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Abstracts of Award Winning and Honorable Mention Essays for 1989

Award Essays

First Award - The Electric Field Induced by a Gravitational Wave in a Superconductor: A Principle for a New Gravitational Wave Antenna by Huei Peng and Douglas G. Torr, Department of Physics, The University of Alabama in Huntsville, Huntsville, AL 35899

Abstract - In this paper the authors investigate the effect of a gravitational wave on a superconductor. They find that the key properties of a superconductor, namely zero resistance and perfect diamagnetism, give rise to an important new effect, the presence of an induced electric field E(r,t) in the interior of the superconductor. The E field reacts with the ions and superelectrons. They argue, that not only is the finding of the coupled interactions of gravitation, electromagnetism and superconductivity inherently interesting, but that the induced E field might provide a significantly more sensitive means of detecting gravitational waves. It appears likely that existing resonant-mass superconducting antennas with L $\simeq$ 3m, Q $\simeq 10^8$ could be readily modified to detect E fields induced by gravitational waves of dimensionless amplitude h $\simeq 10^{-24}$.

Second Award - On the Gravitational Structure of Elementary Particles by E. I. Guendelman, Theoretical Division, T-8, MS B285, Los Alamos National Laboratory, Los Alamos, NM 87545

Abstract - Gravitational Bags are spherically symmetric solutions of higher dimensional Kaluza Klein (K-K) theories, where the compact dimensions become very large near the center of the geometry, although they are small elsewhere. K-K excitations become therefore very light when located near the center of this geometry and this appears to affect drastically the naive tower of masses spectrum of K-K theories. In the context of string theories, string excitations can be enclosed by Gravitational Bags, making them not only lighter, but also localized as observed by somebody that does not probe the central regions. Strings however, can still have divergent sizes, as quantum mechanics seems to demand, since the extra dimensions blow up at the center of the geometry.

Third Award - Axionic Black Holes and Wormholes by Mark J. Bowick, Lyman Laboratory for Physics, Harvard University, Cambridge, MA 02138

Abstract - Theories in which gravity is coupled to a Kalb-Ramond field are known to have black hole solutions characterized by the value of the conserved axion charge. The Kalb-Ramond field configuration for these black holes has vanishing field strength. The axion charge may be measured by an analog of the Aharanov-Bohm interference effect. The axion-charge to mass ratio may be arbitrarily large, as contrasted to the case of the Reissner-Nordstrom black hole where the electric-charge to mass ratio has an upper bound of one. The generic endpoint of semiclassical evaporation of an axionic black hole would therefore be an object of very large axion charge with mass of order the Planck mass. Axion charge also couples to Giddings-Strominger type instantons (wormholes) present in these theories. Instead of evaporating completely, therefore, it is likely that an axionic black hole will be swallowed by a wormhole, avoiding the appearance of a naked singularity. The loss of quantum coherence is a more subtle issue.

Fourth Award - Non-Classical Hair on Black Holes by Lawrence M. Krauss, Center for Theoretical Physics and Department of Astronomy, Sloane Laboratory, Yale University, New Haven, CT 06511

Abstract - Black holes can have non-classical hair, i.e. they can be characterized by observable quantum numbers associated with discrete charges which are not coupled to long range propagating gauge fields. This blurs the apparent distinction between small black holes and elementary particles and has important implications for wormhole physics.

Fifth Award - The Effect of Spacetime Curvature on Hilbert Space by Y. Q. Cai and G. Papini, Department of Physics, University of Regina, Regina Saskatchewan, S4S 0A2, Canada

Abstract - A new, unified basis for the study of gravitational effects in quantum and classical systems described by linear wave equations has been obtained by means of a covariant generalization of Berry's phase. The new formulation reveals aspects of the interaction of particles with weak gravitational fields hitherto thought to apply only to the stationary, nonrelativistic case. Though the emerging gauge structure is that of general relativity, weak gravitational fields behave as non-local vector fields. Their action on wave functions amounts, in first order, to a phase factor. Some effects predicted in the literature are re-calculated and extended to the fully relativistic regime. New effects are also predicted. The new approach affords a more precise description and a better understanding of particle interferometry as a tool to study gravitation.

