GRAVITY RESEARCH FOUNDATION
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Abstracts of Award Winning and Honorable Mention Essays for 1982

Award Winning Essays

First Award - Black Holes and Stability of Gravitation by Gary T. Horowitz, Institute for Advanced Study, Princeton, New Jersey 08540 and Malcolm J. Perry, Department of Physics, Princeton University, New Jersey 08544.

Abstract - The existence of black holes in general relativity provides an effective cut-off to the negative gravitational potential. This results in a fundamental upper limit on the amount of energy that can be radiated away by any isolated system.

Second Award - A Proof of the Cosmic Censorship Hypothesis by Andrzej Krolak, Instytut Fizyki Teoretycznej, Hoza 69, 00-691 Warszawa, Poland.

Abstract - It is shown that, in a weakly asymptotically simple and empty space, no strong curvature singularity visible from infinity can develop from non-singular initial data (according to classical general relativity).

Third Award - Stationary Axisymmetric Space-Times: A New Approach by R.S. Ward, Institute for Theoretical Physics, State University of New York at Stony Brook, Stony Brook, New York 11794 and Department of Mathematics, Trinity College, Dublin, Ireland.

Abstract - This essay describes a new approach to the problem of understanding stationary axisymmetric solutions of Einstein's vacuum equations, different from the "Bäcklund transformation" approach which has recently been extensively developed. It translates the problem into one of complex geometry, using the machinery of twistor theory. This, in turn, leads to a procedure which, in principle, generates all solutions. Some explicit examples are presented.

Fourth Award - How to Mine Energy from a Black Hole by William G. Unruh, Department of Physics, University of British Columbia, Vancouver, B.C. V6T 2A6 Canada and Robert M. Wald, Enrico Fermi Institute, University of Chicago, Chicago, IL 60637

Abstract - The authors describe a process by which energy literally can be mined from a black hole. They argue that the only limit placed by

fundamental considerations on the rate at which energy can be extracted from a black hole by this process is $dE/dt \lesssim 1$ in Planck units $G=c=\hbar=1$. This is far greater than the rate $dE/dt \sim 1/M^2$ at which the black hole spontaneously loses energy by Hawking radiation.

Fifth Award - Pregeometric Origin of the Big Bang by Keiichi Akama, Saitama Medical College, Moroyama, Saitama 350-04, Japan, and Hidezumi Terazawa, International Centre for Theoretical Physics, Miramare-Strada Costiera 11, 34100, Trieste, Italy, and Institute for Nuclear Study, University of Tokyo, Tanashi, Yokyo 188, Japan.

Abstract - The temperature-dependent effective action for gravity is calculated in pregeometry. It indicates that the effective potential for the space-time metric has the minimum at the origin for extremely high temperature. The origin of the big bang can be taken as a local and spontaneous phase transition of the space-time from the pregeometric phase to the geometric one.

Honorable Mention Essays (Alphabetical Order)

1. The Measure of the Discrete Mixmaster Universe by John D. Barrow, Astronomy Centre, University of Sussex, Brighton BN1 9QH, U.K., and David F. Chernoff, Department of Physics, University of California, Berkeley, California 94720.

Abstract - An exact measure-theoretic solution is found for a four dimensional system of nonlinear difference equations describing the evolution of the general relativistic 'Mixmaster' cosmological model. The system exhibits chaotic behavior and other unusual dynamic properties that suggest the existence of a new class of soluble chaotic systems.

2. Is Superluminal Travel a Theoretical Possibility? by N.T. Bishop, Department of Applied Mathematics, University of the Witwatersrand, 1 Jan Smuts Avenue, Johannesburg, South Africa.

Abstract - The theory of relativity forbids the superluminal travel of ordinary matter. However, it is possible to amend the theory of relativity, and a consistent theory permitting superluminal travel is developed. The approach adopted is to keep the changes to relativity to a minimum. The acceptability of the features needed for superluminal travel is discussed.

3. Conformally Connected Universes by Murray Cantor, Department of Mathematics, University of Texas, Austin, Texas 78712 and Tsvi Piran, Racah Institute for Physics, The Hebrew University, Jerusalem, Israel and The Institute for Advanced Study, Princeton, New Jersey 08540.

Abstract - A well known difficulty associated with the conformal method for solution of general relativistic Hamiltonian constraint is the appearance of an aphysical "bag of gold" singularity at nodal surfaces of the conformal factor. This happens whenever the background Ricci scalar is too large. Using a simple

model the authors demonstrate that some of these singular solutions do have a physical meaning, and these can be considered as initial data for Universes containing black holes, which are connected, in a conformally nonsingular way with each other. The relation between the ADM mass and the horizon area in this solutions supports the cosmic censorship conjecture.

