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Abstracts of Award Winning and Honorable Mention Essays for 1990

Award Essays

First Award - Using Gravitational Lenses to Detect Gravitational Waves by Bruce Allen, Department of Physics, University of Wisconsin at Milwaukee, P.O. Box 413, Milwaukee, Wisconsin 53201

Abstract - Gravitational lenses could be used to detect gravitational waves, because a gravitational wave affects the travel-time of a light ray. In a gravitational lens, this effect produces time-delays between the different images. Thus the bending of light, which was the first experimental confirmation of Einstein's theory, can be used to search for gravitational waves, which are the most poorly confirmed aspect of that same theory. Applying this method to the gravitational lens 0957+561 gives new upper bounds on the amplitude of low-frequency gravitational waves in the universe, and new limits on the energy-density during an early "inflationary" phase.

Second Award - New Approaches for Inflationary Cosmology by Frank S. Accetta* and Paul J. Steinhardt+, *Department of Physics, Yale University, New Haven, CT 06511; +School of Natural Sciences, Institute for Advanced Study, Princeton, NJ 08540 and Department of Physics, University of Pennsylvania, Philadelphia, PA 19104.

Abstract - New approaches for inflationary cosmology have been developed which avoid the extreme fine-tuning required by all previous models and which generate a new source of inhomogeneities that could influence the large-scale structure of the universe. The most surprising feature of the new approaches is the role that inflation can play in altering the nature of the gravitational force.

Third Award - Inflation - An Alternative to the Singular Big Bang by Dalia S. Goldwirth and Tsvi Piran, Racah Institute for Physics, The Hebrew University, Jerusalem 91904, Israel.

Abstract - Domains larger than the horizon in which $\dot{\Phi} >$ (a few) xM_{pl} are required for the onset of inflation. Two different, equally plausible, arguments lead us to opposite conclusions about the feasibility of the existence of such regions. It seems that inflation does not free us completely from the need for special initial conditions. However, Linde has pointed out that inflation can be eternal. He stresses the fact that inflation will never cease, but this also means that it did not necessarily have a beginning. The authors argue that this is the simplest solution to the initial value problem and that inflation might not only solve the problems of the Big Bang model, it might also provide an alternative that will replace it altogether.

Fourth Award - Time In Quantum Cosmology From the Self-Measurement of the Universe by Michael B. Mensky, P. N. Lebedev Physical Institute, USSR Academy of Sciences, Lenisky prospect 53, Moscow 117924, USSR.

Abstract - Considerations in quantum cosmology are conventionally based on the Wheeler-DeWitt equation $H\Psi = 0$ resulting in trivial dependence of the Universe wavefunction on time. This leads to difficulties in deriving the time evolution of the quantum Universe and in transition from quantum cosmology to classical cosmology. Recently some work appeared considering the self-measurement of the quantum Universe in an explicit way, with the aim to introduce a classical concept of time. The purpose of the present essay is to treat self-measurement of the quantum Universe in the framework of the path-integral quantum theory of continuous measurements developed by the author. This allows one to explicitly introduce geometrically defined time into quantum cosmology. Evolution of the quantum Universe under continuous measurement of the lapse function and of the scale factor are evaluated and analyzed in the framework of a simple minisuperspace model.

Fifth Award - Feedback Mechanism for the Cosmological Constant - by M. I. Beciu, Department of Physics, Institute for Constructions - B-d Lacul Tei 124, Bucharest, Romania.

Abstract - The author studies the dynamics of the true vacuum in a cosmological phase transition governed by a Higgs field. When the mass of the field depends on the temperature there is a feedback mechanism for relaxing the cosmological constant to a value near zero.

Honorable Mention Awards (Alphabetical Order)

1. Are Gravitational Theories Containing Nonminimal Couplings Really Ruled Out By The Equivalence Principle? by A. J. Accioly, Instituto de Física Teórica, Universidade Estadual Paulista, Rua Pamplona 145, 01405 - São Paulo - S.P., Brazil.

Abstract - Very general scalar and vector gravitational theories whose respective actions explicitly contain products between curvature and matter fields on the one hand and do not violate the equivalence principle on the other are presented. A solution to this apparent paradox is produced.

