Abstracts of Award Winning and Honorable Mention Essays for 1998

Award Essays

First Award - Demise of the Cosmic Censor? - by Viqar Husain, Department of Physics and Astronomy, University of British Columbia, 6224 Agricultural Road, Vancouver, BC V6T1Z1, Canada.

Abstract - Initial data for general relativity may be such that there are trapped surfaces on a spatial initial data surface. Penrose has proposed that if the cosmic censorship hypothesis is true, the ADM mass M of asymptotically flat initial data and the area A of the outermost apparent horizon surface should satisfy the inequality $A \leq 16\pi M^2$. Initial data which does not satisfy this inequality may be viewed as providing a counterexample of the cosmic censorship conjecture. The author describes initial data that violates this inequality, thereby providing such a counterexample.

Second Award - The Inner Structure of Black-Holes - by Shahar Hod and Tsvi Piran, The Racah Institute for Physics, The Hebrew University, Jerusalem 91904, Israel.

Abstract -The authors study the gravitational collapse of a self-gravitating *charged* scalar-field. Starting with a *regular* spacetime, they follow the evolution through the formation of an apparent horizon, a Cauchy horizon and a final central singularity. They find a null, *weak*, mass-inflation singularity along the Cauchy horizon, which is a precursor of a strong, *spacelike* singularity along the $r = 0$ hypersurface. The inner black hole region is bounded (in the future) by singularities. This resembles the classical inner structure of a Schwarzschild black hole and it is remarkably different from the inner structure of a charged static Reissner-Nordström or a stationary rotating Kerr black hole.

Third Award - Gamma-Ray Bursts and Quantum Cosmic Censorship - by T.P. Singh, Tata Institute of Fundamental Research, Homi Bhabha Road, Mumbai 400 005, India.

Abstract -Gamma-ray bursts are believed to result from the coalescence of binary neutron stars. However, the standard proposals for conversion of the gravitational energy to thermal energy have difficulties. The author shows that if the merger of the two neutron stars results in a naked singularity, instead of a black hole, the ensuing quantum particle creation can provide the requisite thermal energy in a straightforward way. The back-reaction of the created particles can avoid the formation of the naked singularity predicted by the classical theory. Hence cosmic censorship holds in the quantum theory, even if it were to be violated in classical general relativity.

Fourth Award - Repulsive Gravity in the Very Early Universe - by M. Gasperini, Dipartimento di Fisica Teorica, Università di Torino, Via P. Giuria 1, 10125 Turin, Italy, and Istituto Nazionale di Fisica Nucleare, Sezione di Torino, Turin, Italy.

Abstract - The author presents two examples in which the curvature singularity of a radiation-dominated Universe is regularized by (a) the repulsive effects of spin interactions, and (b) the repulsive effects arising from a breaking of the local gravitational gauge symmetry. In both cases the collapse of an initial, asymptotically flat state is stopped, and the Universe bounces towards a state of decelerated expansion. The emerging picture is typical of the pre-big bang scenario, with the main difference that the string cosmology dilaton is replaced by a classical radiation fluid, and the solutions are not duality-invariant.

Fifth Award - Black Holes and Gravitational Waves in Concert - A Probe of Superstring Cosmology - by Edmund J. Copeland[*], Andrew R. Liddle[+], James E. Lidsey[*+], and David Wands[#], [*]Centre for Theoretical Physics, University of Sussex, Brighton BN1 9QJ, Great Britain, [+]Astronomy Centre, University of Sussex, Brighton BN1 9QJ, Great Britain, [#]School of Computer Science and Mathematics, University of Portsmouth, Portsmouth PO1 2EG, Great Britain.

Abstract - Two strands of observational gravitation, one the search for astrophysical evidence of primordial black holes and the other the search for gravitational waves, may combine to provide strong evidence in favour of cosmological models based on superstring theory, the leading candidate for unifying gravity with the other fundamental forces.

1. Can General-Relativistic Description of Gravitation be Considered Complete? - by D. V. Ahluwalia, Physics Division (P-25), Mail Stop H 846, Los Alamos National Laboratory, Los Alamos, NM 87545.

