Abstracts of Award Winning and Honorable Mention Essays for 2001

Award Essays

First Award - The Cosmological Constant Problem in Brane-Worlds and Gravitational Lorentz Violations – by Csaba Csáki[*], Joshua Erlich[*] and Christophe Grojean[+], [*]Theory Division T-8, Los Alamos National Laboratory, Los Alamos, NM 87545; [+]Department of Physics, University of California, Berkeley, CA 94720 and Theoretical Physics Group, Lawrence Berkeley National Laboratory, Berkeley, CA 94720.

Abstract - Brane worlds are theories with extra spatial dimensions in which ordinary matter is localized on a (3+1) dimensional submanifold. Such theories could have interesting consequences for particle physics and gravitational physics. In this essay the authors concentrate on the cosmological constant problem in the context of brane worlds. They show how extra-dimensional scenarios may violate Lorentz invariance in the gravity sector of the effective 4D theory, while particle physics remains unaffected. In such theories the usual no-go theorems for adjustment of the cosmological constant do not apply and the authors indicate a possible explanation of the smallness of the cosmological constant. Lorentz violating effects would manifest themselves in gravitational waves traveling with a speed different from light, which can be searched for in gravitational wave experiments.

Second Award - Black Holes Are One-dimensional – by Jacob D. Bekenstein and Avraham E. Mayo, The Racah Institute of Physics, Hebrew University of Jerusalem, Givat Ram, Jerusalem 91904, Israel.

Abstract - The holographic principle has revealed that physical systems in 3-D space, black holes included, are basically two-dimensional as far as their information content is concerned. This conclusion is complemented by one sketched here: as far as entropy or information flow is concerned, a black hole behaves as a one-dimensional channel. The authors define a channel in flat spacetime in thermodynamic terms and contrast it with common entropy emitting systems. A black hole is more like the former: its entropy output is related to the emitted power as it would be for a one-dimensional channel, and disposal of an information stream down a black hole is limited by the power invested in the same way as for a one-dimensional channel.

Third Award - The Generalized Uncertainty Principle and Black Hole Remnants – by Ronald J. Adler[*], Pisin Chen[+], and David I. Santiago[#], [*]Gravity Probe B, W. W. Hansen Experimental Physics Laboratory, Stanford University, Stanford CA 94035; [+]Stanford Linear Accelerator Center, Stanford University, Stanford CA 94309; [#]Department of Physics, Stanford University, Stanford CA 94035.

Abstract - In the current standard viewpoint small black holes are believed to emit black body radiation at the Hawking temperature, at least until they approach Planck size, after which their fate is open to conjecture. A cogent argument against the existence of remnants is that, since no evident quantum number prevents it, black holes should radiate completely away to photons and other ordinary stable particles and vacuum, like any unstable quantum system. Here the authors argue the contrary, that the generalized uncertainty principle may prevent their total evaporation in exactly the same way that the uncertainly principle prevents the hydrogen atom from total collapse: the collapse is prevented, not by symmetry, but by dynamics, as a minimum size and mass are approached.

Fourth Award - Symmetry Breaking for Matter Coupled to Linearized Supergravity from the Perspective of the Current Supermultiplet – by Stephen L. Adler, Institute for Advanced Study, Princeton, NJ 08540.

Abstract - The author considers a generic supersymmetric matter theory coupled to linearized supergravity and analyzes scenarios for spontaneous symmetry breaking in terms of vacuum expectation values of components of the current supermultiplet. When the vacuum expectation of the energy momentum tensor is zero, but the scalar current or pseudoscalar current gets an expectation, evaluation of the gravitino self energy using the supersymmetry current algebra shows that there is an induced gravitino mass term. The structure of this term generalizes the supergravity action with cosmological constant to theories with CP violation. When the vacuum expectation of the energy momentum tensor is nonzero, supersymmetry is broken; requiring cancellation of the cosmological constant gives the corresponding generalized gravitino mass formula.

Fifth Award - A Planck-like Problem for Quantum Charged Black Holes - A. Fabbri[*], D.J. Navarro[+], and J. Navarro-Salas[+], [*]Dipartimento di Fisica dell'Università di Bologna and INFN sezione di Bologna, Via Irnerio 46, 40126 Bologna, Italy; [+]Departamento de Física Teórica and IFIC, Centro Mixto Universidad de Valencia-CSIC, Facultad de Física, Universidad de Valencia, Burjassot-46100, Valencia, Spain.

