Abstracts of Award Winning and Honorable Mention Essays for 2000

Award Essays

First Award - Monopoles and the Emergence of Black Hole Entropy - by Arthur Lue and Erick J. Weinberg, Department of Physics, Columbia University, 538 West 120 Street, New York, NY 10027.

Abstract – One of the remarkable features of black holes is that they possess a thermodynamic description, even though they do not appear to be statistical systems. The authors use self-gravitating magnetic monopole solutions as tools for understanding the emergence of this description in going from an ordinary space-time to one containing a black hole. They describe how causally distinct regions emerge as a monopole solution develops a horizon. They define an entropy that is naturally associated with these regions and that has a clear connection with the Hawking-Bekenstein entropy in the critical black hole limit.

Second Award - Cosmic Censorship: The Role of Quantum Gravity - by Shahar Hod and Tsvi Piran, The Racah Institute for Physics, The Hebrew University, Jerusalem 91904, Israel.

Abstract – The cosmic censorship hypothesis introduced by Penrose thirty years ago is still one of the most important open questions in *classical* general relativity. In this essay the authors put forward the idea that cosmic censorship is intrinsically a *quantum gravity* phenomenon. To that end they construct a gedanken experiment in which cosmic censorship is violated within the purely *classical* framework of general relativity. They prove, however, that *quantum* effects restore the validity of the conjecture. This suggests that classical general relativity is inconsistent and cosmic censorship might be enforced only by a quantum theory of gravity.

Third Award - Chaos in Superstring Cosmology - by Thibault Damour* and Marc Henneaux[+], *Institut des Hautes Etudes Scientifiques, 35 route de Chartres, F-91440 Bures-sur-Yvette, France; [+]Physique Théorique et Mathématique, Université Libre de Bruxelles, C.P. 231, B-1050, Bruxelles, Belgium.

Abstract – The authors show that the general solution of the Einstein-dilaton-antisymmetric tensors field equations of all superstring theories exhibits a chaotic oscillatory behavior of the Belinskii-Khalatnikov-Lifshitz type near a cosmological singularity. This result indicates that superstring cosmology is much more complex than is assumed in the scenarios presently discussed in the literature.

Fourth Award - Black Hole Hawking Radiation May Never Be Observed! - by C. Sivaram, Indian Institute of Astrophysics, Bangalore 560034, India.

Abstract – Thermal Hawking emission from black holes is a remarkable consequence of the unity of quantum physics and gravitation. Black holes of a few solar masses are the only ones which can form in the present universe. However, having temperatures a million times smaller than the ambient cosmic background radiation they cannot evaporate. Primordial black holes of M ~ $10^{14}gm$ would evaporate over a Hubble age and considerable ongoing effort is on to detect such explosions. The author points out, however, that at the early universe epochs when such black holes form, the ambient radiation temperature considerably exceeds their corresponding Hawking temperature. This results in rapid continual accretion (absorption) of ambient radiation by these holes. Consequently by the end of the radiation era their **masses grow much greater** so that their lifetimes (scaling as M^3) would now be enormously greater than the Hubble age implying **undetectably small emission.**

Fifth Award - Probing Quantum Violations of the Equivalence Principle - by G.Z. Adunas, E. Rodriguez-Milla, and D.V. Ahluwalia, ISGBG, Ap. Pos. C-600, Escuela de Fisica de la UAZ, Zacatecas, ZAC 98068, Mexico.

Abstract – The joint realm of quantum mechanics and general-relativistic description of gravitation is becoming increasingly accessible to terrestrial experiments and observation. In this essay the authors study the emerging indications of the violation of equivalence principle (VEP). While the solar neutrino anomaly may find its natural explanation in a VEP, the statistically significant discrepancy observed in the gravitationally induced phases of neutron interferometry seems to be the first indication of a VEP. However, such a view would seem immediately challenged by the atomic interferometry results. The latter experiments see no indications of VEP, in apparent contradiction to the neutron interferometry results. Here the authors show that these, and related torsion pendulum experiments, probe different aspects of gravity; and that current experimental techniques, when coupled to the solar-neutrino data, may be able to explore quantum mechanically induced violations of the equivalence principle. They predict quantum violation of the equivalence principle (qVEP) for next generation of atomic interferometry experiments. The prediction entails comparing free fall of two different linear superpositions of Cesium atomic states.

