PASCOS 2023

Monday 26 June 2023 - Friday 30 June 2023

ISEB

Book of Abstracts

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Modular Average and Weyl Anomaly in Two-Dimensional Schwarzian Theory

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The gauge formulation of Einstein gravity in AdS_3 background leads to a boundary theory that breaks modular symmetry and loses the covariant form. We examine the Weyl anomaly for the cylinder and torus manifolds. The divergent term is the same as the Liouville theory when transforming from the cylinder to the sphere. The general Weyl transformation on the torus also reproduces the Liouville theory.
The Weyl transformation introduces an additional boundary term for reproducing the Liouville theory, which allows the use of CFT techniques to analyze the theory. The torus partition function in this boundary theory is one-loop exact, and an analytical solution to disjoint two-interval Rényi-2 mutual information can be obtained. We also discuss a first-order phase transition for the separation length of two intervals, which occurs at the classical level but is smoothed out by non-perturbative effects captured by averaging over a modular group in the boundary theory.

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Quantum matter and Buchdahl's theorem.

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Very compact stars seem to be forbidden in General Relativity. While Buchdahl's theorem sets an upper bound on compactness, further no-go results rely on the existence of two light rings, the inner of which is associated to gravitational instabilities. However, little is known about the role of QFT in these strong gravity regimes. We show that the renormalized stress tensor for CFTs diverges faster than the classical source as the star's surface approaches the Buchdahl radius rather than the Schwarzschild radius. The backreaction of quantum fields in this regime therefore cannot be ignored.

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Dynamical consistency conditions for rapid turn inflation

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We derive consistency conditions for sustained slow roll and rapid turn inflation in two-field cosmological models with oriented scalar field space, which imply that inflationary models with field-space trajectories of this type are non-generic. In particular, we show that third order adiabatic slow roll, together with large and slowly varying turn rate, requires the scalar potential of the model to satisfy a certain nonlinear second order PDE, whose coefficients depend on the scalar field metric. We also derive consistency conditions for slow roll inflationary solutions in the so called "rapid turn attractor" approximation, as well as study the consistency conditions for circular rapid turn trajectories with slow roll in two-field models with rotationally invariant field space metric. Finally, we argue that the rapid turn regime tends to have a natural exit after a limited number of e-folds.

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Primordial black holes and stochastic inflation beyond slow roll

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Primordial Black Holes (PBHs) may form in the early universe, from the gravitational collapse of large density perturbations, generated by large quantum fluctuations during inflation. Since PBHs form from rare over-densities, their abundance is sensitive to the tail of the primordial probability distribution function (PDF) of the perturbations. It is therefore important to calculate the full PDF of the perturbations, which can be carried out non-perturbatively using the 'stochastic inflation' framework. In single field inflationary models, generating large enough perturbations to produce an interesting abundance of PBHs requires violation of slow roll. It is therefore necessary to extend the stochastic inflation formalism beyond slow roll, and consequently there has been a surge in the research interest in this direction in the recent years. A crucial ingredient for this is the stochastic noise matrix corresponding to the small wavelength fluctuations. In this talk, after providing a brief introduction to PBHs and ultra slow-roll inflation, the speaker will discuss analytical and numerical calculations of these matrix elements for an inflaton potential with a feature which violates slow roll and produces large, potentially PBH generating, perturbations. The seminar will be based on the following work carried out at the Particle Cosmology Group, University of Nottingham, in collaboration with Prof. Edmund J. Copeland and Prof. Anne M. Green : https://arxiv.org/abs/2303.17375

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Inflation with massive spin-2 ghosts

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It is well-known that renormalizable theories of quadratic gravity pose a risk to unitarity of the S-matrix due to the spin-2 ghost degrees of freedom that they inevitably propagate. However, in recent years, a few promising methods to guarantee unitarity in the presence of these ghosts have been proposed. In light of these recent developments, we consider a generic model of quadratic gravity coupled to a single scalar and investigate the effects of gravitational degrees of freedom on inflationary parameters. We find that quantum corrections arising from the massive spin-2 ghost generate significant contributions to the effective inflationary potential and allow for a realization of the spontaneous breakdown of global scale invariance without the need for additional scalar fields. We compute inflationary parameters, compare the resulting predictions to well-known inflationary

models, and find that they fit well within the Planck and BICEP/Keck collaboration's constraints on inflation.

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Quantum cosmology, eternal inflation, and swampland conjectures

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In light of the recent swampland conjectures, we explore quantum cosmology and eternal inflation beyond the slow roll regime. We consider a model of a closed universe with a scalar field ϕ in the framework of tunneling approach to quantum cosmology. The scalar field potential is assumed to have a maximum at $\phi = 0$ and can be approximated in its vicinity as $V(\phi) \approx 3H^2 - \frac{1}{2}m^2\phi^2$. Using the instanton method, we find that for $m < 2H$ the dominant nucleation channel for the universe is tunneling to a homogeneous, spherical de Sitter space. For larger values of m/H, the most probable tunneling is to an inhomogeneous closed universe with a domain wall wrapped around its equator. We determine the quantum state of the field ϕ in the nucleated universe by solving the Wheeler-DeWitt equation with tunneling boundary conditions. Our results agree with earlier work which assumed a slow-roll regime $m \ll H$. We finally show that spherical universes nucleating with $m < 2H$ undergo stochastic eternal inflation with inflating regions forming a fractal of dimension $d > 2$. For larger values of m the field ϕ is unstable with respect to formation of domain walls and cannot be described by a perturbative stochastic approach.

