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# Abstracts of Award Winning and Honorable Mention Essays for 1983

## Award Winning Essays

First Award - New Relativistic Gravitational Effects Using Charged Particle Interferometry by Jeeva Anandan, Max Planck-Institut fur Physik und Astr., Werner Heisenberg-Inst. Für Phys. D-8000 Munich 40, Fed. Rep. of Germany.

Abstract - A new class of gravitational effects, in the quantum interference of charged particles, are described in electron interferometry and superconducting Josephson interferometry. These include phase shifts due to the gravitationally induced Schiff-Barnhill field, rotationally induced London moment and the modification of the Aharonov-Bohm type of phase shifts, due to the general relativistic coupling of the electromagnetic field to the gravitational field. These effects are interesting, even from a purely theoretical point of view, because they involve an elegant interplay between gravitation, electromagnetism and quantum mechanics. But new predictions are also made which, if confirmed, would provide the first observation of relativistic gravitational effects, involving the electric charge, at the quantum mechanical level. The possibility of using these effects to detect gravitational waves is also discussed.

Second Award - The Thermodynamics of Gravitational Radiation by Lee Smolin, The Institute for Advanced Study, Princeton, New Jersey 08540.

Abstract - The author conjectures and shows for a large class of cases that, given a spacelike hypersurface on which is an arbitrary distribution of linearized gravitons and matter satisfying the positive energy condition, the probability that within any finite time each of the gravitons has scattered from, or been absorbed by, the matter is strictly less than one (except for a set of initial configurations of measure zero). Consequences of this result are: 1) the impossibility of any system containing gravitational radiation reaching thermal equilibrium in a finite time, 2) the absence of an ultraviolet catastrophe for gravitational radiation, 3) the impossibility of measuring accurately the quantum state of the linearized gravitational field and 4) the impossibility of constructing a gravitational wave laser.

Third Award - Black Hole Uniqueness from a Hidden Symmetry of Einstein's Gravity by Pawel Oskar Mazur, Jagellonian University, Institute of Physics, 30-059 Krakow, Reymonta 4, Poland.

Abstract - A theorem is proven that the only possible exterior solution for a pseudo-stationary, rotating, electrovacuum black hole with non-degenerate event horizon is the Kerr-Newman solution with $M^2-J^2/M^2-Q^2>$. A special role played in the proof of this theorem by the hidden symmetry group SU(1,2) of Einstein's equations is established.

Fourth Award - From Unstable Minkowski Space to the Inflationary Universe by E. Gunzig and P. Nardone, Université Libre de Bruxelles, Faculté des Sciences, 1050 Brussels, Belgium.

Abstract - It is shown that Minkowski Space is unstable in the context of semi-classical gravity. There exists a threshhold mass, of the quantized matter field, which marks the dividing line between stable and unstable vacuum fluctuations of matter in flat space-time. The Minkowski vacuum gravitational-matter system undergoes a phase transition above this "critical point", the new phase being a self-consistently generated De Sitter Euclidean Cosmology. Its total energy is degenerate with respect to that of empty Minkowski spacetime. It represents an appropriate candidate for the primeval configuration of an inflationary-like universe.

Fifth Award - On A New Gravitational Effect of a Rotating Mass by Bahram Mashhoon, Institut fur Theoretische Physik, Universitat zu Koln, D-5000 Cologne 41, Federal Republic of Germany.

Abstract - A new general relativistic many-body effect is described. It results in an unexpectedly large relative acceleration between neighboring test particles that follow an inclined orbit about a rotating mass. The effect vanishes if the orbit coincides with the equatorial plane of the rotating mass. The existence of this effect is due to a small divisor involving the deviation of the orbital frequency measured by a co-moving clock from the frequency measured by an inertial clock. The influence of the rotation of the Sun on the Earth-Moon system is investigated, and it is shown that the new effect causes a harmonic variation in the Earth-Moon separation with an amplitude of order one meter and dominant periods of 18.6 years, ~ 1/2 year, 1 month and ~ 1/2 month. The confirmation of these results by the lunar laser ranging experiment would provide a significant new test of general relativity and a measurement of the angular momentum of the Sun.

