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Abstracts of Award Winning and Honorable Mention Essays for 1985

Award Winning Essays

First Award - Is the Periodicity in the Distribution of Quasar Redshifts an Evidence of a Multiply Connected Universe? by LI ZHI FANG[+] and HUMITAKA SATO*, [+]Astrophysics Research Division, University of Science and Technology of China, Hefei, Anhui, China and *Research Inst. for Fundamental Physics, Kyoto University, Kyoto 606, Japan.

Abstract - The periodicity in the distribution of quasar redshifts is interpreted assuming that the cosmological space is a topologically compactified manifold like a three dimensional torus. The present size of such a compact space is estimated as being on the order of 600 Mpc.

Second Award - Spacetime Foam as the Universal Regulator by LOUIS CRANE[+] and LEE SMOLIN*, [+]Department of Math., University of Chicago, Chicago, IL 60637 and *Department of Physics, Yale University, New Haven, CT 06511.

Abstract - A distribution of virtual black holes in the vacuum will induce modifications in the density of states for small perturbations of gravitational and matter fields. If these virtual black holes fill the volume of a typical spacelike surface then perturbation theory becomes more convergent and may even be finite, depending on how fast the number of virtual black holes increases as their size decreases. For distributions of virtual black holes which are scale invariant the effective dimension of spacetime is lowered to a noninteger value less than four, leading to an interpretation in terms of fractal geometry. In this case general relativity is renormalizable in the 1/N expansion without higher derivative terms. As the Hamiltonian is not modified the theory is stable.

Third Award - Spacetime is 4-Dimensional by Z. C. WU, Department of Physics, Syracuse University, Syracuse, NY 13210.

Abstract - The quantum state of the universe is described by Hartle and Hawking's ground state which is defined by a path integral over all compact metrics. The most probable classical evolution of the universe can be considered to come from some gravitational instanton by a quantum tunnelling. These arguments have been generalized to the case of Kaluza-Klein models. It is found that in d=11 simple supergravity, with a minisuperspace ansatz, all instantons must have a 4-dimensional sector. It suggests that this is the main reason why spacetime is 4-dimensional.

Fourth Award - Superstring Gravity and the Early Universe by MARK J. BOWICK and L. C. R. WIJEWARDHANA, Department of Physics, Yale University, New Haven, CT 06511.

Abstract - Ten-dimensional superstring theories have been proposed as candidates for a unified description of all the forces of nature. These theories reduce to Einstein gravity coupled to Yang-Mills interactions at scales small compared to the string tension. The phenomenologically promising superstring theory, the heterotic string, is investigated at the high temperatures and short distances relevant in the early universe. The massive string modes alone constitute an unstable thermodynamic system with negative specific heat. The conditions for equilibrium between the massive string modes and the massless modes (radiation) are derived. The large energy fluctuations of the system require the use of the microcanonical ensemble. There is a maximum temperature which exceeds the temperature at which the canonical partition function becomes divergent. Above a critical volume there is a phase transition during which the massive string modes must evaporate. The possibilities of spontaneous compactification, large entropy production and a solution of the horizon and flatness problems are discussed.

Fifth Award - The Gravitational Acceleration of Antiprotons by T. GOLDMAN, M.V. HYNES, and MICHAEL MARTIN NIETO, Theoretical and Physics Divisions, Los Alamos National Laboratory, University of California, Los Alamos, NM 87545.

Abstract - The authors review the theoretical arguments and experimental evidence (both direct and indirect) for the conventional view that the gravitational acceleration of antimatter must be the same as that of matter. They find there is no compelling support for such a belief. Therefore, they propose to measure the gravitational acceleration of antiprotons using a beam extracted from the Low Energy Antiproton Ring (LEAR) at CERN.

Honorable Mention Essays (Alphabetical Order)

1. A New Formulation of the Stationary Gravitational Field Problem, by M. AGOP, Iassy Department of the Romanian Academy, Street 23 Agust, No 8, Iassy (6600) Romania.