Honorable Mention Essays (Alphabetical Order)

1. Vacuum Stress Tensor in an Einstein Universe; Finite Temperature Effects and the Definition of Gravitational Temperature by Selcuk S. Bayin, Department of Physics, Middle East Technical University, 06531, Ankara, Turkey

Abstract - In recent articles the author has introduced Friedmann thermodynamics, where certain geometric parameters in Friedmann models were treated like their thermodynamic counterparts (temperature, entropy, Gibbs potential etc.). This model has the advantage of allowing one to determine the geometry of the universe by thermodynamic stability arguments. In this essay, in search for evidence for the definition of gravitational temperature, the author investigates massless conformal scalar field in (curved background) Einstein universe, in detail. He argues that the gravitational temperature of the Einstein universe is given as $T_g = (1/2\pi)(\hbar c/k)1/R_o$, where R_o is the radius of the universe. This is in accord with the definition of gravitational temperature in Friedmann thermodynamics and determines the dimensionless constant as $1/2\pi$. The author also discusses finite temperature effects and the limitations of the model he is using.

2. Membranes in the Kaluza Klein Theory by Mircea I. Beciu, Department of Physics, Institute of Constructions, Bucharest 73232, Romania

Abstract - In the context of multidimensional theories with the extra dimensions extended and noncompact, the author addresses the question why the extra directions are not perceived. He shows that the supplementary directions can be rendered inobservable if our four dimensional world is considered a null membrane moving in $D > 4$ dimensions. While a pure null membrane meets with some difficulties, a timelike membrane which becomes asymptotically null, does the job.

3. An Experimental Test for Short-Range Failure of the Principle of Equivalence by Wm. R. Bennett, Jr., Dunham laboratory, Department of Physics and Applied Physics, Yale University, New Haven, CT 06520

Abstract - A novel experimental test for short-range failure of the Principle of Equivalence was performed by placing a torsion pendulum made from two different materials (Cu and Pb) next to a giant shipping lock on the Snake River in eastern Washington. Here, a 1.7×10^8 kg source of water could be turned on or off in 12 min. For isospin coupling, this modulated source Eotvos experiment provided results which rule out two previously reported observations of short-range material-dependent gravitational forces at the two-standard deviation level.

4. The Stability of the White Hole Horizon by Steven K. Blau, Theoretical Division, T-8, Mail Stop B285, Los Alamos National Laboratory, Los Alamos, NM 87545 and Alan H Guth, Center for Theoretical Physics, Laboratory for Nuclear Science and Department of Physics, Massachusetts Institute of Technology, Cambridge, MA 02139

Abstract - The authors consider the instability of white holes and its interpretation in terms of an infinite blue shift. They find that the introduction of a small amount of matter ΔM into the Schwarzschild spacetime profoundly affects the geometry within a small radius of order $G\Delta M$ of the horizon, but that there is very little effect on the geometry at larger distances from the horizon. In the geometries they study there are several quantities which grow exponentially with time. They present a coordinate-invariant description of this behavior, and argue that it is misleading to associate this growth with the white hole horizon. On the contrary, the exponential growth is obtained anytime an inward moving spherical shell of matter collapses to a black hole---there need not be a white hole horizon at all. Nonetheless, the white hole may be important as an agent for hastening the accretion of ambient matter.

5. The Origin of Lorentzian Geometry by Luca Bombelli, Department of Mathematics and Statistics, University of Calgary, Calgary, Alberta T2N 1N4 and David Meyer, Department of Physics, Syracuse University, Syracuse, NY 13244-1130

Abstract - Many proposals for a quantum theory of gravity postulate some more fundamental structure from which the spacetime manifold of general relativity should arise in the classical limit. To demonstrate that this can occur, one must show that the fundamental dynamics determines a structure (or set of structures) from which one can reconstruct a Lorentzian manifold which is unique, at least as far as its large-scale properties are concerned. In this essay the authors investigate how a Lorentzian manifold can be reconstructed/approximated by examining countable subsets of points in the manifold together with their causal relations. Although the motivation for these investigations arose in the context of a specific proposal for quantum gravity, the results are of general interest in Lorentzian geometry and approximation theory.

6. The Classical Forces in The Kerr Geometry by Sandip K. Chakrabarti, Tata Institute of Fundamental Research, Bombay, India, and A. R. Prasanna, Physical Research Laboratory, Navarangpura, Ahmedabad, India

Abstract - The authors study the properties of the 'classical forces' acting on a test particle in the field of the Kerr black hole geometry. They show that the centrifugal force and the coriolis force reverse signs at several different locations. They point out the possible relevance of such reversals particularly in the study of the stability properties of the compact rotating stars and the accretion disks in hydrostatic equilibria.