Honorable Mention Essays (Alphabetical Order)

1. How General is General Relativistic Cosmology? by John D. Barrow, Astronomy, Center, University of Sussex, Falmer, Brighton, BNI OQH, U.K. and A.C. Ottewill, Department of Astrophysics, University of Oxford, South Parks Road, Oxford OX1 3RQ, U.K.

Abstract - With a view to assessing the likely influence of quantum effects on classical general relativity, the authors examine cosmological solutions within a generalized gravity theory derived from a lagrangian which is an arbitary function of the space-time curvature. They investigate properties of such cosmological models and determine the extent to which they resemble general relativistic cosmology; the authors prove necessary and sufficient conditions for the existence of cosmological singularities and particle horizonts in such models. They find

and examine deSitter type solutions and assess the significance of these results for the "inflationary" model of the early universe. The authors conclude that small quantum effects can lead to large cosmological consequences today.

2. The Gravitational Constant by Kevin Cahill, Department of Physics and Astronomy, University of New Mexico, Albuquerque, New Mexico 87131.

Abstract - Gravitational theories can be written in terms of rescaled fields without the Planck mass. The rescaled tetrads acquire the dimension of mass. The empirical distribution of energy throughout spacetime causes the tetrads to assume vacuum expected values of the order of the Planck mass, $m_p$. Thus the gravitational constant, $G = \hbar c/m_p^2$, may be viewed not as a fundamental constant, but as a mass scale that is dynamically determined by the large-scale structure of the universe.

3. Detection of Gravitational Waves by Josephson Junctions, A.C.V. Ceapa, Poste Restante, Bacharest 1, Romania.

Abstract - Related by the generalized momentum, the general theory of Josephson junctions and the Lagrangian theory of spinless and spin -1/2 particles found in curved space-time predict the detection of gravitational waves (GWs) by Josephson extra currents they induce.

4. A Note on the Geometric Unification of Gravity and Electromagnetism by Alan A. Coley, Dept. of Applied Mathematics, Univ. of Waterloo, Waterloo, Ontario, Canada N2L 3G1.

Abstract - It is argued that the motivation behind the search for a geometrically unified theory of gravity and electromagnetism is both erroneous and misleading.

5. Time and Singularity by Jacques Demaret, Institut d'Astrophysique, Universite de Liege, B-4200 Cointe-Ougree, Belgium, and Mark J. Gotay, Department of Mathematics and Statistics, The University of Calgary, Calgary, Alberta, Canada T2N 1N4.

Abstract - The authors show that the occurrence of quantum gravitational collapse and, more generally, the validity of the correspondence principle are inextricably linked to the classical choice of time. The crucial distinction is between "fast" and "slow" times, that is, between times which give rise to complete or incomplete classical evolution respectively. They conjecture that unitary slow-time quantum dynamics is always non-singular, while unitary fast-time quantum dynamics inevitably leads to collapse. These findings are illustrated by an analysis of the dust-filled Friedmann universe.

6. Solutions of the Geodesic Deviation Equation, Obtained by Using Hidden Symmetries by P. Dolan, Department of Mathematics, Imperial College, London SW7 2AZ, and N.S. Swaminarayan, Department of Mathematics, Chelsea College, University of London, 552, King's Road, London SW10 OUA.

Abstract - Very few exact solutions of the geodesic deviation equation are given in the general relativity literature even though they are important in the discussion of the gravitational tidal forces. With the aid of an irreducible Killing tensor $\xi_{ij}$ (or hidden symmetry), is is possible to obtain new exact solutions. In this essay the authors show that the geodesics on a tri-axial ellipsoid and the

time-like geodesics in all the space-times of the Carter class possess exact solutions of the geodesic deviation equations due to the existence of the Killing tensor $\xi_{ij}$.

7. Spacetimes With a Stable Adiabatic Vacuum by Tevian Dray and Jürgen Renn, Freie Universitat Berlin, FB Physik, WE FA, Arnimallee 14, 1000 Berlin 33, West Germany.