Abstract - A new generalization of Ernst's complex potential approach is proposed, based on the Matzner and Misner's principle for the construction of the Lagrangeian. Perhaps the most remarkable feature of Ernst's complex potential approach is that it exhibits some internal symmetries which make the action integral easy to construct. Thus for instance the Ernst's equations can be described as equations for a Kähler σ-model and solutions can be generated by available methods. The aim of this paper is to exhibit a certain new symmetry and to generalize Ernst's approach. This is accomplished by introducing a kind of homogeneous coordinates which are the coefficients of binary cubics and to construct from these complex potentials which depend algebraically on coordinates.

2. The Influence of Gravitational Radiation on Superconducting Circuits by JEEVA ANANDAN, Max-Planck-Institut fur Physik und Astrophysik, Werner-Heinsenberg-Institut für Physik, Fohringer Ring 6, 8000 Munchen 40, Federal Republic of Germany.

Abstract - It is shown that quantum mechanical quantization of magnetic flux in a superconducting circuit can, in principle, be used to detect gravitational radiation. The effects of the gravitational wave on two superconducting circuits containing solenoids are obtained. The sensitivity of these devices is also briefly discussed.

3. Holonomy and Gravity by J. W. BARRETT, The Blackett Laboratory, Imperial College, London SW7 2BZ.

Abstract - It is shown how to describe the gravitational field in an invariant way by its 'holonomy set' involving paths in Minkowski space and points in the Lorentz group. The differentiable manifold of gravity does not enter as a basic object, but is constructed in a manner depending on the gauge variables. Thus there is no diffeomorphism symmetry in this description of gravity, nor is the topology of space-time fixed at the outset. It is therefore proposed that the 'holonomy description' of gravity provides a much better starting point for the analysis of quantum gravity. Striking similarities with Yang-Mills gauge theories emerge which shed light on the problem of whether gravity is or is not a gauge theory.

4. Closed Universes: Their Future Evolution and Final State by JOHN D. BARROW[+] and FRANK J. TIPLER*,[+]Astronomy Centre, University of Sussex, Brighton, BN1 9QH, U.K. and *Department of Mathematics and Department of Physics, Tulane University, New Orleans, LA 70118.

Abstract - The authors summarize what is currently known about the future evolution and final state of closed universes: in mathematical language, those which have a compact Cauchy surface. They show that the existence of a maximal hypersurface (a time of maximum expansion) is a necessary and sufficient condition for the existence of an all-encompassing final singularity in a universe with a compact Cauchy surface. Not all closed universes can admit a maximal hypersurface, but the authors state a theorem giving a complete classification of those closed universes which do. The relevance of these results to inflation is also discussed.

5. The Strong CP Problem and the Curvature of the Universe by KEVIN CAHILL, Department of Physics and Astronomy, University of New Mexico, Albuquerque, NM 87131.

Abstract - For a universe of the compact Robertson-Walker cosmology, Gauss's law requires the QCD vacuum angle θ to vanish, taking with it the strong CP problem.

6. Modelling the Observed Velocity of Our Galaxy Relative to the Cosmic Microwave Background by A. A. COLEY[+] and B. O. J. TUPPER*, [+]Department of Mathematics, Statistics and Computing Science, Dalhousie University, Halifax, Nova Scotia, B3H 4H8, Canada, and *Department of Mathematics and Statistics, University of New Brunswick, Fredericton, New Brunswick, E3B 5A3, Canada.

Abstract - The aim of this work is to model the observed velocity of our galaxy relative to the cosmic microwave background that was recently discovered by Smoot et al. A homogeneous and isotropic, flat, relativistic two fluid cosmological model is considered in which two separate fluids act as the source of the gravitational field. In this model one fluid is a comoving radiative perfect fluid modelling the cosmic microwave background and the second a non-comoving imperfect fluid modelling the observed material content of the universe. The model that is obtained is represented as a solution of Einstein's equations and the laws of thermodynamics in which all the physical quantities occurring in the solution are suitably well behaved. In addition, the model is in good agreement with current observations.

7. Spacetime Curvature, Rotation and Pulse Profile of a Fast Pulsar, B. DATTA and R. C. KAPOOR, Indian Institute of Astrophysics, Bangalore-560 034, India.

