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Abstracts of Award Winning and Honorable Mention Essays for 2003

Award Essays

First Award – Initial Conditions for a Universe – by Martin Bojowald, Center for Gravitational Physics and Geometry, The Pennsylvania State University, 104 Davey Lab, University Park, PA 16802.

Abstract – In physical theories, boundary or initial conditions play the role of selecting special situations that can be described by a theory with its general laws. Cosmology has long been suspected to be different in that its fundamental theory should explain the fact that we can observe only one particular realization. This is not realized, however, in the classical formulation and in its conventional quantization; the situation is even worse due to the singularity problem. In recent years, a new formulation of quantum cosmology has been developed which is based on quantum geometry, a candidate for a theory of quantum gravity. Here, the dynamical law and initial conditions turn out to be linked intimately, in combination with a solution of the singularity problem.

Second Award – Supersymmetry, the Cosmological Constant, and a Theory of Quantum Gravity in Our Universe – by T. Banks, SCIPP, University of California, Santa Cruz, CA 95064 and NHETC, Rutgers University, Piscataway, NJ 08854.

Abstract – There are many theories of quantum gravity, depending on asymptotic boundary conditions and the amount of supersymmetry. The cosmological constant is one of the fundamental parameters that characterize different theories. If it is positive, supersymmetry must be broken. A heuristic calculation shows that a cosmological constant of the observed size predicts superpartners in the TeV range. This mechanism for SUSY breaking also puts important constraints on low energy particle physics models.

Third Award – Preheating and Turbulence: Echoes of a Not So Quiet Universe – by H.P. de Oliveira[*] and I. Damião Soares[+], [*]Universidade do Estado do Rio de Janeiro, Instituto de Física, Departamento de Física Teórica, CEP 20550-013, Rio de Janeiro, RJ, Brazil; [+]Centro Brasileiro de Pesquisas Físicas, Rua Dr. Xavier Sigaud, 150 CEP 22290-180, Rio de Janeiro, RJ, Brazil.

Abstract – The authors study the nonlinear decay of the inflaton which causes the reheating of the Universe in the transition from the inflationary phase to the radiation dominated phase, resulting in the creation of almost all matter constituting the present Universe. Their treatment allows them to follow the full dynamics of the system in a long time regime and to describe not only the parametric resonance processes with nonlinear restructuring but also to characterize a final turbulent state in the dynamics by which the energy is nonlinearly transferred to all scales of the system with a consequent thermalization of the created matter.

Fourth Award – Deconstructing the Cosmological Constant – by Vishnu Jejjala[*], Robert G. Leigh[+#], and Djordje Minic[*], [*]Institute for Particle Physics and Astrophysics, Department of Physics, Virginia Tech, Blacksburg, VA 24061; [+]CERN-Theory Division CH-1211, Geneva 23, Switzerland; [#]Department of Physics, University of Illinois at Urbana-Champaign, 1110 W. Green Street, Urbana, IL 61801.

Abstract – Deconstruction provides a novel way of dealing with the notoriously difficult ultraviolet problems of four-dimensional gravity. This approach also leads naturally to a new perspective on the holographic principle, tying it to the fundamental requirements of unitarity and diffeomorphism invariance, as well as to a new viewpoint on the cosmological constant problem. The numerical smallness of the cosmological constant is implied by a unique combination of holography and supersymmetry, opening a new window into the fundamental physics of the vacuum.

Fifth Award – Why Gravity Has No Choice: Bulk Spacetime Dynamics Is Dictated by Information Entanglement across Horizons – by T. Padmanabhan, IUCAA, Post Bag 4, Ganeshkhind, Pune – 411 007, India.

Abstract – The principle of equivalence implies that gravity affects the light cone (casual) structure of the space-time. It follows that there will exist observers (in any space-time) who do not have access to regions of space-time bounded by horizons. Since physical theories in a given coordinate system must be formulated entirely in terms of variables which an observer using that coordinate system can access, the gravitational action functional must contain a *foliation dependent* surface term which encodes the information inaccessible to the particular observer. The author shows that (i) It is possible to determine the nature of this surface term from general symmetry considerations and proves that the entropy of any horizon is proportional to its area. (ii) The gravitational action can be determined using a differential geometric identity related to this surface term. The dynamics of spacetime is dictated by the nature of quantum entanglements across the horizons and the flow of information, *making gravity inherently quantum mechanical at all scales*. (iii) In static space-times, the action for gravity can be given a purely thermodynamic interpretation and the Einstein equations have a formal similarity to laws of thermodynamics. (iv) The horizon area must be quantized with $A_{horizon} = (8\pi G\hbar/c^3)m$ with $m = 1,2,\cdots$ in the semi-classical limit.