Honorable Mention Awards (Alphabetical Order)

1. The Life and Times of Extremal Black Holes - by Fred C. Adams, Physics Department, University of Michigan, Ann Arbor, MI 48109.

Abstract – Charged extremal black holes cannot fully evaporate through the Hawking effect and are thus long lived. Over their lifetimes, these black holes take part in a variety of astrophysical processes, including many that lead to their eventual destruction. This essay explores the various events that shape the life of extremal black holes and calculates the corresponding time scales.

2. Finally Planck-Length Phenomenology - by Giovanni Amelino-Camelia, Dipartimento di Fisica, Universitá di Roma "La Sapienza", P. le Moro 2, I-00185 Roma, Italy and Theory Division, CERN, CH-1211, Geneva, Switzerland.

Abstract – The author's recent proposal (Nature 398, 216) of interferometric tests of Planck-scale-related properties of space-time is here revisited from a strictly phenomenological viewpoint. The results announced previously are rederived using elementary dimensional considerations. The dimensional analysis is then extended to the other two classes of experiments (observations of neutral kaons at particle accelerators and observations of the gamma rays detected from distant astrophysical sources) which have recently been considered as opportunities to explore "foamy" properties of space-time. The emerging picture suggests that there is an objective and intuitive way to connect the sensitivities of these three experiments with the Planck length. Since in previous studies the emphasis was always on some quantum-gravity scenario and the analysis was always primarily aimed at showing that the chosen scenario would leave a trace in a certain class of doable experiments, the community had been developing an intuition for Planck-length phenomenology as a strongly model-dependent field. The analysis here reported takes as its starting point the experiments and, by relating in a direct quantitative way the sensitivities to the Planck length, provides a model-independent description of the status of Planck-length phenomenology.

3. Warm Inflation with Coupled Thermal Quantum Fluctuations: A New Semiclassical Approach - by Mauricio Bellini, Departamento de Física, Facultad de Ciencias Exactas y Naturales, Universidad Nacional de Mar del Plata, Deán Funes, (7600) Mar del Plata, Buenos Aires, Argentina.

Abstract – The author considers a new semiclassical expansion for the inflaton field in the framework of the warm inflation scenario. The fluctuations of the matter field are considered as thermally coupled with the particles of the thermal bath. The coupling parameter depends on the temperature of the bath. The power spectrum remains invariant under this new semiclassical expansion for the inflaton. However, the author finds that the thermal component of the amplitude for the primordial field fluctuations should be very small at the end of inflation.

4. A Rational Approach to Gravity - by Dorje C. Brody* and Lane P. Hughston[+], *Blackett Laboratory, Imperial College, London SW7 2BZ, UK and DAMTP, Wilberforce Road, Cambridge CB3 OWA, UK; [+]Department of Mathematics, King's College London, The Strand, London WC2R, 2LS, UK.

Abstract – The classification of gravitational fields into algebraic types has been one of the most fruitful ideas in general relativity. Less well known is the fact that the Petrov scheme is intimately related to geometric properties of the rational quartic curve in complex projective four-space. This same geometry turns out to be highly useful in the analysis of the quantum state-space for elementary spin-two systems.

5. Quantum Zeno Effect and the Detection of Gravitomagnetism - by Abel Camacho, Astrophysikalisches Institut Potsdam, An der Sternwarte 16, D-14482 Potsdam, Germany.

Abstract – In this work the author introduces two experimental proposals that could shed some light upon the inertial properties of intrinsic spin. In particular he analyzes the role that the gravitomagnetic field of the Earth could have on a quantum system with spin 1/2. He deduces the expression for Rabi transitions, which depend, explicitly, on the coupling between the spin of the quantum system and the gravitomagnetic field of the Earth. Afterwards, the continuous measurement of the energy of the spin 1/2 system is considered and an expression for the emerging quantum Zeno effect is obtained. Thus, it is be proved that gravitomagnetism, in connection with spin 1/2 systems, could induce not only Rabi transitions but also a quantum Zeno effect.

6. How Gravity Breaks Out of the Unified Field - by Marcus Cohen, Department of Mathematical Sciences, New Mexico State University, Las Cruces, NM 88003.