Abstract - Motivated by the parallelism existing between the puzzles of classical physics at the beginning of the XXth century and the current paradoxes in the search of a quantum theory of gravity, the authors give, in analogy with Planck's black body radiation problem, a solution for the exact Hawking flux of evaporating Reissner-Nordström black holes. Their results show that when black-reaction effects are fully taken into account the standard picture of black hole evaporation is significantly altered, thus implying a possible resolution of the information loss problem.

Honorable Mention Awards (Alphabetical Order)

1. Space-time Fluctuations as an Origin of Cosmological CP Violation - by D.V. Ahluwalia[*] and M. Kirchbach[+], [*]ISGBG, Escuela de Fisica de la UAZ, Ap. Postal C-600, Zacatecas 98062, Mexico; [+] Escuela de Fisica de la UAZ, Ap. Postal C-600, Zacatecas 98062, Mexico.

Abstract - The observed cosmological matter-antimatter asymmetry is shown here to arise from asymmetric space-time fluctuations and their interplay with the Stückelberg-Feynman interpretation of antimatter. The thesis presented also suggests that the fine structure constant must have been smaller in the past. Recent studies of QSO absorption lines provide a 4.1 standard deviation support for this prediction.

2. UEHCR and Mk501 Data as a Possible Manifestation of Planck-Scale Physics - by Giovanni Amelino-Camelia[*] and Tsvi Piran[+], [*]Dipart. Fisica Univ. Roma "La Sapienza" and Sez. Roma1 INFN, Piazzale Moro 2, 00185 Roma, Italy; [+]Racah Institute of Physics, Hebrew University, Jerusalem 91904, Israel.

Abstract - The observations of cosmic rays with energies above the Greisen-Zatsepin-Kuzmin threshold and of multi-TeV photons from Mk501 appear to be inconsistent with conventional theories. The authors propose that both paradoxes arise due to a deformation of Lorentz invariance: a "low-energy" manifestation of Planck-scale physics. Lorentz invariance deformation appears in several approaches to Quantum Gravity, including canonical noncommutative geometry found in String Theory, weave states of Loop Quantum Gravity, phenomenological models of "space-time foam," and Lie-algebra noncommutative geometry. The authors show that a Planck-scale modification of the dispersion relation is consistent with all available data. This is the only current model that explains the two threshold anomalies simultaneously. The improved sensitivity of next-generation detectors will allow detailed tests of this interpretation. It might even provide observational tests that could distinguish between the different approaches to Quantum Gravity.

3. The Lazarus Project: New Life in the Theory of Dying Black Hole Binaries – by John Baker, Manuela Campanelli, and Carlos Lousto, Albert-Einstein-Institut, Max-Planck-Institut für Gravitationsphyisik, Am Mühlenberg 1, D-14476 Golm, Germany.

Abstract - The authors advocate a new approach to numerical relativity which brings the field for the first time close to providing useful astrophysical information about the orbital merger of binary black holes relevant for interferometric gravitational wave detectors. Their technique combines the full numerical approach to solve Einstein equations applied in the strongly non-linear regime and linearized perturbation theory around the final distorted single black hole at late times. The authors use this approach to study gravitational radiation from the coalescence of an equal-mass binary system deriving complete waveforms for the dynamics beginning from the innermost stable circular orbit. These early results herald a transformation in the focus of research in this field from code development to astrophysical applications.

4. Einstein Gravity as an Emergent Phenomenon? – by Carlos Barceló[*], Matt Visser[*], and Stefano Liberati[+], [*]Physics Department, Washington University, Saint Louis, MO 63130-4899; [+]Physics Department, University of Maryland, College Park, MD 20742-4111.

Abstract - In this essay the authors marshal evidence suggesting that Einstein gravity may be an emergent phenomenon, one that is not "fundamental" but rather is an almost automatic low-energy long-distance consequence of a wide class of theories. Specifically, the emergence of a curved spacetime "effective Lorentzian geometry" is a common generic result of linearizing a classical scalar field theory around some non-trivial background. This explains why so many different "analog models" of general relativity have recently been developed based on condensed matter physics; there is something more fundamental going on. Upon quantizing the linearized fluctuations around this background geometry, the one-loop effective action is guaranteed to contain a term proportional to the Einstein-Hilbert action of general relativity, suggesting that while classical physics is responsible for generating an "effective geometry," quantum physics can be argued to induce an "effective dynamics." This physical picture suggests that Einstein gravity is an emergent low-energy long-distance phenomenon that is insensitive to the details of the high-energy short-distance physics.

