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Abstracts of Award Winning and Honorable Mention Essays for 2005

Award Essays

First Award – The String Coupling Accelerates the Expansion of the Universe – by John Ellis*, Nikolaos E. Mavromatos[+], and Dimitri V. Nanopoulos[#]; *TH Division, Physics Department, CERN, CH-1211 Geneva 23, Switzerland; [+]Theoretical Physics, Physics Department, King's College London, Strand WC2R 2LS, UK; [#]George P. and Cynthia W. Mitchell Institute for Fundamental Physics, Texas A&M University, College Station, TX 77843, Astroparticle Physics Group, (HARC), Mitchell Campus, Woodlands, TX 77381, Academy of Athens, Division of Natural Sciences, 28 Panepistimiou Avenue, Athens 10679, Greece.

Abstract – Generic cosmological models in non-critical string theory have a time-dependent dilaton background at a late epoch. The cosmological deceleration parameter q_0 is given by the square of the string coupling, g_S^2 up to a negative sign. Hence the expansion of the Universe must accelerate eventually, and the observed value of q_0 corresponds to $g_S^2 \sim 0.6$. In this scenario, the string coupling is asymptotically free at large times, but its present rate of change is imperceptibly small.

Second Award – Does Inflation Provide Natural Initial Conditions for the Universe? – by Sean M. Carroll and Jennifer Chen, Enrico Fermi Institute, Department of Physics, and Kavli Institute for Cosmological Physics, University of Chicago, 5640 S. Ellis Avenue, Chicago, IL 60637.

Abstract – If our universe underwent inflation, its entropy during the inflationary phase was substantially lower than it is today. Because a low-entropy state is less likely to be chosen randomly than a high-entropy one, inflation is unlikely to arise through randomly-chosen initial conditions. To resolve this puzzle, the authors examine the notion of a natural state for the universe and argue that it is a nearly-empty spacetime. If empty space has a small vacuum energy, however, inflation can begin spontaneously in this background. This scenario explains why a universe like ours is likely to have begun via a period of inflation and also provides an origin for the cosmological arrow of time.

Third Award – Gravity from Local Lorentz Violation – by V. Alan Kostelecký* and Robertus Potting[†], *Physics Department, Indiana University, Bloomington, IN 47405; [†]CENTRA, Physics Department, FCT, Universidade do Algarve, 8000 Faro, Portugal.

Abstract – In general relativity, gravitational waves propagate at the speed of light, and so gravitons are massless. The masslessness can be traced to symmetry under diffeomorphisms. However, another elegant possibility exists: masslessness can instead arise from spontaneous violation of local Lorentz invariance. We construct the corresponding theory of gravity. It reproduces the Einstein-Hilbert action of general relativity at low energies and temperatures. Detectable signals occur for sensitive experiments, and potentially profound implications emerge for our theoretical understanding of gravity.

Fourth Award – Gravity-Wave Detectors as Probes of Extra Dimensions – by Chris Clarkson and Roy Maartens, Institute of Cosmology and Gravitation, University of Portsmouth, Portsmouth PO1 2EG, UK.

Abstract – If string theory is correct, then our observable Universe may be a 3-dimensional "brane" embedded in a higher-dimensional spacetime. This theoretical scenario should be tested via the state-of-the-art in gravitational experiments – the current and upcoming gravity-wave detectors. Indeed, the existence of extra dimensions leads to oscillations that leave a spectroscopic signature in the gravity-wave signal from black holes. The detectors, that have been designed to confirm Einstein's prediction of gravity waves, can in principle also provide tests and constraints on string theory.

Fifth Award – Classical and Quantum General Relativity: A New Paradigm – by Rodolfo Gambini* and Jorge Pullin[+], *Instituto de Física, Facultad de Ciencias, Iguá 4225, esq. Mataojo, Montevideo, Uruguay; [+]Department of Physics and Astronomy, Louisiana State University, Baton Rouge, LA 70803-4001.