Honorable Mention Awards (Alphabetical Order)

1. The Asymptotic Structure of Space-Time – by Fred C. Adams, Michael T. Busha, August E. Evrard, and Risa Wechsler, Michigan Center for Theoretical Physics, University of Michigan, Ann Arbor, MI 48109.

Abstract – Astronomical observations strongly suggest that the universe is now accelerating and contains a substantial admixture of dark vacuum energy. Using numerical simulations to study this newly consolidated model (with a constant density of dark energy), the authors show that astronomical structures freeze out in the near future and that the density profiles of dark matter halos approach the same general form. Every dark matter halo grows asymptotically isolated and thereby becomes the center of its own island universe. Each of these isolated regions of space-time approaches a universal geometry and the authors calculate the corresponding form of the space-time metric.

2. Spacetime as Origin of Neutrino Oscillations – by D.V. Ahluwalia-Khalilova[*] and Irina Dymnikova[+], [*]Department of Mathematics, Ap. Postal C-600, University of Zacatecas (UAZ), Zacatecas, ZAC 98062, Mexico; [+]Department of Mathematics and Computer Science, University of Warmia and Mazury, Żołnierska 14, Olsztyn 10-561, Poland.

Abstract – The fundamental question that the authors ask is; What is the spacetime symmetry group around a gravito-electroweak vertex? Arguing in favor of de Sitter over Poincaré in the immediate vicinity of the vertex they decipher the physical origin of neutrino oscillations. With that conjecture, neutrinos are described by eigenstates of the de Sitter Casimirs. Their consequent evolution in the Minkowski region requires these eigenstates to be decomposed in terms of the Casimir invariants of the Poincaré group. The "flavor" emerges due to a change in the symmetry group from de Sitter to Poincaré. The authors find a relation between mass-squared differences for neutrinos and the unification scale for gravity. The measured mass-squared differences then predict a TeV scale for unification and a dominantly bi-maximal mixing for neutrinos. The latter is in agreement with existing data and with the observed *L/E* flatness of the e-like event ratio in Super-Kamiokande's atmospheric neutrino data. This framework also offers a natural explanation for certain anomalous results, which have come to be known as "negative mass squared problem" for $\bar{\nu}_e$.

3. Cosmic Black Holes – by Eun-Joo Ahn[*] and Marco Cavaglià[+], [*]Department of Astronomy and Astrophysics and Center for Cosmological Physics, University of Chicago, 5640 S. Ellis Ave., Chicago, IL 60637; [+]Institute of Cosmology and Gravitation, University of Portsmouth, Portsmouth PO1 2EG, United Kingdom.

Abstract – Production of high-energy gravitational objects is a common feature of gravitational theories. The primordial universe is a natural setting for the creation of black holes and other nonpertubative gravitational entities. Cosmic black holes can be used to probe physical properties of the very early universe that would usually require the knowledge of the theory of quantum gravity. They may be the only tools to explore thermalisation of the early universe. Whereas the creation of cosmic black holes was active in the past, it seems to be negligible at the present epoch.

4. Proposal of a Second Generation of Quantum-Gravity-Motivated Lorentz Symmetry Tests: Sensitivity to Effects Suppressed Quadractically by the Planck Scale – by Giovanni Amelino-Camelia, Dip. Fisica Univ. Roma "La Sapienza" and Sez. Roma1 INFN, Piazzale Moro 2, 00185 Roma, Italy.

Abstract – Over the last few years the study of possible Planck-scale departures from classical Lorentz symmetry has been one of the most active areas of quantum-gravity research. We now have a satisfactory description of the fate of Lorentz symmetry in the most popular noncommutative spacetimes and in loop quantum gravity, and remarkably there are planned experiments with enough sensitivity to reveal these quantum-spacetime effects, if their magnitude is only linearly suppressed by the Planck length. Unfortunately, in some quantum-gravity scenarios even the strongest quantum-spacetime effects are suppressed by at least two powers of the Planck length, and it was until now believed that it would be impossible to test these quadratically-suppressed effects. Exploiting some features of planned cosmic-ray observatories and neutrino observatories, the author proposes an experimental programme that can achieve the sensitivity levels required for testing departures from Lorentz symmetry that are quadratically Planck-length suppressed.