Abstract - The local galactic cluster, the Great attractor, embeds us in a dimensionless gravitational potential of about -3×10^{-5}. In the solar system this potential is constant to about 1 part in 10^{11}. Consequently, planetary orbits, which are determined by the gradient in the gravitational potential, remain unaffected. However, this is not so for the recently introduced flavor-oscillation clocks where the new redshift-inducing phases depend on the gravitational potential itself. On these grounds, and by studying the invariance properties of the gravitational phenomenon in the weak fields, the author argues that there exists an element of incompleteness in the general-relativistic description of gravitation. An incompleteness-establishing inequality is derived and an experiment is outlined to test the thesis presented.

2. Dimensionful Deformations of Poincaré Symmetries for a Quantum Gravity Without Ideal Observers - by Giovanni Amelino-Camelia, Theoretical Physics, University of Oxford, 1 Keble Rd., Oxford OX1 3NP, U.K. and Institut de Physique, Université de Neuchâtel, rue Breguet 1, Neuchâtel, Switzerland.

Abstract - Quantum Mechanics is revisited as the appropriate theoretical framework for the description of the outcome of experiments that rely on the use of classical devices. In particular, it is emphasized that the limitations on the measurability of (pairs of conjugate) observables encoded in the formalism of Quantum Mechanics reproduce faithfully the "classical-device limit" of the corresponding limitations encountered in (*real* or *gedanken*) experimental setups. It is then argued that devices cannot behave classically in Quantum Gravity, and that this might raise serious problems for the search of a class of experiments described by theories obtained by "applying Quantum Mechanics to Gravity." It is also observed that using heuristic/intuitive arguments based on the absence of classical devices one is led to consider some candidate Quantum-Gravity phenomena involving dimensionful deformations of the Poincaré symmetries.

3. A Chaotic Gravitational-Wave Detector - by John Argyris and Corneliu Ciubotariu, Institute for Computer Applications (ICA I), Pfaffenwaldring 27, University of Stuttgart, D-70569 Stuttgart, Germany.

Abstract - In the present paper the authors exhibit the possibility of applying a quantum chaos as an element of high sensitivity which serves to detect small changes in length generated by gravitational waves. They propose the construction of a double-bar antenna with a coupling Josephson junction in its center of mass. In fact the new antenna is a single Josephson junction with massive bulk contacts, like a single-junction SQUID but with free ends. Computer experiments demonstrate that very small changes generated by the variation of the distance between the bulk plates of the junction capacitance will produce a variety of very different intermittency routes to chaos.

4. Stringy Gödel Universes - by John D. Barrow[*] and Mariusz P. Dabrowski[*+], [*]Astronomy Centre, University of Sussex, Brighton BN1 9QJ, U.K.; [+]Institute of Physics, University of Szczecin, Wielkopolska 15, 70-451 Szczecin, Poland.

Abstract -The authors describe new exact solutions for Gödel universes in string theories. These are the first exact solutions of low-energy effective string theories to first-order in the inverse string tension that include the entire spectrum of massless particles: axion, dilaton and graviton. In complete contrast to general relativity, they find stringy Gödel solutions which do not permit time travel. These solutions display suggestively simple relationships between the global rotation of the universe and the inverse string tension. The solutions suggest that string theories can ameliorate some of the unwanted peculiarities of spacetime structure that are allowed in general relativity.

5. The Singularity in Generic Gravitational Collapse Is Spacelike, Local and Oscillatory - by B.K. Berger[*], D. Garfinkle[*], J. Isenberg[+], V. Moncrief[#], M. Weaver[%], [*]Department of Physics, Oakland University, Rochester, MI 48309; [+]Department of Mathematics, University of Oregon, Eugene, OR 97403; [#]Department of Physics and Mathematics, Yale University, New Haven, CT 06520; [%]Department of Physics, University of Oregon, Eugene, OR 97403.

