Abstracts of Award Winning and Honorable Mention Essays for 1994

Award Essays

First Award - String Theory and Gravity - by T. Damour[*] and A. M. Polyakov[+], [*]Institut des Hautes Etudes Scientifiques, 91440 Bures sur Yvette, France; [+]Physics Department, Princeton University, Princeton, NJ 08544.

Abstract - The authors point out that string-loop effects may generate matter couplings for the dilaton allowing this scalar partner of the tensorial graviton to stay massless while contributing to macroscopic gravity in a way naturally compatible with existing experimental data. Under a certain assumption of universality of the dilaton coupling functions, the cosmological evolution drives the dilaton towards values where it decouples from matter. At the present cosmological epoch, the coupling to matter of the dilaton should be very small, but non zero. This provides a new motivation for improving the experimental tests of Einstein's Equivalence Principle.

Second Award - Black Hole Physics and the Universalities of Superradiance and of Grey-body Radiation - by M. Schiffer, Instituto de Matemática, Estatística e Ciências da Computação, Departamento de Matemática Aplicada-Unicamp CP6065, 13081-970 Campinas, SP, Brazil.

Abstract - In this essay the author compares the response of a black hole to incoming radiation to that of a system consisting of a hot source hidden behind a semi-transparent mirror, and they happen to agree. Then, he displays a thermodynamical proof showing that this agreement is not incidental: it is a universal feature of an ideal grey body. As a by-product of this argument the universality of superradiance emerges: absorptive media in rotation instead of damping incoming radiation is responsible for its amplification in superradiant modes. The main conclusion here is that the black hole response to incoming radiation and superandiance are not features that arise because black holes are “exceptional” systems but, on the contrary, because they are very “ordinary” in the sense that they fall into the category of ideal grey bodies.

Third Award - Rydberg Atoms as Gravitational-Wave Antennas - by Fabrizio Pinto, Department of Physics, Boise State University, Boise, ID 83725.

Abstract - The author shows that highly excited Rydberg atoms nearby astrophysical gravitational wave sources are expected to emit significant electromagnetic radiation in the radio through a process of gravitationally induced resonance fluorescence. Semiclassical arguments are discussed and a quantum-mechanical expression for the differential cross section is obtained. This process could provide a new observational tool for the remote detection and study of gravitational waves.

Fourth Award - A Quadratic Spinor Lagrangian for General Relativity - by James M. Nester and Roh Suan Tung, Department of Physics, National Central University, Chung-Li, Taiwan 32054, Republic of China.

Abstract - The authors present a new *finite* action for Einstein gravity in which the Lagrangian is quadratic in the covariant derivative of a spinor field. Via a new spinor-curvature identity, it is related to the standard Einstein-Hilbert Lagrangian by a total differential term. The corresponding Hamiltonian, like the one associated with the Witten positive energy proof is fully 4-covariant. It defines quasi-local energy-momentum and can be reduced to the one recently used by the authors to prove positive energy.

Fifth Award - The Emergence of an Effective two-dimensional Quantum Description from the study of Critical Phenomena in Black Holes - by C. O. Lousto, IFAE-Grupo de Física Teórica, Universidad Autónoma de Barcelona, E-08193 Bellaterra (Barcelona), Spain.

Abstract - The author studies the occurrence of critical phenomena in four-dimensional, rotating and charged black holes, derives the critical exponents and shows that they fulfill the scaling laws. Correlation functions critical exponents and Renormalization Group considerations assign an effective (spatial) dimension, $d = 2$, to the system. The two-dimensional Gaussian approximation to critical systems is shown to reproduce all the black hole's critical exponents. Higher order corrections (which are always relevant) are discussed. Identifying the two-dimensional surface with the event horizon and noting that generalization of scaling leads to conformal invariance and then to string theory, the author arrives at 't Hooft's string interpretation of black holes. From this, a model for dealing with a coarse grained black hole quantization is proposed. The author also gives simple arguments that lead to a rough quantization of the black hole mass in units of the Planck mass, i.e. $M \cong 2^{-1/2} M_{pl} \sqrt{\ell}$ with ℓ a positive integer and then, from this result, to the proportionality between quantum entropy and area.