2. The Backreaction for Conformally Invariant Fields on a Conformally Flat Background by Norbert Van den Bergh*, Edgar Gunzig*, Pascal Nardone*, and Mario A. Castagnino+, *Université Libre de Bruxelles, Service Chimie-Physique, C.P. 231 - Campus Plaine, 1050 Brussels, Belgium; +Instituto de Fisica de Rosario, Av. Pellegrini 250, 2000 Rosario, Argentina.

Abstract - The authors study conformally invariant fields within the context of semi-classical gravity. They claim that, with a single exception, exact conformally flat solutions are necessarily Friedmann-Robertson-Walker models or their "tachyonic fluid" analogs. In both cases the authors rewrite the field equations as a quadratic three dimensional autonomous system of ordinary differential equations, the critical points of which are Minkowski space and de Sitter space. Both these critical points are unstable in the linear as well as in the non-linear theory.

3. Solution of the Dilaton Problem in Open Bosonic String Theories by Z. Bern* and D. C. Dunbar+, *Theoretical Division, MS-P285, Los Alamos National Laboratory, Los Alamos, New Mexico 87545, +D.A.M.T.P., Liverpool University, Liverpool, UK.

Abstract - All string theories naively contain a massless dilaton which couples with the strength of gravity in direct violation of experiment. The authors present a simple mechanism for giving the dilaton a mass in unoriented open bosonic string theories.

4. Relativity Theory: Special, General, Exotic? by Carl H. Brans* and Alwyn Duane Randall+, *Physics Department, Loyola University, New Orleans, LA 70118; +Mathematics Department, Loyola University, New Orleans, LA 70118.

Abstract - Recent discoveries of differentiable structures (exotic) other than the standard one on $\mathbf{R}^4$ and other manifolds suggest strongly that either the relativity principle underlying modern physics be extended to allow arbitrary differentiable structures, or else some basis for their exclusion must be provided. In either case, the possible physical consequences of their existence must be evaluated. It is argued that in some cases, at least, these exotic structures influence the extendibility of solutions to field equations in a manner analogous to that of topological obstructions. Hence, they may provide a model for an entirely new class of sources for physical fields.

5. The Problem with the Cosmological-Constant Problem by Kevin Cahill, Department of Physics and Astronomy, University of New Mexico, Albuquerque, New Mexico 87131.

Abstract - By misinterpreting the Casimir effect, the standard model, and inflation, we may be exaggerating the problem of the cosmological constant.

6. Gravitational Beamstrahlung by Pisin Chen, Stanford Linear Accelerator Center, Stanford University, Stanford, CA 94309.

Abstract - A new phenomenon, which the author calls gravitational beamstrahlung, is investigated. It has been shown that strong EM radiation, called beamstrahlung, occurs during the collision of high energy e^+e^- beams in linear colliders. The high energy particles interact with the strong collective EM field of the on-coming beam and emit beamstrahlung. The author shows that these photons would couple to the same EM field and resonantly excite gravitational waves with much higher frequencies than those from astrophysical signals. If they can be detected, it would bring the study of gravitational waves, or "gravitons", to the laboratory for the first time.

7. General Relativity, Elementary Particles and Anti-Gravity by F. I. Cooperstock, Department of Physics and Astronomy, University of Victoria, Victoria, B.C. Canada V8W 2Y2.

Abstract - Some basic experimental facts about elementary particles, in conjunction with Einstein-Maxwell theory lead to the conclusion that Reissner-Nordstrom repulsion and hence anti-gravity exists near the cores of elementary particle. Apart from its importance as a matter of principle, the existence of negative mass density removes one of the preconditions for the Hawking-Penrose singularity theorems and hence averts the inevitability of gravitational collapse. Further considerations from Einstein-Maxwell theory lead to the conclusion that elementary particles are much larger than 10^{-33} cm, again confirming Einstein's vision that singularities are not proper elements of physical reality. Purely field theoretic models can in principle encompass the elements of mass, charge, spin and magnetic moment of elementary particles.

8. Gravitation at the Planck Scale. A Comparison Between General Relativity and Superstring Theory. by Gerardo Cristofano*, Marco Fabbrichesi+ and Kaj Roland++, *NORDITA, Blegdamsvej 17, DK-2100 Copenhagen Ø, Denmark; +Dipartmento di Scienze Fisiche, Università di Napoli and INFN, Sezione di Napoli, I-80125 Naples, Italy; ++The Niels Bohr Institute, Blegdamsvej 17, DK-2100, Copenhagen Ø, Denmark.

