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Abstracts of Award Winning and Honorable Mention Essays for 1976

Award Winning Essays

First Award - How Fast Can A Black Hole Eat? by Peter Kafka and Peter Mészáros, Max Planck Institut für Physik und Astrophysik, Munchen, Germany.

Abstract - The authors construct stationary spherically symmetric solutions of the equations for accretion of large mass flows onto a black hole, including the interaction of matter and radiation due to Thomson scattering in the diffusion approximation. They discuss the relevance of these solutions with regards to the following question: Does the limitation of the luminosity (Eddington limit) also imply an upper bound to the possible rate of mass flow? The question remains open until all instabilities have been studied. At the moment the authors tend to a negative answer.

Second Award - A New Hamiltonian Structure For The Dynamics Of General Relativity by Arthur A. Fischer and Jerrold E. Marsden, Dept. of Mathematics, University of California, Santa Cruz -- Berkeley.

Abstract - A new compact form of the dynamical equations of relativity is proposed. The new form clarifies the covariance of the equations under coordinate transformations of the spacetime. On a deeper level, new insight is obtained into the infinite dimensional symplectic geometry behind the equations, decompositions of gravitational perturbations and the space of gravitational degrees of freedom. Prospects for these results in studying fields coupled to gravity and the quantization of gravity is outlined.

Third Award - Competition Between Neutrino and Gravitational Radiation by Demosthenes Kazanas and David N. Schramm, Enrico Fermi Institute, University of Chicago, Chicago, Illinois.

Abstract - This essay discusses the competition between neutrino radiation and gravitational radiation for the dominant method by which forming neutron stars radiate away their gravitational collapse energy. It is shown that neutrinos may, in fact, be the dominant mode; thus a failure to detect gravitation radiation from a supernova does not imply an error in general relativity but rather the existence of a more efficient radiation mechanism.

Fourth Award - Why Are Spherical Stellar Systems Relaxed? by David Layzer, Harvard College Observatory, Cambridge, Massachusetts.

Abstract - Spherical stellar systems, from globular star clusters to compact galaxy clusters, appear to be dynamically relaxed. In galaxies and galaxy clusters, collisional relaxation acts too slowly to produce the observed result; and a new argument suggests that the same may be true of globular star clusters. "Violent relaxation" requires special initial conditions, and seems unable to produce sufficiently extended haloes. It is here proposed that dynamical relaxation may result from tidal perturbations by external systems. If this explanation is correct, it has important implications for the early history of galaxies and galaxy clusters.

Fifth Award - Mini-Black-Holes Are Forming Now by Kenneth C. Jacobs and Patrick O. Seitzer, Dept. of Astronomy, University of Virginia, Charlottesville, Virginia 22903.

Abstract - It has been thought that mini-black-holes could only be formed in the very early stages of a big-bang universe. The authors show how they can be forming today in the cores of condensed, stellar-mass objects. The unique interactions of such "contemporary mini-black-holes" with their environment, their courses of evolution, and their astrophysical implications are then described briefly. These latter effects are critically dependent upon the existence of Hawking's "quantum evaporation" process for black holes. A rich and challenging new field--mini-black-hole physics--is thereby introduced.

Honorable Mention Essays (Alphabetical Order)

1. The Range of Gravitation by G.O. Abell, Dept. of Astronomy, University of California, Los Angeles, California.

Abstract - Gravitational theory is very firmly established in the solar system, and is quite firmly established within stars and in binary-star systems. At still larger distances an attractive force is apparent, but evidence for the inverse-square nature of it grows weaker with increasing linear distance. On a scale larger than that of clusters of galaxies there is no firm evidence even for an attractive force. In particular, gravitational forces do not appear to bind together superclusters of galaxies.

2. Quantum Gravity and Quark Confinement by Stephen Blaha, Dept. of Physics, Syracuse University, Syracuse, New York 13210.