Abstract – What *is* gravitational mass? Why is it equal to inertial mass, *m*, the chiral cross-coupling coefficient in the Dirac equation? What is the *mechanism* for Mach's principle, whereby the distant masses *there* cause chiral cross-coupling *here*? Does the "vacuum energy" cause gravitational curvature? What is the invisible dark matter that must comprise at least 70% of the energy in the universe? How can we reconcile singularities like the "big bang" and black holes with the "uncertainty principle?" How does gravity unify with the electro-weak and strong interactions? To answer these questions, the author starts with a new paradigm, a "parent" theory, from which quantum mechanics and general relativity *derive* in different regimes. The mathematical structure of this theory is not new. It is the road pioneered by de Rham, Infeld, and Van der Waerden, of nested spin-*n* currents quantized over *n* chains in curved space-time.

7. Energy Localization and the Nature of Gravitational Waves - by F.I. Cooperstock, Department of Physics and Astronomy, University of Victoria, P.O. Box 3055, Victoria, B.C. V8W 3P6 Canada.

Abstract – The author revisits the issue of energy in general relativity and its relation to gravitational waves. From the hypothesis that energy is localized within the regions of the energy momentum tensor, he confronts the implication that gravity waves do not carry energy in vacuum, that there are no gravitons. For substantiation, he investigates the energetics of the Eddington spinning rod, noting that Eddington had only calculated its 'kinetic' energy loss. The Tolman integral measures total energy including the energy contribution from gravity and is preserved during the dynamic phase, in support of the hypothesis. The rate of matter angular momentum loss substantiates the claim that the Eddington rod cannot remain rigid to higher order, consistent with the fundamental principle of finite velocity of propagation of interactions in relativity. The relationship between information and energy is also addressed.

8. On the Gravitational Roots of the Higgs Potential - by Aharon Davidson, David Karasik, and Yoav Lederer, Physics Department, Ben-Gurion University of the Negev, Beer-Sheva 84105, Israel.

Abstract – What are the necessary conditions for eternal deSitter inflation? Whereas Einstein cosmology humbly calls for a cosmological constant, geodetic brane cosmology requires a full scalar field theory exclusively driven by a (derived) Higgs potential. This reflects the fact that the positive definite total energy density, which governs now the FRW evolution, contains a dark component parameterized by the conserved bulk energy. DeSitter inflation is thus described as a spontaneous symmetry breaking process (the locus of unbroken symmetry being the event horizon), with Regge-Teitelboim cosmology approaching the Einstein limit at the absolute minimum. Furthermore, insisting on a finite non-singular total energy density at the origin, the generic quartic behavior of the scalar potential is dictated by the no-boundary initial conditions. This opens the door for a novel geodetic brane nucleation characterized by bulk energy quantization.

9. Convergence, Collapse, and Cusp Formation for the Einstein Equations - by Arthur E. Fischer* and Vincent Moncrief[+], *Department of Mathematics, University of California, Santa Cruz, CA 95064; [+]Departments of Mathematics and Physics, Yale University, New Haven, CT 06511.

Abstract – Recently developed methods in comparison geometry are used to study the future time evolution of the reduced Einstein equations on a closed 3-manifold M of Yamabe type –1. It is shown that the curve of conformal geometries of any such solution must either (1) *converge* to a hyperbolic geometry, (2) *volume collapse*, or (3) *weakly collapse* as cusps develop. These cases are jointly controlled by the σ-constant of M and the diameters of the evolving geometries. The results are applied to specific Bianchi models. Using known solutions, the authors show by explicit calculation that when these models volume collapse, they do so with bounded curvature and diameter, all precisely as predicted by the general theory.

10. Birth of the Universe as Anti-Tunnelling from the String Perturbative Vacuum - by M. Gasperini, Dipartimento di Fisica, Università di Bari, Via G. Amendola 173, 70126 Bari, Italy and Istituto Nazionale di Fisica Nucleare, Sezione di Bari, Bari, Italy.

Abstract – The decay of the string perturbative vacuum, if triggered by a suitable, duality-breaking dilaton potential, can efficiently proceed via the parametric amplification of the Wheeler-DeWitt wave function in superspace and can appropriately describe the birth of our Universe as a quantum process of pair production from the vacuum.