Abstract - At the Planckian regime of very high center-of-mass energies and small transferred momenta gravity is the dominant interaction. A decoupling of all states but the graviton would allow a direct comparison between superstring theory and classical gravitation, regardless of compactification details. The authors test the extent of such a decoupling by calculating the deflection angle of a graviton in the field of a massive state of the superstring and compare it to the corresponding result of general relativity up to the second order in Newton's constant. There is complete agreement at the leading order. However, the authors find a discrepancy in the respective numerical coefficients at the next order; some of the massless super-partners beside the graviton give a contribution absent in general relativity.

9. Torsion, Wormholes and the Problem of the Cosmological Constant - by Venzo de Sabbata and C. Sivaram, Dipartimento di Fisica, Università di Ferrara, Italy, Indian Institute of Astrophysics, Bangalore, India.

Abstract - The authors consider the effect of torsion in the early universe to see if there is the possibility of explaining the small value (if not zero) of the cosmological constant at the present time. For the gauge theoretic formulation of the Einstein-Cartan theory, they find a wormhole instanton solution which has a minimum (baby universe) radius of the Planck length. The basic difficulty with the wormhole approach is stressed. Finally the authors give an explicit calculation from the expression for the evolution of the scale factor, which shows that the spin dominated interaction term in the very early universe can cancel the cosmological constant term at that epoch.

10. Change of G with Time Suggested by Perturbation Treatment of the Effects of Matter on Space and Time by David H. Frisch, Department of Physics, MIT, Cambridge, MA 02139.

Abstract - A remarkably simple treatment of OPN and 1PN quasi-static effects, based on direct change of Newtonian space and time intervals by matter, works by allowing the speed of light c to be changed by these perturbations. This essay looks at two implications of taking variable c seriously in cosmic evolution. One implication is that the "missing mass" is not missing, but will be provided by a theory that includes an increase of c from lower high density (early time) values to its present value. A second suggestion - probably more easily tested - is that the gravitational constant may well be changing with time at a rate of perhaps 10^{-12}/year, which is about the present experimental uncertainty.

11. Duality, Strings and Inflation by E. I. Guendelman, Theoretical Division, T-8, MS B285, Los Alamos National Laboratory, Los Alamos, NM 87545.

Abstract - Arguments based on thermodynamics and on the analysis of string creation effects in expanding spaces, suggest the existence of an inflationary phase in the Early Universe for theories of closed strings. Einstein's equations on the other hand do not support such expectations. The author solves this apparent paradox noticing that Einstein's equations must be modified at the scale this inflationary phase takes place, so that the new equations satisfy the closed string duality principle. Inflation is natural in the context of such modifications and the author gives an estimate on the amount of inflation in this early epoch.

12. Repulsive Gravitational Effects of Global Monopoles and Strings by Diego Harari and Carlos Loustó, Instituto de Astronomía y Física del Espacio, Casilla de Correo 67 - Sucursal 28, 1428 Buenos Aires - Argentina.

Abstract - A monopole formed as a consequence of the spontaneous breakdown of a global symmetry would have a mass that grows linearly with the distance off its core. It was recently shown by Barriola and Vilenkin that the gravitational effect of this configuration is equivalent to that of a deficit solid angle in the metric, plus that of a relatively tiny mass at the origin. here the authors show that this small effective mass is negative. Global monopoles thus share with other topological defects, such as domain walls and global strings, a repulsive gravitational potential. The authors solve numerically the coupled equations for the metric and the scalar field, in order to determine this repulsive potential precisely and in order to analyze the solution when gravitational effects are already significant close to the monopole core.

13. Is it a small Universe after all? The spatially compact hyperbolic model. by G. Hayward and J. Twamley, Institute of Theoretical Physics, University of Alberta, Edmonton, AB, Canada, T6G 2J1.

Abstract - The authors present a model universe in which the spatial section is a compact hyperbolic 3-manifold. A natural scale for the volume of the manifold is determined by a topological constraint. The volume determined by this scale agrees with observation. Furthermore, the model predicts one dimensional periodic distributions of galaxies of periodicity 100-1000h_o^{-1}Mpc. The model also predicts isotropy of the microwave background for reasonable values of Ω_o and h_o without having to recourse to inflation. Nonetheless, anisotropies at small angular separations may be detectable if randomizing effects due to topological lensing are small. In other respects the model evolves like an open Friedmann universe.