4. A New Look at FRW Cosmologies by A.A. Coley and B.O.J. Tupper, Department of Mathematics and Statistics, University of New Brunswick, Fredericton, N.B., Canada E3B 5A3.

Abstract - The question of whether the material distribution in any cosmological model can be interpreted unambiguously is considered. The authors suggest that the answer is negative, and discuss problems in theoretical cosmology which may arise from this ambiguity of interpretation.

5. Can a Magnetic Resonance Experiment Detect the Rotation of the Earth? by Richard K. Collins, 1620 N. 22nd Street #1, Arlington, Virginia 22209.

Abstract - This essay outlines a brief history of the Sagnac effect. The importance of the Sagnac effect for gravitational research is underlined by citing the recent activity which relies on the Sagnac effect for tests of basic theory. The generalization of the original effect to include massive particles as well as photons is seen as a necessary step in the understanding of the phenomena. The most obvious generalization to closed orbit particle devices such as cyclotrons, betatrons, and ring storage devices is left for another paper; while the subtleties of the interaction of an ensemble of atomic spins with the Earth's rotation is undertaken. It is concluded that the frequency sensitivity of resonance experiments would need to be extended into the submillihertz region. An index is developed related to how sensitive a particular sample will be to rotation. The merits of molecular ring systems, e.g., benzene, aziridine, etc. are discussed relative to simple atoms. The ring currents induced in these compounds may be more suitable objects of study for detection of macroscopic rotation. Finally, this exercise concludes that perhaps it might be considerably easier to construct macroscopic superconducting rings than to use naturally occuring ones. A brief bibliography is included for those interested in pursuing the question further.

6. The Unfolding of Singularities in Superspace by Arthur E. Fischer, Department of Mathematics, University of California, Santa Cruz, California 95064.

Abstract - A method is described for unfolding the singularities of superspace, $\mathcal{G} = \mathcal{M}/\mathcal{D}$, the space of Riemannian geometries of a manifold M. This extended, or unfolded superspace, is described by the projection

$$\mathcal{J}_{F(M)} = \frac{\mathcal{M} \times F(M)}{\mathcal{L}} \to \mathcal{M}/\mathcal{L} = \mathcal{G}$$

where F(M) is the frame bundle of M. The unfolded space $\mathcal{J}_{F(M)}$ is an infinite-dimensional manifold without singularities. Moreover, as expected, the unfolding of $\mathcal{J}_{F(M)}$ at each geometry $[g_o] \in \mathcal{G}$ is parameterized

by the isometry group $I_{g_o}(M)$ of g_o.

The construction is completely natural, gives complete control and knowledge of the unfolding at each geometry necessary to make $\mathcal{J}_{F(M)}$ a manifold, and is generally covariant with respect to all coordinate transformations. This construction considerably improves upon a previous construction that extends superspace by restricting to those coordinate transformations that fix a frame at a point, inasmuch as such a construction is not generally relativistic.

7. Collective Quantum Gravity Effects by L.H. Ford, Deparment of Physics, Tufts University, Medford, Massachusetts 02155.

Abstract - The possibility of effects on a macroscopic scale which arise from the quantum nature of the gravitational field is discussed. In particular, cooperative phenomena (analogous to the cooperative phenomena in condensed matter physics) involving large numbers of gravitons are discussed. An example of such an effect is considered. It is shown that a quantum system in certain states can radiated macroscopic amounts of gravitational radiation in the quantum theory of gravity but not radiate in classical or semiclassical treatments of gravity. This radiation must be considered to be graviton emission rather than classical gravity wave generation and hence illustrates a collective quantum gravity effect.

8. Cancelling Gravity Over a Finite Volume by Dr. Robert L. Forward, Senior Scientist, Hughes Research Laboratories, 3011 Malibu Canyon Road, Malibu, California 90265.

Abstract - Present ultra-low gravity space manufacturing techniques are limited by earth tides and the self-gravity of the sample. The author describes how to cancel all gravity inside a disk of material 30 cm in diameter and 10 cm thick in synchronous orbit. The earth gradients are canceled by six 100 kg masses placed in a 1.56 m ring tanget to the earth. The self-gravity of the sample is smoothed by a guard ring surrounding the disk and guard caps on top and bottom of the disk. The vertical component of the smoothed self-gravity is canceled by two 100 kg masses placed 58.18 cm above and below the disk. The horizontal component is canceled by a 9705.5 sec period rotation.