11. Dirac's Large Numbers Hypothesis – The Link for Unifying Quantum Theory with General Relativity? - by Ronald Gautreau, Physics Department, New Jersey institute of Technology, Newark, NJ 07102.

Abstract – The author describes a method he has previously developed for incorporating Dirac's Large Numbers hypothesis (LNh) into Einstein's standard theory of General Relativity. The method involves Dirac's idea of the existence of two separate times: ephemeris time t_E measured by mechanical processes such as the motion of an oscillating pendulum or a planet orbiting the sun; and atomic time t_A measured by atomic processes such as the periodic vibrations of atoms or the decay rate of radioactive nuclei. In contrast with Dirac's approach, the author's method does not involve the introduction of separate distance standards nor separate ephemeris and atomic metrics. He discusses how his General Relativistic formulation of the LNh could be used as a bridge for unifying atomic theory with General Relativity.

12. Building the Universe From the Subatomic Scale - by E.I. Guendelman and J. Portnoy, Physics Department, Ben Gurion University, Beer Sheva, Israel.

Abstract – The creation of an infinite universe out of a subatomic region, like that of an elementary particle, is considered. As a model of an elementary particle the authors take a (2+1)-dimensional brane evolving in a (3+1)-dimensional space. Gauge fields that live in the brane as well as normal surface tension lead to a stable 'elementary particle' configuration. A non-vanishing vacuum energy inside the bubble leads, when gravitational effects are considered, to the possibility of a quantum decay of such an 'elementary particle' into an infinite universe. Remarkable features of the quantum mechanics of this process are discussed, like the transformation of the wave equations from a stationary Schroedinger equation inside the horizon to a time dependent one outside.

13. A No-Chaos Theorem for Non-Minimally Coupled Scalar Field Cosmology and a New Cosmogenesis Scenario - by E. Gunzig[*], L. Brenig[+], A. Figueiredo[#] and T.M. Rocha Filho[#], [*]Research Group in General Relativity (RggR), Université Libre de Bruxelles, Campus Plaine CP231, Blvd. Du Triomphe, 1050 Bruxelles, Belgium and Instituts Internationaux de Chimie et de Physique Solvay; [+]Service de Physique Statistique, Université Libre de Bruxelles, CP231, 1050 Bruxelles, Belgium; [#]Instituto de Física, Universidade de Brasília, 70.919-970 Brasilia-DF, Brazil.

Abstract – A general dynamical system approach to classical self-consistent scalar field cosmology is presented in the framework of spatially flat FLRW space-times, for arbitrary potentials and arbitrary non-minimal coupling. The authors show that these universes cannot undergo chaotic behavior, thus suggesting a possible new role of inflation in cosmology. An unexpectedly involved topology of the phase-portrait of the cosmological dynamics is exhibited: dynamically forbidden regions, playing a crucial dynamical role, appear. A new exact critical solution, a heteroclinic orbit, connects two deSitter inflationary regimes. The authors suggest a novel intriguing semi-classical cosmogenesis scenario in which the quantized scalar field could tunnel through the classically forbidden region, from the Minkowski space-time towards the nearest classically allowed solution: the critical one.

14. String Motion in Curved Space and the Bianchi Identity - by Richard T. Hammond, North Dakota State University, Physics Department, Fargo, ND 58105.

Abstract – It is shown that the motion of a string in the field of a massive object can be derived from the Bianchi identities using the method of Papapetrou. The time average equation of motion is that of point geodesic only at lowest order; the method may be extended to obtain structure dependent, non-geodesic motion.

15. Gamma-Ray Bursts as the Birth-Cries of Black Holes - by Pankaj S. Joshi[*], Naresh K. Dadhich[+] and Roy Maartens[#], [*]Tata Institute of Fundamental Research, Mumbai 400 005, India; [+]Inter-University Centre for Astronomy and Astrophysics, Ganeshkind, Pune 411 007, India; [#]Relativity and Cosmology Group, School of Computer Science and Mathematics, Portsmouth University, Portsmouth P01 2EG, Britain.

Abstract – The origin of cosmic gamma-ray bursts remains one of the most intriguing puzzles in astronomy. The authors suggest that purely general relativistic effects in the collapse of massive stars could account for these bursts. The late formation of closed trapped surfaces can occur naturally, allowing the escape of huge energy from curvature-generated fireballs, before these are hidden within a black hole.