14. Singularities in String Theory by Gary T. Horowitz and Alan R. Steif, Department of Physics, University of California, Santa Barbara, CA 93106.

Abstract - The authors show that a large class of singular solutions in general relativity are also singular solutions in string theory at the classical level, and most likely at the quantum level as well. Notions of singularity more appropriate for string theory are also discussed.

15. On Black Hole Thermodynamics and Back-Reaction by Chao-guang Huang[*], Liao Liu[+], and Feng Xu[++], [*]Institute of High Energy Physics, Academia Sinica, P.O. Box 918(4), Beijing 100039, China, [+]Department of Physics, Beijing Normal University, Beijing 100875, China, [++]Department of Physics, Yunnan Normal University, Kunming, Yunnan 650092, China.

Abstract - It is shown in this essay that there is a difficulty in conventional black hole thermodynamics. To overcome the difficulty the authors introduce a "surface" near the event horizon as an additional thermodynamical object. The mass and entropy of the additional "surface" are the same as the correction of the mass of the Schwarzschild black hole obtained in the back-reaction program up to a constant factor. This implies that some effects of back reaction are automatically considered in the authors' thermodynamic phenomenological treatment.

16. Collective Effects in String Gravity by V. Alan Kostelecký[*] and Stuart Samuel[+], [*]Physics Department, Indiana University, Bloomington, IN 47405, [+]Physics Department, The City College of New York, New York, NY 10031.

Abstract - Collective effects among closed bosonic strings and their implications for gravity are explored using nonpolynomial string field theory. Self interactions induce the formation of a nonperturbative tachyon condensate. In principle, this condensate can naturally lead to the spontaneous breakdown of the higher-dimensional Lorentz symmetry. The authors also show that the tree-level coupling runs, resulting in asymptotic freedom. The running coupling dramatically affects the spectrum in the nonperturbative vacuum, in particular causing states to disappear. No massless graviton remains. The changes in the spectrum can be triggered by any nonzero expectation value, so similar effects are to be expected in any string theory incorporating the electroweak model.

17. Gravity, Holonomy and Light-Cone Cuts by Carlos Kozameh[*] and Ezra T. Newman[+], [*]FaMaf, University of Cordoba, 5000 Cordoba, Argentina, [+]Department of Physics and Astronomy, University of Pittsburgh, Pittsburgh, PA 15620.

Abstract - A D'Adamard-like formulation for General Relativity, which puts emphasis on the light-cones as basic variables, is presented. Two important aspects of this formalism are: (1) it is possible (in a perturbative sense) to construct the general radiative solution for GR, i.e., one can find a (series of) integral relationships between the field and the free-characteristic data and (2) as the light-cone itself now becomes a basic variable, one can clearly see the difficulties with the conventional view towards the problem of quantum gravity in that there is no natural way to include it in a quantization procedure.

18. Unimodular Theory of Gravity and the Cosmological Constant by Y. Jack Ng and H. van Dam, Institute of Field Physics, Department of Physics and Astronomy, University of North Carolina, Chapel Hill, NC 27599.

Abstract - The unimodular theory of gravity with fixed determinant $g_{\mu\nu}$ is equivalent to general relativity with an arbitrary cosmological constant Λ. Within this framework Λ appears as an integration constant unrelated to any parameters in the Langrangian. In a quantum theory the state vector of the universe is thus expected to be a superposition of states with different values of Λ. Following Hawking's argument the authors conclude that the fully renormalized $\Lambda = 0$ completely dominates other contributions to the integral over Λ in the vacuum functional. In this scenario of the unimodular theory of gravity the cosmological constant problem is solved. Furthermore, the quantum version of the unimodular theory has a normal "Schrodinger" form of time development, giving a simpler interpretation to the equation of the universe.

19. Can Quantum Field Theory be Compatible With General Covariance? by T. Padmanabhan, Theoretical Astrophysics Group, Tata Institute of Fundamental Research, Homi Bhabha Road, Bombay 400 005, India.

Abstract - The author presents certain new difficulties which arise when quantum field theory is interpreted in an arbitrary co-ordinate system with non-static background metric. Quantum field theory in such co-ordinates is discussed and compared with field theory in a constant background electric field expressed in a static and non-static gauges. This comparison highlights the restrictions on the allowed class of co-ordinate transformations in quantum theory.

20. The Higgs Phenomenon in Quantum Gravity by R. Percacci, International School for Advanced Studies, Trieste, Italy and Istituto Nazionale di Fisica Nucleare, Sezione di Trieste.