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QCD axion mass prediction from Adaptive Mesh Refinement simulations

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If the PQ symmetry is broken after inflation then the QCD axion mass that gives rise to the observed dark matter (DM) abundance can in principle be calculated precisely. In practice it remains a computational challenge to accurately predict the DM contribution from nonlinear features of the PQ field such as axion strings, which introduce a large hierarchy of scales between their width and the Hubble length. In this work we employ adaptive mesh refinement (AMR) to simulate the post-inflationary axion field beginning before the PQ phase transition and into the scaling regime, building off of the framework of Buschmann et al. Nature Commun. 2022, which predicted the axion mass to be in the range (40,180) microelectronvolts. We improve the accuracy and precision of the mass prediction by running larger simulations further into the scaling regime and by closely examining sources of systematic uncertainty. For example, for the first time we account for axions produced during domain wall formation and string-network collapse using the AMR simulation framework. Our work leads to a narrow axion mass prediction that directly informs experiments such as ADMX, HAYSTAC, MADMAX, and ALPHA, which target axion DM in the mass range of interest. Moreover, our work helps determine the relevant initial conditions for investigating small-scale structure formation in the post-inflationary scenario.

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Probing Minimal Grand Unification through Gravitational Waves

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Motivated by the direct discovery of gravitational waves (GWs) from black holes and neutron stars, there is a growing interest in investigating GWs from other sources. Among them, GWs from cosmic strings are particularly fascinating since they naturally appear in a large class of grand unified theories (GUTs). Remarkably, a series of pulsar-timing arrays (PTAs) might have already observed GWs in the nHz regime, hinting towards forming a cosmic string network in the early universe, which could originate from phase transition associated with the seesaw scale emerging from GUT. In this talk, I show that if these observations from PTAs are confirmed, GWs from cosmic strings, when combined with fermion masses, gauge coupling unification, and proton decay constraints, the parameter space of the minimal SO(10) GUT becomes exceedingly restrictive. The proposed minimal model is highly predictive and will be fully tested in a number of upcoming gravitational wave observatories.

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Search for new physics in kaon decays at NA62

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Rare kaon decays are among the most sensitive probes of both heavy and light new physics beyond the Standard Model description thanks to high precision of the Standard Model predictions, availability of very large datasets, and the relatively simple decay topologies. The NA62 experiment at CERN has reported the first observation of the ultra-rare $K^+ \to \pi^+\nu\bar{\nu}$ decay, and is collecting data towards a 10% measurement of the decay rate. The experiment also performs a broad rare-decay and hidden-sector physics programme. Recent NA62 results (including a new search for production of hidden-sector mediators in kaon decays) are presented. The plans for kaon experiments at CERN beyond NA62 are discussed.

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Realistic SU(5) GUT with lower dimensional representations

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What is the minimal viable renormalizable $SU(5)$ GUT with representations no higher than adjoints? In this talk I discuss a $SU(5)$ model in which vectorlike fermions $5_F + \overline{5}_F$ as well as two copies of 15_H Higgs fields are introduced in order to accommodate for correct charged fermion and neutrino masses and to reproduce the matter-antimatter asymmetry of the universe. The presented

model is highly predictive and will be fully tested by a combination of upcoming proton decay experiments as well as low energy experiments in search of flavor violations.

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Gravitational wave background from vacuum and thermal fluctuations during axion-like inflation

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We revisit the framework of axion-like inflation, considering a warm inflation scenario in which the inflaton couples to the topological charge density of non-Abelian gauge bosons whose self-interactions result in a rapidly thermalizing heat bath. Including both dispersive (mass) and absorptive (friction) effects, we find that the system remains in a weak regime of warm inflation (thermal friction Hubble rate) for phenomenologically viable parameters. We derive an interpolating formula for vacuum and thermal production of tensor perturbations in generic warm inflation scenarios, and find that the perturbations exhibit a model-independent fˆ3 frequency shape in the LISA window, with a coefficient that measures the maximal shear viscosity of the thermal epoch.

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Non-perturbative effects in indirect detection of dark matter with (pseudo)-scalar interactions

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Indirect detection is one of the most powerful methods to search for annihilating dark matter (DM) covering a broad range of masses and interactions. Recently, non-perturbative effects have been shown to significantly alter model observables. In this work, we investigate the impact of non-perturbative effects in the indirect detection of DM. For this purpose we utilize a minimal model consisting of a fermionic DM candidate in the TeV mass range that interacts via scalar- and pseudo-scalar interactions with a massive scalar mediator mixing with the Standard Model Higgs. The scalar interaction induces an attractive Yukawa potential between DM particles, such that DM annihilation is Sommerfeld enhanced, and DM bound states can form. We discuss the impact on indirect detection for a range of targets and derive bounds on the parameter space of the model.

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MAGPI: Measurement of Axion Gradients with Photon Interferometry

Authors: Jedidiah O. Thompson[1]; Michael A. Fedderke[2]

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In this talk, I will present a novel technique to search for axions with a CP-violating monopole coupling $\tilde{g}_Q$ to bulk SM charges $Q \in \{B, L, B-L\}$. Gradients in the static axion field configurations sourced by matter induce achromatic circular photon birefringence via the axion-photon coupling $g_{\phi\gamma}$. Circularly polarized light fed into an optical or (open) radio-frequency (RF) Fabry-Perot (FP) cavity develops a phase shift that accumulates up to the cavity finesse: the fixed axion spatial gradient prevents a cancellation known to occur for an axion dark-matter search. The relative phase shift between two FP cavities fed with opposite circular polarizations can be detected interferometrically. This time-independent signal can be modulated up to non-zero frequency by altering the cavity orientations with respect to the field gradient. Multi-wavelength co-metrology techniques can be used to address chromatic measurement systematics and noise sources. I will show projections indicating that, with Earth acting as the axion source, this approach could enable reach beyond current constraints on the product of couplings $\tilde{g}_Q g_{\phi\gamma}$ for axion masses $m_\phi < 10^{-5}$eV. If shot-noise-limited sensitivity can be achieved, an experiment using high-finesse RF FP cavities could reach a factor of $\sim 10^6$ into new parameter space for $\tilde{g}_Q g_{\phi\gamma}$ for masses $m_\phi < 10^{-10}$eV.

