tirthabir Biswas and Alessio Notari; Physics Department, McGill University, 3600 University Road, Montréal, QC, H3A 2T8, Canada.

Abstract – Inflation with tunneling from a false to a true vacuum becomes viable in the presence of a scalar field that slows down the initial de Sitter phase. As a by-product this field also sets dynamically the value of the Newton constant observed today. This can be very small if the tunneling rate (which is exponentially suppressed by the barrier) is small enough. Therefore along with Inflation, the authors also provide a natural dynamical explanation for why gravity is so weak today. Moreover they predict a spectrum of gravity waves peaked at around 0.1 mHz, that will be detectable by the planned space interferometer LISA. Finally they discuss interesting predictions on cosmological scalar and tensor fluctuations already relevant in the light of the WMAP 3-year data.

7. How to Bypass Birkhoff through Extra Dimension – by Piotr Bizoń and Bernd G. Schmidt; Max-Planck-Institut für Gravitationsphysik, Albert-Einstein-Institut, Am Mühlenberg 1, D-14476 Golm, Germany.

Abstract – It is fair to say that our current mathematical understanding of the dynamics of gravitational collapse to a black hole is limited to the spherically symmetric situation and, in fact, even in this case much remains to be learned. The reason is that Einstein's equations become tractable only if they are reduced to a 1 + 1 dimensional system of partial differential equations. Due to this technical obstacle, very little is known about the collapse of pure gravitational waves because by Birkhoff's theorem there is no spherical collapse in vacuum. In this essay, the authors describe a new cohomogeneity-two symmetry reduction of the vacuum Einstein equations in five and higher odd dimensions which evades Birkhoff's theorem and admits time dependent asymptotically flat solutions. They argue that this model provides an attractive 1 + 1 dimensional geometric setting for investigating the dynamics of gravitational collapse in vacuum.

8. From de Sitter to de Sitter, A Non-Singular Inflationary Universe Driven by Vacuum – by Saulo Carneiro; Instituto de Física, Universidade Federal da Bahia, Salvador, BA, Brazil, and International Centre for Theoretical Physics, Trieste, Italy.

Abstract – In this essay a semi-classical analysis of vacuum energy in the expanding spacetime suggests that the cosmological term decays with time, with a concomitant matter production. For early times the author finds in Planck units, $\Lambda \approx H^4$, where H is the Hubble parameter. The corresponding cosmological solution has no initial singularity, existing since an infinite past. During an infinitely long period we have a quasi-de Sitter, inflationary universe, with $H \approx 1$. However, at a given time, the expansion undertakes a phase transition, with H and Λ decreasing to nearly zero in a few Planck times, producing a huge amount of radiation. On the other hand, the late-time scenario is similar to the standard model, with the radiation phase followed by a dust one, which tends asymptotically to a de Sitter universe, with vacuum dominating again.

9. Cosmology: A Bird's Eye View – by Alan A. Coley, Sigbjørn Hervik, and Woei Chet Lim; Dalhousie University, Department of Mathematics and Statistics, Halifax, NS, Canada B3H 3J5.

Abstract – In this essay, the authors discuss the differences in views of the Universe as seen by two different observers. While one of the observers follows a geodesic congruence defined by the geometry of the cosmological model, the other observer follows the fluid flow lines of a perfect fluid with a linear equation of state. The authors point out that the information these observers collect regarding the state of the Universe can be radically different; while one observes a non-inflating ever-expanding ever-lasting universe, the other observer can experience a dynamical behavior reminiscent to that of quintessence or even that of a phantom cosmology leading to a 'big rip' singularity within finite time (but without the need for exotic forms of matter).

10. Ultracold Quantum Gases as Probes of the Unruh Effect – by Lawrence B. Crowell; Alpha Institute of Advanced Study, 11 Rutafa Street, H-1165, Budapest, Hungary.

Abstract – The Unruh effect predicts the existence of a thermal bath of radiation on an accelerated frame. The accelerations have to be very large to have any measurable effect. It is proposed here that ultracold quantum gases and Bose-Einstein condensates might be a probe of the Unruh effect. A Bose-Einstein condensate under an experimentally feasible acceleration will be heated by the Unruh radiation to a temperature above the transition temperature. In this essay a method of detection is proposed which should be feasible in the near future.

11. Is the Rindler Horizon Energy Nonvanishing? – by Hristu Culetu; Ovidius University, Department of Physics, B-dul Mamaia 124, 8700 Constanta, Romania.