Abstract - The Higgs phenomenon occurs in theories of gravity in which the connection is an independent dynamical variable. This is best seen by thinking of the connection as being defined in a vectorbundle which is isomorphic, but not identical, to the tangent bundle. General Relativity is discussed as an example. By enlarging the fiber dimension of the vectorbundle, one can describe the unification of gravity with the other interactions, in the strict technical sense of putting together representations of smaller gauge groups into a representation of a larger unifying gauge group. The order parameters of this gravitational Higgs mechanism are the soldering form and a fiber metric. The breaking of the original gauge symmetry is linded to the appearance of geometrical structures on spacetime.

21. Are Flat Rotation Curves Due to Straight Cosmic Strings? by T. R. Seshadri, Department of Physics, University of Delhi, Delhi, 110 007, India.

Abstract - A model has been proposed to explain the origin of the observed features of the rotation curves of spiral galaxies using a straight infinite cosmic string. It is shown that (i) the gross features of the observed rotation curves are reproduced by using infinite cosmic strings, and (ii) to produce the observed rotation curves, the relevant cosmic string requires a symmetry breaking scale which is close to the GUTs scale.

22. Quantum Effect of the Earth's Rotation on Atomic Polarisability by M. P. Silverman, Department of Physics, Trinity College, Hartford, Connecticut 06106.

Abstract - In the noninertial reference frame of the rotating Earth the Coriolis force exerts a chirally asymmetric quantum mechanical effect on the electronic polarisabilities of atoms. As a consequence, terrestrially bound atoms should exhibit a weak circular birefringence--behavior strictly forbidden in an inertial frame (in the absence of weak neutral currents). This circular birefringence falls within the measurement capability of ring-laser polarimeters now under construction. A successful experiment would mark the first demonstration of the influence of planetary motion on the electronic structure of an atom--and would set a precedent for the detection of a naturally occurring chiral interaction.

23. Return of the Wheeler Wormhole by Matt Visser, Physics Department, Washington University, St. Louis, Missouri 63130-4899.

Abstract - Wheeler's wormholes are analyzed using modern minisuperspace techniques. Within the context of a particular minisuperspace model for Wheeler's wormholes, gravity is quantized and the wave-function of the wormhole is explicitly exhibited. The throat of the wormhole is quantum mechanically stabilized. The radius of the throat has an expectation value of order the Planck length. Implications of this result with respect to the process of quantum gravitational topology change are discussed. In particular it is argued that the stability of Wheeler's wormholes serves to forbid fluctuations in topology.

24. The Relational View of Space in the Light of Quantum Theory by William K. Wootters, Santa Fe Institute, 1120 Canyon Road, Santa Fe, NM 87501, Center for Nonlinear Studies and Theoretical Division, Los Alamos National Laboratory, Los Alamos, NM 87545, Department of Physics, Williams College, Williamstown, MA 01267.

Abstract - The relational view of space asserts that points in space are defined only by reference to material entities. The author considers this view in light of the fact that all possible reference objects are quantum mechanical and hence do not have infinitely precise positions. One consequence is that there is a limit to the precision with which a point in space can be defined. The author estimates this limit, which he thinks of as the "fuzziness" or "size" of a point in space, and finds that it varies from place to place, becoming smaller as one approaches a massive object. Defining distance by counting points, one obtains in the vicinity of a massive object an approximation to the spatial part of the Schwarzschild metric.

25. Is There Evidence for the Existence of Torsion? by Zhang Cheng-Min, Research Division of Physics, Hebei Institute of Technology, Tianjin, PR, China.

Abstract - Under the assumption that a pulsar's surface magnetic field originates from the net polarized spin of neutrons, and by using the post-Newtonian approximation of the torsion in the fifth order in (v/c) given by J. Nitsch, one concludes that the spin precession arising from torsion is coordinate dependent. This influences the magnetic field of the pulsar and makes the magnetic inclination close to the rotation axis. Assuming the possibility that the magnetic inclination density has a random alignment at an initial time, the author's conclusions are: most pulsars have smaller inclination at the age of 10^6 years, the inclination decreases with increasing age of the pulsar. These conclusions fit the theoretical statistics and the astronomical observational distribution. It may be the first time that indirect evidence for the existence of torsion predicted by the gauge theory of gravitation has been found.