Abstract – The authors argue that recent developments in discretizations of classical and quantum gravity imply a new paradigm for doing research in these areas. The paradigm consists in discretizing the theory in such a way that the resulting discrete theory has no constraints. This solves many of the hard conceptual problems of quantum gravity. It also appears as a useful tool in some numerical simulations of interest in classical relativity. The authors outline some of the salient aspects and results of this new framework.

Honorable Mention Awards (Alphabetical Order)

1. Strings, Neutrinos, and the Cosmological Constant – by D.V. Ahluwalia-Khalilova, Ashram for the Studies of the Glass Bead Game (ASGBG), Ap. Postal C 600, Zacatecas, ZAC 98060, Mexico; Center for Mathematical, Physical, and Biological Structure of the Universe (CIU), Department of Mathematics, University of Zacatecas (UAZ), Zacatecas, ZAC 98060, Mexico.

Abstract – A Lie-algebraic stability argument for the inevitability of strings is presented. It is shown that it leads to a dramatic softening of the cosmological constant problem and it offers a first-principle hint as to why there exists a coincidence between cosmic vacuum energy density and neutrino masses.

2. Special Relativity Heading for Retirement – by Giovanni Amelino-Camelia, Dip. Fisica Univ. Roma "La Sapienza" and Sez. Roma 1 INFN, Piazzale Moro 2, Roma, Italy.

Abstract – Several recent papers on the quantum-gravity problem have considered the possibility that, as a result of some quantum properties of spacetime, a Planck-scale-accurate description of particle-physics processes should involve modified Lorentz-boost transformation rules. While these previous studies introduced the boost deformation as a characteristic of some specific proposals of quantum properties of spacetime, the author here argues that a Planck-scale-modified action of Lorentz boosts is an inevitable consequence of the role of the Planck length as the absolute limit on the localization of events. Some related astroparticle-physics data should become available within the next 10 years.

3. The Library of Babel – by Vijay Balasubramanian[*], Vishnu Jejjala[+], and Joan Simón[*], [*]David Rittenhouse Laboratories, University of Pennsylvania, Philadelphia, PA 19104; [+]Centre for Particle Theory, Department of Mathematical Sciences, University of Durham, South Road, Durham DH1 3LE, U.K.

Abstract – The authors show that heavy pure states of gravity can appear to be mixed states to almost all probes. Their arguments are made for AdS_5 Schwarzschild black holes using the field theory dual to string theory in such spacetimes. The results follow from applying information theoretic notions to field theory operators capable of describing very heavy states in gravity. For certain supersymmetric states of the theory, the account is exact: the microstates are described in gravity by a spacetime "foam", the precise details of which are invisible to almost all probes.

4. Simple Solutions to the Einstein Equations in Spaces with Unusual Topology – by Mihai Bondarescu, California Institute of Technology MC 452-48, Pasadena, CA 91125.

Abstract – The author discusses simple vacuum solutions to the Einstein Equations in five dimensional space-times compactified in two different ways. In such spaces, one black hole phase and more than one black string phase may exist. Several old metrics are adapted to new background topologies to yield new solutions to the Einstein Equations. He then briefly talks about the angular momentum they may carry, the horizon topology and phase transitions that may occur.

5. Minimum Length from First Principles – by Xavier Calmet*, Michael Graesser+, and Stephen D.H. Hsu#, *Department of Physics and Astronomy, UNC Chapel Hill, NC 27599-3255; +California Institute of Technology, Pasadena, CA 91125; #Institute of Theoretical Science, University of Oregon, Eugene, OR 97403.

Abstract – The authors show that no device or gedanken experiment is capable of measuring a distance less than the Planck length. By "measuring a distance less than the Planck length" they mean, technically, resolve the eigenvalues of the position operator to within that accuracy. The only assumptions in their argument are causality, the uncertainty principle from quantum mechanics and a dynamical criterion for gravitational collapse from classical general relativity called the hoop conjecture. The inability of any gedanken experiment to measure a sub-Planckian distance suggests the existence of a minimal length.