Abstract – A nonvanishing value for the Rindler horizon energy is obtained, by an analogy with the "near horizon" Schwarzschild spacetime, contrary to Padmanabhan's result based on the formalism of Euclideanization of the Einstein action. The author shows that the Rindler horizon energy is given by the same formula $E = \alpha/2$ obtained by Padmanabhan for the Schwarzschild horizon, where α is the gravitational radius.

12. Black Hole Bremsstrahlung: Can It Be an Efficient Source of Gravitational Waves? – by H.P. de Oliveira[*], I. Damião Soares[+], and Eduardo Valentino Tonini[#]; [*]Instituto de Física – Universidade do Estado do Rio de Janeiro, R. São Francisco Xavier, 524. CEP 20550-013, Rio de Janeiro, RJ, Brazil; [+]Centro Brasileiro de Pesquisas Físicas/MCT., R. Dr. Xavier Sigaud, 150. CEP 22290-180, Rio de Janeiro, RJ, Brazil; [#]Centro Federal de Educação Tecnológica do Espírito Santo Avenida Vitória, 1729, Jucutuquara, Vitória CEP 29040-780-ES, Brazil.

Abstract – The authors propose a new source of gravitational waves in the context of full nonlinear General Relativity: the *black hole bremsstrahlung*. As the consequence of the black hole deceleration, a radiative transfer process is set up through which the black hole loses its kinetic energy along with part of its rest mass by the emission of gravitational waves. Depending on the initial velocity and the strength of the deceleration this process can correspond to a high power output in the initial pulse of gravitational radiation emitted.

13. Island Cosmology – by Sourish Dutta and Tanmay Vachaspati; CERCA, Department of Physics, Case Western Reserve University, 10900 Euclid Avenue, Cleveland, OH 44106-7079.

Abstract – The authors propose an alternate cosmological model in which the observable universe is an island of matter in a cosmological constant sea. Initially spacetime is filled with cosmological constant of the currently observed value, Λ, but is otherwise empty. Local quantum fluctuations that violate the null energy condition, create an island universe in the Λ-sea. With further cosmic evolution the island disappears and the local spacetime returns to its initial cosmological constant dominated state. Spacetime is eternal in this model, only matter is created at sporadic Big Bangs.

14. Explain Cosmic Acceleration? First, Correct Einstein – by Homer G. Ellis; Department of Mathematics, University of Colorado, Boulder, CO 80309-0395.

Abstract – In creating his gravitational field equations Einstein unjustifiably assumed that inertial mass, and its energy equivalent, is a source of gravity. Denying this assumption allows modifying the field equations to a form in which a positive cosmological constant appears as a uniform density of gravitationally repulsive matter. This repulsive matter is identified as the back sides of the ‘drainholes’ (called by some ‘traversable wormholes’) introduced by the author in 1973, which attract on the high, front sides and repel more strongly on the low, back sides. The field equations produce cosmological models that ‘bounce’ off a positive minimum of the scale factor and accelerate throughout history. The ‘dark drainholes’ that radiate nothing visible are hypothesized to constitute the ‘dark matter’ inferred from observation, their excess of negative mass over positive active mass driving the accelerating expansion. For a spatially flat universe, with the ratio of scale factor now to scale factor at bounce equal to the Hubble radius over the Planck length, the model gives an elapsed time since the bounce of two trillion years. The solutions for negative spatial curvature exhibit early stage inflation of great magnitude in short times. Cosmic voids, filaments, and walls are attributed to separation of the back sides of the drainholes from the front, driven by their mutual attractive-repulsive interactions.

15. Fundamental Spatiotemporal Decoherence: A Key to Solving the Conceptual Problems of Black Holes, Cosmology, and Quantum Mechanics – by Rodolfo Gambini[*], Rafael A. Porto[+], and Jorge Pullin[*]; [*]Instituto de Física, Facultad de Ciencias, Universidad de la República, Iguá 4225, CP 11400 Montevideo, Uruguay; [+]Department of Physics, Carnegie Mellon University, Pittsburgh, PA 15213; [+]Department of Physics and Astronomy, Louisiana State University, Baton Rouge, LA 70803-4001.