5. Action Based Approach to the Dynamics of Extended Bodies in General Relativity – by Jeeva Anandan[*], Naresh Dadhich[+], and Parampreet Singh[+], [*]Department of Physics and Astronomy, University of South Carolina, Columbia, SC 29208; [+]Inter-University Centre for Astronomy and Astrophysics, Post Bag 4, Ganeshkhind, Pune 411 007, India.

Abstract – The authors present, for the first time, an action principle that gives the equations of motion of an extended body possessing multipole moments in an external gravitational field, in the weak field limit. From the action, the experimentally observable quantum phase shifts in the wavefunction of an extended object due to the coupling of its multipole moments with the gravitational field are obtained. Also, since the theory may be quanitized using the action, the present approach is useful in the interface between general relativity and quantum mechanics.

6. Analogue Models for FRW Cosmologies – by Carlos Barceló[*], Stefano Liberati[+], and Matt Visser[#], [*]Institute of Cosmology and Gravitation, University of Portsmouth, PO1 2EG, England; [+]Physics Department, University of Maryland, College Park, MD 20742-4111; [#]School of Mathematical and Computing Sciences, Victoria University of Wellington, New Zealand.

Abstract – It is by now well known that various condensed matter systems may be used to mimic many of the kinematic aspects of general relativity and in particular of curved-spacetime quantum field theory. In this essay the authors take a look at what would be needed to mimic a cosmological spacetime - to be precise a spatially flat FRW cosmology - in one of these analogue models. In order to do this one needs to build and control suitable time dependent systems. The authors discuss here two quite different ways to achieve this goal. One might rely on an explosion, physically mimicking the big bang by an outflow of whatever medium is being used to carry the excitations of the analogue model, but this idea appears to encounter dynamical problems in practice. More subtly, one can avoid the need for any actual physical motion (and avoid the dynamical problems) by instead adjusting the propagation speed of the excitations of the analogue model. The authors focus on this more promising route and discuss its practicality.

7. Generalized Chaplygin Gas Model: Dark Energy – Dark Matter Unification and CMBR Constraints – by M.C. Bento, O. Bertolami, and A.A. Sen, Instituto Superior Técnico, Departamento de Física, Av. Rovisco Pais 1, 1049-001 Lisboa, Portugal.

Abstract – The generalized Chaplygin gas model allows for a unified description of the recent accelerated expansion of the Universe and the evolution of energy density perturbations. This dark energy – dark matter unification is achieved through an exotic background fluid whose equation of state is given by $p = -A/\rho^{\alpha}$, where A is a positive constant and $0 < \alpha \leq 1$. Stringent constraints on the model parameters can be obtained from recent WMAP and BOOMERanG bounds on locations of the first few peaks and troughs of the Cosmic Microwave Background Radiation power spectrum as well as SNe Ia data.

8. Closed Timelike Curves in Classical Relativity – by W.B. Bonnor, Queen Mary, University of London, London E1 4NS, United Kingdom.

Abstract – Spacetimes of general relativity containing closed timelike curves are usually dismissed as non-physical. However, it is now known that closed timelike lines may appear in spacetimes modeling simple laboratory experiments. Two such experiments are described in this essay. We therefore need a realistic interpretation of closed timelike curves. The author suggests that a region containing closed timelike curves may represent a new type of singularity, called a torsion singularity.

9. Condensation of Planckian Modes and the Inflaton – by Robert Brout, Service de Physique Théorique, CP 225, Université Libre de Bruxelles, Blvd du Triomphe, 1050 Brussels, Belgium.

Abstract – To confront the transplanckian problem encountered in the backward extrapolation of the cosmological expansion of the momenta of the modes of quantum field theory, it is proposed that there is a reservoir depository of transplanckian degrees of freedom. These are solicited by the cisplanckian modes so as to keep their density fixed and the total energy density of vacuum at a minimum. The mechanism is due to mode-reservoir interaction, whereupon virtual quantum processes give rise to an effective mode-mode attraction. A BCS condensate results. It has a massless and massy collective excitation, the latter identified with the inflaton. For an effective non dimensional mode-reservoir coupling constant, $g \cong 0.3$, the order of magnitude of its mass is what is required to account for cosmological fluctuations i.e. $O(10^{-6} - 10^{-5}) m_{Planck}$.