7. A Better Choice of Variables for Density Inhomogeneities by G. F. R. Ellis and M. Bruni, Sissa, Strada Costiera 11, Miramare, Trieste 34014, Italy

Abstract - The gauge problem plagues the study of density inhomogeneities in cosmology. The gauge-invariant quantities determined by Bardeen (1980) are related to density perturbations, but are not those perturbations themselves. The authors introduce a set of variables with a direct physical meaning, characterizing the spatial variation of the relevant physical quantity in the real universe. This representation is both fully covariant and gauge invariant; thus it sidesteps the usual problems. The basic quantity they use is the comoving fractional gradient of the energy density orthogonal to the fluid flow. The authors derive exact non-linear propagation equations for this quantity. They are then linearised to describe the case of a universe that is almost a Friedman-Lemaitre-Robertson-Walker (FLRW) universe. For a pressure-free fluid the usual growing and decaying modes are recovered.

8. Fifth Force and the Gravi-Magnetic Hypothesis by M. Gasperini, Dipartimento di Fisica Teorica dell'Universita', Via P. Giuria 1, 10125 Torino, Italy and I.N.F.N., Sezione di Torino, Italy

Abstract - If there is in nature a massive vector field coupled to baryon number then, as a consequence of its mixing with the photon, every rotating macroscopic mass should be the source of a feeble magnetic field. Such a field, however, should be short-range and with an intensity that, according to observational constraints, is expected to be much smaller than the one prediced by Blackett's gravi-magnetic hypothesis.

9. General Relativity in Newtonian Form - by Ronald Gautreau, Physics Department, New Jersey Institute of Technology, Newark, New Jersey 07102

Abstract - It is shown how the use of coordinates where time is measured with clocks moving radially in a spherically symmetric gravitational field leads to general relativistic dynamical expressions that are exactly identical to corresponding expressions in Newtonian theory. The general formalism is developed for the case where the stress-energy tensor is that of a perfect fluid. Expressions like the Newtonian inverse square gravitational law, the Newtonian equation of continuity for fluid flow, Newtonian conservation of energy, etc., follow quite naturally from the full fledged general relativistic equations. Specific examples involving cosmology and gravitational collapse are given.

10. The Electromagnetic Field Equations in Curved Spacetime - by A. Georgiou, Division of Mathematics, Hatfield Polytechnic, College Lane, Hatfield, Hertfordshire AL10 9AB, United Kingdom

Abstract - In this work the author focuses attention on a controversial issue in the theory of general relativity. The electromagnetic field equations in curved spacetime in general coordinates are nearly always given in terms of the 4-tensor formulation and a great number of researchers seem to have shown that Maxwell's equations are not generally valid. Using the 4-tensor formulation, they derive equations in terms of the electromagnetic spatial vectors which are distinctly different from Maxwell's and very complicated. The author shows that Maxwell's equations are generally valid whether the curvature of spacetime is due to the presence of matter and energy in the vincinity, or to the choice of a particular coordinate system, or both. Finally, the author clearly outlines the errors made by the other researchers.

11. Gravitational Radiation from Cosmic String Collapse by Reinaldo Gleiser, FAMAF, Laprida 854, 5000 Cordoba, Argentina, Jorge Pullin, Phys. Dept. Syracuse University, Syracuse, NY 13244

Abstract - The authors present a new model of interaction of a cosmic string with gravitational radiation based on an exact solution of the Einstein Equations that represents the disappearance of an infinite straight cosmic string due to splitting in two sections. Possible implications to the Cosmic String Galaxy formation scenario are discussed.

