Fall 2018

December 7, 2018 - "Revisiting the Cosmological Constant Problem within Quantum Cosmology," Vesselin G. Gueorguiev, Ph.D., Institute for Advanced Physical Studies, Bulgaria and Ronin Institute for Independent Scholarship, USA.

Abstract: A new perspective on the Cosmological Constant Problem (CCP) is proposed and justified within the approach of Quantum Cosmology. It is assumed that each member of an ensemble of solutions of the Einstein field equations has a characteristic scale 'a' that can be used as an integration variable in the partition function. The estimated averaged characteristic scale is compatible with the Planck length when considering an ensemble of solutions with an effective cosmological constant. The whole ensemble is split in Planck scale solutions with vacuum energy density of order one and a-derivable solutions. This approach to the CCP has the potential to reconcile the Planck-scale huge vacuum energy-density predicted by QFT considerations, as valid for Planck-scale solutions, with the observed small value of the cosmological constant as relevant to an a-derivable solution as observed. This is a joint work with Dr. Andre Maeder of the Geneva Observatory, Switzerland. Slides

November 30, 2018 - "An Operator Algebraic Approach to the Quantum Harmonic Oscillator," Michael Bishop, Ph.D., Department of Mathematics, California State University, Fresno.

Abstract: The quantum harmonic oscillator is a standard example of a quantum variation of a classical system. It inspires many of the elements of quantum field theory. We introduce this model along with the ladder method for solving for all the energy eigenvalues and associated eigenfunctions. From there, we introduce the Gelfand-Naimark-Segal construction which is a method to recover a Hilbert space of states from a Banach Algebra. We then return to the oscillator and apply a similar method to this specific model which, as far as we can tell, has not been done. This is preliminary work with Dr. Gerardo Muñoz of the Physics epartment.

November 2 & 9, 2018 - "Modified Commutation Relationships via the Riemann Hypothesis," Douglas Singleton, Ph.D., Department of Physics, CSU, Fresno.

Abstract: Current approaches to quantum gravity suggest there should be a modification of the standard quantum mechanical commutator. Typical modifications are phenomenological and

designed to result in a minimal length scale. As a motivating principle for the modification of the operators and their commutators, we assume the validity of a version of the Bender-Brody-Muller variant of the Berry-Keating approach to the Riemann hypothesis. We arrive at a family of modifications of the position and momentum operators which lead to a minimal length scale. Additionally, this larger family satisfies and generalizes the structure of the Bender-Brody-Muller approach to the Riemann hypothesis.

October 12 & 26, 2018 - "Towards the Solution of Quantum Mechanics Problems Using Numerical Simulations. Where Do We Stand?" Ettore Vitali, Ph.D., Department of Physics, CSU, Fresno.

Abstract: In this presentation, we introduce state-of-art numerical simulation techniques to study Schrödinger equation for quantum many-body systems. Using the celebrated Hubbard Hamiltonian as an example, we discuss the foundations of the approach and, in particular, the mapping from Schrödinger equation to a random walk in the complex manifold of Slater determinants, where well established approaches are known to study many-fermions systems. We also explain the origin of the famous sign problem, which requires approximations to avoid a divergent noise to signal ratio in the simulations. The main purpose of the presentation is to discuss open questions and stimulate the search for novel approaches to increase the accuracy of the calculations.

October 19, 2018 - "On the Nature of Expansions on Compact and Totally Bounded Metric Spaces and More," Edward Sichel, Master's Student, Mathematics. Research Advisor: Dr. Marat V. Markin.

Abstract: When proving a known result describing expansive mappings on compact metric spaces as isometric surjections, we observe that relaxing the condition of compactness to total boundedness preserves the isometry property, and nearly so that of surjectivity. While a counterexample is found showing that the converse to the above descriptions do not hold, we are able to characterize boundedness in terms of a certain specific type of expansions we call anticontractions.

September 28 & October 5, 2018 - "Toward a GNS Construction for the Unruh Effect," Gerardo Muñoz, Ph.D., Department of Physics, CSU, Fresno.