Honorable Mention Awards (Alphabetical Order)

1. Quantum Measurement, Gravitation, and Locality - by D. V. Ahluwalia, MP-9, MS H-846, Nuclear and Particle Physics Research Group, Los Alamos National Laboratory, Los Alamos, NM 87545.

Abstract - This essay argues that when measurement processes involve energies of the order of the Planck scale, the fundamental assumption of locality may no longer be a good approximation. Idealized position measurements of two distinguishable spin-0 particles are considered. The measurements alter the space-time metric in a fundamental manner governed by the commutation relations $[x_i, p_j] = i\hbar\delta_{ij}$ and the classical field equations of gravitation. This *in-principle* unavoidable change in the space-time metric destroys the commutativity (and hence locality) of position measurement operators.

2. Why the Universe is Not Anisotropic - by John D. Barrow, Astronomy Centre, University of Sussex, Brighton BN1 9QH, UK.

Abstract - A simple, physically realistic boundary condition is introduced for cosmological models. It predicts that general anisotropic universes possess a microwave background temperature anisotropy of $10^{-4}\Omega_0$ on large angular scales today. Thus, even in the absence of long-lasting inflation, the anisotropy of the Universe must be small ($\Delta T/T \sim 10^{-4} - 10^{-6}$) with a generic level that is tantalizingly close to the quadrupole anisotropy, $\Delta T/T \sim 10^{-5}$ recently measured by the COBE satellite.

3. The Geometric Phase of the Universe - by Mircea I. Beciu, Department of Physics and Astronomy, University of South Carolina, Columbia, SC 29208.

Abstract - The author calculates the geometric phase acquired by a Klein-Gordon field and a Maxwell field evolving cyclically in a closed universe, resembling our own. The result suggests that the geometric phase can be added to the list of null values of our Universe (energy, electric charge, spin).

4. Detection of Computer Generated Gravitational Waves in Numerical Cosmologies - by Beverly K. Berger, David Garfinkle, and Vijaya Swamy, Physics Department, Oakland University, Rochester, MI 48309.

Abstract - The authors propose to study the behavior of complicated numerical solutions to Einstein's equations for generic cosmologies by following the geodesic motion of a swarm of test particles. As an example, they consider a cylinder of test particles initially at rest in the plane symmetric Gowdy universe on $T^3 \times R$. For a circle of test particles in the symmetry plane, the geodesic equations predict evolution of the circle into distortions and rotations of an ellipse as well as motion perpendicular to the plane. The evolutionary sequence of ellipses depends on the initial position of the circle of particles. The authors display snapshots of the evolution of the cylinder.

5. Black Holes: The Inside Story - Alfio Bonanno[*+], Serge Droz[*], Werner Israel[*] and Sharon M. Morsink[*], [*]Canadian Institute for Advanced Research Cosmology Program, Theoretical Physics Institute, University of Alberta, Edmonton, Alberta, Canada T6G 2J1; [+]Institute of Astronomy, University of Catania, Viale Andrea Doria 5, 95125 Catania, Italy.

Abstract - Collapse to a black hole leaves a decaying tail of gravitational waves. The fallout from this tail, absorbed into the hole, is strongly blueshifted near the inner horizon, with dramatic effects on the internal geometry. Is the resulting singularity an all-embracing spacelike crunch, as envisioned in the strong cosmic censorship hypothesis? Or is there a mildly singular, lightlike precursor, characterized by inflation of the core mass? The authors review the evidence for each of these possibilities.

6. Time Asymmetry in Semiclassical Cosmology - by M. Castagnino[*+#], E. Gunzig[*], and F. Lombardo[*,+] [*]RggR, Université Libre de Bruxelles, Campus Plaine 231, 1050 Bruxelles, Belgium; [+]Departamento de Física, Facultad de Ciencias Exactas y Naturales Universidad de Buenos Aires, Ciudad Universitaria, 1428 Buenos Aires, Argentina; [#]Instituto de Astronomía y Física del Espacio, Casilla de Correo 67, Sucursal 28, 1428 Buenos Aires, Argentina.