12. A New Approach to the Theory with the Variable Gravitational Constant by L. Sh. Grigorian and A. A. Saharian, Institute of Applied Problems of Physics, Academy of Sciences of the Armenian SSR, Yerevan, Armenia, USSR

Abstract - A theory with the variable gravitational constant, based on the bimetric formulation of General Relativity, is suggested. It is in agreement with the Newtonian and post-Newtonian approximations of the theory of gravitation when the theory parameter $|\zeta| >> 4.10^{-6}$. The statical spherical-symmetric distribution of gravitating masses is investigated. It is shown that the total action (including the self gravitational field of the system) $S = -Mr$ where r is the time in the remote system of reference, relative to which the celestial body is at rest. In the Brans-Dicke theory $|\zeta| >> 1$ and $S \neq -Mr$. The Tolman formula for the mass M in the Einstein theory is also valid in the suggested Generalized Bimetric Theory of Gravitation. External analytical and internal numerical solutions of the field equations are found for the case of incompressible matter. It is shown that static and supermassive configurations may exist if $-0.13 \leq \zeta < 0$.

13. Conformal Alternative to Einstein Gravity and Galactic Rotation Curves by Demosthenes Kazanas, Laboratory for High Energy Astrophysics, NASA/Goddard Space Flight Center, Greenbelt, MD 20771, and Philip D. Mannheim, Department of Physics, University of Connecticut, Storrs, CT 06269

Abstract - The authors examine the viability of an alternative to Einstein gravity in which the gravitational action is constrained by an invariance principle and not just by a covariance one. In particular, they require the action to be locally conformal invariant. They study the fourth order equations of motion for the gravitational field which occur in this theory and obtain their complete, exact, static, spherically symmetric vacuum solution. This solution, which, as far as the authors know, is the first exact exterior solution ever obtained in fourth order gravity, reduces to the familiar Schwarzschild one on stellar distance scales but deviates markedly from it on galactic ones. The solution provides a potential explanation for the observed structure of galactic rotation curves without the need for any dark matter.

14. Quantum Gravity and Brownian Motion by Claus Kiefer, Institute fur Theoretische Physik, Universitat Heidelberg, Philosophenweg 19, D-6900 Heidelberg

Abstract - The emergence of classical properties in quantum gravity can be treated analagously to the theory of Brownian motion. The local scale factor $\sqrt{h}$ of a three geometry, which plays the role of an intrinsic time variable in the Wheeler-DeWitt equation corresponds to the coordinate of a Brownian particle, while the conformal part of the three geometry corresponds to the heat reservoir. It is shown that for small values of the scale factor, where the strong coupling limit $G \to \infty$ applies, there is no interaction between intrinsic time and conformal degrees of freedom. Therefore no classical properties emerge at the Planck scale. As the interaction is switched on, the conformal degrees of freedom lead to a suppression of interferences for different scale factors, and intrinsic time emerges as a classical quantity. A master equation for the reduced density matrix similar to Brownian motion is derived and discussed.

15. The Metric-Mass Problem by V. Alan Kostelecky and Stuart Samuel, Physics Department, Indiana University, Bloomington, IN 47405

Abstract - The authors study phenomenological predictions of the observable four-dimensional gravitational sector in compactified higher-dimensional theories. Particular emphasis is placed on string theories and their natural tensor-induced mechanism for spontaneous Lorentz-symmetry breaking. The results of the investigation significantly constrain theories incorporating extra dimensions, including strings, in their perturbative regime. To avoid the phenomenological difficulties one must confront a metric-mass problem: the need to generate mass for the higher-dimensional components of the metric while leaving massless the physical spacetime components.

16. Causality Violations and Singularities by Marcus Kriele, Faculty of Mathematical Studies, University of Southhampton, Southhampton S09 5NH, United Kingdom

Abstract - The author announces two theorems: (1) A generalization of the singularity theorem of Hawking & Penrose to space-times with chronology violations. Although it is impossible to remove the chronology condition completely the announced theorem is in a well defined sense optimal: The Chronology condition is replaced by a strictly weaker condition that cannot be removed because of counter examples. (2) If the chronology violating set ν has compact closure and the strong energy and generic conditions hold, then $\dot{\nu}$ is generated by incomplete null geodesics. It follows that if the region of causality violation does not extend to infinity then $\dot{\nu}$ contains singularities.

17. The Scattering of Particles at Planck Energies by C. O. Lousto, I.A.F.E. - CONICET, c.c. 67 suc. 28, 1428 Buenos Aires, Argentina and N. Sanchez, DEMIRM, Observatoire de Paris, Section de Meudon, 92195 Meudon Principal Cedex, France

Abstract - The authors study the scattering of ultra-high energetic particles. The ultrarelativistic limit of the boosted Kerr-Newman geometry is found. They find the exact S-matrix describing the scattering of a neutral massive field with the shock wave geometry. Finally, they discuss briefly the relation of this process with that of the scattering of strings.