Abstract - A longstanding conjecture by Belinskii, Khalatnikov, and Lifshitz that the singularity in generic gravitational collapse is spacelike, local and oscillatory is explored analytically and numerically in spatially inhomogeneous cosmological spacetimes. With a convenient choice of variables, it can be seen analytically how nonlinear terms in Einstein's equations control the approach to the singularity and cause oscillatory behavior. The analytic picture requires the drastic assumption that each spatial point evolves toward the singularity as an independent spatially homogeneous universe. In every case, detailed numerical simulations of the full Einstein evolution equations support this assumption.

6. The First Space-Based Gravitational-Wave Detectors - by Robert R. Caldwell, [*] Marc Kamionkowski, [+] and Leven Wadley[+], [*]Department of Physics and Astronomy, University of Pennsylvania, 209 South 33rd Street, Philadelphia, PA 19104; [+]Department of Physics, Columbia University, 538 West 120th Street, New York, NY 10027.

Abstract - Gravitational waves provide a laboratory for general relativity and a window to energetic astrophysical phenomena invisible with electromagnetic radiation. Several terrestrial detectors are currently under construction and a space-based interferometer is envisioned for launch early next century to detect test-mass motions induced by waves of relatively short wavelength. Very-long-wavelength gravitational waves can be detected using the plasma in the early Universe as test masses; the motion induced in the plasma by a wave is imprinted onto the cosmic microwave background (CMB). While the signature of gravitational waves on the CMB temperature fluctuations is not unique, the *polarization* pattern can be used to unambiguously detect gravitational radiation. Thus, forthcoming CMB polarization experiments, such as MAP and Planck, will be the first space-based gravitational-wave detectors.

7. The Bar Instability Revisited in Cosmological Scenario - by Anna Curir, Osservatorio Astronomico di Torino, Strada Osservatorio 20 10025 Pino Torinese, Torino, Italy.

Abstract - About two-third of spiral galaxies are classified as barred, only one third are very strongly barred (SB) and another third are classified as 'intermediate' SB galaxies, i.e. galaxies with a faint bar. Bars are quasi-stationary density waves originated by swing amplification mechanisms. The author uses smooth-particle-hydrodynamical simulations to give insights into the role of triaxiality of the halo on triggering the bar instability and to investigate how tidal interactions act on bar evolution. The author argues that the triaxiality of the primordial halo and the weight of the halo have a fundamental role in monitoring the incidence of the bar instability in spiral galaxies.

8. On Electrogravity Duality - by Naresh Dadhich, Inter-University Centre for Astronomy & Astrophysics, Post Bag 4, Ganeshkhind, Pune - 411 007, India.

Abstract - By resolving the gravitational field into electric and magnetic parts, the author defines an electrogravity duality transformation and discovers an interesting property of the field. Under the duality transformation a vacuum/flat spacetime maps into the original spacetime with a topological defect of global monopole/texture. The electrogravity-duality is thus a topological defect generating process. It turns out that all black hole solutions possess dual solutions that imbibe a global monopole.

9. Gravity, Chaos, and a New Population of Dark Matter - by Thibault Damour[*] and Lawrence M. Krauss[+], [*]Institut des Hautes Etudes Scientifiques, 91440 Bures-sur-Yvette, France, and DARC, Observatoire de Paris-CNRS, F-92195 Meudon, France; [+]Departments of Physics and Astronomy, Case Western Reserve University, Cleveland, OH 44106-7079.

Abstract - Weakly Interacting Massive Particle (WIMP) dark matter can scatter elastically in the Sun, be gravitationally captured, and eventually settle in the Solar core and annihilate. The authors describe here, however, how perturbations due to the planets, combined with the non-Coulomb nature of the gravitational potential inside the Sun, imply that WIMPS which are gravitationally captured by scattering in surface layers of the Sun can evolve chaotically into orbits whose trajectories no longer intersect the Sun. For orbits having a semi-major axis smaller than 1/2 of Jupiter's orbit, WIMPS can persist in the solar system for billions of years. There can thus be a new, previously unanticipated, distribution of WIMPs which intersect the Earth's orbit. For WIMPs which might be detected in the next generation of underground detectors, this solar system distribution could be significant, providing a complementary signal to that of galactic halo dark matter.

10. Quantum Gravity of a Brane-like Universe - by Aharon Davidson and David Karasik, Physics Department, Ben-Gurion University of the Negev, Beer-Sheva, 84105, Israel.

