Irish Theoretical Physics Meeting 2023

Wednesday, 6 September 2023 - Saturday, 9 September 2023

Maynooth University

Book of Abstracts

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Aradhita Chattopadhyaya - Instanton partition functions in Vafa Witten theory

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We analyze the coefficients of partition functions of Vafa-Witten theory for the complex projective plane $\mathbb{CP}^2$. We first introduce the topologically twisted super Yang Mills theory also called Vafa Witten theory on $\mathbb{CP}^2$ whose instanton partition functions can be obtained using algebraic geometry methods. We experimentally study the growth of the coefficients for gauge group $SU(2)$ and $SU(3)$, which are examples of mock modular forms of depth 1 and 2 respectively. We also introduce the notion of "mock cusp form", and study an example of weight 3 related to the $SU(3)$ partition function. Numerical experiments on the first few coefficients suggest that the coefficients of a mock modular form of weight k grow as the coefficients of a modular form of weight k, that is to say as n^{k-1} . On the other hand the coefficients of the mock cusp form appear to grow as $n^{3/2}$, which exceeds the growth of classical cusp forms of weight 3. We provide bounds using saddle point analysis and estimation of the size of Durfee square which exceed the experimental observation.

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Swapnamay Mondal - Supersymmetric black holes and $T\bar{T}$ deformation

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The entropy of supersymmetric black holes in string theory compactifications can be related to that of a D- or M-brane system, which in many cases can be further reduced to a two-dimensional conformal field theory (2d CFT). For black holes in M-theory, this relation involves a decoupling limit where the black hole mass diverges. We suggest that moving away from this limit corresponds to a specific irrelevant perturbation of the 2d CFT, namely the supersymmetric completion of the $T\bar{T}$ deformation. We demonstrate that the black hole mass matches precisely with the $T\bar{T}$ deformed energy levels, upon identifying the $T\bar{T}$ deformation parameter with the inverse of the leading term of the black hole mass. We discuss various implications of this novel realization of the $T\bar{T}$ deformation, including a Hagedorn temperature for wrapped M5-branes, and potential change of degeneracies in the deformed theory.

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Marc Casals - Effects of quantum fields inside black holes

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All black holes in the Universe are believed to be rotating. This poses interesting questions, since rotating black hole solutions of Einstein's equations of General Relativity possess a so-called Cauchy horizon in their interior, which threatens the predictability of Einstein's theory. This then begs the question of whether such inner Cauchy horizons are still present after taking into consideration effects from neighbouring classical matter and quantum fields (which correspond to Hawking radiation in the black hole exterior). It is generally found that effects on Cauchy horizons from quantum fields are in fact dominant over those from classical matter. In this talk, we will review some results on the stability of Cauchy horizons of black holes and we will present recent results on effects due to a quantum field on the Cauchy horizon of a rotating (Kerr) black hole. In particular, we will show that the (renormalized) fluxes from a quantum scalar field generically diverge on the Cauchy horizon of a Kerr black hole that is evaporating via the emission of Hawking radiation.

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Aoibhinn Gallagher - The Evolution of Cosmic Voids in the Schrodinger Poisson Formalism

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We investigate the evolution of cosmic voids in the Schr\"{o}dinger-Poisson formalism, finding wave-mechanical solutions for the dynamics in a standard cosmological background with appropriate boundary conditions. We compare the results in this model to those obtained using the Zel'dovich approximation. We discuss the advantages of studying voids in general and the advantages of Schr\"{o}dinger-Poisson description over other approaches. In particular emphasizing the utility of the free-particle approximation. We also discuss a dimensionless number, similar to the Reynolds number, for this system which allows our void solutions to be scaled to systems of different physical dimensions.

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Eoin O Colgain - In search of signatures of Lambda-CDM model breakdown

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Lambda-CDM (LCDM) cosmology suffers from a longstanding cosmological constant problem. Recently, tensions have appeared in cosmological data sets. Tensions (if not due to systematics) point to LCDM model breakdown. A tell-tale signature of model breakdown is evolution of LCDM parameters with redshift. Starting from purely mathematical arguments, moving through observations, I motivate the case for redshift evolution of LCDM parameters.