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Recent Results of Dark Sector Searches with the BaBar Experiment

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Many scenarios of physics beyond the Standard Model predict new particles with masses well below the electroweak scale. Low-energy, high luminosity colliders such as BABAR are ideally suited to discover these particles. We present several recent searches for low-mass dark sector particles at BABAR, self-interacting dark matter, axion like particles, and dark sector particles produced in B meson decays. These examples demonstrate the importance of B-factories in fully exploring low-mass new physics and dark sectors.

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Electromagnetic interaction and freeze-out abundance of sexaquarks

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The sexaquark, a hypothesized six-quark bound state, has garnered interest as a potential dark matter candidate. At the same time, there are many arguments in the literature that place severe limitations on this possibility. Assuming it exists and is stable, I will advance a compelling case for the limited

viability of the sexaquark as a dark matter candidate by presenting the first calculation of its scattering electromagnetic cross section with Standard Model particles and by investigating its freeze-out abundance. The leading-order term in the electromagnetic cross section is due to the sexaquark's polarizability, which we obtained using lattice QCD. I will show that this implies a direct detection cross section that would be visible for a stable sexaquark constituting even a tiny fraction of the dark matter. I will also explore the expected sexaquark abundance derived from the freeze-out of its interactions in the early universe, and explore the detectability of such a thermally produced sexaquark component.

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Dispersive determination of Higgs boson mass

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We demonstrate that the Higgs boson mass can be extracted from the dispersion relation obeyed by the correlation function of two b-quark scalar currents. The solution to the dispersion relation with the input from the perturbative evaluation of the correlation function up to next-to-leading order in QCD and with the b quark mass $m_b = 4.43$ GeV demands a specific Higgs mass 115^{+13}_{-9} GeV. Our observation offers an alternative resolution to the long-standing fine-tuning problem of the Standard Model (SM): the Higgs mass is determined dynamically for the internal consistency of the SM. The similar formalism leads to the Z boson mass 90.8 GeV and the top quark mass 177 GeV. It is highly nontrivial to predict the above electroweak mass scales with at most 8\% deviation from the measured values using the single parameter m_b.

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Dissipative Genesis of the Inflationary Universe

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Inflationary models, especially those with plateau-type potentials, are consistent with the cosmological data, but inflation itself does not resolve the initial singularity. This singularity is resolved, for example, by the idea of the quantum creation of the Universe from nothing such as the tunneling and no-boundary proposals. The simplest one predicts a closed Universe. Motivated by these facts, we investigate the classical dynamics of a closed Universe with a plateau-type potential. Depending on the initial inflaton field value, the Universe can undergo a variety of events: an immediate Big Crunch, a bounce or cyclic phase, and inflation. Although the non-inflationary solutions may appear irrelevant to our Universe, they can be turned into single or multiple bounces followed by inflation, taking into account the interactions necessary for the reheating of the Universe after inflation. Thus, the dissipative mechanism in our setup explains both the graceful entry to and exit from inflation and gives us an indirect observational handle on the Universe just after creation. We also comment on the implications of these solutions on the probabilistic interpretations of the wave function of the Universe.

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Constraints on Long-Range Dark Matter-Standard Model Interactions From Dynamical Friction in Ultrafaint Dwarf Galaxies

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I will present a new constraint on long-range interactions between dark matter and the Standard Model, based on the effects of dynamical friction in ultrafaint dwarf galaxies (UFDs). Parsec-scale interactions between dark matter and the Standard Model are currently poorly constrained. However, such long-range forces can lead to a gradual transfer of kinetic energy from stars to the dark matter halo, reducing the velocity dispersion of the galaxy's stars at late times. Measurements of velocity dispersions in dwarf galaxies, combined with conservative assumptions about their initial conditions, therefore lead to constraints on such interactions. In particular, observations of the Segue 1 UFD constrain new forces with ranges above O(1) mpc to be no stronger than O(100) times gravity, improving on existing bounds at these ranges by several orders of magnitude.

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Recent results of the CONUS experiment

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In coherent elastic neutrino nucleus scattering (CEνNS), the neutrino interacts with the nucleus as a whole. This leads to a tiny recoil that can be registered with suitable detector technologies. The detection is highly challenging and requires a neutrino source within the coherent energy regime such as a nuclear power plant, a low enough energy threshold of the detectors and an excellent background suppression.
The CONUS experiment, which was located at 17m distance to the reactor core of the Brokdorf nuclear power plant, employed four high-purity Germanium detectors inside an elaborate shield. After successfully upgrading the setup for the latest and final run of the experiment, the energy threshold could be successfully lowered to <250eV$_{ee}$, which significantly enhances the sensitivity for CEνNS. I will report on the preliminary CEνNS analysis results from this run.

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Resurrecting Hitomi for X-ray Probes of Sterile Neutrino and Axion-Like-Particle Dark Matter with Blank Sky Observations

Authors: Chris Dessert[None]; Orion Ning[None]; Nicholas Llewellyn Rodd[1]; Benjamin Safdi[None]

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The Hitomi X-ray satellite mission carried unique high-resolution spectrometers that were set to revolutionize the search for sterile neutrino dark matter (DM) by looking for narrow X-ray lines arising from DM decays. Unfortunately, the satellite was lost shortly after launch, and to-date the only analysis using Hitomi for DM decay during its brief, one-month long live time was for data taken towards the Perseus cluster. In this work we present significantly stronger constraints on decaying DM from an analysis of archival Hitomi data towards blank sky locations, searching for DM decaying in our own Milky Way. The soon-to-be-launched XRISM satellite will have nearly identical soft-X-ray spectral capabilities to Hitomi; we project full-mission sensitivity for XRISM for analyses of their future blank-sky data, and we find that XRISM will have the leading sensitivity to decaying DM for masses between roughly 1 to 20 keV. We interpret the projected sensitivity in the context of sterile neutrino and heavy axion-like-particle DM scenarios.