Abstract - Quantum gravity of a brane-like Universe is formulated, and its Einstein limit is approached. Regge-Teitelboim embedding of Arnowitt-Deser-Misner formalism, parameterized by the coordinates $y^A(t,x^j)$, is governed by some $\rho_{AB}(y,y',y'')$. Invoking a novel Lagrange multiplier λ, accompanying the lapse function N and the shift vector N^i, the authors derive the quadratic Hamiltonian

$$H=\frac{1}{2}N\left[P_A\left((\rho-\lambda I)^{-1}\right)^{AB}P_B+\lambda\right]+N^i y^A_{,i}P_A$$

The inclusion of matter resembles minimal coupling. Setting $P_A=-i\delta/\delta y^A$, they derive a bifurcated Wheeler-Dewitt-like equation. Einstein gravity, associated with λ being a certain 4-fold degenerate eigenvalue of ρ_{AB}, is characterized by a vanishing center-of-mass momentum $\int P_A d^3x=0$. Troublesome $(\rho-\lambda I)^{-1}$ is replaced then by regular M^{-1}, such that $M^{-1}(\rho-\lambda I)$ defines a projection operator, modifying the Hamiltonian accordingly.

11. Quantum Gravity Without Ghosts - by Bryce DeWitt[*] and C. Molina-París[+], [*]Department of Physics, University of Texas, Austin, TX 78712; [+]Theoretical Division T-6 and T-8, Los Alamos National Laboratory, Los Alamos, NM 87545.

Abstract - An outline is given of a recently discovered technique for building a quantum effective action that is completely independent of gauge-fixing choices and ghost determinants. One makes maximum use of the geometry and fibre-bundle structure of the space of field histories and introduces a set of nonlocal composite fields: the geodesic normal fields based on Vilkovisky's connection on the space of histories. The closed-time-path formalism of Schwinger, Bakshi, Mahantappa *et al* can be adapted for these fields, and a set of gauge-fixing-independent dynamical equations for their expectation values (starting from initial conditions) can be computed. An obvious application for such equations is to the study of the formation and radiative decay of black holes, and to other back-reaction problems.

12. Gravitational Potentials and the Existence of Gravitational Green's Tensors - by P.Dolan and B. Muratori, Department of Mathematics, Huxley Building, Imperial College, 180 Queen's Gate London, SW7 2BZ, England.

Abstract - The non-local part of the gravitational field C_{abcd} can be generated by the 16 component Lanczos tensor potential L_{abc}. When 6 gauge conditions are imposed, $L_{ab}{}^{e}{}_{;e}=0$, its 10 degrees of freedom match those of the Weyl tensor. The Penrose wave equation for C_{abcd} can be independently derived from that for $L_{abc.}$ The consistency between L_{abc} and C_{abcd} is also shown by the compatibility of their algebraic classifications. An unexpected insight into the relationship of L_{abc} and C_{abcd} is found in "Euclidean Gravity" which in turn leads to the introduction of a gravitational Green's tensor $G_{abc}^{a'b'c'}(x,x')$ corresponding to the potential L_{abc}

13. Multidimensional Geometrical Model of the Renormalized Electrical Charge with Splitting Off the Extra Coordinates - by V.D. Dzhunushaliev, Department of Theoretical Physics, Kyrgyz State National University, Bishkek, 720024, Kyrgyz Republic; Temporary address: Department of Physics, Virginia Commonwealth University, Richmond, VA, 23284 -2000.

Abstract - A geometrical model of electric charge is proposed. This model has "naked" charge screened with a "*fur-coat*" consisting of virtual wormholes. The 5D wormhole solution in the Kaluza-Klein theory is the "naked" charge. The splitting off of the supplementary coordinates happens on the two spheres (null surfaces) bounding this 5D wormhole. This allows one to sew two Reissner-Nordström black holes onto it on both sides. The virtual wormholes entrap a part of the electrical flux lines coming out of the "naked" charge. This effect essentially decreases the charge visible at infinity so that it satisfies the real relation $m^2 < e^2$, where m and e are the parameters of the Reissner-Nordström solution.

