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Abstracts of Award Winning and Honorable Mention Essays for 1978

Award Winning Essays

First Award - The Causal Universe by R. Brout, F. Englert, E. Gunzig, Faculté des Sciences, Université Libre de Bruxelles, Bruxelles, Belgium.

Abstract - The authors argue that creation of matter is possible in the cosmological context without cost of energy. This creation is regulated by the laws of quantum mechanics and general relativity. These elements are used to conceive a singularity-free causal open homogeneous isotropic cosmology. The history of the universe unfolds in two stages: the "fireball" production stage which occurs as the response to a spontaneous local disturbance which is followed by free expansion. The latter extrapolates back to the former so as to avoid the initial "big-bang" singularity.

Second Award - Quantum Linearization Instabilities by Vincent Moncrief, Department of Physics, Yale University, New Haven, Connecticut 06520.

Abstract - The author discusses quantizing the perturbations of a symmetrical background spacetime and is led to study the quantum analogue of linearization instabilities. He outlines the derivation of the second order quantum constraints which arise whenever perturbations of symmetric spacetimes with compact Cauchy surfaces are quantized. These second order constraints require invariance of all the allowed quantum states (not just the "vacuum" state) under the symmetry group of the background spacetime. This result is discussed in light of the conclusion by Gibbons and Hawking that the thermal radiation produced by event horizons in de Sitter space is invariant under the de Sitter group and thus does not admit a semiclassical interpretation.

Third Award - Cosmic Censorship, Black Holes, and Particle Orbits by William A. Hiscock, Center for Theoretical Physics, Dept. of Physics and Astronomy, University of Maryland, College Park, Maryland 20742.

Abstract - Perhaps one of the main reasons for believing in the cosmic censorship hypothesis is the disquieting nature of the alternative: the existence of naked singularities, and hence loss of predictability, the possibility of closed timelike lines, etc. The consequences of assuming the cosmic censorship hypothesis can also be somewhat strange and unexpected. In particular, the author applies Hawking's black hole area theorem to the study of particle orbits near a Schwarzschild black hole. If the cosmic censorship hypothesis (and hence the area theorem) is true, then there exist stable near-circular orbits arbitrarily close to the horizon at $r = 2M$.

Fourth Award - A Test of the Equivalence Principle Using a Space Borne Clock by R.F.C. Vessot and M.W. Levine, Center for Astrophysics, Harvard College Observatory and Smithsonian Astrophysical Observatory, Cambridge, Massachusetts 20138.

Abstract - An experimental verification of Einstein's equivalence principle has been made using an atomic hydrogen maser in a space probe attaining an altitude of 10,000 km about the earth's surface. At the present stage of the data reduction confirmation is at the 2×10^{-4} level of accuracy. The experiment and the resulting data are described including a comment on the limits to the anisotropy of the velocity of light. The authors believe that this is the first direct, high accuracy test of the question of symmetry in the propagation of light in addition to being a beginning in the use of high accuracy clocks in space to measure relativistic phenomena.

Fifth Award - A Spin-3/2 Theory of Gravitation by I. Bars, and S.W. MacDowell, Dept. of Physics, Yale University, New Haven, Connecticut 06520.

Abstract - Stimulated by ideas occuring in Supergravity the authors develop a gauge theory of gravity based on a spin-3/2 Majorana field. The theory has no metric or vierbein as an elementary field. Classically the theory is in complete agreement with Einstein's metric formulation, but quantum mechanically it differs from ordinary formulations, including supergravity, on the fundamental nature of gravitation. In the approach described here, gravitation arises from a collective effect due to spin-3/2 gravitinos.

Honorable Mention Essays (Alphabetical Order)

1. Particle Creation by Time-dependent Electric and Gravitational Fields: A Transcription of Methods by Jürgen Audretsch, Fachbereich Physik der Universität Konstanz, Postfach 7733, D-7750 Konstanz, W-Germany.

Abstract - The present situation of quantum field theory in curved space-times is briefly described. It is argued that we have reached a new phase in the transfer of quantum field theoretical methods from flat to curved space-time: the adaptation of the various approximation methods and related techniques from atomic and elementary particle physics. In support of the argument that several elaborated techniques can easily be transcribed, the author sketches his transcription of the quasi-classical approximation, until now used for pair creation in time-variable electric fields in Minkowski space, to the problem of cosmological particle creation.

2. Pregalactic Black Holes: A New Constraint by John D. Barrow and Joseph Silk, Berkeley Astronomy Dept., University of California, Berkeley, California 94720.