9. Times in Cosmology and the Spiralling of Planetary Orbits by Ronald Gautreau, Physics Department, New Jersey Institute of Technology, Newark, New Jersey 07102.

Abstract - The author shows how to express zero curvature cosmologies in terms of curvature coordinates. This has the effect of bringing into cosmological considerations a curvature time in addition to the usual isotropic time. Using curvature coordinates, he develops a natural way of imbedding a Schwarzschild field into cosmologies. He then investigates planetary orbits around the imbedded Schwarzschild mass, and shows that planets will spiral in non-static cosmologies. The author's methods and results are compared with recent work on the same subjects by Dirac.

10. A Covariant Concept of Gravitational Energy by E. Gliner and I. Dymnikova, A.F. Joffe Physico-Technical Institute, Leningrad (E. Gliner is presently at Joint Institute for Laboratory Astrophysics, University of Colorado, Boulder, Colorado 80309).

Abstract - A covariant approach is given to the energy description of matter integrally with gravitation. The approach is based on the generalization of the Special Relativity stress-energy tensor up to the fourth rank tensor which introduces the anisotropies of mass, impulse and their fluxes. The components describing anisotropies form the "energy deviator" which is a traceless fourth rank tensor corresponding to Weyl's part of gravitation. The approach uses another possible way to generalize Special Relativity notions than the pseudotensorial approach and gives additional opportunity to understand the role and place of the latter.

11. A Bimetric Machian Approach to Gravitation by Riccardo Goldoni, University of Pisa, Isituto Matematico "L. Tonelli", I-56100 Pisa, Italy and G.N.F.M. of the C.N.R.

Abstract - The author proposes a bimetric machian approach to gravitation with a mathematical structure much simpler than the one of Rosen's bimetric theories. He obtains two cosmological models based on the simplest assumption that the Universe be filled of pure dust matter. One of the two cosmological models is compatible with the till now observed value of the density of dust matter and provides an age of the Universe which is of the order of the inverse of the present Hubble parameter. The other model is a Schwarzschild-like solution and its Newtonian limit together with the modified three Kepler laws which permits that presently $-2.5\ 10^{-10}\ (\mathrm{yr})^{-1} \lesssim (\dot{a}/a) \lesssim -2\ 10^{-10}\ (\mathrm{yr})^{-1}$, a denoting the semi-major axis of the orbit of the test particle. Such a negative value may be interpreted on the basis of the consideration that, since distant matter is expanding, the contribution to the attraction due to local matter becomes more important as time increases.

12. General Relativity in Flatland by J. Richard Gott III, and Mark Alpert, Department of Astrophysical Sciences, Princeton University.

Abstract - General Relativity is formulated for a (2+1) dimensional space-time. In addition to illustrating some of the subtle effects of the dimensionality of space on gravitation theory, this study provides in its point masses the first physically relevant examples of quasi-regular singularities. Solutions to the vacuum field equations are locally flat. There are no gravitational waves and no Newtonian attraction between masses. The geometry around a point mass is a cone (locally flat) where the angle deficit at the apex is proportional to the mass. A uniform density planet has a spherical cap interior and a conical exterior solution. A convex polyhedron represents a closed universe with point masses at its vertices, and approximates a static spherical universe of uniform density dust.

13. Curvature Collineations and the Determination of the Metric from the Curvature in General Relativity by G.S. Hall, Department of Mathematics, Monash University, Clayton, Victoria, Australia 3168.

Abstract - It is shown that for a very general class of space-times, the components $R^{a}{}_{bcd}$ of the curvature tensor determine the metric components up to a constant conformal factor. This general class contains most of those cases which are usually considered to be interesting from the point of view of Einstein's General Relativity Theory. The connection between the above results and the existence of proper curvature collineations is given.

14. Quantum Vacuum Energy in Taub-Nut-Like Cosmologies by William A. Hiscock and D.A. Konkowski, Center for Relativity, Physics Department, University of Texas, Austin, Texas 78712.

Abstract - The authors consider the effects of vacuum polarization on the mildest possible sort of cosmological singularity, the Taub-NUT-like singularities. Unlike stronger cosmological singularity where physical quantities (e.g., curvature energy density) diverge, in these universes the only barrier is a pathological topology. The authors find that quantum effects, thought to play an important role in regions of large spacetime curvature, are also relevant here. On a flat archetype of the Taub-NUT-like universes the authors calculate the vacuum stress-energy tensor of a conformal scalar field. Its divergence at the singularity (and associated Cauchy horizons), together with the "fixed" nature of the topology, suggests that these boundaries will be replaced by curvature singularities in a better approximation to full quantum gravity.