Abstract - The author points out certain formal similarities between gravity and field theoretic models of the strong interaction which realize quark confinement through the Schwinger mechanism. A unified theory of the strong interaction and gravity is constructed based on the requirements of (i) manifest renormalizability and quark confinement in perturbation theory, (ii) simplicity in the choice of a mechanism to realize (i), (iii) a symmetric coordination of the SL(2,C) gauge fields in gravity, and the color SU(3) Yang-Mills fields embodying the strong interaction so that quark confinement and renormalizability of quantum gravity are correlated.

3. Sources, Transmitters, Hertz Potentials and Radiation Fields, by Brian Bramson, Merton College, Oxford, England.

Abstract - The essay is concerned with that class of dynamical systems sufficiently isolated that the gravitational fields which they produce are asymptotically flat. It is argued that as far as the definitions of multipole moments and radiation fields are concerned, whether electromagnetic or gravitational, the original curved manifold is an unsuitable arena for their description. Instead, physical laws are to be formulated in space-times of image points. An example is the equality between the time rate of change of the gravitational quadrupole moment and the spin-two Hertz potential.

4. On The Yang-Mills Structure of Gravitation - A New Issue of the Final State by M. Camenzind, Institut für Theoretische Physik, Universität Hamburg, Hamburg, W. Germany.

Abstract - The Yang-Mills approach to gravity is presented; this extension of general relativity is based on the structures of a gauge theory: the Lorentz frame bundle acts as gauge bundle, the connection on the Lorentz bundle is the basic dynamical field, and the Yang-Mills equations define the dynamics for the connection. As a consequence of this dynamics the equivalence principle will be broken on space-time regions of high curvature, while it remains strictly preserved e.g. for the solar system and for homogeneous and isotropic world models. They are explicitly used to illustrate the extension of the general relativistic dynamics.

5. SL(2,C) Gauge-Field Tbeory of Gravitation; Conservation Laws by M. Carmeli, Department of Physics, Ben Gurion University, Beer Sheva, Israel.

Abstract - Recent developments in formulating general relativity theory as an SL(2,C) gauge field theory enables us to formulate a new continuity equation that has not been exhibited so far. The new conserved "current" $\vec{J}^{\mu}$ is a 4-vector in space-time and simultaneously a 3-vector in the complex inner space of the gravitational gauge group SL(2,C), similar to the conserved current in the usual gauge theory that guarantees that the total isotopic spin is conserved.

6. Gravity Field of Mars by Kenneth Chambers, 258 Mudd, Pomona College, Claremont, California 91711.

Abstract - The most sophisticated models of the gravity field of Mars are at present all derived from analysis of Mariner 9 data. The gravitational field is much "rougher" than that of Earth. The differences are small but significant effecting studies from the density distribution of the planet to general relativity. The purpose of this paper is to compare and contrast the different techniques used in analyzing this data and to report the ramifications. The techniques included are: (1) preliminary radio; (2) combined radio and optical; (3) uniform longitude; and (4) a short arc, or mass point.

7. The Role of Mathematics in Gravitational Physics: From the Sublime to the Subliminal? by C.B. Collins, Dept. of Applied Mathematics, University of Waterloo, Waterloo, Ontario, Canada.

Abstract - Certain physical systems are described for which particular equations of state are singled out by means of purely mathematical considerations. The fact that these equations of state are realistic, and indeed the most relevant to the physical

systems under study, suggests that locked into Einstein's field equations lies dome information about local physical conditions, and that in order to describe gravitating systems, it is not always necessary to draw on extraneous branches of physics.

8. General Relativistic Incompressibility by F.I. Cooperstock and R.S. Sarracino, Dept. of Physics, University of Victoria, Victoria, B.C., Canada.