18. Topology Change and Nonperturbative Instability of Black Holes in Quantum Gravity by Pawel Oskar Mazur, Physics Department, University of California, UCLA, Los Angeles, CA.

Abstract - Topology change in quantum gravity is considered. An exact wave function of the Universe is calculated for topological Chern-Simons 2+1 dimensional gravity. This wave function occurs as the effect of a quantum anomaly which leads to the induced gravity. The author finds that the wave function depends universally on the topology of the two-dimensional space. Indeed, the property of the ground state wave function of Chern-Simons gravity which has an attractive physical interpretation is that it becomes large in the infrared (large distances) if the Universe has "classical" topology $S^2 \times R$. On the other hand, nonclassical topologies $\Sigma_g \times R$, where Σ_g is the Riemann surface of genus g, are driven by quantum effects into the Planckian regime ("space-time foam"). The similar behavior of the quantum gravitational measure on four-manifolds constructed recently is discussed as the next example. The author discusses the new phenomenon of the nonperturbative instability of black holes discovered recently. He finds that the Planck-size black holes are unstable due to topology change. The decay rate is estimated using the instanton approximation. A possible solution to the primordial black hole problem in quantum cosmology is suggested.

19. Journeys Beyond the Cahchy Horizon by Ian Moss, Department of Physics, University of Newcastle upon Tyne, Newcastle upon Tyne. NE1 7RU

Abstract - The wormholes which are present in many black hole spacetimes indicate that it may be possible to travel through a black hole to another universe. Unfortunately, these wormholes generally intersect Cauchy horizons where radiation fluxes tend to diverge. In this essay the author shows that the Cauchy horizon of a charged black hole in de Sitter space is stable and could be crossed. This possibility seems capable of generalisation to black holes in closed Friedmann universes.

20. Cosmological Constant and the Dynamics of the Bianchi Type-1 Models with Spin and Torsion: A Qualitative Investigation by Nguyen Hong Chuong, Institute of Theoretical Physics, National Centre for Scientific Research, Nghia Do - Tu Liem - Hanoi - Vietnam

Abstract - In the minimum quadratic (Poincare) gauge theory of gravity by including cosmological term, the basic equation set for the homogeneous anisotropic Bianchi type-1 spinning-fluid models are obtained. In the case of the linear state equation, using methods of qualitative theory of dynamical systems the author makes the complete qualitative analysis of properties of every possible solutions of these equations. In particular, some solutions with the regular behavior of the metric and the torsion are found.

21. Huygens' Principle for the Wave Equation in Riemannian Spacetimes by Thomas W. Noonan, Physics Department, Brockport State College, Brockport, N.Y. 14420

Abstract - The question of whether a wave equation for a tensor field of arbitrary rank in a Riemannian spacetime satisfied Huygens' principle is examined. A set of differential equations for the Green's function is presented as a necessary and sufficient condition that the wave equation satisfy Huygens' principle. For the cases of the two most-studied physical fields---electromagnetism and gravitational waves---it is found that a necessary and sufficient condition that the wave-equation Green's function in a Riemannian spacetime satisfy Huygens' principle and reduce to the special relativistic Green's function for flat spacetime is that the spacetime be flat. The relevance for electromagnetic waves and gravitational waves propagating through curved spacetime is discussed.

22. Quantum Gravity, Classical Geometry: A Coherent Treatment by M. Novello, Centro Brasileiro de Pesquisas Fisicas, CBPF, Rio de Janeiro, Brazil and Departement de Mecanique, Universite de Paris VI, Jussieu, Paris, France and E. Elbaz, Institut de Physique Nucleaire (and IN2P3), Universite Claude Bernard Lyon 1, 43, bd du 11 Novembre 1918 - 69622 Villeurbanne Cedex, France

Abstract - After the work of many physicists - synthesized in a recent paper by Grishchuk, Petrov and Popova - there is no longer any doubt that the exact Einstein's General Relativity admits a complete formal description in terms of a field theory in an (auxiliary) Minkowski background manifold. The authors explore here this property in order to propose a model in which gravity is to be quantized, although the observable metrical properties of space-time remain a classical structure. Thus, quantum fluctuations of the gravitational field can produce microscopic excitations without recurring to the metrical concept. In the macroscopic world - that is, in the observed domain of General Relativity, e.g., $\ell >> \ell_{Planck}$ - only the geometrical quantities constructed from the classical (non-quantum) metric $g^{\mu\nu}$ produce observable gravitational effects.