14. A New Approach to Black Hole Microstates - by Richard J. Epp and R.B. Mann, Department of Physics, University of Waterloo, Waterloo, Ontario, N2L 3G1, Canada.

Abstract - If one encodes the gravitational degrees of freedom in an orthonormal frame field there is a very natural first order action one can write down (which in four dimensions is known as the Goldberg action). In this essay the authors show that this action contains a boundary action for certain microscopic degrees of freedom living at the horizon of a black hole, and argue that these degrees of freedom hold great promise for explaining the microstates responsible for black hole entropy, in any number of spacetime dimensions. This approach faces many interesting challenges, both technical and conceptual.

15. The Incompleteness of Kruskal-Szekeres Spacetime - by Ronald Gautreau, Physics Department, New Jersey Institute of Technology, Newark, NJ 07102.

Abstract - Novikov has developed a reference system built around times measured by radially moving geodesic clocks that is equivalent to Kruskal-Szekeres coordinates. From analysis of the construction of Novikov's reference system, arguments are given showing that the reference system is geodesically incomplete. Extension of these arguments indicates that the equivalent Kruskal-Szekeres coordinate system is also geodesically incomplete. On both Novikov and Kruskal-Szekeres spacetime diagrams, the left-hand side, corresponding to negative values of the spatial coordinate, should not be included when describing physical spacetime. In turn, this means we have to rethink widely accepted concepts such as black and white holes that arise from the usual picture of a maximally extended Kruskal-Szekeres spacetime.

16. A Model of Compact Galactic Nuclei - by L.Sh. Grigorian and G.S. Sahakian, Department of Physics, Yerevan State University, 1 Alex Manoogian St., 375049 Yerevan, Armenia.

Abstract - Spherically symmetric star clusters (compact galactic nuclei, globular clusters) far advanced during the evolution to the state of statistical equilibrium are investigated. The systems of this kind are shown to be described by the Emden equation with polytropy index equal to 0.5. It is also shown that rapidly spinning neutron stars and white dwarfs are the main constituents of compact galactic nuclei if their age is of the same order as that of the Universe. It is concluded that the pulsars may be born by evaporation of neutron stars from the nucleus of our Galaxy. The number of such pulsars is $\leq 10^{-6}$.

17. Gravity, Cosmology and Particle Physics without the Cosmological Constant Problem - by E.I. Guendelman and A.B. Kaganovich, Physics Department, Ben-Gurion University of the Negev, Beer Sheva, Israel.

Abstract - This essay elucidates recent achievements of the "nongravitating vacuum energy (NGVE) theory" which has the feature that a shift of the Lagrangian density by a constant does not affect dynamics. In the first order formalism, a constraint appears that enforces the vanishing of the cosmological constant Λ. Standard dynamics of gauge unified theories (including fermions) and their SSB appear if a four index field strength condensate is present. At a vacuum state there is exact balance to zero of the gauge fields condensate and the original scalar fields potential. As a result it is possible to combine the solution of the Λ problem with inflation and transition to a $\Lambda = 0$ phase without fine tuning after a reheating period. The model opens new possibilities for a solution of the hierarchy problem.

18. Geometrization of String Theory Gravity - by Richard T. Hammond, North Dakota State University, Physics Department, Fargo, ND 58105.

Abstract - It is shown that the low energy string theory Lagrangian can be interpreted as pure gravity. In particular, it is shown that the Lagrangian is simply R, the curvature scalar of spacetime with torsion, and unlike previous work, the covariant derivative of the metric tensor vanishes. As a consequence, it is shown that the physical origin of the scalar field results from the pseudoscalar invariant. This yields, for the first time, a definite physical origin of the dilaton field in four dimensions.

19. Negative Energies and the Limit of Classical Space-Time - by Adam D. Helfer, Department of Mathematics, University of Missouri, Columbia, MO 65211.