Abstract - The adiabatic particle definition of Parker [1] has found widespread acceptance in the semiclassical approach to quantum gravity. The authors give sufficient conditions on a spacetime so that, using the adiabatic particle definisiton, exactly zero particles are created; for these spacetimes the adiabatic vacuum is stable. The difficulties in formulating necessary conditions are discussed.

8. Exact Interior Solutions in General Relativity Through Implicit Equations of State by John J. Dykla, Department of Physics, Loyola University of Chicago.

Abstract - The author presents an alternative to the usual method for solving the equations determining general relativistic gravitational fiels in the presence of matter described by an equation of state. While allowing for simple confirmation of previously known exact solutions, this approach may be used to generate many new models solvable in closed form. Applications include the creation of analytic intial-value data for studies of time-evolution and artifact-free solutions for testing of numerical techniques used in dealing with equations of state in tabulated form.

9. Resolution of the Quadrupole Controversy: The Quadrupole Formula Is An Asymptotic Approximation by T. Futamase, Department of Applied Mathematics and Astronomy, University College, Cardiff, Wales CF1 1XL, Great Britain, and Bernard F. Schutz, Department of Physics, Washington University, St. Louis, Missouri 63130.

Abstract - The authors develop an approximation shceme to general relativity which yields the standard Newtonian and post-Newtonian approcimations, and which is free from divergent terms at any order. They show that this is in fact a genuine asymptotic approximation to a well-defined sequence of solutions of Einstein's equations, and that it givens the usual near- and far-zone predictions of the "quadrupole formula": orbital period decay in a binary system, and radiation carrying energy far away. They explain how the divergent integrals of previous methods disappear here.

10. A New View of The Big Bang by Ronald Gautreau, Physics Department, New Jersey Institute of Technology, Newark, New Jersey 07102.

Abstract - The author looks at the Big Bang from the point of view of a time coordinate $\tau$ measured by clocks fixed on the galaxies forming the cosmological fluid which is the source of the universe, and a spatial coordinate R that measures proper distance relative to the time coordinate $\tau$. In terms of the coordinates $(R,\tau)$, all galaxies and light signals "explode" from $R = 0$ with infinite speeds at the Big Bang at $\tau = 0$. Further, a light signal coming toward $R = 0$ at some time $\tau > 0$ will, in its past history, have started from $R = 0$ at the Big Bang and have

turned around on the line $2R = 3\tau$, which marks the transition where an R = const line changes from being spacelike to being time like in character. There is also a "tilting" of the null cones along the trajectory of a galaxy.

11. The Significance of Curvature in General Relativity by G.S. Hall, Department of Mathematics, University of Aberdeen, Edward Wright Building, Dunbar Street, Aberdeen, AB9 2TY, Scotland, U.K.

Abstract - In General Relativity, one has several traditional ways of interpreting the curvature of space-time, expressed either through the curvature tensor or the sectional curvature function. This essay asks what happens if curvature is treated on a more primitive level, that is, if the curvature is prescribed, what information does one have about the metric and associated connection of space-time? It turns out that a surprising amount of information is abailable not only about the metric and connection but also, through Einstein's equations, about the algebraic structure of the energy-momentum tensor.

12. Cauchy Horizons, Symmetry and Cosmic Censorship by James Isenberg, Department of Mathematics, University of Oregon, Eugene, OR 97403, and Vincent Moncrief, Department of Physics, Yale University, PO Box 6666, New Haven, CN 06511.

Abstract - The Strong Cosmic Censorship conjecture asserts that the maximal spacetime development of a generic set of Cauchy data on a spacelike initial surface, evolved via a set of field equations such as those of the Einstein theory, should not be extendible across a Cauchy horizon. The authors provide a systematic approach for attacking this conjecture analytically. Results obtained thus far show that if an analytic spacetime contains a compact Cauchy horizon with closed geodesics, and if that spacetime satisfies the Einstein or Einstein-Maxwell equations, then the space-time must contain a symmetry. This result, the authors believe, provides considerable support for Strong Cosmic Censorship.

13. Self-consistent solutions of the Einstein Equations with One-loop Quantum Gravitational Corrections by L.A. Kofman, Institute of Astrophysics and Atmosphere Physics, Estonian Academy of Sciences, Tartu, Toravere, 202444 USSR, and Varun Sahni, Department of Theoretical Physics, Faculty of Physics, Moscow State University, Moscow V-234, USSR.

