YTF 11

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Centre for Particle Theory, Durham

Book of Abstracts

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Gravity amplitudes, observables and classical scattering

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Modern amplitudes techniques offer the tantalising possibility of greatly simplifying theoretical predictions for precision gravitational wave astronomy. One exciting example is the double copy, an enigmatically simple connection between Yang-Mills theory and gravity. In this talk I will discuss our recent work on rigorously obtaining classical scattering observables from quantum amplitudes, and why the double copy makes this pertinent for gravitational radiation.

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Coincident M5-branes and dual singular geometries

Author: Callum Brodie[1]

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Through a web of string dualities, M5-brane configurations in M-theory can be mapped to geometrical features. In particular, I will discuss this map via heterotic/F-theory duality, using a Horava-Witten description of heterotic $E_8 \times E_8$ string theory as the connection to M-theory. Intersecting or coincident M5-branes are mapped to singular base geometries in F-theory, which also correspond to singular geometries in Type IIB string theory. I will explain these dualities, and if I have time I will discuss geometrical transitions corresponding to deforming M5-brane configurations and point out some cute connections with toric geometry.

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Fermionically Generated Superstrata

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The aim of the talk is to present the construction of a new family of smooth horizonless solutions of supergravity that have the same charges as the supersymmetric D1-D5-P black hole. We will begin with a brief review of the Fuzzball proposal for black holes, which states that at the length scale of the horizon a new, fuzzy, phase takes over, allowing outside observers to distinguish between different microstates of the black hole. We will then focus on the three charge supersymmetric D1-D5-P black hole and review some of its microstate geometries. We then present a method of obtaining a new family of solutions using supersymmetry generators. The motivation behind this construction is coming from the dual CFT multiplet structure, where these fermionic generators are used to create

new linearly independent states in the theory. On the gravity side the geometries dual to these new states are generated by the Killing spinors of $\mathrm{AdS}_3 \times S^3 \times T^4$. Hence we present the explicit form of these spinors and use them to construct new solutions to the supergravity equations. Finally we present these new solutions and show that they are simpler than the ones previously known with having a fewer number of excited fields.

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Shedding Light on the Initial Conditions of Inflation with the Eisenhart Lift

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The Hot Big Bang model of cosmology requires very finely-tuned initial conditions in order to explain the degree of flatness and homogeneity we observe in the Universe today. This has led the community to embrace the theory of inflation, since it readily explains these features. But are the initial conditions required to initiate inflation more or less finely-tuned than those required by the Hot Big Bang? Although there are several qualitative arguments to suggest that inflation should happen generically, attempts to quantify these have led to ambiguous answers due to the infinite measure of the total phase space. Previous studies have regularised this measure to get an unambiguous answer, but the results are strongly dependent on the regularisation technique used with some authors concluding that inflation is exponentially likely while others conclude that it is exponentially unlikely.

The Eisenhart lift, which was recently applied to field theories for the first time, is a technique that allows one to convert a theory described by a Lagrangian into an equivalent geometric system. Applying the Eisenhart lift to inflation, one can construct a manifold such that each point represents a different initial condition. Both the total volume of this manifold and the volume that leads to inflation is finite. Thus, we can finally answer quantitatively how finely-tuned the initial conditions of inflation are without the need for a regulator.

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Clustering algorithms for b-jets from BSM Higgs Bosons.

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It is long established that the Standard Model is not a complete theory of nature and at the LHC we hope to see hints of some new physics beyond our current understanding. This project seeks to improve current techniques of jet clustering, in particular from some extended BSM Higgs sector, such as those in 2 Higgs Doublet Models, which include additional particles alongside the 125 GeV SM Higgs detected in 2012.