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Constraints on axion-like polarization oscillations in the cosmic microwave background with POLARBEAR

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Very light pseudoscalar fields, often referred to as axions, are compelling dark matter candidates and can potentially be detected through their coupling to the electromagnetic field. Recently a novel detection technique using the cosmic microwave background (CMB) was proposed, which relies on the fact that the axion field oscillates at a frequency equal to its mass in appropriate units, leading to a time-dependent birefringence. For appropriate oscillation periods this allows the axion field at the telescope to be detected via the induced sinusoidal oscillation of the CMB linear polarization. We search for this effect in two years of POLARBEAR data. We do not detect a signal, and place a median 95% upper limit of 0.65 degrees on the sinusoid amplitude for oscillation frequencies between 0.02 1/days and 0.45 1/days, which corresponds to axion masses between 9.6×10ˆ−22 eV and 2.2×10ˆ−20 eV. Under the assumptions that 1) the axion constitutes all the dark matter and 2) the axion field amplitude is a Rayleigh-distributed stochastic variable, this translates to a limit on the axion-photon coupling g < 2.4×10ˆ−11 GeV−1×(m/10ˆ−21eV).

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Dirac neutrinos in the cosmic microwave background

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Upcoming CMB stage-IV experiments have the potential to measure the effective number of relativistic degrees of freedom in the early Universe, Neff, with percent-level accuracy. Many Dirac-neutrino models that aim to address the Dirac stability, the smallness of neutrino masses or the matter-antimatter asymmetry of our universe endow the right-handed partners νR with additional interactions that can thermalize them, leading to testable deviations in Neff. We discuss well-motivated models for νR interactions such as new gauge bosons and Dirac-leptogenesis mediators, and compare the sensitivity of CMB stage-IV experiments to other experiments, in particular the LHC.

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Exploring New Physics Signatures in an Alternative Left-Right Model

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Co-authors: Chayan Majumdar [2]; Mariana Frank [3]; Poulose Poulose [4]; Urjit A. Yajnik [5]

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Left-Right (LR) theories are one of the successful beyond Standard Model (SM) frameworks that explain the origin of small neutrino masses and low-energy weak parity violation. However, the conventional LR theory faces a challenge due to the presence of flavor changing neutral currents (FCNCs). To address this, we have studied an Alternative LR model (ALRM), which avoids FCNC constraints. Our study shows that ALRM has distinct new physics signatures compared to conventional LR symmetric models in neutrinoless double beta decay and leptogenesis. Specifically, we show that the vector-scalar mediated diagrams contribute significantly in neutrinoless double beta decay while the small Dirac CP-phase in the right handed neutrino sector can saturate the current BAU bound. Additionally, our model predicts several dark matter candidates stabilised by an R-parity, similar to supersymmetry.

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From SuperMAG to SNIPE Hunt: Using the Earth to search for ultralight dark matter

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Co-author: SNIPE Hunt Collaboration

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Ultralight bosonic particles, including axionlike particles and kinetically mixed dark photons, can be promising dark matter candidates. It was recently shown that the Earth can act as a transducer for ultralight dark matter detection, by converting the dark matter into an oscillating monochromatic magnetic field signal across the Earth's surface. This occurs because the ground and ionosphere both act as good conductors, forming a (non-resonant) cavity similar to those in shielded laboratory experiments, like DM Radio. In this talk, I review the Earth transducer effect and recent searches for the effect at low frequencies using geomagnetic field data from the SuperMAG collaboration. I also discuss recent and ongoing efforts by the SNIPE Hunt collaboration to search for this effect at higher frequencies, by measuring the magnetic field in radio-quiet locations. In particular, I focus on how environmental effects lead to large uncertainties in the signal, and how these can be avoided by measuring the local curl of the magnetic field.

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eV-scale sterile neutrino searches with reactor neutrino experiment PROSPECT

Author: Xiaobin Lu[None]

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PROSPECT, the Precision Reactor Oscillation and SPECTrum Experiment, is a short-baseline reactor-based neutrino experiment aiming to make a precision measurement of reactor antineutrino energy

spectra and model-independently search for eV-scale sterile neutrinos. The experiment collected over 50,000 neutrino interactions over the course of five reactor-on cycles at the High Flux Isotope Reactor (HFIR) at Oak Ridge National Laboratory in 2018. Based on the same dataset, we performed relative energy spectra comparison between baselines and found no statistically significant indication of sterile neutrino mixing and disfavored the Reactor Antineutrino Anomaly best-fit point at 2.5σ confidence level. This talk will present an overview of reactor neutrino anomaly and the latest results and updates from PROSPECT.

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Dark Matter p-wave Annihilation Flux Enhancement Near the Supermassive Black Hole at the Center of M87*

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The existence of supermassive black holes at the center of galaxies redistributes the dark matter density profile in the region of influence and creates a higher density region so-called density spike. In the self-interaction dark matter scenario, the velocity dispersion in the spike region scales with a power law of rˆ−1/2, and the density spike scales with a power law of rˆ−(3+a)/4, where "a" is the parameter where the self-scattering scales with velocity. In this work, we calculate the J-factor and Q-factor for Sommerfeld-Enhanced s-wave and p-wave annihilation for the M87* galaxy and show that the p-wave annihilation flux can be enhanced and become at the same order as s-wave annihilation at higher dark matter masses.

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Axion dark matter echoes: a global analysis of astrophysical sources

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Axion dark matter produces echo images of bright radio sources due to stimulated decay. These echo images take the form of a faint radio line centered at half the axion mass with a width determined by the dark matter velocity dispersion. Due to the kinematics of the decay, the echo image can either be antipodal to the incoming source of stimulating radiation (gegenschein) or can be along the same line of sight as the source ("forwardschein"). We present an all-sky analysis of axion dark matter-induced echo images using extragalactic radio point sources (i.e. radio galaxies), supernova remnants (SNRs), and galactic synchrotron radiation as sources of stimulating radiation. Because galactic synchrotron radiation is diffuse and faint compared to point sources, we find that the forwardschein constitutes a large fraction of the signal, particularly in the direction of the Galactic center. We find that existing radio telescopes like the Canadian Hydrogen Intensity Mapping Experiment (CHIME) may already be sensitive to axion dark matter (DM) with just given archival data.