23. The Emergence of Classical Spacetime From the Wavefunction of the Universe by T. Padmanabhan, Astrophysics Group, T.I.F.R., Homi Bhabha Road, Bombay, India 400 005

Abstract - The author constructs the quantum gravitational density matrix $\rho(g_{\alpha\beta}, g'_{\alpha\beta})$ for compact 3-geometries by integrating out a set of unobserved matter degrees of freedom from a solution to the Wheeler-DeWitt equation $\Psi[g_{\alpha\beta}, q_k(\text{matter})]$. In the adiabatic approximation, ρ can be expressed as $\exp(-\ell^2)$ where ℓ^2 $(g_{\alpha\beta}, g'_{\alpha\beta})$ is a specific 'distance' measure in the space of 3-geometries which depends on the volumes of the 3-geometries and the eigenvalues of the Laplacian constructed from the 3-metrics. The 3-geometries which are 'close together' ($\ell^2 << 1$) interfere quantum mechanically; those which are 'far apart' ($\ell^2 >> 1$) are suppressed exponentially and hence contribute decoherently to ρ. Such a suppression of 'off-diagonal' elements in the density matrix signals classical behavior of the system. This analysis provides an explanation for the classical nature of our universe.

24. Some Remarks on the Conformal Group by J. G. Pereira, Center for Ralativity, The University of Texas at Austin, Austin, Texas 78712

Abstract - The role of Poincare and de Sitter groups as subgroups of the conformal group is studied. It is shown that the usual decomposition of the conformal group into Lorentz transformation, translation, special conformal, and dilatation is not possible unless one eliminates the boost transformation generated by one of the de Sitter subgroups of the conformal group.

25. Is the Uniformity of the Microwave Background Radiation an Evidence of a Homogeneity of the Universe? by Ira K. Rozgacheva, Sternberg State Astro. Institute, Univ. Prospect 13, 119899 V-234 Moscow, USSR

Abstract - The light propagation in a weakly inhomogeneous universe is considered. First this problem had been considered by Gunn (Ap.J. 147, 61 (1967)) and Sachs and Wolfe (Ap.J. 147, 73 (1967)). The statistical error introduced by gravitational scattering along the light path by distant objects was investigated by Gunn, the gravitational field of the object being stationary. It was found that, for very small angles, there was a standard deviation proportional to the "true" angle for a fixed redshift z and increasing as $z^{3/2}$. The equations for light rays in the weakly inhomogeneous cosmological model were used by Sachs and Wolfe to estimate the anisotropy of the microwave radiation temperature, assuming the light path did not deviate and the inhomogeneity changed only the redshift. The deviation of the light path in the weakly inhomogeneous cosmological model is investigated in this work. It is found, that the lightlike geodesics are unstable if the inhomogeneities have positive density contrasts. The light signals lose the knowledge of their initial directions of propagation. So in this universe such radiation as the Microwave Background must seem uniform.

26. Constraints on the Fundamental Properties of Gravity From SN 1987A by C. Sivaram and Venzo de Sabbata, World Lab, Geneve, Switzerland, Indian Institute of Astrophysics, Bangalore, India, Department of Physics, Ferrara University, Italy Instituto di Fisica Nucleare, Bologna, Italy

Abstract - There is meager experimental information about several basic aspects of the nature of gravity. In the light of this, the coincidence of photon and neutrino (antineutrino) arrival times to within a few hours from SN 1987A, enables useful and more stringent constraints to be placed on many diverse questions regarding the fundamental properties of gravity. Among these are the validity of the weak equivalence principle for ultrarelativistic particles (including its possible energy dependence), infall of antiparticles, torsion, Post-Newtonian parameters and non metric theories, and on possible C,P, and CP non conserving parameters of the gravitational field. Again stringent constraints on possible long range interactions (predicted for instance by superstring compactification models) can be placed.