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Global Fixed Points of Scalar and Fermionic Theories

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Interacting fixed points in three dimensions have been investigated using modern renormalisation group methods. Investigations focus on the seminal Wilson-Fisher fixed point solution in O(N) symmetric scalar theories and asymptotically safe UV fixed points in fermionic Gross-Neveu models. The main novelty of the study is the use of Padé approximants. Padé approximants have been used to extend local fixed point data that is obtained from polynomial expansions and hence, only valid for small field values to global fixed point solutions for all field values. For both the scalar and fermionic theories this approach is tested in the Large N limit where explicit analytic fixed point solutions can be found. Particular emphasis is put on the large real field and the large imaginary field limits, and converging-limiting singularities in the complex field plane. Finite N models have also been tested for the O(N) symmetric scalar theories. Here exact solutions are not accessible and Padé approximants have been used to make predictions beyond the radius of convergence of polynomial expansions. Padé approximants have also been used to locate singularities exhibited by the given complexified fixed point solutions. In doing this it is seen that the singularities exhibited by Padé approximants themselves form patterns of defects in the complexified field plane that are intimately linked to their ability to converge to high accuracy.

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Resurgence and Non-Perturbative Physics

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Divergent perturbation series are prevalent in all of physics. Notable examples include sums of Feynman diagrams in QFT and sums over Riemann surfaces in string scattering. I will first give a brief introduction to Resurgence theory, starting with ways of summing divergent series which will lead us to Borel summation and then looking at the analytic continuation of the path integrals which will lead us to Resurgence theory. Time permitting I will then discuss Resurgence in the context of $\mathcal{N} = (2, 2)$ on the 2-sphere using results from SUSY Localization.

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Towards a classification of supersymmetric spacetimes

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In this talk, we present a deformation theoretic approach to classifying supersymmetric spacetimes.

It is a postulate of general relativity that spacetime is described by a four-dimensional Lorentzian manifold. However, it is not always convenient to use this description. For example, it may be easier to take the Newtonian limit and work with theories at lower energies. These non-relativistic spacetimes are still useful descriptions and should be incorporated in our classification.

To this end, we notice that the above postulate has an important consequence: the spacetime manifold is fully described by its relativity group. Therefore, we do not ask for manifolds whose relativity group is the Poincaré group, but for geometries with some relativity group. We will show that these groups may be described by kinematical Lie algebras and give the classification of these algebras. We then show how this programme is being extended to the supersymmetric case.

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Developing an amplitude level parton shower.

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Perturbative QCD suffers from multitudes of large logarithms, arising from the miscancellation of infra-red poles. These logarithms can cause enhancements of high order terms and spoil perturbative convergence. Historically there has been two disjoint approaches to solving this problem; resummations and parton showers. Nowadays resummations are performed at high accuracy and are rigorously defined, but they are very time consuming. Parton showers are all purpose and can be implemented computationally. However modern showers are still far from a rigorous definition. We present a new algorithm that aims to unify these two approaches.

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Non-perturbative aspects of Sp(2N) gauge theories.

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The discovery in 2012 of the Higgs boson provided evidence for our understanding of the origin of mass. However there still remain some unanswered questions one of which is the "Naturalness Problem".

Like the other fundamental particles, the Higgs acquires loop corrections to its mass due to its interaction with the quarks, the leptons and itself. If we impose an ultraviolet cutoff, Λ_{UV}, on the Standard Model, these corrections depend quadratically on Λ_{UV}. If Λ_{UV} is sent to infinity, a very large counter term is required to cancel out the quadratic divergence arising from the loop corrections. In order to produce the small observed Higgs mass of 125 GeV, the counter term must be computed to a precision so high that it is not only unnatural - hence the name - but far beyond experimental reach.

One way to resolve this problem is to treat the Higgs not as a fundamental particle but as a constituent one (like the proton or neutron). The need for fine-tuning is simply an effect of the approximation of the Higgs as a fundamental particle breaking down.

The compositeness deals with the issue of fine tuning and the subsequent low mass is achieved by corollary of Goldstone's Theorem. When a symmetry is explicitly broken (e.g. by a mass term) there exists a light boson for each broken generator (as opposed to a massless boson in the case of spontaneous symmetry breaking). The explicit breaking of a new symmetry group could give rise to what is observed as the Higgs boson.

The combination of Goldstone's Theorem and a new symmetry group have potential to explain the low-mass Higgs as a composite particle without the need for fine-tuning. Candidate symmetries are the Symplectic Groups (denoted as Sp($2N$)). Observable quantities of such a Quantum Field can be computed on the lattice and their experimental detection would provide evidence for same.