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XENONnT: The First Results

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The current best limits on properties of potential particle physics candidates for dark matter are set by direct dark matter detectors using high purity liquid xenon. XENONnT, with 5.9 tonnes of instrumented liquid xenon, was commissioned in the middle of 2021, and completed its first science run in 2022. This talk will present the results of the first science run of XENONnT.

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Electroweak Dumbbells and their dynamics

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The "electroweak dumbbell"consists of a magnetic monopole and an antimonopole of the standard electroweak model connected by a string made of Z-magnetic field. The dumbbells formed during the epoch of electroweak symmetry breaking in the early Universe undergo annihilation, and leave behind cosmological relic magnetic fields. Electroweak dumbbells may also be produced in scattering experiments and their lifetimes could have important implications for high energy experimental searches for monopoles. We have studied the structure of static electroweak dumbbells using "constrained relaxation"for a range of separations and twists, and find that dumbbells with a twist have a novel magnetic field structure. Finally, we will use the field configuration provided by our relaxation method to study the dynamics of rotating dumbbells and their lifetimes.

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Recurrent Axinovae and their Cosmological Constraints

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Axion-like dark matter whose symmetry breaking occurs after the end of inflation predicts enhanced primordial density fluctuations at small scales. This leads to dense axion minihalos (or miniclusters) forming early in the history of the Universe.
Condensation of axions in the minihalos leads to the formation and subsequent growth of axion stars at the cores of these halos. If, like the QCD axion, the axion-like particle has attractive self-interactions there is a maximal mass for these stars, above which the star rapidly shrinks and converts an $\mathcal{O}(1)$ fraction of its mass into unbound relativistic axions. This process would leave a similar (although in principle distinct) signature in cosmological observables as a decaying dark matter fraction, and thus is strongly constrained. We place new limits on the properties of axion-like particles that are independent of their non-gravitational couplings to the standard model.

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Gravitational wave signals of ultralight axion dark matter

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We study the gravitational wave signals of ultralight axion dark matter around Kerr black hole by LISA in synergy with SKA.

Plenary / 40

Dark Photons and Magnetic Charge

Author: Christopher Verhaaren[1]

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The gauge bosons of a hidden U(1) sector seems to be one of the simplest extensions of the standard model. However, if this hidden sector includes magnetic charges a host of novel phenomena result. These include new dark matter possibilities with distinctly new way to detect them. I give an overview of some of the phenomena and theoretical understanding that hidden magnetic monopoles provide.

Parallel / 41

Constraints on the muon spin force from co-magnetometer experiments

Authors: Yohei Ema[None]; Ting Gao[None]; Maxim Pospelov[None]

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There are many New Physics scenarios that may affect the current discrepancy between the measurement and the prediction of the muon anomalous magnetic moment. One such possibility is a long-range force created by ordinary atoms acting on the muon spin. If the muon $g-2$ discrepancy is attributed to such a force, it would imply a tiny, $\mathcal{O}(10^{-13})$ eV spin energy splitting between muon state polarized in the vertical direction. However, the absence of nuclear spin coupling to a vertical direction has been tested with $\mathcal{O}(10^{-21})$ eV accuracy in ^{199}Hg/^{201}Hg and ^{129}Xe/^{131}Xe systems. We analyze the radiative transfer of the muon spin coupling to nuclear spin coupling. Despite significant nuclear uncertainties, we show that experiments with ordinary atoms set indirect constraints on the exotic muon spin coupling at a factor of a few more stringent than suggested by the muon $g-2$.

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Computing (Anti)-de Sitter Graviton Function through Generalized On-Shell Recursion Relation

Author: Savan Kharel[None]

Co-author: Soner Albayrak

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I will focus on the computation of graviton function in (Anti)-de Sitter space, specifically concentrating on gravitons with all positive external helicity. To tackle this problem, I will introduce a generalized recursion method inspired by the BCFW (Britto-Cachazo-Feng-Witten) technique. This method involves a deforming of the external momentum of the graviton function by complexifying it and does not require Feynman-Witten diagrams. The main emphasis of my talk will be on the calculation of four graviton of all plus helicity in three-dimension, utilizing the three-dimensional spinor helicity formalism. The final result will be obtained by summing the residues of physical poles. Additionally, I will highlight the implications of this research for the cosmological bootstrap program. Finally, I will discuss future directions of research, including the computation of higher point expressions.

Parallel / 43

Title: Gravitational waves from strongly-coupled theories: a 2PI approach

Author: Eleanor Hall[None]

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Abstract: Gravitational waves from cosmological phase transitions offer the chance to probe the very first second of the universe's history and are one of our most promising signal channels of BSM physics. With space-based detectors such as LISA on the horizon, we urgently need reliable tools for predicting GW signals in strongly-coupled theories. In this talk, I discuss our recent proposal for a new, non-perturbative "quasi-stationary effective action"for false vacuum decay rate calculations based on the functional renormalization group as well as new developments extending our method in the language of the 2PI formalism. This work opens the door to non-perturbative GW predictions in strongly-coupled BSM theories and new avenues for precision calculations in the standard model.

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Probing Left-Right Symmetry at Energies High and Low

Author: Lukas Graf[1]

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Restoration of left-right symmetry at high energy scales provides a well-motivated extension of the Standard Model, which has been scrutinized over the past few decades and that can be viewed as the intermediate step towards grand unification. In my talk, I will investigate whether these models can be probed via the search for a stochastic gravitational wave background induced by the left-right phase transition. A prerequisite for this kind of gravitational wave production is a first-order phase transition, occurrence of which can be found in a significant portion of the parameter space. At the

same time, I will discuss constraints that can be imposed on left-right symmetric models by double beta decay experiments or colliders.

Parallel / **45**

Axion Poltergeist

Author: Keisuke Inomata[1]

Co-authors: Keisuke Harigaya [2]; Takahiro Terada [3]

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Rotations of axion fields in the early universe can produce dark matter and matter-antimatter asymmetry of the universe.
In a class of models, the equation of state of the rotations rapidly changes from a non-relativistic matter-like one to a kination-like one.
We point out that the rapid change can produce an observable amount of gravitational waves through the Poltergeist mechanism.