Abstract - Relativistic quantum field theories predict negative densities, contravening a basic tenet of classical physics and a fundamental hypothesis of the deepest results in classical general relativity. These densities may be sources for exotic general-relativistic effects, and may also lead to pathologies. Combining Ford's "quantum inequality" with quantum restrictions on measuring devices, the author presents an argument that these densities nevertheless satisfy a sort of "operational" positivity: the energy in a region, plus the energy of an isolated device designed to detect or trap the exotic energy, must be non-negative. This will suppress at least some pathological effects. If one supposes also that Einstein's field equation holds, then no local observer can measure the geometry of a negative energy density regime accurately enough to infer a negative energy density from the curvature. This means that the physics of a negative energy regime cannot be adequately modeled by a classical space-time.

20. Age Crises, Scalar Fields, and the Apocalypse - by J.C. Jackson, Department of Mathematics and Statistics, University of Northumbria at Newcastle, Ellison Building, Newcastle upon Tyne NE1 8ST, UK.

Abstract - Recent observations suggest that Hubble's constant is large, to the extent that the oldest stars appear to have ages which are greater than the Hubble time, *and* that the Hubble expansion is slowing down, so that according to conventional cosmology the age of the Universe is less than the Hubble time. The concepts of weak and strong age crises (respectively $t_0 < 1/H_0$ but longer than the age inferred from some lower limit on q_0, and $t_0 > 1/H_0$ and $q_0 > 0$) are introduced. These observations are reconciled in models which are dynamically dominated by a homogeneous scalar field, corresponding to an ultra-light boson whose Compton wavelength is of the same order as the Hubble radius. Two such models are considered, an open one with vacuum energy comprising a conventional cosmological term and a scalar field component, and a flat one with a scalar component only, aimed respectively at weak and strong age crises. Both models suggest that anti-gravity plays a significant role in the evolution of the Universe.

21. Black Holes and Strings: the Polymer Link - by Ramzi R. Khuri, Department of Physics, Queen Mary and Westfield College, Mile End Road, London E1 4NS UK.

Abstract - Quantum aspects of black holes represent an important testing ground for a theory of quantum gravity. The recent success of string theory in reproducing the Bekenstein-Hawking black hole entropy formula provides a link between general relativity and quantum mechanics via thermodynamics and statistical mechanics. Here the author speculates on the existence of new and unexpected links between black holes and polymers and other soft-matter systems.

22. Generation of Ultrahigh-Energy Cosmic Rays - by David W. Kraft[*] and Lloyd Motz[+], [*]Division of Natural Sciences & Mathematics, University of Bridgeport, Bridgeport, CT, 06601; [+]Department of Astronomy, Columbia University, New York, NY 10027.

Abstract - The origin of ultrahigh energy cosmic rays has been an enigma for decades. The various acceleration mechanisms that have been proposed operate on galactic or extragalactic scales and hence the particles must travel great distances to reach the Earth. However, such energetic particles lose energy upon interacting with the microwave background radiation and are therefore of lower energy when they reach the Earth. Thus a source closer to the Earth is required. The authors propose Planck-mass particles accelerated by the gravitational fields of the Sun and Earth as the source. They calculate the velocities of particles arriving at Earth from various locations in the Solar System and find that ultrahigh energies are attained whether the particle starts from a point near the Earth or from afar.

23. Dimensional Reduction - by Corinne A. Manogue[*] and Tevian Dray[+], [*]Department of Physics, Oregon State University, Corvallis, OR 97331; [+]Department of Mathematics, Oregon State University, Corvallis, OR 97331.

Abstract - Using an octonionic formalism, the authors introduce a new mechanism for reducing 10 spacetime dimensions to 4 without compactifaction. Applying this mechanism to the free, 10-dimensional, massless (momentum space) Dirac equation results in a particle spectrum consisting of exactly 3 generations. Each generation contains 1 massive spin-1/2 particle with 2 spin states, 1 massless spin-1/2 particle with only 1 helicity state, and their antiparticles - precisely one generation of leptons. There is also a single massless spin-1/2 particle/antiparticle pair with the opposite helicity and no generation structure. The authors conclude with a discussion of some further consequences of this approach, including those which could arise when using the formalism on a curved spacetime background, as well as the implications for the nature of spacetime itself.