Abstract - Pregalactic black holes accrete matter in the early universe and produce copious amounts of x-radiation. By using observations of the background radiation in the x- and gamma wavebands the authors have been able to impose a strong new constraint upon their possible abundance. If pregalactic black holes are actually present, several outstanding problems of cosmogony can be resolved with typical pregalactic black hole masses of 100 $M_\odot$. Significantly more massive holes cannot constitute an appreciable mass fraction of the universe and are limited by $\Omega_{PGBH}(M) < 10 (M_\odot/M)\Omega^{-1}$.

3. Is Gravity Turbulent Near Cosmological Singularities? by V.A. Belinskii, L.D. Landau Institute of Theoretical Physics, Academy of Sciences of the U.S.S.R., Moscow and M.A.H. MacCallum, Dept. of Applied Mathematics, Queen Mary College, University of London, London E1 4NS.

Abstract - The problem of the cosmic singularity was first raised by the example of the big-bang Friedmann-Robertson-Walker models. This led to discussions among relativists about the meaning and nature of singularities. Perhaps definitions of singularities in terms of incompleteness of geodesics are most satisfactory as they allow singularity theorems to be proved using only very general assumptions. A natural sequel to this development is to inquire about the character of singularities. A Moscow group of relativists has been pursuing a program aimed at analysing the asymptotic approach to a space-time singularity by approximation to a solution of the Cauchy problem. The class of solutions considered proves to have the maximum number of arbitrary functions of their variables assigned on some Cauchy surface; it is in this sense "general" or "generic". The authors describe the time evolution near the singularity of the generic cases. The time evolution of the generic cases near the singularity has a rather complicated oscillating behavior dependent on the matter source and its properties and on a characteristic length. The authors discuss the behavior if the oscillatory behavior depends on a spectrum of characteristic lengths. The geometry then seems to vary drastically in a manner that can be understood by analogy with fluid turbulence.

4. Radio Jets as Tracers of Galaxy Collisions by Roger Blandford and Vincent Icke, California Inst. of Technology, Theor. Astro. 130-33, Pasadena, California 91125.

Abstract - A new method is presented for determining the masses of galaxies. It relies on analyzing the shapes of radio jets that emerge from the nuclei of some active galaxies that are interacting with a nearby companion. The orbits of the galaxies, which are inaccessible to direct observation, can be inferred from the trail left by the jets. Application of this method to 3C31 yields a mass to light ratio of about 11 solar units for the galaxies NGC383 and NGC382.

5. New Observational Limit on the Constancy of the Speed of Light by Kenneth Brecher, Dept. of Physics, Massachusetts Institute of Technology, Cambridge, Massachusetts 02139.

Abstract - Recent observations of regularly pulsating x-ray sources in binary star systems are used to test the second postulate of Special Relativity. Assuming that light emitted by a source moving at velocity v with respect to an observer has a speed $c' = c + kv$ in the observer's rest frame, the author finds that the arrival time of pulses from the binary x-ray sources implies $k < 2 \times 10^{-9}$. This appears to be the most direct and sensitive demonstration that the speed of light is independent of the velocity of the source.

6. Interactions, Currents and Gravity by M. Camenzind, Institut für Theoretische Physik, Universität Hamburg, 2000 Hamburg 36, Germany.

Abstract - The gauge concept for the gravitational interaction leads to the so-called Yang-Mills formulation for gravity, which is essentially based on a current-current interaction between matter. Already on Minkowski space-time, the flow of matter defines six exactly conserved currents, whose charges span the adjoint representation of the Lorentz group acting as structure group of the Lorentz frame bundle of the Minkowski space-time. These six currents generalized for an arbitrary space-time are the generators of the gravitational field in every macroscopic Yang-Mills formulation for gravity. Every term in this new current has a clear physical interpretation.

7. Intrinsic Symmetries in General Relativity by C.B. Collins, Dept. of Applied Mathematics, University of Waterloo, Waterloo, Ontario, N2L, 3Gl, Canada.

Abstract - A discussion is presented which indicates that a stagnation point is being reached in the standard applications of symmetries (especially isometries) in general relativity. In order to continue the advance of this area of research, an attractive alternative is suggested. This alternative involves the use of what are termed "intrinsic symmetries". With this technique, emphasis is placed on underlying symmetries of submanifolds. One particular set of symmetries gives rise to an invariant formulation of the Szekeres inhomogeneous cosmological models, and suggests quite natural generalizations.

8. Gravity, Cosmology, and New Particles by Duane A. Dicus and Edward W. Kolb, Center for Particle Theory, University of Texas, Austin, Texas 78712 and Vigdor L. Teplitz, Dept. of Physics, Virginia Polytechnic Institute and State University, Blacksburg, Virginia 24061.