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Anisotropies in the stochastic gravitational-wave background

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In the new era of gravitational-wave astronomy, one of the most exciting targets for future observations is the stochastic gravitational-wave background (SGWB). While we have yet to detect the SGWB, we expect that by studying the angular power spectrum of its anisotropies, we may learn about the large-scale structure of the Universe (analogous to studies of the CMB). With this in mind, we develop detailed models of the SGWB anisotropies from two important sources of gravitational waves: unresolved compact binary coalescences, and cosmic strings.

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Renormalization Group Properties of the Conformal Mode

Author: Matthew Kellett[1]

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The renormalization group properties of a QFT are of profound importance to the theory. In quantum gravity, one runs into the problem that the kinetic term for the dilaton (or conformal mode) has the wrong sign, causing the Euclidean partition function to be (worse than usually) ill-defined. Imposing a new quantization condition allows us to not only make sense of this, but also potentially would allow us to use standard RG techniques to quantize gravity. We see that the effect of resolving this conformal mode "instability" (as described by Hawking et. al.) is to constrain the size of the manifold by its homogeneity. I will present an outline of how this is done and some results from studies of the torus. If time permits, I will also outline ongoing and future work in this area.

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Different aspects of single top quark and DM channel

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Recently it has been pointed out that associated production of dark matter with single top quark could also provide an interesting reach for dark matter (DM) searches at LHC. I will discuss this in context of simplified dark matter models and in two Higgs doublet model. The top quark produced via this channel is polarized and the polarization depends on the CP of the mediator (simplified dark matter model with spin-0 mediators). I will also talk about the top polarization sensitive angular observables, which along with the cross-section, could be used to probe the CP property of the mediator.

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Bifurcations in the RG-Flow of QCD

Author: Folkert Kuipers[None]

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In this talk, I'll discuss the connection between the theory of dynamical systems and renormalization group flows in quantum field theory. In particular, I'll apply numerical methods from bifurcation analysis to study the RG-flow of an effective model for QCD with a four-fermi interaction and an arbitrary number of colors and massless flavors. Using bifurcation analysis techniques, new fixed points are found in and close to the conformal window. Particular focus will be given to the way in which the fixed points (dis)appear in the model, and how this affects the scaling dimensions of the (ir)relevant operators. Furthermore, I'll discuss how the fixed point structure of the RG-flow changes when a scalar field coupling through a Yukawa interaction is added to the model.

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The orientifold quotient of giant gravitons

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The AdS/CFT correspondence links type IIB string theory on $AdS_5 \times S^5$ to $\mathcal{N} = 4$ super Yang-Mills with gauge group $U(N)$. In 1998, Witten showed that taking an orientifold quotient of the S^5 factor - identifying anti-podal points so as to replace S^5 with $\mathbb{RP}^5$ - can be understood on the gauge theory side by replacing the $U(N)$ gauge group with either $SO(N)$ or $Sp(N)$. I will talk about this quotient from the gauge theory point of view, focusing on the half-BPS sector. This corresponds to taking the quotient of rotating D3-brane states, also called giant gravitons. The mathematics of this quotient leads to surprising connections with plethysms and domino tableaux, which can be tied back to intuitive notions of how the orientifold acts on the branes.

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Quasi-Degenerate Vacua in the KSVZ axion model; A minimal approach to dark energy and dark matter

Authors: Amy Lloyd-Stubbs[1]; John McDonald[1]

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I will present a study of the KSVZ axion model with quasi-degenerate vacua as a minimal model for dark energy and dark matter. I will review axions as dark matter and provide an explanation for dark energy in the form of a difference in vacuum energy density between the electroweak vacuum and a second degenerate minimum in the effective potential, which can be achieved via the scalar threshold effect.

4

Quantum Gravity and the dilaton portal

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In this brief talk I discuss two aspects of a novel approach to quantum gravity, the first of these is the construction of evanescent operators of the dilaton which provides an initial direction to finding solutions to the inherent problems of non-renormalizability of quantum gravity. The second is the use of the Batalin-Vilkovisky anti-field technique and how this can be used with cohomological techniques to restrict the terms in our action. Following this, and time permitting, a brief review of present and future work will be discussed.