Abstract: The Unruh effect is one of the most surprising predictions of relativistic quantum field theory. In a nutshell, it states that while an inertial observer will perceive "empty" space-time as a

zero-temperature vacuum containing no real particles, an accelerated observer may detect a non-zero temperature and an infinite number of particles. Although the temperature is extremely small for realistic accelerations, the Unruh effect is, nevertheless, of profound conceptual importance since the emergence of temperature in physics is, in general, non-trivial; because it forces us to rethink the meaning and role of the concept of particle; and because it provides a bridge to Hawking radiation, the evaporation of black holes and the information paradox. We will present a summary of one approach used by physicists to obtain the Unruh temperature, the thermal state, and its associated particle content in order to illustrate the generic nature of the mathematical difficulties found along the way. It is our hope that a rigorous approach based on the Gelfand-Naimark-Segal (GNS) construction will help overcome these difficulties which obscure the physics at the heart of the Unruh effect.

September 14 & 28, 2018 - "On the Smoothness of Weak Solutions of an Abstract Evolution Equation with a Scalar Type Spectral Operator," Marat Markin, Ph.D., Department of Mathematics, CSU, Fresno.

Abstract: Found are conditions on a scalar type spectral operator A in a complex Banach space necessary and sufficient for all weak solutions of the evolution equation $y'(t) = Ay(t), t \geq 0$, which a priori need not be differentiable, to be infinite differentiable and Gevrey ultradifferentiable, in particular analytic or entire, on $[0, \infty)$ or $(0, \infty)$. Certain interesting inherent smoothness improvement effects are observed.

September 17, 2018 - "3, 5, 7, . . . Body Choreographies on the Lemniscate," Prof. Alexander Turbiner, Instituto de Ciencias Nucleares, Universidad Nacional Autónoma de México.

Abstract: By definition, the choreographic motion of N identical bodies is a periodic motion on a closed orbit “chasing” each other on the orbit with equal time-spacing without collisions. Take N bodies of unit mass on the plane. What are initial positions and velocities for those so that a choreographic motion occur and on what orbit? Is this motion potential? In this talk, we present a constructive analytic solution of the inverse problem: let us choose an algebraic lemniscate as an orbit. Can 3,5,7, ... bodies perform a choreographic motion on the same lemniscate? Is this motion of potential one? How many sets of initial data lead the choreographic motion on the same lemniscate for a given (odd) N? The solution is related to the existence of closed analytic form of the solution of a system of 2N coupled Newton equations (i.e., first-order linear PDE’s for potential).

Spring 2018

April 27 & May 4, 2018 - "Fourier Series by Their History," Jerzy Ryczaj, Ph.D., Faculty of Pure and Applied Mathematics, Wroclaw University of Science and Technology, Poland.

Abstract: The talk presents the development of the Fourier series theory and its strong connection with problems arising in 18th-century physics. Different types of convergence of Fourier series are discussed in that context and related to advances in mathematical analysis in 19th and 20th centuries. The influence of the Fourier series theory on the progress of other areas of mathematics is also considered. The talk is expository (although proofs of a few significant facts are presented) and should be accessible to students with a decent calculus background.

April 13, 2018 - "Linear Algebra, Physics Style," Michael Bishop, Ph.D., Department of Mathematics, California State University, Fresno.

Abstract: This talk will introduce junior physics students and non-physicists to the wonders of Bra-Ket notation, tensor products, and Kronecker products. Bra-Ket notation, developed by Dirac, greatly simplifies some tricky aspects of linear algebra, especially projections. We define the concept of tensor products of both vector spaces and linear operators on those spaces and justify their use in quantum mechanics and surprising phenomena that arise due to this mathematical structure.

April 6, 2018 - "On the Nature of Expansions on Totally Bounded Metric Spaces and More," Edward Sichel, Master's Student, Mathematics. Research Advisor: Dr. Marat V. Markin.

Abstract: While proving a known description of expansions on compact metric spaces, we observe that the condition of compactness appears to be excessive, so we search for a weaker, but still sufficient one. Initially, we attempt to relax the condition of compactness to boundedness, but this falls short of being sufficient. However, compactness tempered to total boundedness is shown to be sufficient, but, unfortunately, not necessary for the description to remain true. We also characterize boundedness in terms of certain specific expansions we call anticontractions.