Abstract - An apparently innocuous property of nature is the universal alignment of the arrow of time for all physical systems, from the subatomic world to the overall cosmological dynamical evolution. This seems to point towards an explanation of irreversibility as the manifestation of a universal intrinsic property, shared by physical systems of arbitrary scales. A major step towards an understanding of this property was taken in quantum mechanics. This required no alteration of the theory itself, but an extension of its mathematical formalism. A natural attitude is therefore to adapt this procedure to cosmological considerations. The present essay is precisely devoted to the description of the peculiarities of this interpretation of the irreversible dynamical behaviour of the cosmological history.

7. Disorder and Localization in Gravitation - by Timir Datta, and John L. Safko, Department of Physics and Astronomy, University of South Carolina, Columbia, SC 29208.

Abstract - Many quantum and classical fields are influenced by disorder. In this essay the authors discuss some effects of disorder on gravitation. The authors analyze a simple model for a gravitating system with random disorder. Results, based on this model, show a lengthening of the affine parameter for the outgoing null geodesics with increasing disorder. This is interpreted as a diffusive slowing down of propagation and hence localization of the gravitational field. The cosmological scaling factor S(t) in the diffusive limit is slow. They calculate $S(t) \sim t^{1/\gamma}$ where $\gamma > 2$. This suggests that, during the strongly disordered Big Bang era, localization could have held back the expansion of the early universe. This caused the observed large-scale nucleation of matter.

8. Gravitational Diholes - by Aharon Davidson and Edward Gedalin, Physics Department, Ben-Gurion University of the Negev, Beer-Sheva 84105, Israel.

Abstract - A finite-length magnetic vortex line solution is derived within the context of (4-dim) dilaton gravity. On the technical side, one recovers the Bonnor metric at the Einstein-Maxwell limit, and the flux tube as a (Euclidean) Kerr horizon at the Kaluza-Klein embedding. Effective string theory gets singled out when analyzing the flux tube world-sheet geometry. Exclusively for string theory, the flux tube serendipitously resembles a (2-dim) black&white dihole. This physical interpretation, analytically accepted by the full 4-dim parent theory, is supported by a Kruskal-type (imaginary time periodic) extension, as well as the Lemaitre-type (synchronous light cone and geodesically complete) representation.

9. Closure of the Universe - by John Bruce Davies, Department of Physics, University of Colorado, Boulder, CO 80309.

Abstract - Whether the Universe is closed or open depends crucially on the value of its mean density. In this research the author obtains an estimate of the mass density of intergalactic space at the time of birth of the Milky Way galaxy. In order to determine the present mean density of the Universe this intergalactic density estimate is projected forward to the present time. Galaxies are considered to be formed by collapse and fragmentation of isothermal protogalactic gas spheroids which are embedded in a uniform intergalactic medium. Subject to conservation of angular momentum, relationships are obtained governing the mass distribution of a galaxy after the collapse has terminated. Using these relationships and estimates of the original radius of the Galaxy, the author deduces the value of the external density at the time the Galaxy formed. Assuming the observed range of redshifts of early galaxies and quasars, the author obtains estimates of the present density of the Universe which are well above the accepted value required for closure of the Universe.

10. A Method of Reduction for Einstein's Equations of Evolution and A Natural Symplectic Structure on the Space

of Quantum Gravitational Degrees of Freedom - by Arthur E. Fischer[*] and Vincent Moncrief[+], [*]Department of Mathematics, University of California, Santa Cruz, Santa Cruz, CA 95064; [+]Departments of Mathematics and Physics, Yale University, New Haven, CT 06511.

Abstract - This essay is concerned with the questions of how to write Einstein's vacuum equations as an *unconstrained* dynamical system where the variables are the *true degrees of freedom* of the gravitational field. The authors refer to this problem as the problem of reduction of Einstein's equations. They outline a program which addresses this problem for Ricci-flat spacetimes. The program consists of three components. The first component consists of identifying the reduced phase space on which the dynamics occurs. The second component consists of finding the proper Hamiltonian function for the unconstrained variables. The third component consists of reconstructing the spacetime from the Hamiltonian flow.