Abstract - Self-consistent solutions of the modified Einstein equations in vacuum have been constructed and a possible classification scheme is described. The interpretation of self-consistent space-times as quantum gravity eigenstates and their relevance to the early Universe is discussed. The possibility of self-consistent space-times forming an important basic constitutent of space-time foam has also been noted.

14. Screening, Confinement, and the Cosmological Constant by Lawrence M. Krauss, Lyman Laboratory of Physics, Harvard University, Cambridge, MA 02138.

Abstract - An attempt is made to relate, on physical grounds, the cosmological constant problem to several fundamental problems in particle and solid state physics for which we have either qualitative or quantitative understandings. The insight we may gain is useful in two respects--first, in uncovering possible new dynamics associated with the cosmological term in quantum gravity, and second, in pointing

out quantitative techniques which may prove useful in the eventual explicit solution of the problem.

15. On the Cosmic Censorship by Andrzej Królak, N. Copernicus Astronomical Center, Polish Academy of Sciences, Bartycka 18, 00-716 Warsaw, Poland.

Abstract - This work is a continuation of author's attempts, first formulated in the Second Award winning essay of the 1982 Gravity Research Foundation essays, to prove the cosmic censorship hypothesis. Additional theorems supporting the cosmic censorship are proved now. Some of them constitute a new approach towards proving Penrose's conjecture. One of them is a generalization of the censorship theorem which was proved in the previous essay to space-times that are not necessarily asymptotically flat. It also provides a different proof of that theorem. It is shown in addition that the regions of causality violation cannot be naked. The role of the cosmic censorship is discussed.

16. The Cosmological Constant Problem and the Definition of Quantum Energy by Nathan P. Myhrvold, Department of Physics and Program in Applied Mathematics, Princeton University, Princeton, NJ 08544.

Abstract - A particle production mechanism which occurs for quantum fields in Curved space-time can act to dynamically reduce any initial cosmological constant to zero. This could explain why the cosmological constant is so small at present, and is related to the fundamental question of how to define quantum zero-point energy in General Relativity.

17. Quantum Cosmology as a Cure for Three Ailments of Classical Cosmology by Jayant V. Narlikar and T. Padmanabhan, Tata Institute of Fundamental Research, Bombay 400 005, India.

Abstract - The standard big bang models of classical cosmology are known to possess three defects. The oldest known defect is of space-time singularity whose existence seems inevitable within the classical framework. The seond defect is the existence of a particle horizon which severely limits communications across distant parts of the universe whose observed homogeneity therefore becomes inexplicable. Recently a third defect has been highlighted, viz the required fine tuning of the early universe close to the flat spatial model in order to account for the present range of its mean density. The authors show here that the injection of quantum ideas holds out hope of a cure for all three ailments described above. Using a simple path integral formalism for quantum cosmology the authors present arguments which suggest that a) it is extremely unlikely that the universe evolved to the present state from quantum states of singularity and particle horizon; b) of all possible Robertson-Walker models that could evolve out of quantum fluctuations of the empty Minkowski universe the flat model is overwhelmingly probable.

18. A Covariant Spinor Form for the Gravitational Hamiltonian by James M. Nester, Theoretical Physics Institute, University of Alberta, Edmonton, Alberta, T6G 2J1, Canada

Abstract - The author obrains a manifestly 4-dimensionally covariant spinor expression for the Hamiltonian 3-form of the Einstein theory of gravity. This expression is easily related to both the 4-covariant field equations and to the

standard 3+1 expressions for the superhamiltonian and supermomentum. It directly provides a unique 4-covariant expression for the total energy-momentum flux integrand over the 2 sphere at infinity; and its surface projection immediately yields the Witten positive energy proof.

19. An Eternal Universe by M. Novello, Centro Brasileiro de Pesquisas Fisicas, Rua Xavier Sigaud No. 150 Rio De Janeiro, Brasil-22290, and H. Heintzmann, Institüt fur Theoretische Physik der Universität Köln, Cologne 41, Federal Republic of Germany.