6. The Cosmic Coincidence in Brans-Dicke Cosmologies – by Saulo Carneiro, Instituto de Física, Universidade Federal da Bahia, 40210-340, Salvador, BA, Brazil.

Abstract – Among the suggested solutions to the cosmological constant problem, the author finds the idea of a dynamic vacuum with an energy density decaying with the universe expansion. The author investigates the possibility of a variation in the gravitational constant as well, induced, at the cosmological scale, by the vacuum decay. He considers an effective Brans-Dicke theory in the spatially flat FLRW spacetime, finding late time solutions characterized by a constant ratio between the matter and vacuum energy densities. By using the observed limits for the universe age, he fixes the only free parameter of the solutions, obtaining a relative matter density in the range $0.25 < \Omega_m < 0.4$. In particular, for $Ht = 1$ he obtains $\Omega_m = 1/3$. This constitutes a possible explanation for another problem related to the cosmological term, the cosmic coincidence problem.

7. The Case for Unquantized Gravity – by F.I. Cooperstock, Department of Physics and Astronomy, University of Victoria, P.O. Box 3055, Victoria, B.C. V8W 3P6, Canada.

Abstract – In this essay the author explores the hypothesis that gravity is best viewed as a non-quantized field, at least not in the usual sense of being quantized. Evidence is gathered from, among other aspects, the peculiar nature of gravitational plane waves and indirectly from the fact that there are no experimental results that point to a necessity for quantization. Should this hypothesis prove to be correct, it would favor the negation of the very existence of gravitons since gravitational waves would be seen as purely classical general relativistic constructs which carry no energy. In spite of this, there are indications to suggest that the study of limiting properties will lead to new insights into both the essence of space-time and the quantum world.

8. Cosmic Time Machines: A New Power House in the Universe – by F. de Felice, Department of Physics, University of Padova, via Marzolo 8, 35131 Padova, Italy, INFN – Sezione di Padova.

Abstract – Continued gravitational collapse gives rise to curvature singularities. If a curvature singularity is globally naked then the space-time may be causally future ill-behaved admitting closed time-like or null curves which extend to asymptotic distances and generate a Cosmic Time Machine (de Felice (1995) Lecture Notes in Physics **455**, 99). It is argued whether Cosmic Time Machines can act as a power-house for impulsive events like Gamma Ray Bursts.

9. Cosmology, the Cosmological Constant and the Mass of the Graviton – by Cédric Deffayet, APC, UMR 7164, CNRS, Université Paris 7, CEA, Observatoire de Paris, 11 Place Marcelin Berthelot, F-75231 Paris Cedex 05, France; IAP/GReCO, UMR 7095, CNRS, Université Paris 6, 98 bis boulevard Arago, 75014 Paris, France.

Abstract – The author shows how the cosmology of the Dvali, Gabadadze, Porrati theory of gravity, a model which shares many common points with theories of "massive gravity", proves invaluable to investigate various crucial questions left over about these, while it offers at the same time a novel alternative to a non-vanishing cosmological constant.

10. Einstein-Planck Formula, Equivalence Principle and Black Hole Radiance – by Alessandro Fabbri* and José Navarro-Salas+, *Dipartimento di Fisica dell'Università di Bologna and INFN sezione di Bologna, Via Irnerio 46, 40126 Bologna, Italy; +Departamento de Física Teórica and IFIC(CSIC), Universidad de Valencia, Dr. Moliner 50, Burjassot-46100, Valencia, Spain.

Abstract – The presence of gravity implies corrections to the Einstein-Planck formula $E = h\nu$. This gives hope that the divergent blueshift in frequency, associated with the presence of a black hole horizon, could be smoothed out for the energy. Using simple arguments based on Einstein's equivalence principle the authors show that this is only possible if a black hole emits, in first approximation, not just a single particle, but thermal radiation.

