GRAVITY RESEARCH FOUNDATION
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Abstracts of Award Winning and Honorable Mention Essays for 1974

Award Winning Essays

First Award - The Shearing of the Universe by Joseph Silk, Department of Astronomy, University of California, Berkeley, California.

Abstract - Density fluctuations in the early Universe generate random shearing motions via their non-linear gravitational interactions. The associated primeval adiabatic and shear-generated temperature fluctuations in the microwave background radiation are estimated, and recent observational constraints are found to require that the deceleration parameter q_0 must exceed 0.1, independently of whether re-scattering by an ionized intergalactic plasma is assumed to weaken the primeval temperature fluctuations. This is because the shear motions generate fluctuations of comparable magnitude. The residual shear flow at the present epoch cannot be reconciled with the galaxy distribution in the local supercluster unless q_0 is less than 0.5.

Second Award - A Determination of the Rate of Change of G by Thomas C. Van Flandern, U.S. Naval Observatory, Washington, D.C. 20390.

Abstract - A new analysis of lunar occultations from 1955-1973 utilizing Atomic Time gives a value for the empirical part of the secular deceleration of the Moon's mean longitude of $(-80\pm10)''/\text{century}^2$. This differs significantly from the portion due to tidal friction of $(-42\pm4)''/\text{century}^2$. Attributing the difference to a changing gravitational constant, as suggested by Hoyle, the implied rate is $\dot{G}/G = (-1.1\pm0.3)\times10^{-10}$ /year. This interpretation is supported by the fact that conservation of angular momentum for tidal forces in the Earth-Moon system would be implied, and by other astrophysical and geophysical data.

Third Award - Black Holes Aren't Black by S.W. Hawking, Department of Applied Mathematics and Theoretical Physics, and Institute of Astronomy, University of Cambridge, Cambridge, Massachusetts.

Abstract - It is shown that quantum effects cause a black hole to radiate like a body with temperature of the order of $10^{26}M^{-1}$ $^{\circ}K$ where M is the mass of the black hole in grams. This thermal radiation means that black holes have a finite life of the order of $10^{-28}M^{3}$ secs.

Fourth Award - A New Approach to Isolated Systems in General Relativity, Essay on the Theory of Gravitation by B.G. Schmidt, Max-Planck-Institut für Physik und Astrophysik, 8 München 40, West Germany.

Abstract - A new method to formulate asymptotic conditions for the gravitational field of isolated systems is presented. It is based on a boundary attached to spacetime, which is determined intrinsically by the conformal structure. The boundary is a generalization of $\mathcal{I}$, defined by Penrose, and constructed using a certain bundle over spacetime. Application to asymptotically simple spacetimes shows that the boundary contains not only $\mathcal{I}$ but further points, corresponding to I^0, I^-, I^+ in Minkowski space. Sufficient conditions for I^0 to be a point are given. In this case one gets the Poincaré group naturally as an asymptotic symmetry group. Further issues, where this new boundary may be quite useful, are discussed.

Fifth Award - The Interaction of Gravity with Quantized Fields by Stephen A. Fulling and Leonard Parker, Physics Department, University of Wisconsin-Milwaukee, Milwaukee, Wisconsin, 53201.

Abstract - A rapidly growing area of gravity research is the study of particle creation by gravitational fields, an effect predicted by quantum field theory. To calculate the influence of the created particles on the gravitational field producing them, it is necessary to find the physically effective renormalized energy-momentum tensor. We discuss an analysis of the concept of physical particle states which seems to lead in a natural manner to the renormalized tensor. Included is a demonstration that our definition of particle states yields physically correct results when applied to the particular Kasner universe which reduces to Minkowski space.

Honorable Mention Essays (Alphabetical Order)

1. The Quantum Mass Spectrum of the Kerr Black Hole by Jacob D. Bekenstein, Center for Relativity Theory, University of Texas at Austin, Austin, Texas, 78712.

Abstract - Using well understood arguments from quantum theory we discuss the nature of the quantum spectra of the mass, charge, and angular momentum of the Kerr black hole. We argue that the mass spectrum is discrete and infer a formula for the allowed mass levels by first pointing out the analogy between the squared irreducible mass of the Kerr hole and the action integral of mechanics, then quantizing the squared irreducible mass by the Bohr-Sommerfeld quantization rule, and finally substituting the results in the Christodoulou mass formula. The result is consistent with the correspondence principle. We close with a discussion of spontaneous transitions of the Kerr hole and of scattering of a quantum on a Kerr hole from the point of view of a discrete mass spectrum.