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Enhanced shortcut to adiabaticity in internal Josephson Junction

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We investigate the preparation of spin-squeezed states in internal Bosonic Josephson Junction, where the interaction strength of the states can be controlled.
This problem has already been treated using the technique called *Shortcut to Adiabaticity* (STA), albeit in an approximate version.
In this work we devise and implement a novel, enhanced STA type protocol called eSTA.
This purely analytical technique expands can be applied to the non-approximated version of the system yielding better fidelity and showing an improvement in the robustness against noise when compared to its STA counterpart.

This poster will outline the general derivation of the eSTA protocol and its application to the internal Bosonic Josephson Junction, as well as giving some outlook for future investigation.

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Lars Fritz - New insights into the physics of ultraclean two-dimensional metals

In this talk I will first review some of the properties of two-dimensional hydrodynamic electrons. An aspect of these systems which has not received a lot of attention is the role of interactions and associated collective excitations. I will show that they can make sizeable contributions, especially to transport properties

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R. Moessner. (O'Raifeartaigh lecture) -Dynamical fractal in a clean topological magnet

Fractals – objects with non-integer dimensions – occur in manifold settings and length scales in nature, ranging from snowflakes and lightning strikes to natural coastlines. Much effort has been expended to generate fractals for use in many-body physics. Here, we identify an emergent dynamical fractal in a disorder-free, stoichiometric three-dimensional magnetic crystal in thermodynamic equilibrium.

This talk starts with a brief introduction to topological magnetism, and goes on to explain how the above phenomenon is born from constraints –arising from a combination of topology and symmetry –on the dynamics of the magnetic monopole excitations in spin ice, which restrict them to move on the fractal. This observation explains the anomalous exponent found in magnetic noise experiments in the spin ice compound Dy2Ti2O7. The capacity of spin ice to exhibit such striking phenomena holds promise of further surprising discoveries in the cooperative dynamics of even simple topological many-body systems.

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L. Borsten - Homotopy algebras, colour–kinematics duality, the double copy.

The string of possibly cryptic words in the title will be discussed. Neither prior knowledge nor interest in all of the terms is assumed. We hope there is something for everyone! Essentially, two ideas that we find interesting will be brought together:

Scattering amplitudes are the most direct bridge between quantum field theory and particle collider experiments. They are also incredibly rich structures that provide deep physical/mathematical insights into the underlying theories. An example is provided by the colour-kinematics duality of gluon amplitudes. While in Yang-Mills theory the internal colour and spacetime Lorentz symmetries ostensibly live independent lives, it seems that they dance to the same tune in the scattering amplitudes. A consequence of this hidden property is that graviton scattering amplitudes are the "double copy"of gluon amplitudes: Einstein = Yang-Mills squared!

Homotopy algebras generalise familiar algebras (matrix, exterior, Lie···) by relaxing the defining identities up to homotopy. The homotopy maps form higher products in corresponding homotopy algebra. A key example is that of homotopy Lie algebras or L∞-algebras. The violation of the familiar Lie bracket [-,-] Jacobi identity is controlled by a unary [-] and ternary bracket [-,-,-], which themselves satisfy nested Jacobi identities up to homotopies controlled by yet higher brackets and so on. They arise naturally and inevitably in a number of mathematical contexts, such as categorified symmetries. They also have deep connections to physics. Indeed, every perturbative Lagrangian quantum field theory corresponds to a homotopy Lie algebra, allowing one to move between the physics of scattering amplitudes and the mathematics of homotopy algebras.

We shall first illustrate how the colour-kinematics duality of scattering amplitudes can be realised at the level of the Batalin–Vilkovisky action: assuming tree-level colour-kinematics duality of the physics S-matrix, there exists an action principle manifesting colour-kinematics duality as a (possible anomalous) conventional symmetry. In homotopy algebraic terms, the associated homotopy commutative algebra (aka the "colour-stripped"homotopy Lie algebra) carries a homotopy BV-box algebras structure. This observation in turn allows us to give simple proofs of tree-level colour-kinematics for a variety of theories, some old, some new, and make progress in characterising what is and isn't possible at the loop-level.