10. Dark Energy as Extra–Dimensional Gravity – by C.P. Burgess, Physics Department, McGill University, 3600 University St., Montréal, Québec, Canada, H3A 2T8.

Abstract – The nature of dark energy, which presently dominates the universal energy budget, remains a complete mystery. Models in which it is currently evolving tend to be overly sensitive to initial conditions, and necessarily involve a very light degree of freedom that is very difficult to obtain from realistic microscopic physics. This essay describes recent progress in understanding how the dark energy can arise as a residue of extra-dimensional gravitation, leading to new insights into how dark-energy cosmology might work. This picture produces dark energy dynamics within which couplings slowly run (or 'walk') over cosmological times. It also has several unusual experimental predictions including measurable modifications to Newton's Law on sub-millimeter scales and dramatic implications at next-generation collider experiments.

11. Black Hole Singularities, Critical Phenomena, the Runaway Universe, and Hyperspace Travel – by Lior M. Burko, Department of Physics, University of Utah, Salt Lake City, UT 84112.

Abstract – Black holes are always irradiated by the cosmic background radiation. This captured radiation field determines the physical and geometrical nature of the singularity inside the black hole. The author finds that a non-compact radiation field (similar to the cosmic background radiation) affects dramatically the singularity and may determine the fate of a falling astronaut. In particular, the dark energy which accelerates the expansion of the universe determines whether the "tunnel" inside the black hole is blocked or whether the possibility of using the black hole as a portal for hyperspace travel may still be possible.

12. Some Consequences of a Generalization to Heisenberg Algebra in Quantum Electrodynamics – by A. Camacho, Physics Department, Universidad Autónoma Metropolitana-Iztapalapa, P.O. Box 55-534, C.P. 09340, México, D.F., México.

Abstract – In this essay it will be shown that the introduction of a modification to Heisenberg algebra (here this feature means the existence of a minimal observable length), as a fundamental part of the quantization process of the electrodynamical field, renders states in which the uncertainties in the two quadrature components violate the usual Heisenberg uncertainty relation. Hence in this context it may be asserted that any physically realistic generalization of the uncertainty principle must include, not only a minimal observable length, but also a minimal observable momentum.

13. On the Vacuum Entropy and the Cosmological Constant – by Saulo Carneiro, Instituto de Física, Universidade Federal da Bahia, 40210-340, Salvador, BA, Brazil.

Abstract – It is generally accepted that the entropy of an asymptotically de Sitter universe is bounded by the area, in Planck units, of the de Sitter horizon. Based on an analysis of the entropy associated to the vacuum quantum fluctuations, the author suggests that the existence of such a holographic bound constitutes a possible explanation for the observed value of the cosmological constant, theoretically justifying a relation proposed 35 years ago by Zel'dovich.

14. Quantum Interference to Measure Spacetime Curvature: A Proposed Experiment at the Intersection of Quantum Mechanics and General Relativity – by Raymond Y. Chiao and Achilles D. Speliotopoulos, Department of Physics, University of California, Berkeley, CA 94720-7300.

Abstract – An experiment in Low Earth Orbit is proposed to measure components of the Riemann curvature tensor using atom inerferometry. The authors show that the difference in the quantum phase $\Delta\phi$ of an atom that can travel along two intersecting geodesics is given by $mR_{oioj}/\hbar$ times the spacetime volume contained within the geodesics. The expression for $\Delta\phi$ also holds for gravitational waves in the long wavelength limit.

15. The New Planck Scale: Quantized Spin and Charge Coupled to Gravity – by F.I. Cooperstock[*] and V. Faraoni[+], [*]Department of Physics and Astronomy, University of Victoria, P.O. Box 3055, Victoria, B.C. V8W 3P6, Canada; [+]Physics Department, University of Northern British Columbia, 3333 University Way, Prince George, B.C. V2N 4Z9, Canada.