11. The Problem of Time in Parametrized Theories - by Fabián H. Gaioli and Edgardo T. Garcia-Alvarez, Departamento de Física, Facultad de Ciencias Exactas y Naturales, Universidad de Buenos Aires, 1428 Buenos Aires, Argentina.

Abstract - A common feature of parametrized theories is the difficulty involved in identifying an appropriate evolution parameter and in constructing a Hilbert space on states. Two well known examples of such theories are the relativistic point particle and the canonical formulation of quantum gravity. The strong analogy between them (specially for minisuperspace models) is considered in order to stress the correspondence between the "localization problem" and the "problem of time," respectively. A possible solution for the first problem was given by the proper time formulation of relativistic quantum mechanics. The authors extrapolate the main outlines of such a formalism to the quantum gravity framework. As a consequence, a proposal to solve the problem of time arises.

12. Birth and Death of a Black Hole - by Ronald Gautreau[*] and Jeffrey Cohen[+], [*]Physics Department, New Jersey Institute of Technology, Newark, NJ 07102; [+]Physics Department, University of Pennsylvania, Philadelphia, PA 19104.

Abstract - The authors study a body that collapses from some initial radius to R = 0 and then expands back to its initial radius. They observe the birth of a black hole when the surface of the body collapses from the initial maximum radius through its gravitational radius. As the body expands from R = 0 to return to its maximum radius, the black hole disappears when the surface of the body expands through its gravitational radius. The collapse-expansion process can be continued to describe a pulsating black hole. The times associated with a pulsating black hole the size of a neutron star are of the order of milliseconds.

13. Kaluza-Klein Quantum Cosmology with Primordial Negative Cosmological Constant - by E. I. Guendelman and A. B. Kaganovich, Physics Department, Ben Gurion University of the Negev, Beer Sheva 84105, Israel.

Abstract - In many interesting models, including superstring theories, a negative vacuum energy is predicted. Although this effect is usually regarded as undesirable from a cosmological point of view, the authors show that this can be the basis for a new approach to the cosmology of the early Universe. In the framework of quantum cosmology (in higher dimensions) when the authors consider a negative cosmological constant and matter that could be dust or, alternatively, coherent excitations of a scalar field, the role of cosmic time can be understood. Then the authors predict the existence of a "quantum inflationary phase" for some dimensions and a simultaneous "quantum deflationary phase" for the remaining dimensions. The authors discuss how it may be possible to exit from this inflation-compactification era to a phase with zero cosmological constant which allows a classical description at late times.

14. A Zero-Point Field Model of Gravity and Inertia - by Bernhard Haisch, 519 Cringle Drive, Redwood City, CA 94065.

Abstract - The proposal of Sakharov linking gravity to the zero-point field was developed by Puthoff into a quantitative representation of Newtonian gravity. The presence of a particle reacting to the zero-point field fluctuations was shown to cause a distortion in the field that would give rise to an electromagnetic force on any other particle having the apparent properties of Newtonian gravitation. The principle of equivalence thus suggests that inertia may also have an external origin in matter-zero-point field interactions. Moreover, the Davies-Unruh effect predicts that in accelerated reference frames the otherwise uniform and isotropic zero-point field will be distorted. This connection between a distortion of the zero-point field and acceleration has been developed into a quantitative model of inertia by Haisch, Rueda and Puthoff (Phys. Rev. A., 49, 678, 1994).

15. String Theory and Duality Symmetry between Curved and Flat Space-times - by C. Klimčík[*] and A. A. Tseytlin[+], [*]Theory Division, Nuclear Centre, Charles University, 180 00 Prague 8, Czech Republic; [+]Theory Group, Blackett Laboratory, Imperial College, London SW7 2BZ, U.K.