2. Non-Gravitating Objects in General Relativity by Carl H. Brans, Joseph Henry Laboratories, Princeton University, Princeton, New Jersey.

Abstract - Arguments are proposed for investigating the possibility of solutions to the Einstein equations corresponding to objects described by physically acceptable matter tensors but which do not gravitate externally, at least for a finite time, because of a balancing negative gravitational energy.

3. The Application of Gravity Free Metallurgy for the Production of New Materials by James Carter, Box 831, Avalon, California, 90704.

Abstract - The science of gravity free metallurgy is proposed for the purpose of creating several new materials not possible in an accelerating environment such as the gravity of the earth's surface. The vacuum bubble is examined as the basic structural unit of a new material for aircraft construction. The possibility of making new alloys with undreamed of properties is also discussed.

4. A New Approach to the Two-Body Problem in General Relativity by F.I. Cooperstock, Laboratoire de Physique Theorique, Institut Henri Poincaré, Paris, France.

Abstract - The advantages of the analysis of the two body problem from an initially static configuration are discussed. The stress which maintains the static equilibrium of two bodies is removed and the complementary phenomena of stress breaking and mass motion lead to a dynamic metric perturbation and radiation. The distinctions between the stress-breaking and free-fall phases of the motion are clearly delineated.

5. An Unbound Universe? by J. Richard Gott, III, California Institute of Technology, Pasadena, California, James E. Gunn, Hale Observatories, California Institute of Technology and Carnegie Institution of Washington, David N. Schramm, The University of Texas at Austin, Austin, Texas, Beatrice M. Tinsley, The University of Texas at Austin and at Dallas, Dallas, Texas.

Abstract - Probably the most important question in cosmology today is whether the universe is gravitationally unbound, open and will expand forever or whether it is gravitationally bound, closed and will eventually cease expanding and contract. This essay presents a variety of arguments which strongly suggest that the density of the universe is no more than a tenth of the value required for closure. Loopholes in this reasoning may exist, but if so are primordial and invisible, or perhaps just black.

6. Gravitational Repulsion in the Solar System by Richard Greenberg, Lunar and Planetary Laboratory, University of Arizona, Tucson, Arizona.

Abstract - Collisions and close approaches between bodies in the solar system are often prevented by their gravitational interaction. This mutual repulsion results when Newtonian forces act in an orbit-orbit resonance. In this paper, illustrative examples are described, the resonance mechanism is explained qualitatively, and the significance of the phenomenon in the dynamical history of the solar system is discussed.

7. Gravity, Tides on the Sun, and Climatic Change by John Gribbin, Assistant Editor, Nature, London, England.

Abstract - Gravity is vital in establishing the patterns of climate on Earth; it is the force responsible for the pressure gradient under the influence of which our atmosphere moves. But gravity also modulates our climate, through the tidal influence of the planets on the Sun's output. This explains variations in the climate which can be correlated with solar variations over the 11 year cycle and longer; in addition the author suggests that a 179 year variation in the planetary influence both accounts for the present droughts in Africa and India and offers hope of predicting such occurrences in future.

8. Experiments to Determine the Gravitational Deflection of Polarized Radiation by Martin Harwit and R.V.E. Lovelace, Center for Radiophysics and Space Research, Cornell University, Brian K. Dennison and David L. Jauncey, Center for Radiophysics and Space Research, Cornell University and National Astronomy and Ionosphere Center, John Broderick, National Astronomy and Ionosphere Center, Cornell University, Ithaca, New York.

Abstract - Theories of gravitation are not specific on how orthogonally polarized photons should act in strong gravitational fields and in the fields of massive rotating objects. We give a brief argument to show that differences in polarization should strongly affect the behavior of photons in these limiting situations. While the sun is neither massive nor in rapid rotation, it is possible that some hint of differential deflection of orthogonally polarized radiation passing near the sun could be detected by highly sensitive observations. We report on experiments that place upper limits -- in some cases as small as one part in 10^6 -- on the difference in angular deflection of orthogonally polarized photons.

9. The Spin of Elementary Particles as a Source of a New Gravitational Interaction by Friedrich W. Hehl and G. David Kerlick, Joseph Henry Laboratories, Princeton University, Princeton, New Jersey, 08540.

Abstract - The geometrization of physics which served Einstein so well is here applied to the description of the gravitational interaction of spinning elementary particles. The resulting "U_4 theory" which uses a Riemann-Cartan geometry is internally consistent and as compatible with experiment as Einstein's theory. It predicts a new universal spin-spin contact interaction. The deviations from Einstein's theory can be felt in the domain of elementary particles and at very high matter densities. Thus the occurrence of singularities in cosmological models may be prevented.