Abstract – In the standard approach to defining a Planck scale where gravity is brought into the quantum domain, the Schwarzchild gravitational radius is set equal to the Compton wavelength. However, ignored thereby are the charge and spin, the fundamental quantized aspects of matter. The gravitational and null-surface radii of the Kerr-Newman metric are used to introduce spin and charge into a new extended Planck scale. The fine structure constant appears in the extended Planck mass and the recent discovery of the α variation with the evolution of the universe adds further significance. An extended Planck charge and Planck spin are derived. There is an intriguing suggestion of a connection with the α value governing high-energy radiation in Z-boson production and decay.

16. Holographic Bounds on Hilbert Space – by Lawrence B. Crowell, Alpha Institute of Advanced Study, 11 Rutafa Street, H-1165, Budapest, Hungary.

Abstract – This essay discusses the squeezing of states and the holographic principle. A volume of space will contain field modes determined by the boundary surrounding the volume. Consider a black hole within this volume. The fields within this volume will approach the black hole and become "pinned" to the event horizon as seen by an exterior observer. The metric fluctuations within this volume predicted by the holographic principle are demonstrated to exhibit a parametric amplification. As a consequence quantum states as they approach the black hole become squeezed states. This is then used to recover the entropy of the black hole. These results indicate that there are bounds on the size of Hilbert space that are scale dependent.

17. General Relativity Provides New Hints for a Quantum Theory of Gravity – by Olaf Dreyer, Perimeter Institute for Theoretical Physics, 35 King Street North, Waterloo, Ontario N2J 2W9, Canada.

Abstract – The search for a quantum theory of gravity has followed two parallel but different paths. One aims at arriving at the final theory starting from a priori assumptions as to its form and building it from the ground up. The other tries to infer as much as possible about the unknown theory from the existing ones and to use our current knowledge to constrain the possibilities for the quantum theory of gravity. Probably the biggest success of the second path has been the results of black hole thermodynamics. The subject of this essay is a new, highly promising such result, the application of quasinormal modes in quantum gravity.

18. Hidden Structures in Three Closed Cosmological Models – by Arthur E. Fischer* and Vincent Moncrief+, *Department of Mathematics, University of California, Santa Cruz, CA 95064; +Departments of Mathematics and Physics, Yale University, New Haven, CT 06511.

Abstract – Using known Bianchi models, the authors study three closed cosmological models whose physical metrics have spatial volumes that expand to infinity, and curvatures that flatten to zero as befits models of this expanding type. However, they show that in each of these three models, there are hidden structures whose characteristics are very different from these well-known physical characteristics. By conformally deforming the physical variables, it is shown that the conformal volume collapses rather than expands to infinity while, remarkably, the conformal curvature invariants remain bounded and non-zero. Thus these three models provide *naturally occurring relativistic examples of Riemannian manifolds, which exhibit precisely the phenomenon of volume collapse with bounded non-zero curvature,* exactly as occurs in certain geometrization conjectures of 3-manifold topology.

19. Discrete Quantum Gravity: a Mechanism for the Darwinian Selection of Universes – by Rodolfo Gambini* and Jorge Pullin+, *Instituto de Física, Facultad de Ciencias, Universidad de la República, Iguá esq. Mataojo, CP 11400 Montevideo, Uruguay; +Department of Physics and Astronomy, Louisiana State University, 202 Nicholson Hall, Baton Rouge, LA 70803-4001.

Abstract – Smolin has put forward the proposal that the universe fine-tunes the values of its physical constants through a Darwinian selection process. Every time a black hole forms, a new universe is developed inside it that has different values for its physical constants from the ones in its progenitor. The most likely universe is the one that maximizes the number of black holes. Here the authors present a concrete quantum gravity calculation showing that fundamental physical constants change in a random fashion when tunneling through a singularity.

20. <u>Information Entropy in Cosmology</u> – by Akio Hosoya[*], Thomas Buchert[*+#], and Masaaki Morita[&%], [*]Department of Physics, Tokyo Institute of Technology, Oh-Okayama, Meguro-ku, Tokyo 152-0033, Japan; [+]Theoretische Physik, Ludwig-Maximilians-Universität, Theresienstr. 37, D-80333 München, Germany; [#]Department of Physics and Research Center for the Early Universe (RESCEU), School of Science, The University of Tokyo, Tokyo 113-0033, Japan; [&]Department of Physics, Ochanomizu University, Ohtsuka, Bunkyo-ku, Tokyo 112-8610, Japan; [%]Advanced Research Institute for Science and Engineering, Waseda University, Ohkubo, Shinjuku-ku, Tokyo 169-8555, Japan.