Abstract - Space-time duality is one of the fundamental properties of string theory being a direct consequence of the extended nature of strings which can wind around compact dimensions. The authors present some examples of string backgrounds related by duality emphasizing that even in the simplest point-like approximation an invariant content of the string geometry is described not just by the metric but by a combination of the metric, antisymmetric tensor and dilaton with all the three fields playing complementary roles. Particular properties of the metric (e.g. its curvature and causal structure) are not, in general, invariant under duality, i.e. under string symmetry group. For example, a flat space (with some compact dimensions) viewed as a solution of the string theory can be equivalent to a curved space with a non-trivial dilaton and/or antisymmetric tensor. While the momentum string modes move in the original flat geometry, the winding modes present in the 'flat' string spectrum propagate in a dual curved background. The backgrounds the authors discuss have null Killing vectors and are exact string solutions (to all orders in α'). A further study of duality symmetry may help to illuminate unusual properties of string geometry which should be a basis of string theory of gravity.

16. Stringy Quantum Cosmology of the Bianchi Class A - by James E. Lidsey, NASA/Fermilab Astrophysics Center, Fermi National Accelerator Laboratory, Batavia, IL 60510.

Abstract - The quantum cosmology of the string effective action is considered within the context of the Bianchi class A minisuperspace. An exact unified solution is found for all Bianchi types and interpreted physically as a quantum wormhole. The solution is generalized for types VI_0 and VII_0. The Bianchi type IX wave-function becomes increasingly localized around the isotropic Universe at large three-geometries.

17. Collapse and Rebound of a Charged Dust-like Star - by Carlos A. López, Departamento de Física, Facultad de Ciencias Físicas y Matemáticas, Universidad de Chile, Casilla 487-3, Santiago, Chile.

Abstract - It is shown that a charged spherically symmetric star, made out of a continuous superposition of thin shells with Poincaré stresses, undergoes gravitational collapse in free fall like an uncharged star of dust. The interior solution is a Friedmann universe matching the Reissner-Nordström geometry at the boundary of the star. When the absolute value of the charge Q does not exceed the mass M, the star rebounds elastically inside the event horizon at the radial coordinate $Q^2/(2M)$. The further history of the charged star after the bounce is analyzed. Besides, a simple mechanism which accounts for the development of Poincaré stresses in an originally charged star of dust is suggested. It is also verified that the energy density is nonnegative all along the collapse process.

18. On the Possibility of the Centrifugal Force Reversal in Removable Gravitational Fields - by G. Z. Machabeli and A. D. Rogava, Department of Theoretical Astrophysics, Abastumani Astrophysical Observatory, Kazbegi str. N2[a], Tbilisi 380060, Republic of Georgia.

Abstract - The necessity for a further basic revision in understanding the essential character of the centrifugal force is pointed out. In particular, it is shown that under certain circumstances, in removable gravitational fields (i.e., in rotating special-relativistic reference frame) the centrifugal force, acting on a moving body changes its usual sign and attracts towards the axis of rotation. Such effect, found earlier in strong, irremovable gravitational fields, may also appear in accelerated (rotating) special-relativistic reference frames. This is demonstrated for the simple, "the pipe and the head" gedanken experiment. The possible appearance and importance of this effect in real astrophysical situations is briefly discussed.

19. Metric of an Axisymmetric Neutron Star - by V. S. Manko, J. Martín, and E. Ruiz, Area de Física Teórica, Universidad de Salamanca, 37008 Salamanca, Spain.

Abstract - The simplest exact four-parameter model able to describe the exterior field of an axisymmetric neutron star is presented.

20. Do Inertial Electric Charges Radiate with Respect to Uniformly Accelerated Observers? - by George E. A. Matsas, Instituto de Física Teórica, Rua Pamplona 145, 01405-900, São Paulo, SP, Brazil.

Abstract - The author revisits the long standing problem of analyzing an inertial electric charge from the point of view of uniformly accelerated observers in the context of semi-classical gravity. He chooses a suitable set of accelerated observers with respect to which there is no photon emission coming from the inertial charge. He compares this result to those of previous investigators.

21. On a Possibility of Gravitational Radiation Detection Using Geometric Phase of a Light Beam - by Nikolai V. Mitskievich and Alexander I. Nesterov, Facultad de Ciencias Físico-Matemáticas, Universidad de Guadalajara, Guadalajara, Jalisco, Mexico.