Abstract – Unitary is a pillar of quantum theory. Nevertheless, it is also a source of several of its conceptual problems. The authors note that in a world where measurements are relational, as is the case in gravitation, quantum mechanics exhibits a fundamental level of loss of coherence. This can be the key to solving, among others, the puzzles posed by the black hole information paradox, the formation of inhomogeneities in cosmology and the measurement problem in quantum mechanics.

16. A New Scale in the Sky – by M. Gasperini; CERN, Theory Unit, Physics Department, CH-1211 Geneva 23, Switzerland and Dipartimento di Fisica, Università di Bari, Via G. Amendola 173, 70126 Bari, Italy.

Abstract – The existence of a new ultraviolet scale $\Lambda = gM_p$ for effective theories with gravity and U(1) gauge fields has recently been conjectured as a possible criterion for distinguishing parts of the swampland from the string landscape. Here the author discusses a possible phenomenological signature of this scale, for electromagnetic fields, in astrophysical observations.

17. Dark Energy from Gravitational Collapse? – by László Á. Gergely; Departments of Theoretical and Experimental Physics, University of Szeged, Hungary.

Abstract – The author discusses the status of both cosmological and black hole type singularities in the framework of the brane-world model of gravity. He points out that the Big Bang is not properly understood yet. He also shows new features of the gravitational collapse on the brane, the most important being the production of dark energy during the collapse.

18. The Gravity of Quantum Pressure – A New Test of General Relativity – by G.T. Gillies* and C.S. Unnikrishnan[+]; *School of Engineering and Applied Science, University of Virginia, Charlottesville, VA 22904-4746; [+]Gravitation Group, Tata Institute of Fundamental Research, Homi Bhabha Road, Mumbai – 400 005, India.

Abstract – Matter confined to a small volume generates quantum pressure and general relativity in which mass, energy, stress and pressure are all sources of gravity then implies space-time curvature induced by the quantum pressure. Quantum Fermi pressure in nuclei and degeneracy pressure in stars should measurably alter space-time, and thus provide a new test of classical general relativity in which relativistic quantum effects on matter manifest as a modification of classical relativistic gravity. But the situation is subtle owing to the gravity with opposite sign form the surface tension at boundaries confining such quantum matter. The authors discuss the general scenario, the first quantitative empirical investigation, and a successful high precision test of the gravity of quantum pressure.

19. Geometrical Origin of a Cosmological Term – by Richard T. Hammond; Department of Physics, University of North Carolina, Chapel Hill, NC 27599.

Abstract – Nonmetricity derived from a scalar field is shown to exist as a cosmic field, without direct coupling to matter. It leads to a variable cosmological term, a term that dominates the expansion in the early universe but dies away at later time.

20. The Inertia of Heat and its Role in the Dynamics of Dissipative Collapse – by L. Herrera; Escuela de Física, Facultad de Ciencias, Universidad Central de Venezuela, Caracas, Venezuela.

Abstract – The decreasing of the inertial mass density, established in the past for dissipative fluids, is found to be produced by the "inertial" term of the transport equation. Once the transport equation is coupled to the dynamical equation one finds that the contribution of the inertial term diminishes the effective inertial mass and the "gravitational" force term, by the same factor. An intuitive picture and prospective application of this result to astrophysical scenarios are discussed.

21. Black Hole in a Model with Dilaton and Monopole Fields – by E. Kyriakopoulos; Department of Physics, National Technical University, 157 80 Zografou, Athens, Greece.

Abstract – The author presents an exact black hole solution in a model having, besides gravity, a dilaton and a monopole field. The solution has three free parameters, one of which can be identified with the monopole charge, and another with the ADM mass. The metric is asymptotically flat and has two horizons and an irremovable singularity only at $r = 0$. The dilaton field is singular only at $r = 0$. The dominant and the strong energy conditions are satisfied outside and on the external horizon. According to a formulation of the no hair conjecture the solution is "hairy".

22. Probing AdS/CFT with the CMB – by James E. Lidsey and David Seery; Astronomy Unit, School of Mathematical Sciences, Queen Mary, University of London, Mile End Road, London, E1 4NS, U.K.

Abstract – The Randall-Sundrum braneworld scenario may be interpreted within the context of the AdS/CFT correspondence as an approximate four-dimensional CFT coupled to Einstein gravity. It is shown that in this dual formulation, the standard inflationary consistency equation relating the scalar and tensor perturbation spectra becomes modified. The next generation of CMB polarization experiments will be able to detect such a modification if the scalar-to-tensor radio exceeds $r \gtrsim 0.06$.