10. The Nature of Our Universe by Kenneth C. Jacobs, Leander McCormick Observatory and Department of Astronomy, University of Virginia, Charlottesville, Virginia, 22903.

Abstract - The Robertson-Walker models of our Universe are consequences of classical general relativity theory; they are generally thought to emerge from singular "beginnings". However, a careful analysis of the hadron era -- that regime where 10^{-44} second $\lesssim$ t $\lesssim 10^{-4}$ second -- reveals that we must combine second-quantized field theory for a Hagedorn hadronic ensemble with the classical metrical field equations of general relativity to properly describe events. The consequences of this semi-classical approach are these: Our Universe most probably did not experience a singular "beginning", but rather "bounced" from a previous (positive curviture) collapse phase into our present (positive curvature) expanding phase. The "magic number" 10^{40} arises prominently in this result.

11. A Second "Second-Order" Gravitation Experiment by Jack Jaffe, Department of Physics, Boston College, Chestnut Hill, Massachusetts and Weston Observatory, Weston, Mass.

Abstract - The number of gravitation experiments undertaken since the advent of Einstein's theory of gravitation is less than a handful, with only the famous perhelion advance experiment being able to measure a non-linear, second order effect. It now appears possible that, for the first time, another distinct test of the second-order term may be feasible, through the use of very stable atomic clocks. This experiment, which would measure the second-order gravitational redshift, is a bona fide test of the field equations of gravity, not just a test of the underlying principle of equi-

12. Statistical Physics, Mach's Principle, and the Cosmological Coincidences by J.K. Lawrence, Department of Physics and Astronomy, California State University at Northridge, Northridge, California, G. Szamosi, Department of Physics, University of Windsor, Windsor 11, Ontario, Canada.

Abstract - The authors assume that the physical parameters of elementary particles are not identical, but form statistical distributions about average values. By requiring that the spread in the parameters not be detectable in the age of the universe and that the universe be gravitationally bound, they are able to derive most of the familiar "cosmological coincidences" relating microscopic quantities to cosmic ones. In addition, they find a reasonable upper limit for the mass of an elementary particle, that $e^2/\hbar c$ is a constant and a new coincidence involving the magnetic moment of an elementary particle.

13. The Einstein Field Equations by David Lovelock, Department of Applied Mathematics, University of Waterloo, Waterloo, Ontario, Canada, N2L 3G1.

Abstract - The purpose of this essay is to focus attention on those mathematical assumptions which are usually made in general relativity from which the Einstein equations are derived. These assumptions are discussed and criticized and it is explained why, in general, they are far too severe. Attention is drawn to the fact that in many instances they can be considerably relaxed in a manner which, nevertheless, still ensures that the Einstein field equations are an inevitable consequence in a space of four dimensions.

14. Gravity as a Gauge Theory by James M. Nester, University of Maryland, College Park, Maryland, 20742.

Abstract - Gravity is treated as a gauge theory; the ways in which it is similar to and different from other gauge theories are noted. The theory of gravity which emerges is a modification of the Einstein theory to a Riemann-Cartan space time whose metric in each tangent plane is determined by the matter stress energy tensor and whose torsion, which describes the relative rotation of nearby tangent planes, is determined by the intrinsic spin density of matter.

15. An Essay on the Self-Interaction of a Rotating Object with its Gravitational Radiation by J. Pachner, Department of Physics and Astronomy, University of Saskatchewan, Regina, Saskatchewan, Canada.

Abstract - It is shown that the applicability of the Penrose theorem on the inevitable occurrence of a gravitational collapse is seriously restricted in the actual Universe. Because of the conservation of the angular momentum the angular velocity of a first slowly rotating astronomical object steadily increases during its contraction and may reach such a high value that stops its radial contraction and reverts it to a new expansion and simultaneously generates a gravitational wave strong enough to prevent the collapse in the axial direction as well. A proof is given that this effect is not caused by an incoming wave.

16. How to Detect Gravitational Radiation: From Supernova to Superconductor by Ho Jung Paik, Department of Physics, Stanford University, Stanford, California, 94305.