Abstract - The year 1977 was a time of fruitful collaboration between gravitational physics and elementary particle physics, as well as between gravitational physicists and elementary particle physicists. Both disciplines were able to make statements about the properties and gravitational effects of massive, neutral, weakly-interacting leptons and bosons. In the essay, the results of the collaboration are reviewed and some new results are mentioned.

9. Life in the Infinite Universe by G.F.R. Ellis and G.B. Brundrit, Dept. of Applied Mathematics, University of Cape Town, Cape Town, South Africa.

Abstract - In a low-density Robertson-Walker Universe, it is highly probable that there exist infinitely many worlds on which there are 'duplicate' populations (i.e. populations identical in number and genetic structure) to that on our own world. One can avoid this 'paradox' if (i) the gravitational field is sufficiently strong to close the space-sections of the Universe; or (ii) some property of the initial singularity endows flat or hyperbolic space-sections in the University with 'unnatural' finite topologies, not induced by the gravitational field; or (iii) the universe is inhomogeneous, with life only occurring in preferred regions.

10. Black Holes at the Centers of the X-Ray Sources in Globular Clusters and in the Bulge, by Arrigo Finzi, Dept. of Mathematics, Technion, Haifa, Israel.

Abstract - X-ray sources in population II systems seem to result from collisions of collapsed stars with normal stars. After a collision the material of the normal star evolves into a semi-transparent envelope of radius $\sim 10^{17}$cm around the collapsed star; the x-rays are emitted by matter from the envelope accreting onto the collapsed star. Study of the semi-transparent envelopes leads to a number of interesting conclusions: (1) With the exception of the innermost regions, the envelope is cold and the fractional ionization is only $\sim 10^{-4}$. The calculated flux of Ly α photons from the envelope is in agreement with the observations of Grindlay and Liller. (2) There is a cut-off for the mass of the envelope, proportional to the mass M_c of the collapsed star squared. Only when $M_c >> 3M_\odot$, is this cut-off comparable to the mass of the parent star, and the efficiency of x-ray generation is adequate. We conclude that the masses of collapsed stars in observed sources are likely to exceed the limiting mass of neutron stars. (3) The observed emission of x-rays is erratic in time, but accretion of matter never stops. Accretion without emission of radiation is possible only in black holes, not in neutron stars.

11. Symmetry Breaking in General Relativity by Arthur E. Fischer and Jerrold E. Marsden, Dept. of Mathematics, University of California, Santa Cruz and Berkeley, California.

Abstract - Bifurcation theory is used to analyze the space of solutions of Einstein's equations near a spacetime with symmetries. The methods developed here allow one to describe precisely how the symmetry is broken as one branches from a highly symmetric spacetime to nearby spacetimes with fewer symmetries and finally to a generic solution with no symmetries. This phenomenon of symmetry breaking is associated with the fact that near symmetric solutions, the space of solutions of Einstein's equations does not form a smooth manifold, but rather has a conical structure. The geometric picture associated with this conical structure enables one to understand the breaking of symmetries. Although the results are described for pure gravity, they may be extended to classes of fields coupled to gravity, such as gauge theories. Because our universe is so nearly isotropic and homogeneous on a large scale, the study of how symmetries are broken takes on considerable cosmological significance.

12. Instantons in Quantum Gravity by G.W. Gibbons, Dept. of Applied Mathematics and Theoretical Physics, Cambridge University, Cambridge, England.

Abstract - The author discusses the possible role of classical, positive definite solutions of Einstein's equations (Instantons) in the path integral formulation of Quantum Gravity. The ideas are applied to: (1) gravitational thermodynamics; (2) baryon annihilation by gravitational fields; (3) the role of gravitational monopoles in quantum gravity; and (4) the high temperature limit of quantum gravity.

13. Model Universes with Black Holes, White Holes, A Big Bang and Little Bangs by Edward G. Harris, Dept. of Physics, University of Tennessee, Knoxville, Tennessee 37916.

Abstract - A class of solutions of the equations of general relativity utilizing co-moving coordinates is found. Among these solutions are those in which Friedmann solutions are joined to Schwarzschild solutions. These are used to construct model universes containing white holes and black holes. The white holes begin their expansion at a later time than that of the big bang.

14. Waveless Approximation Theories of Gravity by James A. Isenberg, Dept. of Physics and Astronomy, University of Maryland, College Park, Maryland 20742.