23. Area and Entropy: A New Perspective – by Jarmo Mäkelä; Vaasa Polytechnic, Wolffintie, 30 FIN-65200, Vaasa, Finland.

Abstract – The author considers a spacelike two-plane originally at rest with respect to electromagnetic radiation in thermal equilibrium. He finds that if the plane is moved with respect to radiation, the plane shrinks such that the maximum amount of entropy carried by radiation through the plane is, in natural units, exactly one-half the decrease in the area of the plane. This result suggests that the equivalence between area and entropy may not be limited to black holes, nor even to the spacetime horizons only, but the equivalence between horizon area and entropy may be just a special case of some general and simple, still undiscovered, fundamental principle of nature.

24. The Holographic Wave Function of the Universe – by Alexander Maloney; SLAC Theory Group, MS 81, 2575 Sand Hill Rd., Menlo Park, CA 94025.

Abstract – The author considers quantum gravity in a closed universe with big bang and big crunch singularities. He provides a holographic description of this spacetime in terms of Euclidean conformal field theory. This resolves many basic conceptual issues in quantum cosmology. The Euclidean CFT defines a Hilbert space and picks out a ground state – essentially, the Hartle-Hawking wave function – for this cosmology. Euclidean CFT correlation functions compute the amplitude for the universe to emerge form the big bang singularity with a given geometry and configuration of particles. In one limit, this state describes a thermal distribution of particles emerging from the big bang. Moreover, CFT correlation functions encode information about the big bang/crunch singularities via a subtle analytic continuation.

25. Dark Energy in Motion – by Antonio L. Maroto; Departamento de Física Teórica, Universidad Complutense de Madrid, 28040 Madrid, Spain.

Abstract – Recent large-scale peculiar velocity surveys suggest that large matter volumes could be moving with appreciable velocity with respect to the CMB rest frame. If confirmed, such results could conflict with the Cosmological Principle according to which the matter and CMB rest frames should converge on very large scales. In this work, the author explores the possibility that such large scale bulk flows are due, not to the motion of matter with respect to the CMB, but to the flow of dark energy with respect to matter. Indeed, when dark energy is moving, the usual definition of the CMB rest frame as that in which the CMB dipole vanished is not appropriate. He finds instead that the dipole vanishes for observers at rest with respect to the *cosmic center of mass*, i.e. in motion with respect to the background radiation.

26. Quantum Determinism from Quantum General Covariance – by Hrvoje Nikolić; Theoretical Physics Division, Rudjer Bošković Institute, P.O.B. 180, HR-10002 Zagreb, Croatia.

Abstract – The requirement of general covariance of quantum field theory naturally leads to quantization based on the manifestly covariant De Donder-Weyl formalism. To recover the standard noncovariant formalism without violating covariance, fields need to depend on time in a specific deterministic manner. This deterministic evolution of quantum fields is recognized as a covariant version of the Bohmian hidden-variable interpretation of quantum field theory.

27. *Quantum* Gravity Points out the Existence of a New Physical Constant in *Classical* Gravity – by Alejandro Perez and Carlo Rovelli; Centre de Physique Theorique de Luminy, F-13288 Marseille, European Union.

Abstract – The quantization of general relativity in the loop representation leads to the appearance of a new constant, the Immirzi parameter. However, it turns out that when gravity is minimally coupled to fermionic matter, the Immirzi parameter affects only the *classical* equations of motion. Therefore in the presence of fermions the Immirzi parameter is measurable also in classical physics, contrary to what is commonly believed. In fact, it is a constant affecting the strength of an effective four-fermion interaction. It is remarkable that research in *quantum* gravity has led to the identification of a *classical* physical coupling constant.

28. A Trapped Dipolar BEC Interferometry Test of $E = mc^2$ – by Fabrizio Pinto; InterStellar Technologies Corporation, 115 North Fifth Avenue, Monrovia, CA 91016.

Abstract – It is shown that, by arranging the atoms in a Bose-Einstein condensate gas within an optical lattice, it is possible to directly verify experimentally that the van der Waals potential energy contributes an effective change to the gravitational mass of the atoms trapped in the array sites equal to that predicted by Einstein's mass-energy equivalency equation, $E = m_g c^2$. Some original results of electrostatics and quantum mechanics in curved space are discussed and strategies to amplify and observe these effects are quantitatively evaluated to illustrate the feasibility of the novel test proposed herein.