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Renormalised vacuum polarisation on topological black holes

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Anti-de Sitter spacetime is a solution of Einstein's equations with a negative cosmological constant. This fact allows for unusual black hole solutions with non-spherical horizon topology. We calculate the renormalised vacuum polarisation for black holes with spherical, flat and hyperbolic event horizons, following the "extended coordinates"method, which uses a mode-sum representation for the Hadamard parametrix. Renormalisation counter terms are subtracted from the Green's function mode-by-mode, leaving each individual term manifestly finite.

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Heterotic M2-Branes

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M-Theory has been conjectured as a single theory in which we can find each of the various superstring theories, and as such provides a UV completion of 11d supergravity. Instead of strings, we have M2-branes and M5-branes. The classic Horava-Witten result says that a compactification of M-theory on $S^1/\mathbb{Z}_2$ retrieves the $E_8 \times E_8$ heterotic theory, with the wrapped M2-brane as the "fundamental" string. In this work, we reproduce this result from the perspective of the ABJM theory, a world volume theory conjectured to capture the low-energy behaviour of multiple M2-branes. In particular, we find that the subtle nature of Chern-Simons matter theories delivers a new perspective on the GSO projection and the non-supersymmetric $SO(16) \times SO(16)$ heterotic theory.

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Semiclassical gravity in the far field of stars and black holes

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In semiclassical gravity, the expectation value of the stress-energy operator $\langle T_{\mu\nu} \rangle$ is an infinite quantity. To avoid having to renormalize it, one can calculate the difference in $\langle T_{\mu\nu} \rangle$ between a pair of quantum states in such a manner that the divergent parts cancel. However, another technique explored more recently is to take the difference in $\langle T_{\mu\nu} \rangle$ between two different spacetimes, while in the same quantum state. I will summarize prior work on this method and detail how we have applied it to calculate the difference $\Delta \langle T_{\mu\nu} \rangle$ between the spacetimes of a non-Newtonian star and a Schwarzschild black hole.

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What do knots, quantum computation and field theories have in common?

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Knots are deceivingly simple mathematical objects. Showing whether two knots are the same or not is a hard problem. While it can be done easily by inspection for simple knots, the problem becomes hard very quickly. Ideally, to distinguish between inequivalent knots we have to define knot invariants. At first sight, this may not have anything to do with quantum computation or field theories. However, it turns out that these subjects are intimately related to each other through an algebraic object called a modular tensor category (MTC). In this talk, I will describe an MTC and explain how it forms the bridge between the aforementioned topics.

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A Gentle Introduction to Supersymmetric Localization

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Localization is a powerful technique utilised in supersymmetric field theories to reduce troublesome infinite dimensional path integrals to pleasant finite dimensional integrals. The aim of this talk is to provide an introduction to this topic and discuss its applications. In particular, I will explain how this technique is used to compute the exact partition function and the expectation values for certain operators in supersymmetric theories.

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Isospin breaking corrections to leptonic decay rates on the lattice

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Lattice QFT is a method for calculating non-perturbative physics and has been used extensively to calculate properties of low energy QCD. Over the last decade calculation's of a number of non-perturbative QCD quantities have reached a good precision, with agreement from across the lattice community.
In general isospin breaking (IB) effects have not been included in these calculations because until now IB effects have not been a limiting source of systematic error. Isospin breaking effects enter in two ways, the difference in the mass of the up and down quark (strong IB) and the difference in the QED charge of up and down type quarks (QED IB). Considering power counting these effects are expected to be of the order 1% of the decay rate. Due to the introduction of QED effects, we must calculate the full QCD + QED path integral on the lattice and this introduces a number of complications.
In this presentation, I will introduce Lattice QCD+QED as a calculation method for flavour physics observables and discuss how leptonic decay rates are calculated on the lattice with the inclusion of isospin breaking effects.