27. A Natural Inflation by M. M. Som, Instituto de Fisica, U.F.R.J., Rio de Janeiro, RJ 21945 - Brasil

Abstract - The author considers the equation of state in the perfect fluid cosmology as $p = \alpha\rho$, where α is a time dependent parameter. Using the ansatz $\dot{p}/\dot{\rho} = a\alpha$, $a < 1$ a constant, he finds from the Einstein equations that for large values of the scale factor R(t) in the Robertson-Walker space-time, $\alpha \to 0$ and $R \to t^{2/3}$. In the vicinity of $R = 0$, where the contribution from the spatial curvature is negligible $\alpha \to -1$ and $\rho \to$ constant inducing an inflationary phase in the very early epoch of the universe. The time-dependent α furnishes us with a natural mechanism for violating the Hawking-Penrose Theorem and gives rise to two-epoch evolution of the universe.

28. Gravitation a la String by Victor Tapia, International School for Advanced Studies, 34014 Trieste, Italy

Abstract - The author develops a model for the gravitational interaction in which the gravitational field is identified with the functions describing the embedding of space-time in a higher dimensional flat space. These embedding fields have the advantage of a simple physical meaning: they are the functions measuring the deviation from flatness of space-time. In terms of the embedding fields the metric decomposes into a background flat metric and a piece measuring the deviation from flatness depending only on the embedding fields. The metric is therefore decomposed into the sum of a flat metric, the inertial part, plus the rest, a dynamical part, measuring the deviation from it, representing the gravitational contribution. The Lagrangian for the model is the Hilbert one but considered as a functional of the embedding functions instead of the metric. The field equations are the Einstein ones contracted with the six Gauss tensors of the embedding, they are therefore a valid generalisation of the Einstein equations. The energy-momentum tensor turns out to be a symmetric tensor density with values which are physically relevant for the formulation of consistent conservation laws; in fact it is proportional to the Einstein tensor. For a static spherically symmetric field the correct asymptotic behavior is obtained, the Schwarzschild one, and therefore the model gives the same physical predictions. The quantisation of the gravitational field is in principle possible since it is reduced to the quantisation of a field theory in a Minkowski space. What remains to be done is not very difficult: that is, the quantization of a four-dimensional surface embedded in a higher-dimensional space-time. Since the advent of string theories we already have some experience on how to quantise two-dimensional surfaces in space-time. We must only generalize these quantization methods for the case of four-dimensional space-times.

29. Wormholes and Interstellar Travel by Matt Visser, Theoretical Division, T-8, Mail Stop B-285, Los Alamos National Laboratory, Los Alamos, New Mexico 87545

Abstract - In this essay the author undertakes a serious scientific discussion of wormholes suitable for interstellar travel. While interstellar travel is the sine qua non of most science fiction, essentially zero serious work has been performed on this very interesting if extremely speculative topic. The classical traversable wormholes discussed in this essay are toy models sufficiently simple that detailed analyses of their properties may be carried out. General arguments imply that traversable wormholes must contain negative energy matter. It is, however, possible for a traveller to traverse such wormholes without directly encountering a region of such "exotic" matter. Though the requirement that the wormhole contain some negative energy matter is alarming, the author argues that this requirement is not physically fatal.

30. Does the Flat Rotation Curve Provide an Evidence for Higher Order Gravitational Theory? by Xu Chongming, Lehrstuhl fur Theoretische Astrophysik, Auf der Morgenstelle 12C, D-7400 Tubingen, FRG and Department of Physics, Fudan University, Shanghai, P.R. China, Ali El-Tahir, Department of Physics, University of Khartoum, Khartoum, Sudan, and Wu Xuejun, Lehrstuhl fur Theoretische Astrophysik, Auf der Morgenstelle 12C, D-7400 Tubingen, FRG and Department of Physics, Fudan University, Shanghai, P.R. China

Abstract - The problem of the flat rotation curves of galaxies are interpreted by means of higher order gravitational theory. The Lagrange is $R + \gamma R^2$. The field equation consists of the terms of Einstein general relativity plus higher order terms. An approximate equation is obtained in the static, weak and linear case and solved with a spherical symmetric metric. The solution shows that te gravitational potential φ contains two parts: the r^{-1} form and the Yukawa form. In the region of the solar system, the potential agrees with the Newtonian one to very high precision. When the distance is extended to galactic dimensions the potential requires the rotation curve of the galaxy to be flat. Maybe, the flat rotation curve is an evidence for a higher order gravitational theory.