Abstract - An effect of geometrical phase shift is predicted for a light beam propagating in the field of a gravitational wave. For the beam travelling orthogonally to the direction of propagation of the gravitational wave from an observer and returning back after being reflected, this phase is shown to grow proportionally to L/λ where L is distance between the observer and reflecting system, and λ characteristic wavelength of the gravitational wave packet (for light propagating parallel or antiparallel to the gravitational wave, the geometric phase shift is absent). Gravitational radiation detection experiments are proposed using this new effect, the corresponding estimates being given.

22. The Formation of Stars, Globular Clusters and Galaxies - by Lloyd Motz[*] and David W. Kraft[+], [*]Department of Astronomy, Columbia University, New York, NY; [+]Department of Physics, United States Military Academy, West Point, NY.

Abstract - The authors show that the Jeans condition for the growth of self-gravitating structures such as stars, globular clusters and galaxies could have been fulfilled after decoupling between the cosmic radiation and the baryons that now constitute the visible matter in the universe if Planck-mass particles were also present. They also show that baryons alone are not massive enough to have been the seeds for the growth of the self-gravitating structures that now populate the universe but that Planck-mass particles serve this purpose very well.

23. Unreasonable Postulate in the Perturbative Approach to Quantum Gravity - by Noboru Nakanishi, Research Institute for Mathematical Sciences, Kyoto University, Kyoto 606-01, Japan.

Abstract - The conventional perturbative approach to quantum gravity is based on the expansion in powers of $\sqrt{\kappa}$ where κ denotes the Einstein gravitational constant. The introduction of a square root is due to the unreasonable postulate that the $\kappa \to 0$ limit of the gravitational field is a *c*-number. It is more natural that it is a *q*-number, which can be determined explicitly by the theory, and then the expansion becomes that in powers of κ but not of $\sqrt{\kappa}$ Thus the nonrenormalizability of Einstein gravity should be completely reconsidered in the light of the new expansion.

24. Geometrodynamics of Evaporating Black Holes and the Loss of Information Paradox - by Renaud Parentani and Tsvi Piran, Racah Institute of Physics, The Hebrew University, Jerusalem, Israel 91904.

Abstract - The authors present a model for the entire evolution of the space-time around an evaporating black hole. The numerical solution exhibits many features of black hole evaporation, such as the evaporation law $\dot{M} \propto -M^{-2}$ which have been anticipated for a long time but never demonstrated dynamically. The authors discover that the evaporation takes place at a shrinking throat that connects a macroscopic interior "universe" to the exterior. The evaporation ends either by pinching off the throat leaving a closed "universe" and a Minkowskian exterior or by freezing up when the throat's radius approaches a Planck size. In either case the macroscopic inner "universe" contains the information lost during the evaporation. This concealed "universe" offers a possible resolution of the loss of information paradox, that hinders black hole physics for the last eighteen years: information is not lost, it is just hidden.

25. A Steady State Cosmological Model in a Closed Space: Resolution of the Entropy Problem - by Peter R. Phillips, Department of Physics, Washington University, St. Louis, MO 63130.

Abstract - The author briefly describes the closed-space steady-state cosmological model, which involves continuous creation of matter in one region of space and annihilation in another. This process is represented as the interconversion of two types of matter, primary and secondary, with secondary matter being the familiar form. Primary matter flows in one direction and secondary matter in the other. A model of this sort can satisfy the basic requirements of a cosmology, but it presents a fundamental problem: how can the counterflow be maintained when our experience tells us that entropy will increase until the flow ceases? The author shows that the contrasting requirements of gravitation and quantum mechanics, on a cosmological scale, lead to a novel situation in which a counterflow is possible.

26. Is Minimal Coupling Procedure Compatible with Minimal Action Principle? - by Alberto Saa, Instituto de Física, Universidade de São Paulo, Caixa Postal 20516, 01452-990 São Paulo, Brazil.