Parallel / **46**

Precise Estimate of Decay of Charged Fermion in Electroweak-Charged Dark Matter Model

Authors: Masahiro Ibe[1]; Masataka Mishima[2]; Satoshi Shirai[3]; Yuhei NAKAYAMA[4]

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An electroweak-charged dark matter Model a well-motivated dark matter candidate. The Wino, Higgsino and 5plet fermions are typical examples.
In these models, the charged partner becomes metastable.
Disappearing charged tracks and soft objects produced by the charged partner are important for the test of this model in collider experiments.
The signals strongly depend on the lifetime and decay branching ratio of the charged partner.
Therefore, accurate theoretical calculations of the decay are required.
In this talk, I will present the state-of-the-art results incorporating with loop corrections for these decays and discuss implications for the collider signal.

Parallel / **47**

Resurgence and self-completion in renormalized gauge theories

Author: Juan Carlos Vasquez[1]

Co-author: Alessio Maiezza

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Under certain assumptions and independent of the instantons, we show that the logarithm expansion of dimensional regularization in quantum field theory needs a nonperturbative completion to have a renormalization-group flow valid at all energies. Then, we show that such nonperturbative completion has the analytic properties of the renormalons, which we find with no reference to diagrammatic calculations. We demonstrate that renormalon corrections necessarily lead to analyzable functions, namely, resurgent transseries. A detailed analysis of the resurgent properties of the renormalons is provided. The self-consistency of the theory requires these nonperturbative contributions to render the running coupling well-defined at any energy, thus with no Landau pole. We illustrate the point within the case of QED. This way, we explicitly realize the correspondence between the nonperturbative Landau pole scale and the renormalons. What is seen as a Landau pole in perturbation theory is cured by the nonperturbative, resurgent contributions.

Parallel / **48**

An SZ-Like Effect on Stochastic Gravitational Wave Backgrounds

Authors: Marcell Howard[None]; Morgane Konig[1]; Tatsuya Daniel[2]

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Stochastic gravitational wave backgrounds (SGWBs) are the conglomeration of unresolved gravitational wave signals from the early universe and from astrophysical sources, which make them a promising tool for cosmologists. Because gravitons decouple from the cosmic plasma early on, one can consider interactions between gravitons and any particle species that were present in the very early universe. Analogous to the cosmic microwave background, inverse Compton scattering on any stochastic background will induce small distortions in its energy density spectrum. We then quantify how small these spin dependent spectral distortions are when attributed to the dark matter in the early Universe. In a more general approach, looking at the spin dependent distortion of the SGWB could indicate possible Beyond the Standard Model physics.

Parallel / **49**

Baryogenesis and Dark Matter In Multiple Hidden Sectors

Author: Daniel Stolarski[1]

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I will describe a unified mechanism for generating a baryon and dark matter asymmetry in models with multiple hidden sectors that are Standard Model-like but with varying Higgs mass parameters. These models have a unique cosmology with the different sectors reheated asymmetrically

to relatively low temperature. A hidden sector with positive Higgs mass squared can accommodate dark matter with its baryon asymmetry, and the larger abundance of dark matter relative to baryons is explained by the fact that the dark sphaleron is active all the way down the hidden sector QCD scale. This scenario predicts that dark matter is clustered in large dark nuclei and that $\Delta N_{\rm eff} > 0.05$.

Parallel / 50

First WIMP search results from LZ and outlook

Author: Hao Chen[None]

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LUX-ZEPLIN (LZ) is located at Sanford Underground Research Facility (SURF) in Lead, South Dakota. It uses a dual-phase xenon time projection chamber to search for Weakly Interacting Massive Particles (WIMP) and other new physics beyond the Standard Model. LZ completed its first science run in 2022. With its low background and large mass (7 tonne) of liquid xenon, LZ has set the most stringent limits on WIMP-nucleon cross-sections for WIMP masses above 9 GeV. This talk will provide an overview of the LZ detector, its first WIMP search results and future plans.

Parallel / 51

A Parametric Model for Self-Interacting Dark Matter Halos

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We propose a parametric model for studying self-interacting dark matter (SIDM) halos. The model uses an analytical density profile, calibrated using a controlled N-body SIDM simulation that covers the entire gravothermal evolution, including core-forming and -collapsing phases. By normalizing the calibrated density profile, we obtain a universal description for SIDM halos at any evolution phase. The model allows us to infer properties of SIDM halos based on their cold dark matter (CDM) counterparts. As a basic application, we only require two characteristic parameters of an isolated CDM halo at $z = 0$. We then extend the model to incorporate effects induced by halo mass changes, such as major mergers or tidal stripping, making it applicable to both isolated halos and subhalos. The parametric model is tested and validated using cosmological zoom-in SIDM simulations available in the literature. It can be integrated into semi-analytic CDM models to generate theoretical predictions at all scales.

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The DarkSide experimental program: Dark Matter detection with liquid argon targets

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Among the numerous technologies developed in the field of Dark Matter direct detection, noble element dual-phase time projection chambers (TPC) have proved to be an outstanding solution, scalable to extremely high target masses without dramatic increases in read-out complexity. The DarkSide programme pioneered the use of liquid argon as a DM scattering target in such detectors and is now preparing to build a multi-tonne experiment.
In my talk I will first review the major scientific accomplishments of DarkSide-50, a 50kg active mass detector which operated since mid-2015 with a fill of low-radioactivity argon from underground sources. I will give particular emphasis to the recent, world-leading results obtained on Light Dark Matter (for candidates with mass $< 20GeV/c^2$). I will then detail the design of the DarkSide-20k detector, currently under construction. Like its predecessor, DarkSide-20k will be housed at the INFN Gran Sasso (LNGS) underground laboratory. This experiment features a 20-tonne fiducial mass target hosted in dual-phase argon TPC, which is read out by novel SiPM-based cryogenic photosensors. DarkSide-20k is expected to attain a cross-section 90% C.L. exclusion sensitivity of $7.4 \times 10^{-48}\ cm^2$ during a 200 tonne-year run for a $1\ TeV/c^2$ WIMP, down to the level where scattering from atmospheric neutrinos become the limiting background.