16. Quantum Singularity of Quasiregular Space-Times - by D.A. Konkowski[*] and T.R. Helliwell[+], [*]Department of Mathematics, U.S. Naval Academy, Annapolis, MD, 21402; [+]Department of Physics, Harvey Mudd College, Claremont, CA, 91711.

Abstract - Some of the mildest singularities in classical general relativity are shown to be singular quantum mechanically as well. A class of the mild, topological singularities known as quasiregular singularities remains singular when probed by quantum wave packets. These static space-times possessing dislocations and disclinations are quantum-mechanically singular since the spatial portion of the wave operator is not essentially self-adjoint and thus the evolution of a test quantum wave packet is not uniquely determined by the initial wave function.

17. Testing Newtonian Gravity at Ultra-Short Distances - by Dennis E. Krause[*] and Ephraim Fischbach[+], [*]Wabash College, Crawfordsville, IN 47933-0352; [+]Purdue University, West Lafayette, IN 47907-1396.

Abstract – The appearance of new fundamental forces and extra-dimensional modifications to gravity in extensions of the Standard Model has motivated considerable interest in testing Newtonian gravity at ultra-short distances ($\leq 10^{-4}$m). New experiments, which attempt to probe these distances, will encounter formidable new obstacles, including large intermolecular forces, which could obscure weak new forces or small modifications to Newton's law of gravity. Here the authors review the motivation for conducting such ultra-short distance gravity experiments, and discuss some of the new problems that may arise in future experiments. Finally, they suggest a schematic design for a null experiment which would address some of these problems using the "iso-electronic" effect.

18. Dimension in a Radiative Stellar Atmosphere - by J.P. Krisch and E.N. Glass, Department of Physics, University of Michigan, Ann Arbor, MI 48109.

Abstract – Dimensional scales are examined in an extended Vaidya atmosphere surrounding a Schwarzschild source. At one scale, the Vaidya null fluid vanishes and space-time contains only a single spherical 2-surface. Both of these behaviors can be addressed by including higher dimensions in the space-time metric.

19. Extremal Black Holes and the Limits of the Third Law - by Stefano Liberati*, Tony Rothman[+] and Sebastiano Sonego[#], *International School for Advanced Studies, via Beirut 2-4, Trieste 34014, Italy, INFN sezione di Trieste; [+]Dept. of Physics, Illinois Wesleyan University, Bloomington, IL 61702; [#]Università di Udine, Via delle Scienze 208, 33100 Udine, Italy.

Abstract – Recent results of quantum field theory on a curved space-time suggest that extremal black holes are not thermal objects and that the notion of zero temperature is ill defined for them. If this is correct, one may have to go to a full semi-classical theory of gravity, including back reaction, in order to make sense of the third law of black hole thermodynamics. Alternatively, the status of extremality in black hole thermodynamics may have to be drastically revised.

20. Pragmatic Computation of the Gravitational Radiation Reaction in Binary Black Hole Systems - by Carlos O. Lousto, Max-Planck-Institut für Gravitationsphysik, Albert-Enstein-Institut, Am Mühlenberg 1, D-14476 Golm, Germany.

Abstract – The author studies the relativistic orbit of black holes in binary systems with small mass ratio. The trajectory of a particle (representing another smaller hole or a neutron star) is determined by the geodesic equation of the perturbed massive black hole space-time. The particle itself generates the perturbations leading to a problem that needs regularization. Here he studies those perturbations around a Schwarzschild black hole using Moncrief gauge invariant formalism. He decomposes the perturbations into P-multipoles to show that all P-metric coefficients are C^O at the location of the particle. Summing over P, to reconstruct the full metric, gives a formally divergent result. The author succeeds in bringing this sum to a ζ–function regularization scheme and shows that this is tantamount to subtracting the $P \rightarrow \infty$ piece to each multipole. He explicitly carries out this regularization and numerically computes the first order geodesics.

21. Resolving the Black Hole Information Paradox - by Samir D. Mathur, Department of Physics, The Ohio State University, Columbus, OH, 43210.