29. Cosmological Acceleration from Structure Formation - by Syksy Räsänen; CERN, Physics Theory Department, CH-1211 Geneva 23, Switzerland.

Abstract – The author discusses the Buchert equations, which describe the average expansion of an inhomogeneous dust universe. In the limit of small perturbations, they reduce to the Friedmann-Robertson-Walker equations. However, when the universe is very inhomogeneous, the behavior can be qualitatively different from the Friedmann-Robertson-Walker case. In particular, the average expansion rate can accelerate even though the local expansion rate decelerates everywhere. The author clarifies the physical meaning of this paradoxical feature with a simple toy model, and he demonstrates how acceleration is intimately connected with gravitational collapse. This provides a link to structure formation, which in turn has a preferred time around the era when acceleration has been observed to start.

30. How Many Universes Do There Need to Be? - by Douglas Scott and J.P. Zibin; Department of Physics and Astronomy, University of British Columbia, Vancouver, BC, V6T 1Z1 Canada.

Abstract – In the simplest cosmological models consistent with General Relativity, the total volume of the Universe is either finite or infinite, depending on whether or not the spatial curvature is positive. Current data suggest that the curvature is very close to flat, implying that one can place a lower limit on the total volume. In a Universe of finite age, the 'particle horizon' defines the patch of the Universe which is observable to us. Based on today's best-fit cosmological parameters it is possible to constrain the number of observable Universe sized patches, N_U. Specifically, using the new WMAP data, one can say there are at least 10 patches out there the same volume as ours. Moreover, even if the precision of our cosmological measurements continues to increase, density perturbations at the particle horizon size limit us to never knowing that there are more than about 10^5 patches out there.

31. Fermion Condensation in a Stellar Black Hole: Arrested Collapse and Macroscopic Equilibrium – by M.P. Silverman; Department of Physics, Trinity College, Hartford, CT 06070.

Abstract – Compressed to ultra-nuclear densities, the fermionic matter of a collapsing relativistic degenerate star with mass beyond the Oppenheimer-Volkhoff limit can condense to form a Bose-Einstein condensate. Such condensates have been proposed to produce neutron superfluidity and possibly proton superconductivity in neutron stars. In this essay, the author shows how nucleon condensation to a Bose-Einstein condensate, in conjunction with relativistically exact expressions for fermion energy and degeneracy pressure and the relations for thermodynamic equilibrium in a spherically symmetric spacetime with Schwarzschild metric, lead to stable macroscopic equilibrium states of stellar black holes with no central singularity.

32. String Theory, Quantum Mechanics and Non-commutative Geometry: *A New Perspective on the Gravitational Dynamics of D0-Branes* – by T.P. Singh; Tata Institute of Fundamental Research, Homi Bhabha Road, Mumbai 400 005, India.

Abstract – The symmetries underlying string theory are not known. Furthermore, there must exist an inherently quantum, and spacetime independent, formulation of this theory. Independent of string theory, there should exist a description of quantum mechanics which does not refer to a classical spacetime manifold. The author proposes such a formulation of quantum mechanics based on noncommutative geometry. This description reduces to standard quantum mechanics whenever an external classical spacetime is available. However, near the Planck energy scale, self-gravity effects modify the Schrödinger equation to the non-linear Doebner-Goldin equation. Remarkably, this non-linear equation also arises in the quantum dynamics of D0-branes. This suggests that the non-commutative quantum mechanics proposed here is actually the quantum gravitational mechanics of D0-branes, and that automorphism invariance is a symmetry of string theory.

33. Quasinormal Spectrum and the Black Hole Membrane Paradigm – by A.O. Starinets; Perimeter Institute for Theoretical Physics, Waterloo, ON N2L 2Y5, Canada.

Abstract – The membrane paradigm approach to black hole physics introduces the notion of a stretched horizon as a fictitious time-like surface with physical characteristics such as entropy, viscosity, and electrical conductivity attributed to it. The author shows that certain properties of stretched horizons are encoded in the quasinormal spectrum of black holes. He computes analytically the lowest quasinormal frequency of the vector-type perturbation for a generic black hole with a translationally invariant horizon (black brane) in terms of the metric components. The resulting dispersion relation is identical to the one obtained in the membrane paradigm treatment of the diffusion on stretched horizons. He also shows that in the long wavelength limit the generic black brane spectrum of gravitational perturbations exhibits a universal, purely imaginary quasinormal frequency.