March 23, 2018 - "New Geometric and Field Theoretic Aspects of the Radiation Dominated Universe," Sujoy Modak, Ph.D., University of Colima, Mexico.

Abstract: The homogeneous and isotropic radiation dominated universe, following the inflationary stage, is expressed as a spherically symmetric and inhomogeneous space-time upon a power law type conformal transformation of the null (cosmological)coordinates. This new metric has a few interesting properties. The symmetry of the metric offers a new unitarily inequivalent quantization of the massless scalar field and provides a new example of particle creation in curved space. The new set of observers, detecting particles, are freely falling in asymptotic past and future, but accelerated in between.

March 16, 2018 - "On a Spectral Gap Characterization and Other Spectral Features Inherent to Scalar Type Spectral Operators," Marat Markin, Ph.D., Department of Mathematics, CSU, Fresno.

Abstract: Important spectral features, such as the emptiness of the residual spectrum, the countability of the point spectrum, provided the space is separable, and a characterization of spectral gap at 0, known to hold for bounded scalar type spectral operators, are shown to naturally transfer to the unbounded case.

February 23 & March 9, 2018 - "Banach Algebras with Involution and the Commutative Gelfand-Naimark Theorem," Przemyslaw Kajetanowicz, Ph.D., Department of Mathematics, California State University, Fresno.

Abstract: The talk addresses unital Banach algebras with involution, with attention being focused on commutative algebras. We observe how a purely algebraic concept of an involution interplays with the topological structure of a Banach algebra. An important special case of a C*-algebra is discussed, with the commutative version of Gelfand-Naimark Theorem as the central point. The talk is expository in nature and accessible to students with basic knowledge of abstract algebra, topology, and functional analysis. Some of the most significant portions of the proof of the Gelfand-Naimark Theorem are considered in detail.

March 2, 2018 - "Solitons and Hirota’s Method," Zhanna Sagidullayeva, Ph.D. Student , L.N. Gumilyov Eurasian National University, Astana, Kazakhstan.

Abstract: Solitons are structurally stable solitary waves propagating in a nonlinear medium. Due to their special properties, solitons behave like particles (particle-like waves). When interacting with each other or with some other perturbations, they do not collapse, but continue to move, keeping their

structure unchanged. This property opens huge opportunities for the use of solitons. In this talk we will review Hirota's direct method for finding soliton solutions of the generalized Landau-Lifshitz equation.

Fall 2017

November 29 & December 6, 2017 - "Group Theory in Physics," Gerardo Muñoz, Ph.D., Department of Physics, CSU, Fresno.

Abstract: Symmetries are an essential part of the foundations of modern physics. They also provide - through their connection to conservation laws - practical tools in the solutions of a wide range of specific problems in physics, chemistry, and other fields. This talk will review basic concepts in group theory, introduce Lie groups and Lie algebras, and provide a few examples of applications to concrete problems in physics.

November 20, 2017 - "Quantum n-Body Problem: Generalized Euler Coordinates," Prof. Alexander Turbiner, Instituto de Ciencias Nucleares, Universidad Nacional Autónoma de México.

Abstract: By definition the potential of n-body problem, both classical and quantum, depends on relative (mutual) distances between bodies. Generalized Euler coordinates: relative distances + angles. New approach: we study trajectories in classics and eigenstates in quantum, which depends on relative distances alone. It is shown it is equivalent to $n(n-1)/2$-dimensional quantum (classical) particle in curved space and the Euler-Arnold quantum (classical) $sl(n(n-1)/2)$ algebra top as well. This curved space has a number of remarkable properties. In 3-body case the de-quantization of quantum Hamiltonian leads to a classical Hamiltonian which solves the 250-years old problem by Lagrange about description of 3-body planar motion.

November 8, 2017 - "Introduction to Magnetic Charge and Connection to Fiber Bundle," Douglas Singleton, Ph.D., Department of Physics, CSU, Fresno.

Abstract: We review the Dirac formulation of magnetic charge where one has a string singularity and discuss how this leads to the Dirac quantization condition between electric and magnetic charge. We then show how C.N. Yang was able to formulate a theory of magnetic charge using fiber bundle and how this formulation complements and contrasts with Dirac's original string formulation. Slides

October 25, 2017 - "Weak Contractions and Expansions on a Compact Metric Space," Edward Sichel, Master's Student, Mathematics. Research Advisor: Dr. Marat V. Markin.