Abstract - Propagation of photons in the spacetime exterior to a rapidly rotating neutron star is investigated using a rotationally perturbed spherical metric to determine the pulse profile of fast pulsars. The authors find that spacetime curvature produces substantial amount of divergence in the pulse beam and flattening of the pulse. Rotational effects are comparatively small, but it has the important effect of producing a tilt of the pulse cone in the direction of rotation and a deformation of the cone. The asymmetry in the pulse profile so caused introduces a time delay in the arrival of photons emitted within the cone. This phenomenon of time delay will be crucial in determining the duty cycle of the pulsar.

8. Gravitational Waves and Massive Tensor Particles by V.DE SABBATA[+] and M. GASPERINI*, [+]Istituto di Fisica dell'Universita, Bologna, Italy, and *Istituto di Fisica Teorica dell'Universita, Torino, Italy and I. N. F. N., Sezione di Torino, Italy.

Abstract - Starting from the generally covariant version of the Pauli-Fierz mass term, it is stressed that the tensor fields representing spin-2 particles, eigenstates of strong and gravitational interactions, are linear combination of one massive and one massless state. This implies that any hadronic reaction, in which massive tensor particles are produced, can be regarded also as an effective source of gravitons; conversely, any process in which gravitational radiation of sufficiently high energy is emitted, is also a source of strongly interacting tensor particles which decay into photons and neutrinos. These two effects could be used for producing and detecting gravitational waves.

9. Gravity, Spin, and Atomic Physics by EPHRAIM FISCHBACH[+], MARK P. HAUGAN[+], and WICK C. HAXTON* [+]Department of Physics, Purdue University, West Lafayette, IN 47907 and *Department of Physics, University of Washington, SEattle, WA 98195.

Abstract - Renewed interest in efforts to detect directly gravitomagnetic phenomena stems from their crucial role in models of extragalactic radio sources, like quasars, and the plasma jets that seem to power them. The authors' interest in the manifestation of gravitomagnetic effects in quantum mechanical systems leads them to consider atomic systems where the coupling gravity to spin can be studied. The authors show that recent atomic physics experiments have attained sensitivities sufficient to explore the possibility of non-metric couplings to spin. The authors emphasize that experiments on atomic systems can achieve far greater sensitivity to velocity-dependent couplings to spin than can any experiments previously proposed.

10. Simple Ingredients of First Order Post-Newtonian Gravitation by DAVID H.FRISCH, Department of Physics, MIT, Cambridge, MA 02139.

Abstract - Three simple effects - a scalar contraction of all space dimensions and a scalar dilation of time in the presence of gravitating mass M at distance r; gravitation by potential energy; and Special Relativity - superposed onto Newtonian dynamics give precisely the experimentally tested Solar System predictions of General Relativity, plus the as-yet-untested DeSitter precession. On using this space contraction factor to give to direction entrainment, the Lense-Thirring rotational precession is also predicted in agreement with General Relativity, except for a factor of two in magnitude. The total gravitational radiation of a homopolar rotating dipole is also estimated rather well using the same approach. It is hoped that this treatment will allow the introduction of post-Newtonian gravitation to a larger audience.

11. The Gravitational Anomaly: An Elementary, Coordinate-Space Approach by S. A. FULLING, Department of Mathematics, Texas A&M University, College Station, Texas 77843.

Abstract - Alvarez-Gaumé and Witten have shown that energy-momentum conservation must be violated in certain parity-violating quantum field theories involving gravity. In two dimensions this effect can be studied without the aid of Feynman diagrams or calculations in momentum space. The arguments parallel those for the conformal (trace) anomaly; as in that case, there are two kinds of arguments, one based on the conservation equations themselves plus some very general assumptions, and the other based on explicit calculations and renormalization in a model theory with a linear field equation. The basic point is that if matter is created at all by the gravitational field, it must appear in both left-moving and right-moving modes if the conservation law is to hold always.

12. Gravitational Models of a Lorentz Extended Electron by RONALD GAUTREAU, Physics Department, New Jersey Institute of Technology, Newark, NJ 07102.