15. A Stationary Solution of the Gravitational Two Body Problem by C. Hoenselaers, Max-Planck-Institut für Astrophysik, 8046 Garching, FRG and W. Dietz, Institut für Astronomie und Astrophysik, der Universität Würzburg, Am Hubland, 8700 Würzburg, FRG.

Abstract - The authors construct the metric of a stationary axisymmetric space-time which describes the gravitational field of two bodies balanced by their gravitational spin-spin interaction. The space-time is asymptotically flat and regular everywhere except for two isolated singularities.

16. The Fate of a Closed Universe by Demosthenes Kazanas, NASA/Goddard Space Flight Center, Code 665, Greenbelt, MD 20771.

Abstract - It is argued that the evolution of a closed universe containing black holes, drastically departs from that of a homogeneous and isotropic Robertson-Walker model. During its recollapse phase the mass of any black hole diverges long before quantum gravity effects become important, thus alleviating any hope for subsequent evolution in a Robertson-Walker state. The implications and constraints resulting from this argument are discussed.

17. Is the Black Hole the Final State? by Alexander Neacsu, Department of Physics, RLM 5.218, University of Texas, Austin, Texas 78712.

Abstract - The non-linearity of Einstein's field equation suggests the introduction of bifurcation theory to analyze the singulary due to gravitational collapse--the so called black hole. The Geroch definition of a singularity is ammended to include the Hawking property of stability and the postulate is made that the black hole is a bifurcation point of space-time. New stable solutions

to Einstein's field equation emerge from unstable (physically unrealizable) solutions to imply that the black hole is not a final state, but a branch point of a continuing process. A quantum-gravity effect is described as part of the process which involves a space-time-energy discontinuity.

18. Gödel's Container by M. Novello and I. Damiao Soares, Centro Brasileiro de Pesquisas Fisicas, Rua Xavier Sigaud No. 150 Rio De Janeiro, Brasil - 22290.

Abstract - Some gravitational inhomogeneous features of Godel's cosmos are singled out by an analysis of all geodesics of the space time. A two-dimensional surface emerges which acts as a confining barrier and bounds particles gravitationally, independent of the classical energy of the particles. The authors use this property to construct a gravitational container. This structure is highly stable, since there is no singularity in its interior, and independent of the energy of the particles confined in it.

19. Quantum Cosmology and Stationary States by T. Padmanabhan, Astrophysics Group, Tata Institute of Fundamental Research, Homi Bhabba Road, Bombay 400005, India.

Abstract - A model for quantum gravity, in which the conformal part of metric is quantized using the path integral formalism, is presented. Einstein's equations can be suitably modified to take into account the effects of quantum conformal fluctuations. A closed Friedman model can be described in terms of well defined stationary states. The 'ground state' sets a lower bound (at Planck length) to the scale factor preventing the collapse. A possible explanation for matter creation and quantum nature of matter is suggested.

20. Accretion Disks - What do we Know About Them? by A.R. Prasanna, Physical Research Laboratory, Ahmedabad 380 009, India.

Abstract - This essay briefly describes the present status of research on accretion disks around compact objects - in particular black holes, covering both the thin and thick disks. Significant results from various analysis regarding the structure and stability of such disks are presented. It is pointed out that the magnetic field has a very important role to play in the disk structure as it contributes mainly to the turbulent viscosity which has a primary role in the dynamics of disks. Attention is drawn to the fact that a fully detailed analysis of accretion disks should take into account self-consistent electromagnetic field, which could get enhanced due to space-time curvature effects, in a fully general relativistic treatment.

21. Massive Photinos in Cosmology and Galactic Astronomy by D.W. Sciama, International School of Advanced Studies, Trieste, Italy, and Department of Astrophysics, Oxford University, England.

Abstract - It is shown that if the Universe has the critical density in massive photinos (the spin ½ partners of photons in supersymmetric theories) then the mass of the photino is uniquely determined and is close to 100 electron volts for a Hubble constant of 50 km. sec^{-1} Mpc^{-1}. The age of the Universe would then be compatible with globular cluster ages. Such a massive photino would

decay into a photon and a goldstino with a lifetime $\sim 10^{27}$ seconds. Such photons might then account for the ionisation observed (or inferred) of hydrogen and helium in the intergalactic medium and of silicon and carbon in galactic halos (including our own). This last point could be tested by searching for a monochromatic line at ~50 eV in the galactic background radiation.

22. Cosmic Background Anisotropy: The Ultimate Probe by Joseph Silk, Department of Astronomy, University of California, Berkeley, California 94720.