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J. Caetano - Large Charge 't Hooft Limit of N = 4 Super Yang-Mills

In this talk, I will show that the large charge sector of the SU(2) N=4 SYM provides a solvable corner of the theory which exhibits striking similarities with the standard planar limit. In particular, I will describe how to compute the spectrum of local operators and higher point correlation functions involving two large charge operators and several light operators.

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M. Walters - A New Framework for Strongly-Coupling Physics

While quantum field theory has given us a successful description of physical phenomena at many different length scales, almost all computations are currently limited to systems which are weakly-coupled. I will present a new theoretical framework for solving general strongly-interacting physical systems, which uses universal short-distance data to numerically compute long-distance observables. After presenting a general framework which can be applied to quantum field theories in any number of dimensions, I will then discuss its application to multiple strongly-coupled systems, focusing in particular on recent results studying non-equilibrium dynamics at finite temperature and nonperturbative scattering.

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Ronan McNulty - Understanding QCD: searching for the glueball

and the odderon.

The strong force is the least precisely tested constituent of the Standard Model due to our inability to make precise predictions at low energies. Colour-charged objects can not be isolated and while the quark model describes most observed hadrons, the expected binding of gluons to form real or virtual states is less clearly understood. Recent and prospective results from the LHC that illuminate this problem will be discussed.

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Weird Matter at MU

https://www.eventbrite.ie/e/weird-matter-at-mu-tickets-698896978677

Maynooth University and the Dublin Institute for Advanced Studies invite you to a night of science celebrating the weird and wonderful ways matter can manifest in our universe.

In the first of two back-to-back general audience talks, Prof. Roderich Moessner (MPI-PKS and this year's O'Raifeartaigh speaker at ITP2023) will explore the strange phenomena of fractionalisation in complex quantum systems and the remarkable ways that quantum matter can behave at low temperatures.
Our second speaker, Prof. Peter Coles (MU) will discuss our modern ideas of space and time, and how the Euclid mission will try to test whether or not they are correct by shedding light on the nature of dark matter and dark energy.

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Cora Uhlemann - Large-deviation statistics for the cosmic large-scale structure

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Des Johnston - (Wealth) Condensation

We discuss a simple statistical mechanical model - the "zeta-urn" model, which displays a real space condensation transition. In the model L (indistinguishable) balls are distributed amongst N boxes and L, N are sent to infinity at some fixed ratio. The weight $p(n)$ for having n balls in a box is $1/n^{\beta}$. Since the simplicity of the model allows for explicit evaluation of the partition function and the order of the transition can be tuned by varying β, it provides a useful toy model for illustrating/testing various finite size scaling concepts.

We also cynically relabel some of the quantities of the model to get more mileage out of it as a (highly non-serious) model of wealth condensation in an economy composed entirely of (very) rich people.

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Kay Lehnert - Artificial Insights into String Theory - What Chat-GPT (doesn't) know about the Swampland and why it's useful anyway.

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C Nash - Entropy de Sitter space and von Neumann algebras

I will discuss recent work connected with the title.

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A Hunter-McCabe - The Unruh Effect and Shaking Photons From the Vacuum

Acceleration radiation—or Unruh radiation—the thermal radiation observed by an ever-accelerating observer or detector, although having similarities to Hawking radiation, so far has proved extremely challenging to observe experimentally. One recent suggestion is that, in the presence of a mirror, constant acceleration of an atom in its ground state can excite the atom while at the same time cause it to emit a photon in an Unruh-type process. In this talk I will give a brief introduction to the Unruh effect and will discuss work my collaborators and I did to show that merely by shaking the atom, in simple harmonic motion for example, can have the same effect and stimulate photon emission.

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D O'Connor - The confining/de-confining phase transition, lessons from matrix models.