Abstract - The authors present a new generalized solution of Maxwell-Einstein equations (which are non-minimally coupled) which leads to some fascinating aspects of the Universe. The Cosmos has no singularity due to the coupling of longitudinal electromagnetism with space-time. It contains the Milne-Schucking cosmos as a limiting case. The model contains a free parameter (the longitudinal electromagnetic field) which allows one to fix the density of highest compression of the Cosmos. Alternatively the parameter allows one to adjust the model cosmos to the presently observed Hubble constant and the deceleration parameter. The model seems to be a viable candidate for the real cosmos as it allows one to extend the time scale of the Universe to arbitrarily large values i.e., it is able to provide the necessary time scale for the origin of life. The authors speculate that the entropy is finite but intelligence in the Universe may be infinite.

20. Accretion Disks, Precessing Jets, and the Asymmetric Emission Lines of QSOs by G.A. Shields, Department of Astronomy, University of Texas at Austin 78712.

Abstract - The broad line profiles of active galaxies are consistent with emission from the surface of an accretion disk ionized by an ultraviolet continuum emitted from a linear or point source of continuum above the disk. If the point source is offset from the axis of the disk, then the line peak is shifted from zero velocity in a way that resembles observed cases. This misalignment could result from the Lense-Thirring precession of a rotating black hole.

21. Origin of the Gravitational Constant and its Behaviour at Very High Energies by C. Sivaram, Indian Institute of Astrophysics, Bangalore, India.

Abstract - Recent progress in the unification of strong, weak and electromagnetic interactions suggests that the high energy behaviour of these interactions would be different from their observed low energy characteristics. For instance their coupling constants would become a function of the energy (momentum) of the interacting particles and would become comparable at a particular large energy scale. Extension of these ideas to gravitation would imply that the high energy behaviour of gravity (well described by Einstein's general relativity (a non-abelian gauge theory) at low energies) may also be different and in particular the gravitational constant will become energy dependent. At the very large energy scales involved in the earliest epochs of the unverse and in gravitational collapse, (near singularities), these modifications to the low energy theory could have interesting consequences for quantum gravity.

22. Geometrization of Spin and the Proof of the Weyssenhoff Fluid Conjecture by Larry S. Smalley, Space Science Laboratory, Marshall Space Flight Center, Al 35812 and Department of Physics, The University of Alabama in Huntsville, Huntsville, AL 35899 and John R. Ray, Department of Physics, Clemson, University, Clemson, SC 29631

Abstract - The authors prove that the logical treatment of spinning perfect fluids occurs in a metric-torsion spacetime with mass conservation. The consequence is the geometrization of spin, that is, the authors obtain the exact Weyssenhoff form relating spin and torsion without any ad hoc assumption.

23. Einstein's Vacuum Equations by George A.J. Sparling, Department of Mathematics and Statistics, University of Pittsburgh, PA 15260.

Abstract - The vacuum equations are reformulated as the defining equations for a differential ideal in the spin bundle. Hypersurface twistors are integral manifolds of this ideal.

24. A Geometrical Foundation of a Unified Field Theory by Gerald E. Tauber, Tel Aviv University, Tel Aviv.

Abstract - Generalizing a work by Einstein and Mayer it is assumed that at each point of space-time there exists an N-dimensional linear vector space with $N \geq 5$. This space is decomposed into a four-dimensional tangent space and an (N-4) -dimensional internal space. On the basis of geometrical considerations alone one arrives at a number of fields, the field equations being derived from a variational principle. Among the fields obtained there are the electromagnetic field, Yang-Mills gauge fields, and fields that can be interpreted as describing matter. As a simple example, the case $N = 6$ is considered.

25. Spontaneous Creation of Universes by Alexander Vilenkin, Physics Department, Tufts University, Medford, MA 02155, U.S.A.

Abstract - The author discusses a cosmological model in which the universe is created by quantum tunneling from "nothing" into a de Sitter space. The tunneling is described semiclassically using de Sitter-Hawking-Moss instanton. After the tunneling the universe evolves along the lines of the new inflationary scenario. This model does not have a big bang singularity and does not require any initial or boundary conditions.