24. Chaos and a Resonance Mechanism for Structure Formation in Inflationary Models - by H.P. de Oliviera[*] and I. Damião Soares[+], [*]Universidade do Estado do Rio de Janeiro, Instituto de Física - Departamento de Física Teórica, CEP 20550-013 Rio de Janeiro, RJ, Brazil; [+]Centro Brasileiro de Pesquisas Físicas, Rua Dr. Xavier Sigaud, 150, CEP 22290, Rio de Janeiro - RJ, Brazil.

Abstract - The authors exhibit a resonance mechanism of amplification of density perturbations in inflationary models, using a minimal set of ingredients (an effective cosmological constant, a scalar field minimally coupled to the gravitational field and matter), common to most models in the literature of inflation. This mechanism is based on the structure of homoclinic cylinders, emanating from an unstable periodic orbit in the neighborhood of a saddle-center critical point, present in the phase space of the model. The cylindrical structure induces oscillatory motions of the scales of the universe whenever the orbit visits the neighborhood of the saddle-center, before the universe enter a period of exponential expansion. The oscillations of the scale functions produce, by a resonance mechanism, the amplification of a selected wave number spectrum of density perturbations, and can explain the hierarchy of scales observed in the actual universe. The transversal crossings of the homoclinic cylinders induce chaos in the dynamics of the model, a fact intimately connected to the resonance mechanism occurring immediately before the exit to inflation.

25. The Complete Non-Linear Graviton: Twistor Construction for General Vacuums - by Roger Penrose, Mathematical Institute, 24-29 St.Giles, Oxford, OX1 3LB UK.

Abstract - A new twistor concept is introduced, whereby twistor space now incorporates the *entire* gravitational (radiation) information, including its *self*-dual part (the anti-self-dual part having been incorporated twenty years ago in an earlier "non-linear graviton" construction). This twistor space, pieced together using *free* holomorphic data, is a complex 4-manifold containing an unorthodox foliation. Its *global* structure encodes all relevant space-time information (the local structure containing no continuous information). Space-time points are interpreted in terms of a family of particular "surgery" operations that can be applied to the twistor space. Each such surgery is associated with a 1-form ξ whose exterior derivative serves to define not only the space-time metric but also the "Sparling 3-form", whose closedness yields Einstein's vacuum equations.

26. The Gravitational Vavilov - Cherenkov Effect - by Alberto Saa and Marcelo Schiffer, Departamento de Matemática Aplicada, IMECC, Universidade Estadual de Campinas, C.P. 6065, 133081-970 Campinas, SP, Brazil.

Abstract - In this essay the authors show that an uncharged black-hole moving superluminally in a transparent dielectric medium violates Hawking's area theorem. The violation is overcome through the emission of radiation. Since modes cannot emerge from the black hole itself, this radiation must originate from a collective effect in the medium, in complete analogy with the Vavilov-Cherenkov effect. However, because the black-hole is uncharged, the emission mechanism must be different. The authors discuss the physical origin of the effect and obtain a Newtonian estimate. Then they obtain the appropriate equations in the relativistic case and show that the field which is radiated away is a combination of gravitational and electromagnetic degrees of freedom. Possible astrophysical relevance for the detection of primordial black-hole and binary systems is discussed.

27. Wormholes, Gamma Ray Bursts and the Amount of Negative Mass in the Universe - Diego F. Torres[*+], Gustav E. Romero[#] and Luis A. Anchordoqui[%], *Astronomy Centre, University of Sussex, Falmer, Brighton, BN1 9QJ, United Kingdom; [+]Departamento de Física, Universidad Nacional de La Plata, C.C. 67, 1900 La Plata, Argentina; [#]Instituto Astronômico e Geofísico, USP, Av. M. Stefano 4200, CEP 04301-904, São Paulo, Brazil; [%]Instituto Argentino de Radioastronomía, C.C. 5, 1894 Villa Elisa, Argentina.

Abstract - In this essay the authors assume that negative mass objects can exist in the extragalactic space and analyze the consequences of their microlensing on light from distant Active Galactic Nuclei. They find that such events have very similar features to some observed Gamma Ray Bursts and use recent satellite data to set an upper bound to the amount of negative mass in the universe.