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Abstracts of Award Winning and Honorable Mention Essays for 2011

Award Essays

First Award – Stimulated Creation of Quanta during Inflation and the Observable Universe – by Ivan Agullo[1] and Leonard Parker[2], [1]Institute for Gravitation and the Cosmos, Physics Department, Penn State, University Park, PA 16802-6300, [2]Physics Department, University of Wisconsin-Milwaukee, P.O. Box 413, Milwaukee, WI 53201; e-mail: agullo@gravity.psu.edu leonard@uwm.edu

Abstract – Inflation provides a natural mechanism to account for the origin of cosmic structures. The generation of primordial inhomogeneities during inflation can be understood via the spontaneous creation of quanta from the vacuum. We show that when the corresponding *stimulated* creation of quanta is considered, the characteristics of the state of the universe at the onset of inflation are not diluted by the inflationary expansion and can be imprinted in the spectrum of primordial inhomogeneities The non-gaussianities (particularly in the so-called squeezed configuration) in the cosmic microwave background and galaxy distribution can then tell us about the state of the universe that existed at the time when quantum field theory in curved spacetime first emerged as a plausible effective theory.

Second Award – Relative Locality: A Deepening of the Relativity Principle – by Giovanni Amelino-Camelia[1], Laurent Freidel[2], Jerzy Kowalski-Glikman[3], and Lee Smolin[2], [1]Dipartimento di Fisica, Università "La Sapienza" and Sez. Roma1 INFN P. le A. Moro 2, 00185 Roma, Italy, [2]Perimeter Institute for Theoretical Physics, 31 Caroline Street North, Waterloo, Ontario N2J 2Y5, Canada, [3]Institute for Theoretical Physics, University of Wroclaw, Pl. Maxa Borna 9, 50-204 Wroclaw, Poland; e-mail: amelino@roma1.infn.it lfreidel@perimeterinstitute.ca jkowalskiglikman@ift.uni.wroc.pl, lsmolin@perimeterinstitute.ca

Abstract – We describe a recently introduced principle of relative locality which we propose governs a regime of quantum gravitational phenomena accessible to experimental investigation. This regime comprises phenomena in which $\hbar$ and G_N may be neglected, while their ratio, the Planck mass $M_P = \sqrt{\hbar / G_N}$, is important. We propose that M_P governs the scale at which momentum space may have a curved geometry. We find that there are striking consequences for the concept of locality. The description of events in spacetime now depends on the energy used to probe it. But there remains an invariant description of physics in phase space. There is furthermore a reasonable expectation that the geometry of momentum space can be measured experimentally using astrophysical observations.

Third Award – The Value of the Cosmological Constant – by John D. Barrow and Douglas J. Shaw, DAMTP, Centre for Mathematical Sciences, Cambridge University, Cambridge CB3 0WA, United Kingdom; e-mail: J.D.Barrow@damtp.cam.ac.uk D.Shaw@damtp.cam.ac.uk

Abstract – We make the cosmological constant, Λ, into a field and restrict the variations of the action with respect to it by causality. This creates an additional Einstein constraint equation. It restricts the solutions of the standard Einstein equations and is the requirement that the cosmological wave function possess a classical limit. When applied to the Friedmann metric it requires that the cosmological constant measured today, t_U, be $\Lambda \sim t_U^{-2} \sim 10^{-122}$, as observed. This is the classical value of Λ that dominates the wave function of the universe. Our new field equation determines Λ in terms of other astronomically measurable quantities. Specifically, it predicts that the spatial curvature parameter of the universe is $\Omega_{k0} \equiv -k/a_0^2H^2 = -0.0055$, which will be tested by Planck Satellite data. Our theory also creates a new picture of self-consistent quantum cosmological history.