Abstract - In order to resolve the controversy over Weber's experiments and reach for theoretically predicted gravitational wave events one should improve the sensitivity by three to five orders of magnitude. The only way to accomplish this aim is by cooling the detector to the order of 10^{-3}°K. A superconducting tunable-diaphragm transducer can be made with essentially unity coupling without lowering the antenna Q. A low noise superconducting magnetometer enables one to observe an energy of $\frac{rT}{500}$ at $T = 3 \times 10^{-3}$°K. This improved sensitivity by 10^6 over Weber's makes cryogenic detectors gravitational wave telescopes that can reach for supernova explosions beyond the Milky Way.

17. Gravitation and the Formation of Toroidal Universes by Kim A. Papp, 3131-39 Street, S.W., Calgary, Alberta, Canada T3E 3G9.

Abstract - Using topological analysis, specifically Morse Theory and the theory of singular points on complex manifolds, applied to the static Schwarzschild solution of Einstein's field equations - transformed into the Kruskal-Szekeres system, the general manifold and the singularities at r=2m and r=0 are studied. The author finds that the general manifold is that of a torus with a contour. The event horizon (r=2m) is a torus with a clover leaf knot wrapped around it. Both these and the r=0 singularity then permit a description of multiple universes as nested torii.

18. A Perfectly Oscillating Universe by A. Prakash, Center for Radiophysics and Space Research, Cornell University, Ithaca, New York, 14850.

Abstract - The question of what preceded the initial singularity and what lies "beyond the end of time" is answered by proposing a model of the universe which is in accord with Einstein's theory of gravity and in which the singularity is treated not as an embarrassing entity where the laboratory-proven laws of physics breakdown but as a reality which requires an appropriate interpretation. The resulting model makes the collapse of Einstein's closed universe not a catastrophe but the 'moment of truth' for the most general laws of physics.

19. Einstein-Cartan Theory Or The Geometrisation of Mass and Spin by A.R. Prasanna, Institut für Theoretische Kernphysik der Universität Bonn, Bonn, West Germany.

Abstract - The Einstein-Cartan Theory has been briefly discussed on the basis of Trautman's recent formulation, sketching some plausible arguments for considering this theory. Results are mentioned which indicate the necessity of a systematic study of boundary conditions and for considering the effects of Strong-gravity in the framework of this theory.

20. Gravitation in Systems of Galaxies by Herbert J. Rood, Department of Astronomy and Astrophysics, Michigan State University, East Lansing, Michigan, 48824.

Abstract - Classical double galaxies, double compact galaxies, double supergiant galaxies in rich clusters, compact groups, loose groups, rich clusters, and superclusters have a ratio of virial mass to luminous mass (M_{vt}/M) which increases from about 1 to 100 as the virial velocity dispersion (V) increases from 100 to 1000 km/sec. These results and a careful examination of the hypotheses which have been advanced to explain the mass discrepancy suggest that scientists may have to take a more detailed look at gravitational theory.

21. Gravity and Chains of Galaxies by Wallace L.W. Sargent and Edwin L. Turner, Hale Observatories, California Institute of Technology and Carnegie Institution of Washington.

Abstract - Some chains of galaxies are illustrated and their physical properties are described. It has been proposed that these formations are examples of newly formed galaxies along magnetic tubes in intergalactic space or that they represent the ejection of galaxies from the nuclei of parent galaxies by unknown physical forces. The authors show by a computer simulation that the chains result from transient chance projection effects in normal small clusters of galaxies that are interacting under gravitational forces alone.

22. Electromagnetic Radiation from Colliding Black Holes by Frank J. Tipler, Department of Physics and Astronomy, University of Maryland, College Park, Maryland, 20742.

Abstract - It is shown that the collision of two black holes would result in the emission of electromagnetic radiation with a very distinctive wave form. If, as Hawking has suggested, the gravitational radiation events reported by Weber are produced by black hole collisions in the galactic center, then the associated electromagnetic pulses would have, in the microwave band, a maximum flux of 6×10^{-5} f.u. This flux lies at the limit of detectability with present day radio astronomy technology.

23. Energy Limits on the Penrose Process by Robert M. Wald, Department of Physics and Astronomy, University of Maryland, College Park, Maryland, 20742.

Abstract - If a body in the vicinity of a rotating black hole breaks apart into two or more fragments, then under appropriate conditions the rotational energy of the black hole can be used to enhance the energy of one of the fragments (Penrose process). Wheeler and others have suggested that this process could have important astrophysical consequences since it allows one to extract energy from the vast storehouse of rotational energy provided by the black hole. In particular, it has been suggested that the Penrose process could serve as an energy mechanism for jets. In this essay the author presents a simple derivation of strict limits on the energies which can be achieved by the Penrose process.