5. All Universes Great and Small – by John D. Barrow[*] and Hideo Kodama[+], [*]DAMTP, Centre for Mathematical Sciences, Wilberforce Rd., Cambridge CB3 0WA, UK; [*]Yukawa Institute for Theoretical Physics, Kyoto University, Kyoto 606-8502, Japan.

Abstract - If the topology of the universe is compact the authors show how it significantly changes our assessment of the naturalness of the observed structure of the universe and the likelihood of its present state of high isotropy and near flatness arising from generic initial conditions. The authors also identify the most general cosmological models with compact space.

6. Ultra-High Energy Cosmic Rays and Symmetries of Spacetime – by O. Bertolami, Instituto Superior Técnico, Departamento de Física, Av. Rovisco Pais, 1049-001 Lisboa, Portugal.

Abstract - High energy cosmic rays allow probing phenomena that are inaccessible to accelerators. Observation of cosmic rays, presumably protons, with energies beyond 4×10^{19} eV, the so-called Greisen-Zatsepin-Kuzmin cut-off, give origin to two puzzles: How do particles accelerate to such energies? Are their sources within 50-100 Mpc from Earth, or is Lorentz invariance actually a broken symmetry? The author suggests an astrophysical test to verify the latter alternative and explores a possible connection with an alternative theory of gravity that exhibits preferred-frame effects.

7. Decoherence-Induced Violations of Einstein Equivalence Principle – by A. Camacho, Department of Physics, Instituto Nacional de Investigaciones Nucleares, Apartado Postal 18-1027, México, D. F., México.

Abstract - In this essay it will be shown that the Decoherence Model and the Einstein Equivalence Principle are conceptually incompatible. In other words, the present work concludes that we face two possibilities: (i) if the Decoherence Model provides a correct description of nature at the quantum level, then there are systems which violate Local Position Invariance, or, (ii) if all the postulates behind the Einstein Equivalence Principle are valid, even on the quantum realm, then the Decoherence Model breaks down in curved spacetimes. Finally, the present results will render a counterexample to Schiff's conjecture.

8. A Sensitive and Wideband Resonant Mass Detector of Gravitational Waves: the Dual Sphere – by M. Cerdonio[*], L. Conti[*], J.A. Lobo[+], A. Ortolan[#], L. Taffarello[%], and J. P. Zendri[%], [*]Dipartimento di Fisica, Univ di Padova, and INFN-Padova, Via Marzolo 8, I-35131 Padova, Italy; [+]Departament de Física Fonamental, Universitat de Barcelona, Diagonal 647, E-08028 Barcelona, Spain; [#]INFN Laboratori Nazionali di Legnaro, Via Romea 4, I-35020 Legnaro (Padova), Italy; [%]INFN-Padova, Via Marzolo 8, I-35131 Padova, Italy.

Abstract - The authors present the concept of a new class of resonant mass gravitational wave detectors, which would allow *wideband* operation in the kHz frequency range, to complement in sensitivity the interferometric detectors of the future and thus expand significantly the detection frequency range. They consider a solid sphere nested inside a hollow one. The differential radial displacement is read out by a *non*-resonant optomechanical transducer consisting of a high finesse and high power Fabry-Perot cavity. At liquid helium temperatures, the system can be operated close to the displacement Standard Quantum Limit. The authors suggest Beryllium as a possible choice for the material to be considered for a feasibility study, in view of its favorable mechanical and thermal properties.

9. Geodesic Deviation in the Black String Spacetime – by H. Culetu, Ovidius University, Department of Physics, B-dul Mamaia 124, 8700 Constanta, Romania.

Abstract - The equation of motion of test particles in the geometry of a black string trapped on a domain wall embedded in a five dimensional AdS spacetime is studied. With an inversion transformation on the fifth coordinate "w", the author obtains a simple form of the geodesics and the geodesic deviation. The equations for the separation vector ξ^{α} between two nearby geodesics are found, with $\xi^{5}(\lambda) = \xi^{5}_{(0)}\sin(\lambda/l)$ independent of the Schwarzchild potential U(r) (l – the AdS radius).

10. Can Black Holes Decay to Naked Singularities? – by Saurya Das[*], J. Gegenberg[+], and V. Husain[+], [*]Department of Physics, University of Winnipeg, Winnipeg, Manitoba, Canada R3B 2E9; [+]Department of Mathematics and Statistics, University of New Brunswick, Fredericton, New Brunswick, Canada E3B 5A3.