11. Adding a Cosmological Constant in Higher Dimensions to a Rotating Black Hole – by G.W. Gibbons*, H. Lü+, Don N. Page#, and C.N. Pope+, *DAMTP, Centre for Mathematical Sciences, Cambridge University, Wilberforce Road, Cambridge CB3 OWA, U.K.; +George P. & Cynthia W. Mitchell Institute for Fundamental Physics, Texas A&M University, College Station, TX 77843-4242; #Theoretical Physics Institute, 412 Physics Lab, University of Alberta, Edmonton, Alberta T6G 2J1, Canada.

Abstract – One of the greatest discoveries within Einstein's theory of gravity was the 1963 Kerr metric, the stationary vacuum solution for a rotating black hole in four dimensions. Within five years, Carter found a generalization that included a cosmological constant. In 1986, Myers and Perry found the stationary vacuum solution for a rotating black hole in all higher dimensions. However, except for special cases found by Hawking, Hunter, and Taylor-Robinson in 1999, the generalization to include a cosmological constant in higher dimensions was not known until our recent discovery of the general Kerr-de Sitter metrics in all dimensions. This infinite class of new solutions of Einstein's equations also gives new smooth Einstein spaces on associated S^{D-2} bundles over S^2, infinitely many for each odd dimension $D \geq 5$.

12. Horizon Mass Theorem – by Yuan K. Ha, Department of Physics, Temple University, Philadelphia, PA 19122.

Abstract – A new theorem for black holes is found. It is called the horizon mass theorem. The horizon mass is the mass which cannot escape from the horizon of a black hole. For all black holes: neutral, charged or rotating, the horizon mass is always twice the irreducible mass observed at infinity. Previous theorems on black holes are: 1. the singularity theorem, 2. the area theorem, 3. the uniqueness theorem. The horizon mass theorem is possibly the last general theorem for classical black holes. It is crucial for understanding Hawking radiation and for investigating processes occurring near the horizon.

13. Causally Pathological Spacetimes are Physically Relevant – by Veronika E. Hubeny[*+], Mukund Rangamani[*+], and Simon F. Ross[*], [*]Centre for Particle Theory & Department of Mathematical Sciences, Science Laboratories, South Road, Durham DH1 3LE, U.K.; [+]Department of Physics & Theoretical Physics Group, LBNL, University of California, Berkeley, CA 94720.

Abstract – The authors argue that in the context of string theory, the usual restriction to globally hyperbolic spacetimes should be considerably relaxed. They exhibit an example of a spacetime which satisfies only the causal condition, and so is arbitrarily close to admitting closed causal curves, but which has a well-behaved dual description, free of paradoxes.

14. How Red Is a Quantum Black Hole? – by Viqar Husain and Oliver Winkler, Department of Mathematics and Statistics, University of New Brunswick, Fredericton, NB, Canada E3B 5A3.

Abstract – Radiating black holes pose a number of puzzles for semiclassical and quantum gravity. These include the transplanckian problem – the nearly infinite energies of Hawking particles created near the horizon, and the final state of evaporation. A definitive resolution of these questions likely requires robust inputs from quantum gravity. The authors argue that one such input is a quantum bound on curvature. They show how this leads to an upper limit on the redshift of a Hawking emitted particle, to a maximum temperature for a black hole, and to the prediction of a Planck scale remnant.

15. Gravity from a Modified Commutator – by Mark G. Jackson, Particle Astrophysics Center, Fermi National Accelerator Laboratory, Batavia, Illinois 60510.

Abstract – The author shows that a suitably chosen position-momentum commutator can elegantly describe many features of gravity, including the IR/UV correspondence and dimensional reduction ('holography'). Using the most simplistic example based on dimensional analysis of black holes, the author constructs a commutator which exhibits qualitatively these novel properties of gravity. Dimensional reduction occurs because the quanta size grows quickly with momenta, and thus cannot be "packed together" as densely as naively expected. The author conjectures that a more precise form of this commutator should be able to reproduce quantitatively all these features.