Abstract - The author shows how the Einstein-Maxwell field equations of general relativity can be used to construct a Lorentz model of an electron as an extended body consisting of pure charge and no matter. In contrast with Lorentz's approach using inertial mass, he associates the mass of the electron with its Schwarzschild gravitational mass. The Schwarzschild mass of an extended charged body as seen at infinity arises from the charge as well as the matter that the extended body possesses. The field equations for a Lorentz type pure charge extended electron are obtained by setting the matter terms equal to zero in the field equations for a spherically symmetric charged perfect fluid. Several explicit solutions to the pure charge field equations are examined.

13. The Rindler Condensate by ULRICH H. GERLACH, Department of Mathematics, The Ohio State University, Columbus, OH 93210.

Abstract - In the space of a linearly uniformly accelerated observer a free field condenses into a configuration having the attributes of a superfluid. The existence of this condensate is a macroscopic expression of the coherent nature of the quantum mechanical ground state of the free field viewed by that accelerated observer. The ground state consists of a coherent superposition of pairs of particles and antiparticles travelling in two opposite directions. This state breaks the translational symmetry. The macroscopic order parameter of the ground state is the renormalized expectation value of the stress-energy tensor of the field. The ground state is, in the way of Rayleigh-Ritz, the state of least energy of the observer Hamiltonian of the accelerated observer. A non-zero entropy constraint raises the temperature of the system to a non-zero value. As the temperature is raised the macroscopic coherence and the order parameter deminish until the Unruh-Davies temperature is reached. At this point, these quantities become zero, translational symmetry is restored: the system makes a phase transition from a macroscopically ordered superfluid system to a disordered system.

14. Repulsive Semi-Classical Gravitational Interaction: The Agent for a Spontaneously Symmetry Broken Origin of the Universe by E. GUNZIG and P. NARDONE, Universite Libre de Bruxelles, Pool de Physique, Campus Plaine, Bd.du Triomphe, CP 238, 1050 Bruxelles, Belgium.

Abstract - The existence of the universe is unavoidable due to the puzzling nature of the semi-classical gravitation, regulated by Einstein's equations and the laws of quantum mechanics. This interaction appears to be controlled by a mass-dependent effective gravitational coupling constant. The latter undergoes an unexpected transition from classical gravitational attractive to anti-gravitational repulsive regime, when the corresponding mass of a quantum matter field passes through a definite threshold. This induces in turn a gravitational spontaneously broken symmetry phenomenon responsible for the presence of a unusual non-Minkowskian ground state: the inflationary De-Sitter space-time. This then acquires the status of the primordial cosmological vacuum, the generic configuration of our cosmological history. The fundamental agent for symmetry breakdown is the creation of the universe itself!

15. General Upperlimits to Age of the Universe by P. S. JOSHI, Tata Institute of Fundamental Research, Homi Bhabha Road, Bombay-400005, India.

Abstract - The author models inhomogeneous and anisotropic cosmologies by means of a general class of relativistic spacetimes. The past extension of timelike galaxies worldlines from the present epoch is examined under reasonable assumptions. Conclusions are derived concerning the most general upperbounds that can be set on the age of the universe within this framework.

16. New Gravitational Tests of Early Universe Cosmology by LAWRENCE M. KRAUSS, Lyman Laboratory of Physics, Harvard University, Cambridge, Mass. 02138.

Abstract - Gravitational waves and lenses were among the earliest predictions of General Relativity. The author demonstrates here how both these phenomena can, in conjunction with newly discovered astrophysical objects, be used to test fundamental aspects of early universe cosmology-including (a) scenarios for galaxy formation, and (b) non-adiabatic expansion before and after nucleosynthesis.

17. On Kaluza-Klein Relativity by M. D. MAIA, Universidade de Brasilia, Departmento de Matematica,Brasilia, Brazil, and Department of Physics, University of Washington.