Abstract - The authors investigate thermodynamic properties of two types of asymptotically anti-de Sitter spacetimes: black holes and singular scalar field spacetimes. They describe the possibility that thermodynamic phase transitions can transform one spacetime into another, suggesting that black holes can radiate to naked singularities.

11. Cosmological Term as a Source of Mass - Irina Dymnikova, Institute of Mathematics and Informatics, University of Warmia and Mazury in Olsztyn, Zolnierska 14, 10-561 Olsztyn, Poland.

Abstract - In the spherically symmetric case the weak energy condition, together with the requirement of finiteness of the ADM mass and of the derivative of a density profile, distinguish the class of globally regular and globally neutral solutions to the Einstein equations asymptotically de Sitter as $r \to 0$ and asymptotically Schwarzschild as $r \to \infty$. The source term corresponds to an r – dependent cosmological term $\Lambda_{\mu\nu}$ invariant under boosts in the radial direction and evolving from the de Sitter vacuum $\Lambda g_{\mu\nu}$ in the origin to the Minkowski vacuum at infinity. In the range of masses $m \geq m_{cr}$, de Sitter-Schwarzschild geometry describes a vacuum nonsingular black hole (ΛBH), and for $m < m_{crit}$ it describes G-lump – a vacuum selfgravitating particlelike structure without horizons. The ADM mass is related to the cosmological term by $m = 4\pi \int_0^{\infty} \Lambda^t_t r^2 dr$, with de Sitter vacuum replacing a central singularity at the scale of symmetry restoration. Quantum energy spectrum of G-lump is shifted down by the binding energy, and zero-point vacuum mode is fixed at the value corresponding to the Hawking temperature from the de Sitter horizon.

12. Quintessential Cosmodynamics – by Kenneth J. Epstein, 6400 N. Sheridan #2604, Chicago, IL 60626-5331.

Abstract - "Quintessence," treated as a nonrelativistic "dark gas" of virtual (vacuum generated) particles with the exotic property of negative pressure, yields a vacuum dominated universe whose expansion is accelerated by repulsive gravity. The result is qualitatively consistent with acceleration detected in type Ia supernova observations. The acceleration is enhanced by a positive cosmological constant, and offset by a negative cosmological constant. On the other hand, quintessence, treated as ultrarelativistic "dark radiation," or "dark energy" (as it is usually called), gives a scale factor which implies zero gravity and no acceleration unless a positive cosmological constant is allowed. If a negative cosmological constant is allowed, the scale factor is consistent with older phoenix models, as well as contemporary inflation models.

13. The Phase Portrait of the Reduced Einstein Equations – 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 - The authors discuss the phase portrait of the reduced Einstein (3+1)-equations on a compact manifold of Yamabe type –1. They show that the flow for these equations either has a unique fixed point if the underlying manifold M is hyperbolizable or no fixed points if M is not hyperbolizable. Thus the topology of M is a critical determinant of the phase portrait of the reduced equations. If, additionally, M is rigid, the fixed point is a local attractor, thereby answering an important question regarding the stability of these model universes. In the non-hyperbolizable case, under certain conditions, the reduced Einstein flow predicts that the conformal volume collapses M.

14. Singularity Avoidance by Collapsing Shells in Quantum Gravity – by Petr Hájíček[*] and Claus Kiefer[+], [*]Institut für Theoretische Physik, Universität Bern, Sidlerstrasse 5, 3012 Bern, Switzerland; [+]Fakultät für Physik, Universität Freiburg, Hermann-Herder-Straβe 3, 79104 Freiburg, Germany.

Abstract - The authors discuss a model describing exactly a thin spherically symmetric shell of matter with zero rest mass. They derive the reduced formulation of this system in which the variables are embeddings, their conjugate momenta, and Dirac observables. A non-perturbative quantum theory of this model is then constructed, leading to a unitary dynamics. As a consequence of unitarity, the classical singularity is fully avoided in the quantum theory.

15. Gravity and the Ultimate Computation – by Lawrence M. Krauss and Glenn Starkman, Departments of Physics and Astronomy, Case Western Reserve University, Cleveland, OH 44106-7079.