Fourth Award – Losing Information outside the Horizon – by Samir D. Mathur, Department of Physics, The Ohio State University, Columbus OH 43210; e-mail: mathur@mps.ohio-state.edu

Abstract – If a system falls through a black hole horizon, then its information is lost to an observer at infinity. But we argue that the *accessible* information is lost *before* the horizon is crossed. The temperature of the hole limits information carrying signals from a system that has fallen too close to the horizon. If we attempt to bring the system back to infinity, acceleration radiation destroys the information. For systems in string theory where we pack information as densely as possible, this acceleration constraint is found to have a geometric interpretation. Thus in theories of gravity we should measure information not as a quantity contained inside a given system, but in terms of how much of that information can be reliably accessed by another observer.

Fifth Award – Quantum Gravity and Dark Matter – by Chiu Man Ho[1], Djordje Minic[2], and Y. Jack Ng[3], [1]Department of Physics and Astronomy, Vanderbilt University, Nashville, TN 37235, [2]Department of Physics, Virginia Tech, Blacksburg, VA 24061, [3]Institute of Field Physics, Department of Physics and Astronomy, University of North Carolina, Chapel Hill, NC 27599; e-mail: chiuman.ho@vanderbilt.edu dminic@vt.edu yjng@physics.unc.edu

Abstract – We propose a connection between global physics and local galactic dynamics via quantum gravity. The salient features of cold dark matter (CDM) and modified Newtonian dynamics (MOND) are combined into a unified scheme by introducing the concept of MONDian dark matter which behaves like CDM at cluster and cosmological scales but emulates MOND at the galactic scale.

1. Dark Energy, Dirac's Scalar Field and the Cosmological Constant Problem – by Olga V. Babourova and Boris N. Frolov, Moscow State Pedagogical University, Department of Physics and Informational Technologies, MSPU, M. Pirogovskaya, 29, 119992 Moscow, Russian Federation; e-mail: baburova@orc.ru frolovbn@orc.ru

Abstract – The two sets of solutions of the field equations of the conformal theory of gravity with a Dirac scalar field in a Weyl-Cartan space-time at very early universe are obtained. In this theory a dark energy (described by an effective cosmological constant) is a function of the Dirac scalar field β. One of these solutions describes an exponential decreasing of β at the first exponential stage of inflation that solves the fundamental cosmological constant problem. The second set of solutions describes the last power-law stage of inflation with a slowly decreasing cosmological constant.

2. Persistence of Black Holes through a Cosmological Bounce – by B. J. Carr[1], A. Coley[2], [1]Astronomy Unit, Queen Mary University of London, Mile End Road, London E1 4NS, UK, [2]Department of Mathematics and Statistics, Dalhousie University, Halifax, NS B3H 3J5, Canada; e-mail: B.J.Carr@qmul.ac.uk aac@mathstat.dal.ca

Abstract – There are a number of bouncing cosmological scenarios, both classical and quantum gravitational, that are currently of great interest. We discuss whether black holes could persist in a universe which recollapses and then bounces into a new expansion phase. In particular, we investigate in what mass range can black holes survive a bounce and whether we can differentiate observationally between black holes formed just after and just before the big bounce. We also briefly discuss whether it is possible that the universe becomes higher-dimensional, or goes through a sequence of dimensional changes, as it passes through the big bounce.

3. On the Measure of Spacetime and Gravity – by Naresh Dadhich, IUCAA, Pune 411007, India; e-mail: nkd@iucaa.ernet.in

Abstract – By following the general guiding principle that nothing should be prescribed or imposed on the universal entity, spacetime, we establish that it is the homogeneity of spacetime that requires not only a universally constant invariant velocity but also an invariant length given by its constant curvature, Λ and spacetime is completely free of dynamics. Thus c and Λ are the only two true constants of the spacetime structure and no other physical constant could claim this degree of fundamentalness. As c was determined by the Maxwell electrodynamics, similarly Λ is determined by the cosmology and accounts for the accelerating expansion of the Universe which could be thought of measuring in terms of the Planck area 10^{120} units!