16. Thomson Scattering of SNe Ia Radiation and the Expansion History of the Universe – by David W. Kraft, University of Bridgeport, Bridgeport, CT 06601.

Abstract – The observed distances to SNe Ia objects are corrected for the Thomson scattering of their radiation by free electrons. An independent calculation of the density of free electrons contained in a dark intergalactic plasma is adequate for close agreement of the corrected distances with predictions of the luminosity-distance relation. Hence the apparent dimming of SNe Ia objects can be understood without recourse to a cosmic acceleration or jerk.

17. The Cosmological Constant Problem: A String Theory Approach – by Jnanadeva Maharana, Institute of Physics, Bhubaneswar - 751005, India.

Abstract – The author proposes that stringy symmetries play a crucial role in the resolution of the cosmological constant problem. In the presence constant fluxes along compact directions, it is possible to construct potentials for the moduli. For suitable choice of fluxes, they admit minima with nonzero cosmological constant and such solutions break duality symmetry. The corresponding duality symmetric solutions have vanishing cosmological constant. The naturalness hypothesis of 't Hooft may be invoked to argue that the cosmological constant must remain small since symmetry preserving solutions correspond to vanishing cosmological constant.

18. Information Storage in Black Holes – by M.D. Maia, The Institute of Physics, University of Brasilia, 70919-970, Brasília, DF, Brasil.

Abstract – The information loss paradox for Schwarzschild black holes is examined, using the ADS/CFT correspondence extended to the $M_6(4,2)$ bulk. It is found that the only option compatible with the preservation of the quantum unitarity is when a regular remnant region of the black hole survives to the black hole evaporation process, where information can be stored and eventually retrieved.

19. Black Holes Radiate but Do Not Evaporate – by Hrvoje Nikolić, Theoretical Physics Division, Rudjer Bošković Institute, P.O.B. 180, HR-10002 Zagreb, Croatia.

Abstract – During the black hole radiation, the interior contains *all* the matter of the initial black hole, together with the negative energy quanta entangled with the exterior Hawking radiation. Neither the initial matter nor the negative energy quanta evaporate from the black hole interior. Therefore, the information is not lost during the radiation. The black hole mass eventually drops to zero in semiclassical gravity, but this semiclassical state has an infinite temperature and still contains all the initial matter together with the negative energy entangled with the exterior radiation.

20. A New Perspective on Gravity and Dynamics of Spacetime – by T. Padmanabhan, IUCAA, Post Bag 4, Ganeshkhind, Pune – 411 007, India.

Abstract – The Einstein-Hilbert action has a bulk term and a surface term (which arises from integrating a four divergence). The author shows that *one can obtain Einstein's equations from the surface term alone.* This leads to (i) a novel, completely self-contained, perspective on gravity and (ii) a concrete mathematical framework in which the description of spacetime dynamics by Einstein's equations is similar to the description of a continuum solid in the thermodynamic limit.

21. Self-Coupling of Excited Atoms in Curved Spacetime – by Fabrizio Pinto, InterStellar Technologies Corporation, 115 North Fifth Avenue, Monrovia, CA 91016.

Abstract – It is well known that an excited atom, placed near a boundary, such as a mirror, undergoes an energy shift due to its interaction with the reflected field. In this paper, the author uses a generalized Hertz potential to prove that a radiating dipole embedded in a *continuously* inhomogeneous medium also experiences a position-dependent self-interaction energy shift and a corresponding self-force. Consequently, an excited atom inside a cylindrical cavity embedded in a *quasi*-homogeneous gravitational field, which acts as an effective "soft" boundary, is shown to experience an effective gravitational acceleration dependent on the atomic quantum state. The author predicts that excited trapped atom interferometers will thus provide an unexpected tool for ground-based experimentation on radiation backscattering in a Schwarzschild background.