Abstract – The effective evolution of an inhomogeneous cosmological model may be described in terms of spatially averaged variables. The authors point out that in this context, quite naturally, a measure arises which is identical to a fluid model of the 'Kullback-Leibler Relative Information Entropy', expressing the distinguishability of the local inhomogeneous mass density field from its spatial average on arbitrary compact domains. They discuss the time-evolution of 'effective information' and explore some implications. The authors conjecture that the information content of the Universe – measured by Relative Information Entropy of a cosmological model containing dust matter – is increasing.

21. <u>Precursors See inside Black Holes</u> – by Veronika E. Hubeny, Department of Physics, Stanford University, Stanford, CA 94305.

Abstract – The author considers, within a string theoretic context, the accessibility of events inside a black hole horizon. The author presents a gedanken experiment that uses the nonlocal nature of precursors in the AdS/CFT correspondence, as well as the global nature of event horizons, to argue that the dual field theory does contain information about physics inside black holes. This alleviates the causal obstacles to accessing behind-the-horizon physics, thereby rendering more tractable certain long-standing questions of quantum gravity, such as the information paradox and possibly even singularity resolution.

22. <u>Classical Scale of Quantum Gravity</u> – by Kirill A. Kazakov, Department of Theoretical Physics, Physics Faculty, Moscow State University, 119899, Moscow, Russian Federation.

Abstract – The characteristic length scale of the post-Newtonian corrections to the gravitational field of a body is given by its gravitational radius r_g. The role of this scale in the quantum domain is discussed in the context of the low-energy effective theory. The question of whether quantum gravity effects appear already at r_g leads to the question of the correspondence between classical and quantum theories, which in turn can be unambiguously resolved considering the issue of general covariance. The $O(\hbar^0)$ loop contributions turn out to violate the principle of general covariance, thus revealing their essentially quantum nature. This violation is $O(1/N)$, where N is the number of particles in the body, which leads naturally to a macroscopic formulation of the correspondence principle.

23. <u>Affine Quantum Gravity</u> – by John R. Klauder, Department of Physics, University of Florida, Gainesville, FL 32611-2085.

Abstract – Any approach to quantum gravity must contend with several issues associated with Einstein's gravitational theory. Three major issues are addressed in the author's essay. The first issue requires that spatial distances between distinct points are manifestly positive in acceptable quantum formulations. The nest issue involves coordinate invariance and the associated constraint equations. Corresponding quantum constraints exhibit inconsistencies that must be overcome. The last issue is the perturbative nonrenormalizability of the standard formulation and the consequent lack of a closed formulation that ensues. The new program of affine quantum gravity addresses these issues: metric positivity is deliberately built in; the projection operator method incorporates inconsistent constraints naturally: and the hard-core picture of non-renormalizable interactions is proposed as a resolution.

24. How Does the Universe Expand? – by Samir D. Mathur, Department of Physics, The Ohio State University, Columbus, OH 43210.

Abstract – Quantization of gravity suggests that a finite region of space has a finite number of degrees of freedom or 'bits'. What happens to these bits when spacetime expands, as in cosmological evolution? Using gravity/field theory duality the author argues that bits 'fuse together' when space expands.

25. Variability of Fundamental Constants – by Asher Peres, Department of Physics, Technion – Israel Institute of Technology, 32000, Haifa, Israel.

Abstract – Are universal fundamental constants really constant over cosmological times? Recent observations of the fine structure of spectral lines in the early universe have been interpreted as due to a variation of the fine structure constant $e^2/4\pi\varepsilon_0\hbar c$. From the assumed validity of Maxwell equations in general relativity and well known experimental facts, it is proved that e and $\hbar$ are absolute constants. One the other hand, the speed of light need not be constant.

26. Interplay of the Quantum Vacuum, the Gravitation of All the Universe and the Fourth Heisenberg Relation – by Antonio F. Rañada; Facultad de Física, Universidad Complutense, E-28040 Madrid, Spain.

Abstract – A recently proposed model that accounts for the observed time dependence of the fine structure constant is summarized. It is shown that it suggests moreover an explanation of the unmodeled acceleration $a_P \cong 8.5 \times 10^{-10}$ m/s^2 found in the Pioneer 10 spacecraft, as a combined effect of the fourth Heisenberg relation, the quantum vacuum, and the gravitation of all the universe.