Abstract - The large-angular scale anisotropy of the cosmic microwave background radiation provides an unrivalled probe of the early Universe. It directly reflects the seed inhomogeneities from which structure evolved. Unique signatures are imposed on the large-scale anisotropy by different theories of galaxy origin. With adequate sky coverage of the multiple structure of the radiation background, one could hope to distinguish between the heirarchical clustering and pancake fragmentation theories of galaxy formation, unfold the role of massive neutrinos or gravitinos in modifying the primordial fluctuation spectrum, and even measure the curvature radius of the Universe. All of these engimas are encoded in the large-scale anisotropy: deciphering it promises to be one of cosmology's greatest and most rewarding challenges.

23. Incompatibility of Gauge Field Theories and Gravitation? by Larry L. Smalley, Department of Physics, University of Alabama in Huntsville, Huntsville Alabama 35812 and Space Sciences Laboratory, NASA/Marshall Space Flight Center, Alabama 35812.

Abstract - The author has considered a simplified generic form of a gauge theory of gravity. He finds that these theories are non-conservative gravitational theories which are also in disagreement with experiment. He is therefore drawn to the conclusion, that this class of gauge theories of gravitation are nonviable theories of gravity.

24. On the Behavior of the Gravitational Field at Extremely Short Distances by Lee Smolin, The Institute for Advanced Studies, Princeton, New Jersey 08540.

Abstract - The author shows that the problem of the behavior of the gravitational field at Planck scales and shorter has a straightforward solution in terms of ordinary renormalized quantum field theory. The asymptotic behavior is fixed by the requirement of asymptotic scale invariance, which is necessary for the existence of any sensible quantum field theory. At least in the case that the number of matter fields in nature is not small, the semiclassical theory gives the dominant contributions to the theory at all scales. The quantum fluctuations of the gravitational field itself are weakly coupled, and their effects are small and computable. One consequence is that quantum effects probably do not prevent the existence of spacetime singularities.

25. The Twistor Theory of Hypersurfaces in Space-Time by George A.J. Sparling, Department of Physics and Astronomy, University of Pittsburgh, Pittsburgh, Pennsylvania 15260.

Abstract - Cauchy Riemann structures are described for the bundles of null directions of spacelike hypersurfaces in spacetime. Their Feffermann conformal

metrics are obtained. One is led to suggest a canonical quantization of holomorphic type for gravity.

26. Microcanonical Quantum Gravity by Andrew E. Strohminger, The Institute for Advanced Study, Princeton, New Jersey 08540.

Abstract - Quantum gravity is equivalent to a statistical mechanical system of classical fields in 4 + 1 dimensions at temperature $\hbar$. It is generically true that systems involving gravitation do not exist at fixed temperature. The author therefore proposes a fixed action description of quantum gravity. The formalism for a fixed action description of quantum field theory is developed. It is found to be equivalent to the canonical fixed $\hbar$ formalism for renormalizable field theories. It is also found that, in precise analogy to the microcanonical formulation of statistical mechanics, it describes a wider class of theories than the canonical formalism.

27. On the Polarization of the Cosmological Microwave Radiation by Brian W. Tolman, Center for Relativity, The University of Texas, Austin, Texas 78712, and Richard A. Matzner, Department of Astrophysics, Oxford University, South Parks Road, Oxford OX1 3RQ, England.

Abstract - The microwave background radiation is expected to be linearly polarized to a degree soon to be observable. In homogeneous cosmological models of the universe, spatial curvature is capable of rotating photon polarization vectors relative to their direction at last scattering, which is directly correlated with the axis of the intensity anisotropy. This rotation will produce patterns of polarization on the sky which are sufficiently different in closed (type IX), flat (types I or VII_0) and open (types V or VII_h) models to allow observational discrimination among them. Further, the mere existence in principle of such a rotation leads us to ascribe to the universe a property called "handedness", and this handedness would be observed by noting the direction in which the photons were rotated.

28. Gravity as a Dynamical Consequence of the Other Three Fundamental Interactions by A. Zee, Department of Physics, University of Washington.

Abstract - The author discusses the possibility that Einstein's theory of gravity is generated by quantum fluctuations due to the strong, weak, and electromagnetic interactions and is to be interpreted as an effective phenomenological theory adequate for describing phenomena on distance scales large compared to the Planck length. Newton's constant G is then not a fundamental parameter but can be calculated in terms of other fundamental constants. It may be possible to understand someday why G is positive. The author derives a general formula for G which is easy to understand heuristically. The intuitive basis for this field theoretic formula is given. A model calculation determines the sign of G in terms of purely group theoretic numbers.