4. The Real Problem with MOND – by Scott Dodelson, Center for Particle Astrophysics, Fermi National Accelerator Laboratory, Batavia, IL 60510, Department of Astronomy & Astrophysics, The University of Chicago, Chicago, IL 60637, Kavli Institute for Cosmological Physics, Chicago, IL 60637; e-mail: dodelson@fnal.gov

Abstract – Gravitational potentials in the cosmos are deeper than expected from observed visible objects, a phenomenon usually attributed to dark matter, presumably in the form of a new fundamental particle. Until such a particle is observed, the jury remains out on dark matter, and modified gravity models must be considered. The class of models reducing to MOdified Newtonian Dynamics (MOND) in the weak field limit does an excellent job fitting the rotation curves of galaxies, predicting the relation between baryonic mass and velocity in gas-dominated galaxies, and explaining the properties of the local group. Several of the initial challenges facing MOND have been overcome, while others remain. Here I point out the most severe challenge facing MOND.

5. Observational Constraints on Strong Gravity – by Chris Done, Department of Physics, University of Durham, South Road, Durham DH1 3LE, UK; e-mail: chris.done@durham.ac.uk

Abstract – Accretion onto a black hole transforms the darkest objects in the Universe to the brightest. The high energy radiation emitted from the accretion flow before it disappears forever below the event horizon lights up the regions of strong spacetime curvature close to the black hole, enabling strong field tests of General Relativity. I review the observational constraints on strong gravity from such accretion flows and show how the data strongly support the existence of such fundamental General Relativistic features of a last stable orbit and the event horizon. However, these successes also imply that gravity does not differ significantly from Einstein's predictions above the event horizon, so any new theory of quantum gravity will be very difficult to test.

6. Fully Reciprocal Lorentz Transformations and the Universality of the Speed of Light – by Arthur E. Fischer, Department of Mathematics, University of California, Santa Cruz, Santa Cruz, California 95064; e-mail: aef@ucsc.edu

Abstract – There are two postulates in Einstein's *Special Theory of Relativity*. The first postulate asserts that the laws of physics are the same in all inertial systems. The second postulate asserts that the speed of light is the same in all inertial systems. In this essay we state results that mathematically prove that the second postulate is a consequence of the first postulate and is therefore redundant. This result considerably simplifies the assumptions underlying the foundation of special relativity and therefore much of modern physics. Along the way, we introduce a *fully reciprocal form* of the Lorentz transformation, whose transformation from an inertial frame S to an inertial frame $\bar{S}$ is functionally *exactly* the same as the inverse transformation from $\bar{S}$ to S, as required by the *Special Principle of Relativity*. Applications of this work to the *General Theory of Relativity* are discussed.

7. Real Clocks and Lorentz Invariance in Quantum Gravity – by Rodolfo Gambini[1], Jorge Pullin[2], Saeed Rastgoo[1], [1]Instituto de Física, Facultad de Ciencias, Iguá 4225, esq. Mataojo, Montevideo, Uruguay, [2]Department of Physics and Astronomy, Louisiana State University, Baton Rouge, LA 70803-4001; e-mail: rgambini@fisica.edu.uy pullin@lsu.edu saeed@fisica.edu.uy

Abstract – Approaches to quantization like loop quantum gravity are potentially Lorentz violating in two different ways. On the one hand, the emergence of discrete structures in space suggests that spatially one already may have difficulties. But the fact that space and time are treated differently in the canonical approach is another potential source of Lorentz non-invariance. We will argue that in model calculations Lorentz violations may remain small if one uses real clocks to keep track of time. That is, solving the problem of time may also lead to a restoration of Lorentz invariance in quantum gravity.

8. Rindler Force at Large Distances – by Daniel Grumiller and Florian Preis, Institute for Theoretical Physics, Vienna University of Technology, Wiedner Hauptstrasse 8-10/136, A-1040 Vienna, Austria; e-mail: grumil@hep.itp.tuwien.ac.at fpreis@hep.itp.tuwien.ac.at

Abstract – Given some assumptions it is possible to derive the most general theory of gravity at large distances. The force law derived from this theory contains a Rindler term in addition to well-known contributions, a Schwarzschild mass and a cosmological constant. The same force law recently was confronted with solar system precision data. The Rindler force, if present in Nature, has intriguing consequences for gravity at large distances. In particular, the Rindler force is capable of explaining about 10% of the Pioneer anomaly and simultaneously ameliorates the shape of galactic rotation curves.