Abstract: We examine the nature of weak contractions and expansions on a compact metric space. Inspired by the celebrated Banach Fixed-Point Theorem, we explore relaxing the contractiveness condition on the mapping to weak contractiveness, while strengthening the completeness condition on the space to compactness. We show, under the new conditions, that the fixed point for the mapping still exists and is unique. We also show that expansive mappings on a compact metric space are limited to isometries.

September 27 & October 18, 2017 - "Neutron Transfer Reactions for Deformed Nuclei Using Sturmian Basis," Vesselin G. Gueorguiev, Ph.D., Institute for Advanced Physical Studies, Bulgaria and Ronin Institute for Independent Scholarship, USA.

Abstract: Thermo-nuclear reactions in the stars would lead to iron (Fe-56) - the most stable nucleus, so how are the heavier elements generated? How can we determine the reaction cross-sections for processes that involve unstable nuclei that cannot be studied in a laboratory setting? The idea is to model relevant (surrogate) reactions that can be studied experimentally. As a first step in understanding the neutron pick up reaction on unstable nucleus (155Gd+n → 156Gd*), we study the spin-parity distribution P(Jπ,E) of 156Gd excited states that are expected to be populated via the surrogate reaction 157Gd(3He,4He)156Gd*. The calculations show that, within the model assumptions and computational modeling, the reaction 3He+157Gd → 4He+156Gd* has a well-behaved formation probability P(Jπ,E) within the energy range relevant to the desired reaction 155Gd+n → 156Gd*. This will allow information from the surrogate reaction channels to be extracted and be applicable towards the desired reaction on the unstable nucleus. Slides

October 4 & 11, 2017 - "A Basic Introduction to Gauge Theory," Douglas Singleton, Ph.D., Department of Physics, CSU, Fresno.

Abstract: Maxwell's equations have an underlying and important symmetry that was only discovered and formalized in the 1920s by Weyl and others. All interactions can be thought of as gauge interactions in some sense. We will review the basic feature of E&M as an Abelian gauge theory. Time permitting, we will also discuss non-Abelian gauge theories. Slides

September 13 & 20, 2017 - "On the Mean Ergodicity of Weak Solutions of an Abstract Evolution Equation," Marat Markin, Ph.D., Department of Mathematics, CSU, Fresno.

Abstract: Found are conditions of rather general nature sufficient for the existence of the limit at infinity of the Cesaro means for every bounded weak solution $y(\cdot)$ of the abstract evolution equation $y'(t) = Ay(t)$, $t \geq 0$ with a closed linear operator A in a Banach space X.

August 23, 2017 - "Evolution of Maximally Symmetric Spaces under the Ricci Flow," Prof. Alfredo Herrera-Aguilar, Benemérita Universidad Autónoma de Puebla.

Abstract: In this talk, we present exact solutions to the Ricci flow equations in 3 and 4 dimensions. We solve the flow equations starting with an ansatz for the metric and the DeTurck vector field in $n = 3$. Our solution belongs to the family of maximally symmetric spaces and the treatment can be easily generalized to $n \geq 4$. Our solutions can be divided into maximally symmetric spaces with positive and negative curvature. The flow always increases the curvature for both de Sitter and Anti-de Sitter spaces. Between both scenarios there is a “critical point” where the curvature blows up. An interesting feature of the solution with $n \geq 4$ is that the flow equations are satisfied with a Euclidean or Lorentzian signature. Another interesting effect of the flow consists in a change of signature in the metric when passing from a de Sitter space to an Anti-de Sitter space throughout the flow.

Spring 2017

May 15, 2017 - "Broken Scale Invariance, Gravity Mass, and Dark Energy in Two-measure Generalized Einstein-Finsler Gravity Theories with Modified Dispersions," Sergiu I. Vacaru, QGR-Topanga, California and UAIC, Iasi, Romania.