Abstract - The concept of incompressibility in general relativity is re-examined and it is argued that neither Schwarzschild nor Eddington had a proper definition. A new operational definition is presented which, in conformity with basic concepts of relativity, is unattainable in nature. The Eddington definition is classically motivated, the Schwarzschild definition is special relativistic and a new equation of state which generalizes the Schwarzschild definition to general relativity is proposed and analyzed. This is found to be stiffer than the other two, leading to a larger upper limit to gravitational red shift.

9. A New Spin Test for the Equivalence Principle by N.D. Hari Dass, The Niels Bohr Institute, University of Copnehagen, Copenhagen, Denmark.

Abstract - The existing impressive tests for the strong equivalence principle are reviewed and their classical nature are emphasized. The possibility is raised here that intrinsic quantum spins may behave differently from orbital angular momentum in gravitational fields. The techniques developed to measure the electric dipole moment of the neutron are shown to offer hopes of testing this hypothesis. Einstein's theory predicts a null result for this experiment. This would constitute the first quantum test for the strong equivalence principle.

10. On The Possibility of Dissipative Forces in Gravitation by P. Dolan and P. Choudhury, Dept. of Mathematics, Imperial College, London SW7, U.K.

Abstract - In this essay it is shown that a phenomenological treatment of dissipative forces requires the introduction of a torsion tensor field. This shows up as a damping term in the equation for relative accelerations between neighbouring test particles assuming the physical principle that in the absence of non-gravitational forces all such particles follow the simplest stable motions. In cosmology a new form of Raychaudhuri's equation is obtained which has a dual interpretation as either (i) renormalization of active gravitational mass density or as (ii) volume corrections giving alterations to Hubble's constant and the deceleration parameter.

11. Distortions in the Large-Scale Dynamics by A.J. Fennelly, Dept. of Physics and Astronomy, Western Kentucky University, Bowling Green, Kentucky 42101.

Abstract - Recent observational evidence has failed to settle controversy concerning the large-scale dynamics of the universe. Opinion is divided on the microwave background radiation, homogeneity and isotropy of the Hubble expansion, existence of superclusters, large-scale clumping of galaxy distributions, interpretation of the radio-source number counts, and orientation of galaxy images. Discussions on resolutions of the conflict have invoked critical interpretation of the data sampling and reduction procedures or new variables and parameters in the dynamical analysis. The author analyzes the situation using hydrodynamics with distorted flows to show what augmented use may be made of gravitation to understand the data. In particular, large-scale (even global) inhomogeneity and vorticity may play a larger role than previously believed.

12. Gravity, Dust and Solar Neutrions by John Gribbin, Science Policy Research Unit, University of Sussex, Falmer, Brighton, Sussex, England.

Abstract - A disturbance in the convective equilibrium of the Sun, resulting from accretion of dust during the recent passage of the Solar System through the dust lane associated with the Orien Arm of our Galaxy, may explain why the physical processes expected to produce large quantities of neutrinos are not taking place in the Sun at present.

13. The Microscopic Structure of Space-Time-Geometry Without Geometry-by Kenji Hayashi, Institute of Physics, University of Tokyo, Komaba, Merguro-ku, Tokyo 153, Japan.

Abstract - A new approach to the unification of General Relativity and Quantum Mechanics is suggested. A set of 2-component spinor wave functions, defined on a microscopic space-time, is taken as the basic constituents of matter. The geometry derived from the fundamental spinor fields is rather simple: The semimetric condition holds good. This result is improved by physical arguments. A spinor connexion involves two vector fields: A scale gauge field, which violates the metric condition, does not couple to any spinor fields at all and can be eliminated; A fermion-number gauge field universally interacts with any spinor fields but only too weakly to be detected, and it is also negligible. The spinor connexion is finally shown to be essentially traceless. In consequence the metric condition is derived from the assumed spinor structure of the microscopic space-time.

14. On the Compatibility of Paradoxical Redshifts, Observed in Galaxies and Quasars, With the Theory of Gravitation by Z. Horak, Technical University of Prague, Prague, Czechoslovakia.