9. Non Singular Origin of the Universe and the Cosmological Constant Problem – by E. I. Guendelman, Physics Department, Ben Gurion University of the Negev, Beer Sheva, 84105, Israel; e-mail: guendel@bgu.ac.il

Abstract – We consider a non singular origin for the Universe starting from an Einstein static Universe in the framework of a theory which uses two volume elements $\sqrt{-g}\,d^4x$ and Φd^4x where Φ is a metric independent density, also curvature, curvature square terms, first order formalism and, for scale invariance, a dilaton field φ are considered in the action. In the Einstein frame we also add a cosmological term that parameterizes the zero point fluctuations. The resulting effective potential for the dilation contains two flat regions, for $\varphi \to \infty$ relevant for the non singular origin of the Universe and $\varphi \to -\infty$, describing our present Universe. Surprisingly, avoidance of singularities and stability as $\varphi \to \infty$ imply a positive but small vacuum energy as $\varphi \to -\infty$. Zero vacuum energy density for the present universe is the"threshold" for universe creation.

10. On the Meaning of General Covariance and the Relevance of Observers in General Relativity – by L. Herrera, Departamento de Física Teorica e Historia de la Física, Universidad del Pais Vasco, Bilbao, Spain; e-mail: lherrera@usal.es

Abstract – Since the appearance of General Relativity, its intrinsic general covariance has been very often misinterpreted as implying that physically meaningful quantities (and conclusions extracted from the theory) have to be absolutely independent of observers. This incorrect point of view is sometimes expressed by discarding the very concept of observer in the structure and applications of the theory. As we shall stress in this essay, through some examples, the concept of observer is as essential to General Relativity as it is to any physical theory.

11. Gravitation, Holographic Principle, and the Number of Spatial Dimensions – by Shahar Hod, The Hadassah Institute, HaNeviim 37, Jerusalem 91010, Israel; e-mail: shaharhod@gmail.com

Abstract – The holographic bound asserts that the entropy S of a system is bounded from above by a quarter of the area $\mathcal{A}$ of a circumscribing surface measured in Planck areas: $S \le \mathcal{A}/4\ell_P^2$. This bound is widely regarded a desideratum of any fundamental theory of nature. In fact, the bound is known to be valid for generic systems in *three* spatial dimensions. However, in this essay we explicitly show that hyper-entropic systems (those violating the holographic entropy bound) do exist in *higher*-dimensional spacetimes. This is a new and surprising result which should be taken into account in the construction of any fundamental quantum theory of gravity.

12. Subtle Is the Lord: On the Difference between Newtonian (Lyapunov) Stability Analysis and Geometrical Stability Analysis of Gravitational Orbits – by L. P. Horwitz, A. Yahalom, M. Lewkowicz and J. Levitan, Ariel University Center of Samaria, Ariel 40700, Israel; e-mail: larry@post.tau.ac.il asya@ariel.ac.il lewkow@ariel.ac.il levitan@ariel.ac.il

Abstract – In this essay we show that although the application of standard Lyapunov analysis predicts that completely integrable Kepler motion is unstable, the geometrical analysis of Horwitz, Ben Zion, Lewkowitz, Schiffer, and Levitan predicts the observed stability. This seems to us to provide evidence for both the incompleteness of the standard Lyapunov analysis and the strength of the geometrical analysis. Moreover, we apply this approach to the three body problem in which the third body is restricted to move on a circle of large radius which induces an adiabatic time dependent potential on the second body. This causes the second body to move in a very interesting and intricate but periodic trajectory; however, the standard Lyapunov analysis incorrectly predicts chaotic behavior. The geometric approach predicts the correct stable motion in this case as well.