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Central charge of self-dual strings from holography

Authors: Andy O'Bannon[1]; Brandon Robinson[1]; Darya Krym[2]; John Estes[3]; Ronnie Rodgers[1]

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M-theory is a candidate for a theory of quantum gravity. Its fundamental objects are called M2-branes and M5-branes. The low-energy theory describing coincident M5-branes is poorly understood in many respects, with holography providing one of the most useful tools to further that understanding. It is known that the theory should possess solitonic solutions called "self-dual strings". I will review the holographic description of these strings, and show how calculation of entanglement entropy provides a way of calculating an important quantity characterising them: their central charge.

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Non-Minimal Flavour Violation in the MSSM from a flavoured SU(5) GUT

Authors: Steve King[1]; Sam Rowley[1]; Jordan Bernigaud[2]; Bjorn Herrmann[2]

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We study flavour-violation in a SU(5) setup inspired by flavoured GUTs. We investigate the impact of various observables at low scales on the high-energy parameters of the theory including mu->e gamma and the relic density of dark matter. An interesting interplay between the quark and lepton sectors becomes apparent due to the cohabitation of various fields in representations of the unifying group. Correlations between high scale parameters in the context of current experimental flavour data are shown to manifest. We show that movement away from the Minimal Flavour Violation paradigm is perfectly possible within the context of current limits.

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Applications of gauge/gravity duality

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This talk will discuss scenarios where the gauge/gravity duality can be applied to non-perturbative regimes in physics. The standard model explains many phenomena seen in nature but relies on techniques that only work in small coupling. The gauge/gravity duality is a way in which we can try to obtain theoretical predictions for areas such as strongly coupled condensed matter and the low energy regime of QCD. Specifically this talk will focus on momentum dissipation effects on zero sound in strange metals and the benefit of exploring holographic imaginary chemical potential in the QCD phase diagram.

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Supergravity on a 3-Torus: Quantum Linearisation Instabilities with a Supergroup

Author: Lasse Schmieding[1]

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For closed universes, the Einstein equations (EE) are linearisation unstable. Perturbing around any background with Killing symmetries the linearised EE admit solutions which are not themselves linearisations of solutions to the non-linear EE. To control these spurious solutions, quadratic linearisation stability conditions are imposed. However, in the quantum theory these stability conditions require that all physical states must be invariant under the background symmetries, which can complicate the construction of the physical Hilbert space. I will review linearisation stability conditions in both classical and quantum gravity, and then discuss a simple supersymmetric model to study quantum linearisation instabilities with a supergroup.

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Light charged Higgs boson with dominant cb decay from 3HDM and its search at LHC and future colliders

Authors: Andrew Akeroyd[1]; Stefano Moretti[2]; Muyuan Song[1]

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I am working with Professor Stefano Moretti and Doctor Andrew Akeroyd on charged Higgs phenomenology in the University of Southampton recently. We posted the paper in October 2018 on arXiv:1810.05403.

The possibility of a light charged Higgs boson H± that decays predominantly to quarks (cs and/or cb) and with a mass in the range 80 GeV ≤ mH± ≤ 90 GeV is studied in the context of Three- Higgs-Doublet Models (3HDMs). At present the Large Hadron Collider (LHC) has little sensitivity to this scenario, and currently the best constraints are from LEP2 and Tevatron searches. The branching ratio of H± ⟶ cb can be dominant in two of the five types of 3HDM, and we determine the parameter space where this occurs. The decay H± ⟶ cb has recently been searched for at the LHC for the first time, and with increased integrated luminosity one would expect sensitivity to the region 80 GeV ≤ mH± ≤ 90 GeV due to the smaller backgrounds with respect to H± ⟶ cs decays.

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Production and thermalisation of isolated sectors

Author: Hannah Tillim[1]

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An increasingly attractive alternative to the WIMP model is that of an 'isolated' dark sector - i.e. one which interacts with the standard model only via gravity and which therefore is unbounded by direct detection. We present a possible production mechanism for this sector in the early Universe (Hawking emission from primordial black holes) as well as predictions for the subsequent evolution and ultimate fate of initially highly non-equilibrium populations.

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Higher Order QCD Calculations with NNLOJET

Author: Duncan Walker[1]

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I will present some recent results of higher order QCD calculations in vector boson processes at colliders using the Monte Carlo framework NNLOJET. Recent developments are opening up a new world of precision phenomenology for study, improving our understanding of QCD/EW interactions at a fundamental level.