Abstracts - Both Newtonian and Einsteinian theories of gravitation lead to the known velocity-distance relation for "free" galaxies. Yet within a group of galaxies at a distance D with a common velocity of recession V = HD a companion galaxy may have a greater transverse velocity w and thus a greater relativistic redshift

$$z = (1 + V/c)[1 - (V^2 + w^2)/c^2]^{-\frac{1}{2}} - 1$$

than the one of the main galaxy. For a binary system the actual distance D and the opposite transverse velocities of the members can be computed from their observed redshifts and estimated ratio of masses. So the redshift excess of the companion galaxies may be explained and the apparent suprerelativistic speeds in expanding radio sources avoided, in full agreement with the velocity-distance law.

15. The Fate Of Nonlinear Fluctuations In The Early Universe by E.P.T. Liang, Dept. of Astronomy and Astrophysics, Michigan State University, East Lansing, Michigan 48824.

Abstract - The author summarizes the current status of our knowledge of nonlinear density fluctuations in the early (radiation dominated) universe. He discusses the origins of such fluctuations at the classical level, and their evolutions after entering the Jeans length. Severe damping due to shock formation, viscosity and thermal conduction wipes out short wavelength adiabatic fluctuations with masses less than galactic mass no matter how large their original amplitude is, while very large masses suffer little damping. Hence the primeval fluctuation spectrum must be a steep monotonic decreasing function of mass. Various astrophysical consequences of such a mini-chaos picture are discussed.

16. On Jacobi Fields by M. Novello, I. Damião Soares, J.M. Salim, Centro Brasileiro de Pesquisas Fisicas, Brazil.

Abstract - The authors define curves on a Riemannian manifold as integrals of generalized Jacobi fields. They show that the force term that deviates the trajectory from the geodesic motion can be constructed as a functional of the metric tensor. These curves can be interpreted as particles (observers) coupled non-minimally with gravitation which can provide a class of residual observers for the inevitable singularity - as shown in the text.

17. Conservation Laws For The Adiabatic Collapse Of A Rotating Star by J. Pachner, Programs in Mathematical Sciences, University of Texas at Dallas, Richardson, Texas 75080.

Abstract - On the basis of two fundamental conservation laws, that of energy momentum tensor and of the equation of continuity and of the normalization equation for the four-velocity it is proved that the angular velocity of a rotating star steadily increases during its adiabatic collapse. The Penrose-Hawking-Ellis theorem on the inevitable gravitational collapse of a star with an overcritical mass into a black hole may thus not be applied in the actual Universe because the theorem supposes that the deviations of the star from the spherical symmetry are not too great.

18. Matter Tensor From the Hilbert Variational Principle by Dave Pandres, Jr., Dept. of Mathematics, North Georgia College, University System of Georgia, Dahlonega, Georgia 30533.

Abstract - The author shows that the usual analysis of Hilbert's action integral $\int\sqrt{-g}\ R\ d^4x$, leading to the Einstein vacuum field equations, contains an implicit assumption concerning the equivalence of observer-frames which is not justified by the equivalence principle. The assumption is that the laws of physics are the same in all frames regardless of whether or not they are freely-falling and nonrotating. By avoiding this assumption, he obtains a generally covariant theory with Einstein equations which contain a stress-energy tensor that describes matter.

19. Viability Tests For Gravitation Theories by Richard Pavelle, Innovation Industries, 3 Fieldstone Drive, Woburn, Massachusetts 01801.

Abstract - Tests with which certain classes of gravitation theories can be shown to be non-viable are described. The tests are used to demonstrate that a recent theory of Yang, the Brans-Dicke theory, and an infinite number of theories attributed to Eddington can be shown to possess unphysical solutions and are therefore not viable theories.