13. Uncertainty Relations for Cosmological Particle Creation and Existence of Large Fluctuations in Reheating – by Ali Kaya, Boğaziçi University, Department of Physics, 34342, Bebek, Istanbul, Turkey; e-mail: ali.kaya@boun.edu.tr

Abstract – We derive an uncertainty relation for the energy density and pressure of a quantum scalar field in a time-dependent, homogeneous, and isotropic, classical background, which implies the existence of large fluctuations comparable to their vacuum expectation values. A similar uncertainty relation is known to hold for the field square since the field can be viewed as a Gaussian random variable. We discuss possible implications of these results for the reheating process in scalar field driven inflationary models, where reheating is achieved by the decay of the coherently oscillating inflaton field. Specifically we argue that the evolution after back reaction can be seriously altered by the existence of these fluctuations. For example, in one model the coherence of the inflaton oscillations is found to be completely lost in a very short time after back reaction starts. Therefore we argue that entering a smooth phase in thermal equilibrium is questionable in such models and reheating might destroy the smoothness attained by inflation.

14. The Invisibility of Torsion in Gravity – by H. Kleinert, Institut für Theoretische Physik, Freie Universität Berlin, Arnimallee 14, 14105 Berlin, ICRANeT, Piazzale della Republica 1, 10 -65122, Pescara, Italy; e-mail: h.k@fu-berlin.de

Abstract – It is shown that torsion can be moved partially or totally into the curvature in a new kind of gauge transformation without changing the physical content of Einstein's theory of gravitation. This explains its invisibility in any gravitational experiment.

15. Can the Graviton Have a Mass? – by Kazuya Koyama, Gustavo Niz , Gianmassimo Tasinato, Institute of Cosmology & Gravitation, University of Portsmouth, Dennis Sciama Building, Portsmouth, PO1 3FX, United Kingdom; e-mail: Kazuya.Koyama@port.ac.uk Gustavo.Niz@port.ac.uk Gianmassimo.Tasinato@port.ac.uk

Abstract – In this essay, we address two long-standing problems of massive gravity: the ghost mode found by Boulware and Deser and the incompatibility with General Relativity in the massless limit, better known as the vDVZ discontinuity. We present a recent candidate for a ghost-free theory and show how Einstein's gravity is recovered within a certain macroscopic radius from a mass source, via the Vainshtein mechanism. We also exhibit an exact solution which could account for the late time acceleration of the Universe by means of a small graviton mass.

16. We Probably Live on an Inflating Brane-World – by Ishwaree P. Neupane, Department of Physics and Astronomy, University of Canterbury, Private Bag 4800, 8041 Christchurch, New Zealand; e-mail: ishwaree.neupane@canterbury.ac.nz

Abstract – Brane-world models where observers are trapped within the thickness of a 3-brane offer novel perspectives on gravitation and cosmology. In this essay, I would argue that the problem of a late epoch acceleration of the universe is well explained in the framework of a 4-dimensional de Sitter universe embedded in a 5 dimensional de Sitter spacetime. While a 5D anti de Sitter space background is important for studying conformal field theories – for its role in the AdS/CFT correspondence – the existence of a 5-dimensional de Sitter space is crucial for finding an effective 4D Newton constant that remains finite and a normalizable zero-mode graviton wave function.

17. Birkhoff's Theorem in Higher Derivative Theories of Gravity – by Julio Oliva[1] and Sourya Ray[2], [1]Instituto de Física, Facultad de Ciencias, Universidad Austral de Chile, Valdivia, Chile, [2]Centro de Estudios Científicos (CECS), Casilla 1469, Valdivia, Chile; e-mail: julio.oliva@docentes.uach.cl ray@cecs.cl

Abstract – In this paper we present a class of higher derivative theories of gravity which admit Birkhoff's theorem. In particular, we explicitly show that in this class of theories, although generically the field equations are of fourth order, under spherical (plane or hyperbolic) symmetry, all the field equations reduce to second order and have exactly the same or similar structure to those of Lovelock theories, depending on the spacetime dimensions and the order of the Lagrangian.