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D Johnston - Renormalization/Renormalisation

Brian has remained studiously neutral in the great transatlantic debate on how to spell renormalisation/renormalization, with 4 papers on each.

I'll discuss one of his earlier works on renormalization.

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R Szabo - Double Copy of Noncommutative Gauge Theory

This talk will summarise recent work attempting to understand how standard noncommutative gauge theories, such as those which arise naturally from string theory, fit into the paradigm of colour-kinematics duality and the double copy of gauge theory to gravity. Along the way we shall encounter some novel noncommutative scalar field theories with rigid colour symmetry that have no commutative counterparts, whose double copy prescriptions are deformations of some integrable theories related to self-dual Yang-Mills theory and gravity in four dimensions.

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T Tchrakian - Skyrme–Chern-Simons densities in all dimensions

I present the prescription for constructing Skyrme–Chern-Simons densities in all dimensions. These are related to Witten's Anomalies in 3+1 dimensions. One example in 2+1 dimensions is presented.

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Masud Haque - Approaching the classical limit of Lindblad dynamics — emergence of limit cycles, fixed points and algebraic decay

Iconic features of classical dissipative dynamics include persistent limit-cycle oscillations and critical slowing down at the onset of such oscillations, whereby the system relaxes purely algebraically in time. On the other hand, quantum systems subject to generic Markovian dissipation decohere exponentially in time, approaching a unique steady state. Here we show how coherent limit-cycle oscillations and algebraic decay can emerge in a quantum system governed by a Markovian master equation. We illustrate these mechanisms using a single-spin model motivated by Landau-Lifshitz-Gilbert dynamics, and using a bosonic model with dissipation.

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John Brennan - Accelerating Astrophysics Simulations with Neural Networks

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Phillip Cussen Burke - Temperature in finite isolated quantum systems

The concept of connecting quantum mechanical systems to statistical mechanics often arises in the study of "thermalization" in isolated many-body systems. One fundamental challenge in establishing this connection is the definition of temperature. In this talk, we explore two approaches to defining temperature in such systems.

First, we will introduce a definition of temperature inspired by the eigenstate thermalization hypothesis, which posits that the eigenstates of a thermalizing system contain information about the thermalization process. We will consider temperatures derived from the structure of eigenstate density matrices as a means to extract this information.

Following this, we consider the standard temperature-entropy relation from statistical mechanics. This relation establishes a connection between temperature and microcanonical entropy. We will investigate various methods for defining the microcanonical entropy in finite isolated quantum systems and numerically compute the corresponding temperature.

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Hannah O'Brennan - Predicting the number density of heavy-

seed massive black holes due to an intense Lyman-Werner field

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A plausible origin of supermassive black holes (M ≥ 1e6 solar masses) which fuel bright active galactic nuclei (L > 1e47 erg /s) at galactic centres are so-called heavy-seed black holes that have formed in the early Universe (z>15). These heavy seeds are theorised to have masses of 1e3 to 1e5 solar masses.
Gravitational waves (GWs) from their mergers would have a frequency range of 1e-4 to 1e-2 Hz, outside the frequency range of current generation GW detectors LIGO/Virgo. Detection of these low-frequency GWs will be one of the goals of LISA (due to launch in 2034).Thus modelling their number density and merger rate is a matter of considerable urgency.
In this talk, I provide an updated estimate of the number density of these heavy seeds as a function of redshift z. I consider the influences of Lyman-Werner radiation emitted by the earliest generations of stars, metal pollution from their supernovae and genetic metal pollution from previous episodes of star formation. In future, I will use the Renaissance simulation suite to derive a new Lyman-Werner luminosity function for the number density computation.

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Dale Lawlor - On the speed of sound in dense QC_2D

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A quick update

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Ronan McNulty - Ireland and CERN

In November 2022, Minister Harris announced that his department would prepare a submission for Government to consider joining CERN. The current status, roadmap, and opportunities of this announcement will be reviewed from the perspective of the Irish CERN users community.