20. Toroidal Black Holes? by P.C. Peters, Dept. of Physics, University of Washington, Seattle, Washington 98195.

Abstract - A solution of the static, axially symmetric field equations is exhibited which, at first glance, seems to represent a toroidal black hole. Further examination shows that there is a ring singularity outside the horizon, so there is no violation of the black hole uniqueness theorems. However, the toroidal horizon is nonsingular, and the curvature invariants on the horizon can be chosen to be arbitrarily small. Continuation of the solution through the horizon shows a spacelike throat to another toroidal solution, as in the Schwarzschild metric, and timelike trajectories into a universe which is topologically closed in two dimensions.

21. Surface Brightness of Extended Sources: A New Cosmological Tool by Vahé Petrosian, Stanford University, Stanford, California.

Abstract - Nearly half a century has passed since Hubble's discovery of the expansion of the universe. Despite the fact that the distance over which Hubble's diagram (the relationship between distance and recession velocity) can now be observed is one hundred times larger than the original one and despite the fact that, by now well established, Einstein's theory of general relativity provides an excellent description of the expanding universe, the exact cosmological model of our universe remains unknown to the extent that some cosmologists still question even the validity of the expansion of the universe or the general relativistic models. It is proposed here that observations of surface brightness of certain galaxies could provide answers to some of the above questions and bring us a step closer to the determination of the cosmological model of our universe.

22. Symmetries and Solutions to the Gravitational Field Equations by John R. Ray, Dept. of Physics and Astronomy, Clemson University, Clemson, South Carolina 29631.

Abstract - Investigations of exact solutions to the Einstein gravitational field equations are described. A systematic search for solutions with certain symmetries leads to several interesting properties of the gravitational field equations.

23. Non Linear Lagrangian Theories of Gravity by Ian W. Roxburgh, Queen Mary College, University of London, London, England.

Abstract - Gravitational theories derived from an action principle where the Lagrange density is a power of the curvature scalar, R^n are investigated. For all values of n the theories have the correct Newtonian limit and for $n \neq 1$ the same weak field solution, which predicts a bending of light of three quarters of the value predicted by general relativity (n = 1).

24. General Relativity, Gravitation and Quantum Theory by Ernst Schmutzer, Sektion Physik der Friedrich-Schiller-Universitat, DDR-69 Jena, Max-Wien-Platz 1, E. Germany.

Abstract - The fact, that the traditional quantum mechanics does not fulfill the requirement of Einstein's General Principle of Relativity is the reason for presenting this paper. Here a new foundation of quantum theory is given. The fundamental quantum laws proposed are the following: (1) time-dependent simultaneous laws of motion for the operators, general states and eigenstates; (2) commutation relations; (3) time-dependent eigenvalue equations. The main results are the following: (1) Meta-quantum-theory including macroscopie phenomena (thermodynamics etc.), which can be specialized to usual quantum mechanics. (2) The fundamental laws are picture-free and valid for arbitrary frames of reference (covariant). (3) New method of calculation for time dependent-problems.

25. On The Astrophysical Significance of the Dimensionless Gravitational Coupling Constant by Joseph Silk, Institute for Advanced Study, Princeton, New Jersey.

Abstract - Simple arguments involving gravitational fragmentation indicate that in order for the Universe to contain galaxies and stable nuclear-burning stars, the dimensionless gravitational coupling constant α_G ($=G m_p^2/hc$) must lie within several orders of magnitude of its actual value (5×10^{39}). The characteristic mass of a

galaxy is shown to be $\alpha^{5}\ \alpha_{g}^{-2}$ nucleons: consequently there should be some α^{-5} galaxies in the observable universe. If galaxies form by gravitational instability and fragmentation of cluster-sized inhomogeneities in the early Universe, the large-scale structure of the Universe imposes a lower bound, and the instability requirement an upper bound (equal to $\alpha_{g}^{-\frac{1}{4}}$), on the entropy per particle.

26. Inhomogeneous Cosmologies by Alan Spero and Ralph Baierlein, Dept. of Physics, Wesleyan University, Middletown, Connecticut 06457.