Abstract – The recent progress in string theory strongly suggests that formation and evaporation of black holes is a unitary process. This fact makes it imperative that we find a flaw in the semi-classical reasoning that implies a loss of information. The author proposes a new criterion that limits the domain of classical gravity: the hypersurfaces of a foliation cannot be *stretched* too much. This conjectured criterion may have important consequences for the early Universe.

22. Cosmological Constant and the Speed of Light - by W.R. Espósito Miguel*[+] and J.G. Pereira*, *Instituto de Física Teórica, Universidade Estadual Paulista, Rua Pamplona 145, 01405-900 São Paulo SP, Brazil; [+]Observatório Municipal de Campinas Jean Nicolini, Av. Dr. Heitor Penteado 2145, 13087-000 Campinas SP, Brazil.

Abstract – By exploring the geometrical optics relationship between the propagation of electromagnetic waves in a gravitational field and the light propagation in a refractive medium, it is shown that, in the presence of a positive cosmological constant, the velocity of light will be smaller than its special relativity value. Then, restricting again to the domain of validity of geometrical optics, the same result is obtained in the context of wave optics. It is conjectured that this phenomenon and anisotropy in the velocity of light in a gravitational field are produced by the same mechanism.

23. A Small but Nonzero Cosmological Constant - by Y. Jack Ng*[+] and H. van Dam[+], *Center for Theoretical Physics, Laboratory for Nuclear Science and Department of Physics, Massachusetts Institute of Technology, Cambridge, MA 02139; [+]Institute of Field Physics, Department of Physics and Astronomy, University of North Carolina, Chapel Hill, NC 27599-3255.

Abstract – Recent astrophysical observations seem to indicate that the cosmological constant is small but nonzero and positive. The old cosmological constant problem asks why it is so small; we must now ask, in addition, why it is nonzero (and is in the range found by recent observations), and why it is positive. In this essay, the authors try to kill theses three metaphorical birds with one stone. That stone is the unimodular theory of gravity, which is the ordinary of theory of gravity, except for the way the cosmological constant arises in the theory.

24. Towards Spinor and Tensor Methods in the Positive Energy Problem - by Volodymyr Pelykh, Pidstryhach Institute Applied Problems in Mechanics and Mathematics, Ukrainian National Academy of Sciences, 3B Naukova Str., Lviv, 79601, Ukraine.

Abstract – The author discusses the investigation of the results of correlations between spinor and tensor methods in the positive energy problem and points the approach to a final solution of the problem using the results of the qualitative theory of differential equations with partial derivatives. Also the author ascertains the existence of a preferred frame, uniquely up to global frame rotations and homotheties defined by the Sen-Witten equation and boundary values, and shows that Nester's triad on maximal hypersurface is the Sen-Witten triad.

25. Still Flat after All These Years! - by Elena Pierpaoli*[+], Douglas Scott*, and Martin White[#], *Department of Physics and Astronomy, University of British Columbia, 6224 Agricultural Road, Vancouver, BC V6T 1Z1 Canada; [+]Canadian Institute for Theoretical Astrophysics, Toronto, ON M5S 3H8, Canada; [#]Harvard-Smithsonian Center for Astrophysics, Cambridge, MA 02138.

Abstract – The universe could be spatially flat, positively curved or negatively curved. Each option has been popular at various times, partly affected by an understanding that models tend to evolve away from flatness. The curvature of the Universe is amenable to measurement, through tests such as the determination of the angles of sufficiently large triangles. The angle subtended by the characteristic scale on the Cosmic Microwave sky provides a direct test, which has now been realized through a combination of exquisite results from a number of CMB experiments. After a long and detailed investigation, with many false clues, it now seems that the mystery of the curvature of the Universe is now solved. It's an open and shut case: the Universe is flat!

26. On the Role of Planck's Mass in Cold Atom Beam Scattering by a Massive Sphere - by Fabrizio Pinto, InterSteller Technologies Corporation, 639 W. Foothill Blvd., Monrovia, CA 91016.

Abstract – The scattering of a cold atomic beam by a perfectly conducting spherical mass when gravitational and quantum electrodynamical retarded dispersion forces are simultaneously relevant allows one to naturally introduce and realistically measure Planck's mass in the laboratory.