Abstract - The recognition that the cosmological constant may be non-zero dramatically alters our picture of the likely future evolution of the Universe. Ultimately, our future will depend on a careful interplay of gravity, quantum mechanics, and thermodynamics. The authors demonstrate here that in a cosmological constant dominated universe there is a maximum size to the ultimate computation that can be performed, even over an infinite time. This puts an upper limit on quantities ranging from the longevity of civilizations to unbreakable codes, and implies an ultimate end to the utility of pursuing Moore's Law.

16. Spin-Down Power in Astrophysics – by Feng Ma, Prc-Mrc 2nd Floor/R9950, The University of Texas at Austin, Austin, TX 78712, USA.

Abstract – While the accretion power in astrophysics has been studied in many astronomical environments, the "spin-down power" is often neglected. In this essay the author demonstrates that the spin-down power alone may drive a rotating system from sub-critical condition to critical condition with a small but finite probability. In the case of an isolated spinning-down neutron star, the star may undergo a quark-hadron phase transition in its center and become observable as a soft gamma repeater or a cosmological gamma-ray burst. For a spinning-down white dwarf, its Chandrasekhar mass limit will decrease and may reach the stellar mass, then the star explodes to a type Ia supernova. Gravity wave detectors may be able to test these models.

17. Exactly Solvable Model for Evaporating Black Holes in de Sitter and Anti de Sitter Space – by Jorge G. Russo, Departamento de Física, Universidad de Buenos Aires, Ciudad Universitaria, Pab. I, 1428 Buenos Aires, Argentina.

Abstract - The author constructs a model in two-dimensional dilation gravity where the vacuum solution is de Sitter or anti de-Sitter space (according to the sign of the cosmological constant). The formation and semiclassical evaporation of black holes are described by exact solutions which incorporate quantum effects and the black reaction of the geometry. The model provides a setting to investigate quantum properties of black holes in homogeneous spaces in terms of simple analytic formulas.

18. The Universality of Physical Laws: from Black Holes to Sonoluminescence – by Marcelo Schiffer, The College of Judea and Samaria, Ariel, 44837, Israel.

Abstract - The importance of black hole physics to everyday life phenomena is reviewed. Guided by black hole physics the author discusses the electric polarization of (neutral) dielectric media by gravitational fields. The equivalence principle guarantees the emergence of inertial polarization fields inside accelerated media. The author also explores two consequences of this effect: the electric polarization inside planar shock waves and the emission of radiation by corrugation instabilities of imploding shocks. In the latter case, the spectral distribution of the emitted light is displayed and shown to reproduce the general features of the Sonoluminescent spectra. Since cataclysmic astrophysical events involve large accelerations or gravitation fields in a medium, it is conjectured that many of the spectacular radiation bursts observed in the sky are sonoluminescent-like effects at astrophysical scales.

19. Experimental Hints of Gravity in Large Extra Dimensions? – by Steinn Sigurdsson, 525 Davey Laboratory, Department of Astronomy & Astrophysics, Pennsylvania State University, University Park, PA 16802.

Abstract - Recent conjectures suggest the universe may have large extra dimensions through which gravity propagates. This implies gross departures from Newton's law of gravity at small length scales. Here the author considers some implications for particle dynamics on scales comparable to the compactification radius, R_c . 1 mm. During planet formation, coalescence of micron sized dust grains to planetesimals is a rate critical step. Blum et. al. found dust grain aggregates form low fractal dimension structures in microgravity, consistent with high angular momentum coalescence. The author considers the effects of non-Newtonian gravity on dust aggregation on scales less than R_c and shows that they naturally coalesce into low dimensional structures with high specific angular momentum. He infers $R_c \approx 80$ microns.

20. Degenerate Bose-Enstein Dark Matter: A Galactic Superfluid? – by M. P. Silverman[*] and R. L. Mallett[+], [*]Department of Physics, Trinity College, Hartford, CT 06106; [+]Department of Physics, University of Connecticut, Storrs, CT 06268.

Abstract - Spontaneous symmetry breaking of a neutral scalar field coupled to gravity leads to ultra low mass bosons with a critical condensation temperature far above the temperature of the cosmic microwave background. The particles comprise a degenerate Bose-Enstein condensate (BEC) with coherence length determined by equilibrium between quantum pressure and gravitational tension. BEC dark matter neither collapses to form density spikes within galactic cores, nor free-streams away from overdense regions. A BEC halo may manifest suprfluid behavior such as quantized vorticity. Using the dwarf spiral galaxy M33 as an example, the authors estimate the mass of a dark matter scalar boson and the coherence length, particle density, critical temperature, critical rotation frequency, and vortex line density of a dark matter condensate composing the halo.