27. Black Hole Thermodynamics Need Not Constrain Varying Constants – by C. Sivaram, Indian Institute of Astrophysics, Bangalore 560034, India.

Abstract – Recent observations especially of distant supernovae and anisotropies in the cosmic microwave background seem to provide strong evidence of a strong energy (or quintessence) dominating the dynamics of the universe with indications that this repulsive component may even be varying with time. Observational evidence of shifted spectral lines in distant quasars has added to the recent excitement, in that it suggests that the fine structure constant has slowly increased over cosmological time scales. This may provide support to some recent theories suggesting a varying electric charge or varying speed of light to solve some of the cosmological conundrums. The author makes a critical study of how black hole thermodynamics can constrain variations of several constants including a varying cosmological constant. He concludes that such variations are not necessarily ruled out by black hole physics.

28. The Pauli Exclusion Principle and $SU(2)$ vs. $SO(3)$ in Loop Quantum Gravity – by John Swain, Department of Physics, Northeastern University, Boston, MA 02115.

Abstract – Recent attempts to resolve the ambiguity in the loop quantum gravity description of the quantization of area has led to the idea that $j = 1$ edges of spin-networks dominate in their contribution to black hole areas as opposed to $j = ½$ which would naively be expected. This suggests that the true gauge group involved might be $SO(3)$ rather than $SU(2)$ with attendant difficulties. The author argues that the assumption that a version of the Pauli principle is present in loop quantum gravity allows one to maintain $SU(2)$ as the gauge group while still naturally achieving the desired suppression of spin-1/2 punctures. Areas come from $j = 1$ punctures rather than $j = ½$ punctures for much the same reason that photons lead to macroscopic classically observable fields while electrons do not.

29. The Bubbling Universe – by Tanmay Vachaspati, Department of Physics, Case Western Reserve University, 10900 Euclid Avenue, Cleveland, OH 44106-7079.

Abstract – The scenario of an expanding universe envisioned in the early part of the 20th century has been replaced by one where we live in a chaotic, eternally bubbling universe. Every bubble has the potential for developing into a new habitable universe. In this essay the author describes how large-scale quantum effects could be driving the chaotic bubbling universe.

30. The Evolution of the Universe – by Mian Wang, Department of Physics, Henan Normal University, Xinxiang, Henan, China, 453002.

Abstract – Inflationary cosmology predicts that the universe after inflation is flat. Recent observations confirm this with $\Omega = \Omega_m + \Omega_{DM} + \Omega_{DE} = 1$ and $-0.7 < w < -0.3$. The dark energy is responsible for the cosmic acceleration as well as for determining the future evolution of the universe. In this paper, the author discusses the evolution of the universe in the framework of a scalar-tensor cosmology. The universe is created from the instanton effect of the gravitational field ϕ and immediately undergoes inflation by virtue of the cosmological function $\lambda(\phi)$. The inflationary period is followed by an era of power-law expansion and then the universe goes into a period of acceleration, which is followed successively by periods of deceleration and eventual contraction.

31. Is Mass Quantized? – by Paul S. Wesson, Dept. of Physics, University of Waterloo, Ontario N2L 3G1, Canada.

Abstract – The cosmological constant combined with Planck's constant and the speed of light implies a quantum mass of approximately 2×10^{-65} g. This follows either from a generic dimensional analysis, or from a specific analysis where the cosmological constant appears in 4D spacetime as the result of a dimensional reduction from higher dimensional relativity (such as 5D induced-matter and membrane theory). In the latter type of theory, all the particles in the universe can be in higher-dimensional contact.

32. Radiation Reaction and the Principle of Equivalence – by Bernard F. Whiting and Steven Detweiler, Department of Physics, P.O. Box 118440, University of Florida, Gainesville, FL 32611-8440.

Abstract – The principle of equivalence is shown to extend to situations involving radiation reaction. For example, the Lorentz force law governs the motion of a small isolated charge undergoing radiation reaction. In the case of an isolated uncharged particle of small mass, it is the geodesic equation that governs the motion, even when radiation reaction is included. For a local observer to understand such motion he must subtract the singular field of the particle from the actual electromagnetic and gravitational fields he measures. With the correct subtraction of the singular part, locally source-free fields are then used in computing the motion of each particle.