27. One-Parameter Class of Cosmological Fluids with Time Dependent Adiabatic Indices for Accelerating Universes - by Haret C. Rosu, Institute of Physics, Guanajuato State University, P.O. Box E-143, Leon, Gto, Mexico and International Center for Relativistic Astrophysics, Rome-Pescara, Italy.

Abstract – A one-parameter family of time dependent adiabatic indices is introduced for any given type of cosmological fluid of constant adiabatic index by a mathematical method belonging to the class of Darboux transformations. The procedure works for zero cosmological constant at the price of introducing a new constant parameter related to the time dependence of the adiabatic index. The author argues that these are the real cosmological fluids that are encountered at cosmological scales and that they can provide a simple and efficient explanation for the recent experimental findings regarding the present day accelerating universe.

28. Lense-Thirring Effect and Cosmological Inflation - by Bernard F. Schutz, Max Planck Institute for Gravitational Physics, The Albert Einstein Institute, Potsdam, Germany and Department of Physics and Astronomy, University of Wales College of Cardiff, Cardiff, UK.

Abstract – The Lense-Thirring effect is an aspect of gravitomagnetism, which seems widely believed to follow naturally from making Newtonian gravity relativistic. By adapting an elegant argument of Feynman, the author makes this notion precise and shows that the strength of gravitomagnetism depends sensitively on the first relativistic correction to the source of the gravitational field, the *active gravitational mass*. In general relativity this source density is $\rho+3p$; but in a relativistic theory with $\rho-3p$, gravitomagnetism would be entirely *absent*. This density is also crucial for inflationary cosmology: the inflaton field drives inflation by making $\rho+3p$ negative. Measurement of the Lense-Thirring effect therefore is a measurement of the form of the active gravitational mass and of the possibility of inflation in cosmology.

29. Formation of Planets and Gravity in Large Extra Dimensions - by Steinn Sigurdsson, 525 Davey Laboratory, Department of Astronomy & Astrophysics, Pennsylvania State University, University Park, PA 16802.

Abstract – Recent conjectures suggest the universe may have large extra dimensions, through which gravity propagates. This implies gross departures from Newton's law of gravity at small length scales. These models are testable, and, if true, there are major implications for physics on large and small scales. Here the author considers some implications for particle dynamics on scales comparable to the compactification radius, # 1mm. During planet formation, coalescence of micron sized dust grains to planetesimals is a rate critical step. Observations seem to require the dust grains grow to > mm size rapidly. Rapid grain coalescence happens naturally under non-Newtonian gravity, implied by theories of large extra dimensions, if dust disks are dynamically cold and moderately dense. Non-Newtonian gravity on small scales makes planet formation more efficient.

30. The Topological Origin of Black Hole Entropy - by Zhong Chao Wu, Beijing Normal University, Beijing 100875, China.

Abstract – In gravitational thermodynamics, the origin of a black hole's entropy is the topology of its instanton or constrained instanton. The author proves that the entropy of an arbitrary nonrotating black hole is one quarter the sum of the products of the Euler characteristics of its horizons with their respective areas. The Gauss-Bonnet-like form of the action is not only crucial for the evaluation, but also for the existence of the entropy. This result covers all previous results on the entropy of a nonrotating black hole with a regular instanton. The argument can be extended readily into the lower or higher dimensional model. The problem of quantum creation of such a black hole is completely resolved.

31. Gravitational Thermodynamics and Black-Hole Mergers - by Simon F. Portegies Zwart* and Stephen L. W. McMillan[+], *Institute of Astronomical Research, Boston University, 725 Commonwealth Ave., Boston, MA 02215; [+]Department of Physics, Drexel University, Philadelphia, PA 19104.

Abstract – Black holes become the most massive objects early in the evolution of star clusters. Dynamical relaxation then causes them to sink to the cluster core, where they form binaries which become more tightly bound by superelastic encounters with other cluster members. Ultimately, these binaries are ejected from the cluster. The majority of escaping black-hole binaries have orbital periods short enough and eccentricities high enough that the emission of gravitational waves causes them to coalesce within a few billion years. The rate at which such collisions occur is on the order of 10^{-7} per year per cubic megaparsec. This implies event rates for gravitational-wave detectors substantially greater than current estimates of the corresponding rates from neutron-star mergers or black-hole mergers stemming from pure binary evolution.