22. Metastable Massive Gravitons from an Infinite Extra Dimension – by Sanjeev S. Seahra, Institute of Cosmology and Gravitation, University of Portsmouth, Portsmouth, PO1 2EG, UK.

Abstract – Motivated by stringy considerations, Randall and Sundrum have proposed a model where all the fields and particles of physics, save gravity, are confined on a 4-dimensional brane embedded in 5-dimensional anti-deSitter space. Their scenario features a stable bound state of bulk gravity waves and the brane that reproduces standard general relativity. The author demonstrates that in addition to this zero-mode, there is also a discrete set of metastable bound states that behave like massive 4-dimensional gravitons, which decay by tunneling into the bulk. These are resonances of the bulk-brane system akin to black hole quasinormal modes—as such, they give rise to the dominant corrections to 4-dimensional gravity. The phenomenology of braneworld perturbations is greatly simplified when these resonant modes are taken into account, which is illustrated by considering gravitational radiation emitted from nearby sources and early universe physics.

23. Gravitationally-Induced Particle Resorption into the Vacuum: A General Solution to the Problem of Black Hole Collapse – by M.P. Silverman, Departments of Physics, Trinity College, Hartford, CT 06070.

Abstract – The process of gravitationally-induced particle creation (Hawking radiation), if it exists, necessitates, in accordance with general thermodynamic principles, a corresponding process of gravitationally-induced particle resorption into the vacuum. Although the former process occurs in the external vicinity of the Schwarzschild surface where matter density is relatively low, the latter process would be expected to occur inside the Schwarzschild radius where the stellar material is enormously compressed and fermions fill all quantum states up to the Fermi level. The author shows that the occurrence of particle resorption provides a general mechanism, irrespective of the interactions of the constituent particles, which halts the collapse of a black hole to a singular point and leads to an equilibrium state of macroscopic extent.

24. Dark Energy, Ripping of Black Holes and Entropy – by C. Sivaram, Indian Institute of Astrophysics, Bangalore 560034, India.

Abstract – Current cosmological observations imply a universe dominated by dark energy with its associated negative pressure. There are even indications that this may be increasing with epoch which could result ultimately in a Big Rip and disruption of all bound structures. In this essay the effects of the ambient dark energy on the disruption of black holes are studied. The contrasting effect of dark energy on wormholes is discussed. There are interesting consequences for the formation of naked singularities. Some intriguing conclusions result when the total entropy released from the (dark energy induced) ripping of all the black holes is matched with the entropy of the asymptotic (dark energy dominated) spacetime suggesting links between two major problems.

25. Information-Preserving Black Holes Still Do Not Preserve Baryon Number and Other Effective Global Quantum Numbers – by Dejan Stojkovic[*], Glenn D. Starkman[+], and Fred C. Adams[*], [*]MCTP, Department of Physics, University of Michigan, Ann Arbor, MI 48109-1120; [+]Department of Physics, Case Western Reserve University, Cleveland, OH 44106-7079.

Abstract – It has been claimed recently that the black-hole information-loss paradox has been resolved: the evolution of quantum states in the presence of a black hole is unitary and information preserving. The authors point out that, contrary to conventional wisdom, information-preserving black holes still violate baryon number and any other quantum number which follows from an effective (and thus approximate) or anomalous symmetry.

26. Entropy and Area in Loop Quantum Gravity – by John Swain, Department of Physics, Northeastern University, Boston, MA 02115.

Abstract – Black hole thermodynamics suggests that the maximum entropy that can be contained in a region of space is proportional to the area enclosing it rather than its volume. The author argues that this follows naturally from loop quantum gravity and a result of Kolmogorov and Bardzin' on the realizability of networks in three dimensions. This represents an alternative to other approaches in which some sort of correlation between field configurations helps limit the degrees of freedom within a region. It also provides an approach to thinking about black hole entropy in terms of states inside rather than on its surface. Intuitively, a spin network complicated enough to imbue a region with volume only lets that volume grow as quickly as the area bounding it.