Abstract - Starting with the hypothesis that the spacetime is locally embedded in a 4 + n-dimensional flat space M_{4+n}, a geometric Kaluza-Klein theory is derived with SO(10) gauge symmetry and an additional spin two field represented by the second fundamental form b_{ij}. This quadratic form imposes a natural boundary on the complementary subspace orthogonal to the spacetime, regarded as the internal space. The Gauss-Coddazi-Ricci equations are combined to produce low energy field equations where b_{ij} enters as a source field. High energy dynamics is described by a continuous family of spacetime pertubations in M_{4+n} induced by b_{ij}, satisfying Einstein-Yang-Mills equations. The space M_{4+n} is regarded as a particular space representing the ground state of a more general theory yet to be constructed.

18. Black Hole Fireballs by I. G. MOSS, School of Physics, The University of Newcastle upon Tyne, NEI 7RU, Great Britain.

Abstract - Exploding black holes may become surrounded by regions of restored particle symmetries or other high temperature states of matter. The conditions for this to occur seem to be satisfied for a quark gas state or certain restored symmetry phases. As a result the external appearance of an exploding black hole is substantially altered and the effect may lead to features in the γ-ray background and other observational consequences.

19. Vacuum Fluctuations, the Cosmological Constant and the Entropy of the Universe by EMIL MOTTOLA, Institute for Theoretical Physics, University of California, Santa Barbara, CA 93106.

Abstract - Vacuum Fluctuations are an essential part of quantum field theory. Yet, the extreme smallness of the scalar curvature of the universe suggests that the zero point energy of these fluctuations does not couple to gravitation. A way out of this puzzle is proposed by the observation that the quantum vacuum behaves like a dissipative, as well as a fluctuating medium. Through the mechanism of particle creation, realtivistic quantum fields can effectively transform coherent curvature energy into incoherent matter/radiation modes, generating a large amount of entropy in the process. The very small average curvature and the very large entropy of the universe may then be understandable in terms of this single general property of the quantum vacuum.

20. Gravity and Irreversibility by ALEXANDER NEACSU, Department of Physics, University of North Carolina at Chapel Hill, Chapel Hill, NC.

Abstract - At the crossroads of general relativity and non-equilibrium thermodynamics stands the notion of the internal time operator M(T). A geometric basis for the internal time operator is closely related to the incorporation of irreversibility into the geometry (topology) of space-time. It is, thus analogous to the relativistic incorporation of gravity into the metrical curvature of space-time. The enriching of space-time geometry by including topological as well as metrical features leads to fresh concepts in "non-classical" geometrodynamics and involves many outstanding issues in the modern application of statistical mechanics to general relativity.

21. The Validity of the Formula $E = mc^2$ For Gravitational Energy by THOMAS W.NOONAN, Physics Department, Brockport State College, Brockport, NY 14420.

Abstract - Theoretical evidence for the validity of the formula $E = mc^2$ for gravitational energy in general relativity is reviewed, with an emphasis on recent contributions by the author. For isolated bodies the formula applies to both the inertial mass and the mass as a source of gravity. The formula also applies in the case of the mass density (as a source of gravity) of an inhomogeneous medium with small-scale gravitational interactions.

22. Vaccuum Fluctuations in Einstein's Elevator by T. PADMANABHAN, Astrophysics Group, Tata Institute of Fundamental Research, Homi Bhabha Road, Bombay 400 005, India.

Abstract - Vacuum fluctuation in the Einstein's elevator (which mimics a constant gravitational field) is analysed without introducing a plethora of extraneous vacuum states. In the elevator there is no particle creation, though the vacuum appears polarized.

23. A Gravitational Analogue of Faraday Rotation by TSVI PIRAN[+] and PEDRO N. SAFIER*, [+]Racah Institute of Physics, The Hebrew University, Jerusalem, Israel and Institute for Advanced Study, Princeton, NJ, and [+]Racah Institute of Physics, The Hebrew University, Jerusalem, Israel.

Abstract - The authors study the non linear interaction of cylindrical gravitational waves. They find that the interaction can be described as a gravitational analogue of Faraday Rotation.