Abstract: We study new classes of generic off-diagonal and diagonal cosmological solutions for effective Einstein equations in modified gravity theories, MGTs, with modified dispersion relations, MDRs, encoding possible violations of (local) Lorentz invariance, LIVs. Such MGTs are constructed for actions and Lagrange densities with two non-Riemannian volume forms and associated bimetric and/or biconnection geometric structures. The generic off-diagonal solutions of gravitational field equations in TMTs are determined by generating functions, effective sources and integration constants and characterized by nonholonomic frame torsion effects.

May 3, 2017 - "Gelfand Representation Theory on Commutative Banach Algebras," Przemyslaw Kajetanowicz, Ph.D., Department of Mathematics, California State University, Fresno.

Abstract: Commutative unital Banach algebras will be given a closer look at. The correspondence between maximal ideals and complex continuous homomorphisms will be presented. We will see how that correspondence leads to the representation of a commutative Banach algebra as a subalgebra of all continuous functions on a compact Hausdorff space. The commutative version of Gelfand-Naimark Theorem for C*-algebras will be addressed. The talk will be expository in nature, therefore accessible to students who are familiar with elementary concepts of functional analysis. Proofs of some facts will be presented, however, to demonstrate how nicely the algebraic and the topological structures are linked in that special case.

April 26, 2017 - "The Role of Time for Reparametrization-Invariant Systems," Vesselin G. Gueorguiev, Ph.D., Institute for Advanced Physical Studies, Bulgaria and Ronin Institute for Independent Scholarship, USA.

Abstract: The existence of time operator T in quantum mechanics is a difficult question due to Pauli's theorem of its non-existence if T is viewed as conjugate operator to the Hamiltonian H of a system. The problem can be related to the interpretation of the H of a system as its energy operator and generator of the time evolution. We discuss the problem of defining H when changing from Lagrangian into Hamiltonian formulation for ReParametrization-Invariant Lagrangian Systems(rPILS). The geometrical motivation for studding rPILS and examples of physically relevant systems such as relativistic particle and string theory Lagrangian will be discussed. Quantization via extended Hamiltonian system H will be introduced as possible resolution of the time operator problem as well as a possible path towards formulating quantum mechanics for ReParametrization-Invariant Systems. If time permits the Dirac equation will be justified within the given formalism using the Rund's technique for introducing the algebra of the γ-matrices without resolving to the Klein-Gordon equation as well as connection to non-commutative geometry. Slides

April 19, 2017 - "Convexity in Banach Spaces," Jerzy Ryczaj, Ph.D., Faculty of Pure and Applied Mathematics, Wroclaw University of Science and Technology, Poland.

Abstract: Various aspects of the notion of convexity will be discussed. The classical definition together with historical notes and various generalizations will be given. Special attention will be paid to the extreme points of convex sets in Banach spaces. The Hahn-Banach, Banach-Alaoglu, and Krein-Milman theorems will also be discussed in the context of convexity in locally convex spaces. Certain applications to the theory of Banach spaces will be considered.

March 29 & April 5, 2017 - "A Brief Introduction and Overview to PT-symmetric Quantum Mechanics,"Douglas Singleton, Ph.D., Department of Physics, CSU, Fresno.

Abstract: In quantum mechanics, one often requires that the Hamiltonian of a system to be Hermitian (i.e., H=H†, where † is the usual Dirac Hermitian conjugation). This ensures that energy eigenvalues are real and time evolution is unitary. In recent years it has been shown that one might replace Hermiticity of H by P(arity)T(ime) symmetric version of QM. A basic (very basic) introduction and overview to this interesting new approach to quantum mechanics will be given. Slides

March 15 & 22, 2017 - "Recovering Hilbert Spaces Using the Gelfand-Naimark-Segal Construction," Michael Bishop, Ph.D., Department of Mathematics, California State University, Fresno.

Abstract: In quantum mechanics, we typically start with a space of wave functions and then construct physical observables as operators on this space. The Gelfand-Naimark-Segal (GNS) construction starts from the observables and recovers the Hilbert spaces. This talk will outline the construction in abstraction and apply it to an infinite lattice example.

March 1 & 8, 2017 - "Spectral Analysis in Algebras," Marat Markin, Ph.D., Department of Mathematics, CSU, Fresno.

Abstract: In this set of talks, we introduce and study the purely algebraic concept of the spectrum of an element of an algebra and its inherent bonds to analysis, the algebra being equipped with norm.