18. The Hydrodynamics of Atoms of Spacetime: Gravitational Field Equation is Navier-Stokes Equation – by T. Padmanabhan, IUCAA, Post Bag 4, Ganeshkhind, Pune - 411 007, India; e-mail: paddy@iucaa.ernet.in

Abstract – There is considerable evidence to suggest that the field equations of gravity have the same conceptual status as the equations of hydrodynamics or elasticity. We add further support to this paradigm by showing that Einstein's field equations are identical in form to Navier-Stokes equations of hydrodynamics, when projected on to any null surface. In fact, these equations can be obtained directly by extremising of entropy associated with the deformations of null surfaces thereby providing a completely thermodynamic route to gravitational field equations. Several curious features of this remarkable connection (including a phenomenon of "dissipation without dissipation") are described and the implications for the emergent paradigm of gravity are highlighted.

19. A Crucial Hypothesis for Inflation – by Giandomenico Palumbo, Dipartimento di Fisica Nucleare e Teorica, Università degli Studi di Pavia and Istituto Nazionale di Fisica Nucleare, Sezione di Pavia, via A. Bassi 6, 27100 Pavia (Italy); e-mail: giandomenico.palumbo@pv.infn.it

Abstract – There are many different inflationary models that can explain the accelerated expansion that occurred in the early Universe. It is possible that there exists some fundamental property of Inflation that allows us to derive exactly a field theory for this phenomenon. For a single scalar field that drives the inflationary phase, we obtain uniquely the inflationary potential and the coupling term between the scalar field and the space-time geometry by a crucial hypothesis: during Inflation, the Ricci scalar remains constant. The potential that we derive is a standard potential in the inflationary scenario and our theoretical prediction for spectral index n_s is in perfect agreement with its experimental value. It is interesting to observe that in two dimensions our model is equivalent to Liouville gravity.

20. Corrections to the Apparent Value of the Cosmological Constant Due to Local Inhomogeneities – by Antonio Enea Romano[1,2], Pisin Chen[1,2,3,4], [1]Department of Physics, National Taiwan University, Taipei 10617, Taiwan, R.O.C, [2]Leung Center for Cosmology and Particle Astrophysics, National Taiwan University, Taipei 10617, Taiwan, R.O.C, [3]Graduate Institute of Astrophysics, National Taiwan University, Taipei 10617, Taiwan R.O.C, [4]Kavli Institute for Particle Astrophysics and Cosmology, SLAC National Accelerator Laboratory, Menlo Park, CA, 94025; e-mail:aer@phys.ntu.edu.tw pisinchen@phys.ntu.edu.tw

Abstract – Supernovae observations strongly support the presence of a cosmological constant, but its value, which we will call apparent, is normally determined assuming that the Universe can be accurately described by a homogeneous model. Even in the presence of a cosmological constant we cannot exclude nevertheless the presence of a small local inhomogeneity which could affect the apparent value of the cosmological constant. Neglecting the presence of the inhomogeneity can in fact introduce a systematic misinterpretation of cosmological data, leading to the distinction between an apparent and true value of the cosmological constant. Modeling the local inhomogeneity with a ΛLTB solution we compute the relation between the apparent and true value of the cosmological constant.

Contrary to previous attempts to fit data using large void models our approach is quite general. The correction to the apparent value of the cosmological constant is in fact present for local inhomogeneity of any size and should always be taken appropriately into account both theoretically and observationally.

21. Time and Irreversibility in an Accelerating Universe – by Gustavo E. Romero[1,2] and Daniela Pérez[1], [1]Instituto Argentino de Radioastronomía (IAR, CCT La Plata, CONICET), C.C. No. 5, 1894, Villa Elisa, Buenos Aires, Argentina, [2]FCAyG, Observatorio de La Plata, Paseo del Bosque s/n, CP 1900 La Plata, Argentina; e-mail: romero@iar-conicet.gov.ar danielaperez@iar-conicet.gov.ar

Abstract – It is a remarkable fact that all processes occurring in the observable Universe are irreversible, whereas the equations through which the fundamental laws of physics are formulated are invariant under time reversal. The emergence of irreversibility from the fundamental laws has been a topic of consideration by physicists, astronomers and philosophers since Boltzmann's formulation of his famous "H" theorem. In this paper we shall discuss some aspects of this problem and its connection with the dynamics of space-time, within the framework of modern cosmology. We conclude that the existence of cosmological horizons allows a coupling of the global state of the Universe with the local events determined through electromagnetic processes.