Abstract - Since its inception, relativistic cosmology has focused on spatially-homogeneous models of the universe. To answer the question, Why is the universe the way it is?, cosmology must investigate inhomogeneous models as well. The authors herein describe a new tool for analyzing inhomogeneous space-times. Although the method is both abstract and general, they choose the context of a specific inhomogeneous space - the Gowdy three-torus - to describe the method here. Already in this limited context, nice questions of topology and evolution arise, including the surprise that an inhomogeneous space-time can become more nearly homogeneous as one goes back in time toward its singular origin.

27. Cosmological Constraints On A Varying Gravitational "Constant" by Gary Steigman, National Radio Astronomy Observatory, Green Bank, West Virginia.

Abstract - In this essay the author develops the idea that the evolution of the Universe can serve as a laboratory in which theories of gravity may be tested. To illustrate this point he notes that the rate at which the Universe expands depends on the strength of the gravitational coupling "constant" and, hence, a varying G can seriously affect processes occurring during the evolution of the Universe. From a consideration of the microwave background radiation and of primordial nucleosynthesis follow cosmological constraints which significantly limit the possible variation of G between the early Universe and the present. These cosmological limits are more restrictive than those which may be derived from solar system experiments; they case doubt on the theory of gravity proposed by Dirac and Jordan and they restrict to a limited set of models, the theory of Brans and Dicke.

28. A Measurable Result From A Purely Philosophical Approach to the Cosmological Coincidences by G. Szamosi, Dept. of Physics, University of Windsor, Windsor 11, Ontario, Canada and J.K. Lawrence, Dept. of Physics and Astronomy, California State University, Northridge, Northridge, California 91324.

Abstract - The authors assume two philosophical principles concerning the nature of the Universe. First, a "bootstrap" principle requires that all elementary particles mirror the properties of the Universe as a whole. Second, a "cognizability" principle requires that an observable universe have properties that permit the evolution of complex, sentient beings. These allow the derivation of the well-known "cosmological coincidences" and lead to a verifiable prediction that the Pauli principle for nucleons has a lifetime $\sim cR \times 10^{4}$, where R is the characteristic length of the observable Universe.

29. Singularities in Universes with Negative Cosmological Constant by Frank J. Tipler, Dept. of Physics and Astronomy, University of Maryland, College Park, Maryland 20742.

29. Abstract - It is well-known that many universes with negative cosmological constant contain singularities. The author generalizes this result by proving that all closed universes with negative cosmological constant are both future and past timelike geodesically incomplete if the strong energy condition holds. No global causality conditions or restrictions on the initial data are used in the proof. Furthermore, the author shows that all open universes with a Cauchy surface and a negative cosmological constant are singular if the strong energy condition holds.

30. A Former Major Planet of the Solar System by Thomas C. Van Flandern, U.S. Naval Observatory, Washington, D.C. 20390.

Abstract - Recent dynamical calculations by M.W. Ovenden have given strong indications of the former existence of a planet with a mass ninety times that of the Earth, present in the asteroid belt. These calculations have now been strikingly supported by the discovery that very-long-period comets apparently originated from the break-up of such a planet. This new evidence is present independently in the distributions of each orbital element of 60 well-observed very-long-period comets, and intensifies if the effects of galactic tidal perturbations are removed by a numerical integration backwards in time to the indicated epoch of the break-up, 6×10^6 years ago.

31. Particles and the Vacuum State in Curved Spacetime by N.M.J. Woodhouse Joseph Henry Laboratories, Princeton University, Princeton, New Jersey 08540.

Abstract - After a brief summary of previous attempts to construct a generally covariant occupation number formalism, a new approach to this problem is suggested. It is based on the WKB approximation rather than on a symmetry principle. It is argued that this new approach will help to clarify the particle interpretation of quantum field theory in curved spacetime and that it will lead to a stimulating interaction between general relativity and geometric quantization theory.