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Probing Axionic Instabilities in the late Universe via CMB-B mode

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We study the cosmological signatures of a completely secluded dark sector consisting of axion-like particles (ALPs) with anomalous coupling to a dark Abelian gauge boson. The lighter ALP starts rolling during matter domination and produces dark photons through tachyonic instabilities. The resulting exponential growth in dark photon quanta sources tensor and scalar perturbations which are uncorrelated with the inflationary initial perturbation. These perturbations generate temperature and polarization (E and B mode) anisotropies in the CMB. We constrain the parameter space of the ALP-dark photon system using the CMB measurement from Planck and B mode constraints from the BICEP-Keck array. For most of the viable parameter space, the B mode signal is well within the reach of future B mode experiments. Additionally, this scenario exhibits intrinsic CP violation and produces non-zero EB correlation in the CMB spectrum. We analyze the CP violating signature in light of the recent measurement of cosmic birefringence from Planck data which shows striking deviation from CP symmetry.

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Neutrino Mass Ordering from Discrete Flavor Symmetry

Authors: Cesar Bonilla Díaz[1]; Eduardo Peinado[2]; Johannes Herms[3]; Omar Medina[4]

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We present a model that explains the origin of the neutrino mass ordering through the spontaneous breaking of a discrete flavor symmetry. Our model addresses the hierarchy between neutrino masses by combining the seesaw and scotogenic mechanisms, both emerging naturally from an A_4 discrete symmetry broken at the electroweak scale. The model incorporates a scalar dark matter particle stabilized by a residual $\mathbb{Z}_2$ symmetry, as well as an extensive beyond the Standard Model scalar sector, and it provides a prediction for neutrino masses.

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Evaporation Barrier for Dark Matter in Celestial Bodies

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The minimum testable dark matter (DM) mass for almost all DM signatures in celestial bodies is determined by the rate at which DM evaporates. DM evaporation has previously been calculated assuming a competition between the gravitational potential of the object, and thermal kicks from the celestial-body matter. I will point out a new effect, where mediators with a range larger than the interparticle spacing induce a force proportional to the density gradient of celestial objects, forming an evaporation barrier for the DM. This effect can be so significant that evaporation does not occur even for sub-MeV DM, in stark contrast to previous calculations. This opens up a wide range of new light DM searches, many orders of magnitude in DM mass below the sensitivity of direct detection.

Parallel / 59

A New Window into Gravitationally Produced Scalar Dark Matter

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In this presentation, I discuss the production of a spectator scalar dark matter field that directly couples to the inflaton. Conventional scenarios of purely gravitationally produced dark matter with masses below the Hubble parameter at the end of inflation are in tension with Cosmic Microwave Background (CMB) constraints on the isocurvature power spectrum. We explore a more general scenario with a non-minimal coupling between the scalar dark matter field and gravity, which allows for significantly lighter scalar dark matter masses compared to minimal coupling predictions. By imposing relic abundance, isocurvature, Lyman-α, and Big Bang Nucleosynthesis (BBN) constraints, we show the viable parameter space for these models. Our findings demonstrate that the presence of a non-minimal coupling expands the parameter space, yielding a dark matter mass lower bound of 2x10^{-4} eV.

Parallel / 60

Latest results from the CUORE experiment

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The Cryogenic Underground Observatory for Rare Events (CUORE) is the first bolometric experiment searching for $0\nu\beta\beta$ decay that has been able to reach the one-tonne mass scale. The detector, located at the LNGS in Italy, consists of an array of 988 TeO_2 crystals arranged in a compact cylindrical structure of 19 towers. CUORE began its first physics data run in 2017 at a base temperature of about 10 mK and in April 2021 released its 3rd result of the search for $0\nu\beta\beta$, corresponding to a tonne-year of TeO_2 exposure. This is the largest amount of data ever acquired with a solid state detector and the most sensitive measurement of $0\nu\beta\beta$ decay in ^{130}Te ever conducted, with a median exclusion sensitivity of 2.8×10^{25} yr. We find no evidence of $0\nu\beta\beta$ decay and set a lower bound of 2.2×10^{25} yr at a 90% credibility interval on the ^{130}Te half-life for this process. In this talk, we present the current status of CUORE search for $0\nu\beta\beta$ with the updated statistics of one tonne-yr. We finally give an update of the CUORE background model and the measurement of the ^{130}Te $2\nu\beta\beta$ decay half-life.

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Cosmic Stasis from Primordial-Black-Hole Evaporation and Its Phenomenological Implications

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Cosmic stasis is a phenomenon in which the abundances of multiple cosmological energy components —components such as matter, radiation, or vacuum energy —remain effectively constant despite the expansion of the universe. One mechanism which can give rise to an extended period of cosmic stasis is the evaporation of a population of primordial black holes (PBHs). In this talk, I review how PBH evaporation can lead to a stasis epoch and examine the observational consequences of such a modification to the cosmic expansion history. These include implications for inflationary observables, for the stochastic gravitational-wave background, and for the production of dark matter and dark radiation.

Parallel / 62

The role of dimension-8 operators in an EFT for the 2HDM

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The Standard Model effective field theory (SMEFT) is a standard tool for parametrizing the effects of new physics. The ordiinary approach to SMEFT is to use the truncation at dimension-6, which would typically be the leading contribution beyond the Standard Model. We perform the matching

to dimension-8 in the two-Higgs-doublet model (2HDM) and critically examine the dimension-6 and dimension-8 truncations. We find that the dimension-6 truncation fails to capture important physics contributions in the 2HDM.