22. On Implications of the Equivalence Principle for Modified Gravity Theories – by M. M. Sheikh-Jabbari, School of Physics, Institute for Research in Fundamental Sciences (IPM), P.O.Box 19395-5531, Tehran, Iran; e-mail: jabbari@theory.ipm.ac.ir

Abstract – One of the manifestations of the Einstein Equivalence Principle is that a freely falling particle in a gravitational field is following a geodesic. In Einstein's general relativity this is built into the formulation by *assuming* the connection to be the Levi-Civita connection. The latter may, however, be demanded to be implied by the dynamics of a generic modified gravity theory, within the Palatini formulation. We show that for extensions of the Einstein GR which are described by a Lagrangian $\mathcal{L} = \mathcal{L}(g_{\mu\nu}, R_{\mu\alpha\beta\nu})$, where $g_{\mu\nu}$ is the metric and $R_{\mu\alpha\beta\nu}$ is the Riemann curvature tensor, this manifestation of the Einstein Equivalence Principle is only fulfilled for a special class of Lagrangians, the Lovelock gravity theories. Our analysis also implies that within the above mentioned set of modified gravity theories only for Lovelock gravity theories are the metric and the Palatini formulations equivalent.

23. Hydrodynamics, Horizons, Holography and Black Hole Entropy – by C. Sivaram, Indian Institute of Astrophysics, Bangalore, 560034, India; e-mail: sivaram@iiap.res.in

Abstract – The usual discussions about black hole dynamics involve analogies with laws of thermodynamics especially in connection with black hole entropy and the associated holographic principle. We explore complementary aspects involving hydrodynamics of the horizon geometry through the membrane paradigm. New conceptual connections complementing usual thermodynamic arguments suggest deep links between diverse topics like black hole decay, quantum circulation, and viscosity. Intriguing connections between turbulence cascades, quantum diffusion via quantum paths following the Fokker-Planck equation and Hawking decay also result from this combination of thermodynamic and hydrodynamic analogies to black hole dynamics.

24. A Gravitational Mechanism for Cosmological Screening – by N. C. Tsamis[1] and R. P. Woodard[2], [1]Department of Physics, University of Crete, GR-710 03, Heraklion, HELLAS, [2]Department of Physics, University of Florida, Gainesville, FL 32611; e-mail: tsamis@physics.uoc.gr woodard@phys.ufl.edu

Abstract – Infrared gravitons are continually produced during inflation. Like all particles, their contribution to the vacuum energy comes not only from their bare kinetic energy but also from the interactions they have with other gravitons. These interactions can be substantial – despite the particles being highly infrared – because they occur over the enormous spatial volume of the universe. Furthermore, the interactions grow with time evolution because more and more such gravitons come into causal contact with one another. Since gravity is universally attractive, these interactions can act to slow and eventually stop accelerated expansion.

25. Universality in the Gravitational Stretching of Clocks, Waves, and Quantum States – by C. S. Unnikrishnan[1] and G. T. Gillies[2], [1]Gravitation Group, Tata Institute of Fundamental Research, Homi Bhabha Road, Mumbai - 400 005 India, [2]School of Engineering and Applied Science, University of Virginia, Charlottesville, VA 22904-4746; e-mail: unni@tifr.res.in gtg@virginia.edu

Abstract – There are discernible and fundamental differences between clocks, waves, and physical states in classical physics. These fundamental concepts find a common expression in the context of quantum physics in gravitational fields; matter and light waves, quantum states, and oscillator clocks become quantum synonymous through the Planck-Einstein-de Broglie relations and the equivalence principle. With this insight, gravitational effects on quantum systems can be simply and accurately analyzed. Apart from providing a transparent framework for conceptual and quantitative thinking on matter waves and quantum states in a gravitational field, we address and resolve with clarity the recent controversial discussions on the important issue of the relation between atom interferometry and gravitational time dilation.