24. A New Projective Relativity Theory by E. SCHMUTZER, Department of Physics, Friedrich Schiller University, Jena, GDR.

Abstract - The main ideas of a new Unified Projective Field Theory are presented. Geometrical basis: 5-dimensional projective space with curvature and torsion, 4-dimensional space-time with Riemannian geometry. Einstein-like 5-dimensional field equations are postulated whose projection into space-time lead to generalized Einstein equations, Maxwell equations and a scalar field equation. The projection of the corresponding 5-dimensional conservation law into space-time gives the equation of motion and the electric continuity equation. Main physical outcome: The theory transcends the framework of the Einstein-Maxwell theory, but reduces to the Einstein theory for electrically neutral matter.

25. The Photino and The Universe by JOSEPH SILK, Department of Astronomy, University of California, Berkeley, CA 94720.

Abstract - If the universe contains a critical density of dark matter in massive photinos, and our galactic halo is dominated by the same form of dark matter as dominates the density of the universe, then significant fluxes of sub-GeV cosmic ray antiprotons are produced by photino annihilations in the halo. Moreover halo photinos are gravitationally captured by the sun and annihilate in the solar core, producing a flux of high energy neutrinos that should be observable in underground proton decay experiments.

26. Einstein Gravity as a Low Energy Effective Theory: Comparison with Weak and Strong Interactions by C. SIVARAM, Indian Institute of Astrophysics, Bangalore-560034, India.

Abstract - Einstein's theory which correctly describes gravity at long distances (low energies) is first compared with Fermi's theory (which describes weak interactions at low energies). Analogous to strong interactions at high energies being described by the gauge invariant finite theory of Quantum chromodynamics (QCD), gravity at high energies would be described by an asymptotically free scale invariant theory. Then just as an effective theory of pions (describing low energy strong interactions) emerges from QCD at low energies, Einstein's theory would be the low energy effective counterpart of this gauge invariant high energy theory, ironically arising from the scale invariance being broken by quantum fluctuations. Analogies between QCD and scale invariant gravity are discussed and the cosmological constant problem is also considered in this context.

27. Spacelike Congruences in General Relativity by MICHAEL TSAMPARLIS, Department of Physics, Division of Astronomy-Astrophysics-Mechanics, University of Athens, Panepistimiopolis, Athens 15771, Greece.

Abstract - The author presents a 3+1 description of spacetime geometry and physics resulting from the spacelike projection operator $h_{ab}=g_{ab}+u_a u_b$ where u^a is the timelike congruence defined by the fluid of observers. He then introduces the hybrid fluid (u^a,n^a) where n^a is the normalized tangent vector to the field lines of a vector field observed by u^a and the associated screen projection operator $p_{ab} = h_{ab}-n_a n_b$. The later produces a 2+1+1 decomposition of spacetime quantities with certain advantages which, among others, are: (i) the geometrization of the spacelike field equations (ii) general results in spacelike conformal motions, (iii) a physical classification of Bianchi types spacetimes, (iv) geometrical studies of Newtonian vector fields with global results and (v) a spacelike version of the Ellis' observational Cosmology Program.

28. The Penrose Process in Active Galactic Nuclei? by SANJAY M. WAGH*, S. V. DHURANDHAR+ and N. DADHICH*, *Department of Mathematics, +Department of Physics, University of Poona, Pune - 411 007, India.

Abstract - The authors suggest an approach to a mechanism, based on the Penrose process of energy extraction from black holes in electromagnetic fields, to power the central engine in active galactic nuclei. The astrophysical possibilities considered are the microphysical processes in a plasma, and the tidal breakup of stars in black hole vicinity.

29. Existence Theorems for Static Single and Multiparticle Solutions in Kaluza-Klein Geometries by HUSEYIN YILMAZ, Electro-Optics Technology Center, Tufts University, Medford, MA 02155.

Abstract - The long suspected theorem that in general relativity there exist no static multiparticle solutions is proved. The theorem is generalized to any D=s+y+1 dimensional space of Kaluza-Klein type. Conditions under which static single and multiparticle solutions can exist are determined and the corresponding solutions are explicitly found. It is seen that when s = 3 these solutions are able to recover the standard experimental tests of relativistic gravity intact. It is hoped that the theorems so established might be of help in the current efforts toward a Grand Unification of natural forces (including gravity) within a multidimensional geometry of Kaluza-Klein type.