Abstract - The analysis of a general multibody physical system governed by Einstein's equations is quite difficult, even if numerical methods (on a computer) are used. Some of the difficulties -- many coupled degrees of freedom, dynamic instability -- are associated with the presence of gravitational waves. The author has developed a number of "waveless approximation theories" (WAT) which repress the gravitational radiation and thereby simplify the analysis. The matter, according to these theories, evolves dynamically. The gravitational field, however, is determined at each time step by a set of elliptic equations with matter sources. There is reason to believe that for many physical systems, the WAT-generated system evolution is a very accurate approximation to that generated by the full Einstein theory.

15. What Happens at Galactic Centers? by W. Kundt, Astrophysikalisches Institut der Universität Bonn, Auf dem Hügel 71, D-5300 Bonn, Germany.

Abstract - A rotating Supermassive Magnetized Disk looks versatile enough to account for Quasars as well as all the other violent phenomena related to galactic centers. The disk feeds a fast-rotating supermassive core which emits Low Frequency magnetic radiation, and accelerates magnetospheric charges to extremely relativistic energies. Confined by the surrounding discal wind, these charges are focussed into two axial beams. Torsional oscillations between core and disk give rise to a chopped beam, and a breathing double-onion shape of the LFW windzone can explain an apparent superluminal expansion of the two relativistically escaping charge clouds. A nuclear explosion ends each duty cycle.

16. On Gravity as a Dispersive Force, E.P.T. Liang, Institute of Theoretical Physics, Dept. of Physics, Stanford University, Stanford, California 94305.

Abstract - The role of gravity as a dispersive force is exploited in the context of nonlinear dynamics. Exact gravity-induced acoustic solitary and periodic waves in a Newtonian perfect fluid are discussed. Such nonlinear structures may be relevant to the origin of cosmological inhomogeneities. The non-dispersiveness of pure gravitational waves in vacuum in general relativity and its dispersiveness in other theories of gravity are also discussed. They bear on the problem of searching for pure gravitational solitons.

17. Gravitation, Ancient Eclipses, and Mountains by R.A. Lyttleton, Institute of Astronomy, University of Cambridge, Madingley Road, Cambridge, CB3 OHA, England.

Abstract - The ancient-eclipse data, after allowance for tidal decelerations of the Earth, reveal a residual rotatory acceleration. The explanation must be geophysical involving decreasing moment-of-inertia. The phase-change hypothesis for the nature of the core predicted such contraction (and acceleration) in close agreement with the subsequently detected values. The driving forces are radioactivity plus gravitation. The contraction is sufficient for some twenty periods of mountain-building. The iron-core hypothesis fails. A decreasing G cannot be entirely dismissed but would imply unacceptably large errors in the apparent secular accelerations of the Sun and Moon.

18. Proposed Null Experiment to Test the Inverse Square Nature of Gravitation by Allen P. Mills, Jr., Bell Laboratories, Murray Hill, New Jersey 07974.

Abstract - A null Cavendish experiment is proposed for testing the validity of the inverse square gravitational force law: one searches for spherically symmetric excitations in a hollow spherical fluid-filled resonator in the presence of a mass quadrupole rotating at half the lowest resonant frequency of the fluid sphere. By Gauss' law, there is no non-static Newtonian coupling to the resonator. The experiment can be made sensitive enough to detect a Yukawa-type force with a strength less than $10^{-3}G$ and a range on the order of 10 cm.

19. Quantum Fluctuations Near the Classical Space-Time Singularity by Jayant V. Narliker, Tata Institute of Fundamental Research, Bombay 400 005, India.

Abstract - Many well known theorems have shown the inevitability of space-time singularity in compact manifolds and in cosmology. These theorems are based on classical general relativity. This article describes some recent calculations which take account of quantum fluctuations. The technique of path integrals is used to work out explicit solutions for problems of the gravitational collapse of a homogeneous dust ball and of Bianchi type-I anisotropic cosmologies. In all cases the result emerges that the quantum fluctuations are so great that the classical singularity ceases to have any significance. In particular one can have finite probabilities of avoiding singularities by the quantum mechanical tunnel effect.

20. The Stability of a Rotating Universe, M. Novello and M.J. Reboucas, Centro Brasileiro de Pesquisas Fisicas, Rio de Janiero, 20,000, Brasil.

Abstract - The authors present an exact cosmological solution of Einstein's equation which has expansion, shear and rotation. The source of this geometry is a fluid which has not been thermalized. The model tends asymptotically to Gödel's cosmos - thus making the solution a previous era of Gödel's Universe.