27. From Qubits to Black Holes: Entropy, Entanglement and All That – by Daniel R. Terno, Perimeter Institute for Theoretical Physics, 31 Caroline St, Waterloo, Ontario, Canada N2L 2Y5.

Abstract – Entropy plays a crucial role in the characterization of information and entanglement, but it is not a scalar quantity and for many systems it is different for different relativistic observers. Loop quantum gravity predicts the Bekenstein-Hawking term for black hole entropy and logarithmic correction to it. The latter originates in the entanglement between the pieces of the spin networks that describe the black hole horizon. Entanglement between gravity and matter may restore the unitarity in the black hole evaporation process. If the collapsing matter is assumed to be initially in a pure state, then the entropy of the Hawking radiation is exactly the entanglement created between matter and gravity.

28. The Equivalence Principle as a Probe for Higher Dimensions – by Paul S. Wesson, Departments of Physics and Applied Mathematics, University of Waterloo, Waterloo, Ontario N2L 3G1, Canada.

Abstract – Higher-dimensional theories of the kind which may unify gravitation with particle physics can lead to significant modifications of general relativity. In five dimensions, the vacuum becomes non-standard, and the Weak Equivalence Principle becomes a geometrical symmetry which can be broken, perhaps at a level detectable by new tests in space.

29. Are There Supermassive Black Holes, Accretion Disk and X-ray Jet in Gamma-Ray-Loud Blazar PKS 1510-089? by G.Z. Xie[*#] and Hong-Tao Liu[*+], [*]National Astronomical Observatories/Yunnan Observatory, Chinese Academy of Sciences, P.O. Box 110, Kunming Yunnan, 650011, P.R. China; [+]The Graduate School of the Chinese Academy of Sciences, Beijing, P.R. China; [#]Yunnan Astrophysics Centre, Yunnan University, Kunming 650092, P.R. China.

Abstract – In the current working picture of active galactic nuclei (AGN), the underlying power source is thought to be an accretion disk around a jet-emitting supermassive black hole (SMBH) in which shear stress causes matter to sink down in the potential of the SMBH. The presence of the accretion disk around the jet-emitting SMBH in AGN, although appealing from a theoretical perspective and generally assumed, had received only limited and indirect observational support until a few years ago, when direct dynamical evidence became available. Here the authors report five new unusual observational features from gamma-ray-loud blazar PKS 1510-089. In the first unusual observed feature, the H_β double-peaked profiles show that the red peak seems to be higher than the blue peak. In the second, the X-ray jet like the arcsecond radio jet has been bent. In the third, the rapid optical outburst with variability of 0.54 mag lasted for about 48 minutes. Assuming that the variations are produced in the vicinity of the SMBH, the timescale implies a SMBH mass of $1.0 \times 10^{8.0}\ M_\odot$. In the fourth, there are large Eddington ratio ($\dot{m} \approx 1$) and big blue-bump components, which are regarded as two important evidences for the existence of the accretion disk. In the fifth, the lightcurves show quasi-periodic variations. These five observationally disparate phenomena seem to have a common physical origin. Their physical origin seems to be the supermassive binary black hole system in the center of PKS 1510-089. The masses of the primary and secondary black holes are about $10^{8.0}\ M_\odot$ and $10^{6.2}\ M_\odot$ respectively. An accretion disc would be around the jet-emitting primary black hole.

30. Interacting Dark Energy and Cosmological Equations of State by Winfried Zimdahl, Institute für Theoretische Physik, Universität zu Köln D-50937 Köln, Germany.

Abstract – Interactions within the cosmic medium modify its equation of state. The author discusses implications of interacting dark energy models both for the spatially homogenous background and for the perturbation dynamics.