Abstract - When space-time is assumed to be non-Riemannian the minimal coupling procedure (MCP) is not compatible, in general, with minimal action principle (MAP). This means that the equations gotten by applying MCP to the Euler-Lagrange equations of a Lagrangian □ do not coincide with the Euler-Lagrange equations of the Lagrangian obtained by applying MCP to □. Such compatibility can be restored if the space-time admits a connection-compatible volume element. The author shows how these concepts can alter qualitatively the predictions of the Einstein-Cartan theory of gravity.

27. Is *CMBR* Anisotropy Due to Fluctuations in G? - by T. R. Seshadri, Mehta Research Institute of Mathematics and Mathematical Physics, 10, Kasturba Gandhi Marg, (Old Kutchery Road), Allahabad 211 002, India.

Abstract - Large-angle anisotropy in the Cosmic Microwave Background Radiation (CMBR) arises due to the spatial variation of the gravitational potential at the surface of last scatter. In those theories of gravity in which gravitational coupling *G* is a constant, gravitational potential fluctuations arise purely due to the inhomogeneities in the matter distribution. However, in the theories in which the gravitational constant is not spatially uniform, gravitational potential fluctuations will have contribution from *G* variations also. Extended inflationary models involve Brans-Dicke theory of gravity. In these theories, *G* is determined by the value of the Brans-Dicke field. Quantum fluctuations in the Brans-Dicke field lead to fluctuations in *G* on the surface of last scatter which in turn leads to the anisotropy in the CMBR through the variation in the gravitational potential.

28. Weighing the Sun with a Clock - by Robert F. C. Vessot, Smithsonian Astrophysical Observatory, 60 Garden Street, Cambridge, MA 02138.

Abstract - High stability atomic clocks now offer the highest precision for both time and distance measurements. By comparing the changes in frequency, Δf, of a highly stable atomic oscillator (or clock) in a space probe going very close to the sun with the frequency of a similar clock on earth one can use the clock to measure the product of the mass of the sun, M_s, times the gravitational constant, G, from the redshift relation

$$\frac{\Delta f}{f} = \frac{GM_s}{c^2}\left[\frac{1}{R_e} - \frac{1}{R_p}\right]$$

where R_e and R_p are the distances of the earth clock and of the space clock from the sun's center. These data should allow a test of the first order redshift at the 10^{-9} level and the second order redshift at the 10^{-3} level. A signature from the oblateness of the sun should also be visible in the time-evolution of the data as the probe passes from pole-to-pole. The technology described for making the measurements is realistically based on the 1976 NASA/SAO redshift test.

29. Geometry and Quantum Processes - by James T. Wheeler, Utah State University, Logan, UT 84322-4415.

Abstract - The author examines a class of geometries in which timelike and spacelike geodesics reaching conformal boundaries of the spacetime become null even though the spacetimes are extendible and the boundaries are reached in a finite proper time. Since corresponding behavior occurs in the extension, and geodesics of each causal type become null at the boundary, geodesics can change causal type in passing the boundary. Such boundaries might arise in microscopic regions from quantum sources, providing a geometric model of a particle-antiparticle annihilation process. A single particle field could create and traverse a pair of such boundaries, reversing the time sense of its motion. The geometries displayed indicate the importance of finding combined solutions to general relativity and quantum field theories.

30. Fluid Cosmology with Decay and Production of Particles - by Winfried Zimdahl[*] and Diego Pavón[+], [*]Institut für Theoretische Physik, Universität Düsseldorf, D-40225 Düsseldorf, Germany; [+]Departament de Física, Universitat Autònoma de Barcelona, E-08193 Bellaterra (Barcelona), Spain.

Abstract - The authors investigate the influence of particle number nonconserving processes on the thermal history and the dynamics of the universe. There occurs a backreaction both on the temperature and on the scale factor if particles of one species decay into particles of another species, or if the overall particle number changes. This backreaction is determined by the ratios of the relevant decay and production rates to the Hubble expansion rate. It causes reheating phenomena and modifications of the standard Friedmann-Lemaitre-Robertson-Walker expansion laws. A high production rate at the Planck scale tends to avoid the cosmological singularity.