21. Momentum Transfer in Gravitational Theory by T.N. Palmer, Dept. of Astrophysics, South Parks Road, Oxford, England.

Abstract - An inductive flux of gravitational momentum in Newtonian theory, and a radiative flux of gravitational momentum in General Relativity, whilst being physically dissimilar quantities, are shown to be formally equivalent by expressing them in terms of a symplectic form on the solution space of the respective field equations. The conditions under which the relativistic flux may be considered inductive are then investigated, and a physical example of how this might occur is given in the setting of a strongly curved space-time.

22. Gravitational Waves from X-ray Stars, by J. Papaloizou and J.E. Pringle, Inst. of Astronomy, Madingley Road, Cambridge CB3 OHA, United Kingdom.

Abstract - The authors propose that the most powerful steady emitters of gravitational radiation in our galaxy are a subset of the recently discovered binary X-ray stars. In low mass, long lived X-ray stars, the accreting neutron star can be spun up sufficiently that it becomes unstable to the emission of gravitational radiation. About 10 per cent of the total accretion energy, known from the X-ray emission to be $\sim 10^{37}$ erg s^{-1}, can be emitted as gravitational radiation.

23. The Role of Space-Time Curvature in the Study of Plasma Processes Near Neutron Stars and Black Holes by A.R. Prasanna, Physical Research Laboratory, Navrangpura, Ahmedabad, India.

Abstract - As neutron stars and black holes are very compact massive objects with possibly high magnetic fields, their surrounding space-time curvature should be treated important while considering plasma processes for explaining radiation emission nearby such objects. In this essay we make a case for considering plasma processes on curved geometry (general relativistic framework), through considering detailed orbits of charged particles in electromagnetic fields on Schwarzschild and Kerr background.

24. On Gravitational Conductors, Waveguides, and Circuits by William H. Press, Dept. of Physics and Center for Astrophysics, Harvard University, Cambridge, Mass. 02138.

Abstract - The author shows that a material with sufficiently large elastic shear modulus or shear viscosity will act like a gravitational conductor or "metal". It will reflect gravitational waves, and it can be used to make gravitational waveguides and circuits. Unlike electromagnetism, a gravitational wave can be guided by a single conductor in transverse mode. Gravitational conductors can obey the dominant energy condition, and they can be larger than their Schwarzschild radius, but they must violate a new condition that is probably satisfied by all existing forms of matter. Direct-current gravitational circuits, although limits of guided gravitational waves, have a simple Newtonian interpretation.

25. The Constant of Gravity in General Relativity by Ian W. Roxburgh, Queen Mary College, University of London, London, England.

Abstract - It is shown that the coupling constant in general relativity is arbitrary and does not enter the dynamical equations governing the motion of bodies. By considering the Universe plus one body we are able to show that gravity is necessarily attractive, independent of the magnitude or sign of the coupling constant, and that the 'constant of gravity' that enters the equations of motion is given by the large scale distribution of matter in motion in the Universe.

26. Mach's Principle Vindicated? by D.W. Sciama, Mount Holyoke College, Massachusetts.

Abstract - Mach's principle has been an active source of controversy since the early 18th century. It inspired Einstein to develop general relativity, in which the inertial-gravitational field has as its source the energy-momentum tensor of matter and radiation. Mach's principle can then be regarded as providing a rule for choosing boundary conditions for physically satisfactory solutions of the field equations. According to Raine universes which are homogeneous and Machian must also be isotropic. Recently it has been shown observationally that the Universe was probably highly isotropic at the big bang. Mach's principle appears to provide the best explanation of this result.

27. de Broglie Waves in Gravitational Fields by Leo Stodolsky, Max-Planck-Institute für Physik and Astrophysik, München, Germany.

Abstract - The problem of the quantum mechanics of a particle in a general gravitational field is examined in the semi-classical limit. A simple formula for the phase acquired by the particle, $\phi = 1/2 \int h_{\mu\nu} P^{\mu} dx^{\nu}$, is obtained. This formula is then used to discuss some possible types of interference experiments for matter waves in gravitational fields.

28. Gravitational Encounters in Rich Clusters of Galaxies by S.E. Strom and K.M. Strom, Kitt Peak National Observatory, Tucson, Arizona 85726.

Abstract - Gravitational encounters in dense clusters may significantly alter the structural properties of elliptical galaxies. New observational data presented here suggest that ellipticals located near the dense, central regions of spiral-poor and cD clusters of galaxies may lose up to 50 percent of their initial mass, while their characteristic sizes may decrease by a factor of 4 or more. Comparison of these results with numerical simulation of galaxy encounters lends support to the view that tidal stripping of halo stars is a plausible cause of these evolutionary changes. E galaxies located in lower-density, spiral-rich clusters appear to be far less affected by gravitational encounters. Their structural properties may be sufficiently homogeneous to permit the definition of a standard metric suitable for cosmological tests.