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Cosmologically Varying Kinetic Mixing

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The portal connecting the invisible and visible sectors is one of the most natural explanations of the dark world. However, the early-time dark matter production via the portal faces extremely stringent late-time constraints. To solve such tension, we construct the scalar-controlled kinetic mixing varying with the ultralight CP-even scalar's cosmological evolution. To realize this and eliminate the constant mixing, we couple the ultralight scalar within the mass range 10−33eV«m0«eV with the heavy doubly charged messengers and impose the Z2 symmetry under the dark charge conjugation. Via the varying mixing, the keV–MeV dark photon dark matter is produced through the early-time freeze-in when the scalar is misaligned from the origin and free from the late-time exclusions when the scalar does the damped oscillation and dynamically sets the kinetic mixing. We also find that the scalar-photon coupling emerges from the underlying physics, which changes the cosmological history and provides the experimental targets based on the fine-structure constant variation and the equivalence principle violation.

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'DarkPACK': A modular software to compute BSM squared amplitudes for particle physics and dark matter observables

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DarkPACK is a software that automatically generates a numerical library of scattering amplitudes from the Lagrangian density of the model, to compute dark matter observables such as relic density. It relies on MARTY and SuperIso relic and is written in C++. In the current version, DarkPACK can easily generate all the squared amplitudes of 2 NP particles into 2 Standard Model particles at leading order. Thanks to its modularity, it is easy to link it with other software and to extend its features.

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Imprints of Ultra-light Axions in the Halo Bias

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Ultra-light axions with masses $10^{-33} < m_\phi/\mathrm{eV} < 10^{-22}$ are allowed to constitute only a small fraction of the observed dark matter abundance. Nevertheless, they may yet produce a visible impact on the cosmology due to their macroscopic quantum scale. Next generation galaxy survey data are poised to challenge this possibility, but in order to do so, all aspects of structure formation in this quasi-linear regime must be accounted for consistently and precisely. This includes modeling not only the effect of these axions on the background cosmology and matter fluctuations, but also on the halo bias that governs the tracers we observe, namely galaxies. In this work we discuss the effect of ultra-light axions on cosmological observables, and present a prescription for computing the growth-induced scale-dependent bias in their presence. We find that these axions introduce a step in the halo bias at their characteristic Jeans scale, representing - even at percent-level abundances - a sizable increase in the total scale-dependence of the bias, compared to the ΛCDM fiducial. We implement this prescription as a function of axion mass and relic abundance, in a public package which we dub {\tt RelAxiFast}, an extension of the extant {\tt RelicFast}.

Parallel / 66

Is Cosmic Birefringence model-dependent?

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Exciting clues to isotropic cosmic birefringence have recently been detected in the EB cross-power spectra of the polarization data of the cosmic microwave background (CMB). Early Dark Energy (EDE) models with a pseudoscalar field coupled to photons via a Chern-Simons term can be used to explain this phenomenon, and can also potentially be used to simultaneously resolve the H_0 tension. In this work we incorporate an early dark energy scalar field, including a Chern-Simons coupling, into an existing Boltzmann solver and numerically recover the EB cross-power spectrum for two models in the literature; the α-attractor, and the Rock 'n' Roll field. We find that both the models fit the EB spectra, and the EB spectra alone do not possess sufficient constraining power to distinguish the two models based on current data.

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Probing Axions via Light Circular Polarization and Event Horizon Telescope

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The impact of axion-like particles on the light polarization around the horizon of supermassive black hole (SMBH) is discussed in the light of the latest polarization measurement of the Event Horizon Telescope (EHT). We investigate different sources of the polarization due to axion interaction with photons and the magnetic field of SMBH. These can modify the linear and circular polarization parameters of the emitted light. We have shown that a significant circular polarization can be produced via the photon scattering from the background magnetic field with axions as off-shell particles. This

can further constrain the parameter space of ultralight axion-like particles and their couplings with photons.

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Probing the Local Dark Matter Halo with Neutrino Oscillations

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Dark matter particles can form halos gravitationally bound to massive astrophysical objects. The Earth could have such a halo where depending on the particle mass, the halo either extends beyond the surface or is confined to the Earth's interior. We consider the possibility that if dark matter particles are coupled to neutrinos, then neutrino oscillations can be used to probe the Earth's dark matter halo. In particular, atmospheric neutrinos traversing the Earth can be sensitive to a small size, interior halo, inaccessible by other means. Depending on the halo mass and neutrino energy, constraints on the dark matter-neutrino couplings are obtained from the halo corrections to the neutrino oscillations.

Plenary / 70

Top-Down Aspects of Modular and Eclectic Flavor Symmetries

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Modular transformations of string theory are shown to play a crucial role in the discussion of discrete flavor symmetries in the Standard Model. They include CP transformations and provide a unification of CP with traditional flavor symmetries within the framework of the eclectic flavor scheme. The unified flavor group is non-universal in moduli space and exhibits the phenomenon of "Local Flavor Unification", where different sectors of the theory (like quarks and leptons) can be subject to different flavor structures.

Parallel / 71

Metaplectic Flavor symmetries from magnetized tori

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Modular flavor symmetries have gained significant attention as a promising method for predicting lepton mixing parameters. However, in a bottom-up approach, the lack of precise control over the parameters in the kinetic terms limits their predictability . To address this, we propose deriving the Yukawa couplings from an underlying geometry, specifically magnetized tori.

In this talk, we will present a systematic methodology to derive the Yukawa couplings based on magnetized tori, utilizing Euler's theorem. Furthermore, we will explore the modular transformations of these couplings to unravel the underlying modular flavor symmetry. Our findings demonstrate the emergence of the metaplectic modular groups as the flavor symmetry governing the system. Finally, we will discuss potential models that can be constructed using this approach

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Neutrino Mass and Mixing From Eclectic Flavor Symmetry

Author: Xiang-Gan Liu[1]

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The Kahler potentials of modular symmetry models receive unsuppressed contributions which may be controlled by a flavor symmetry, where the combination of the two symmetry types is referred to as eclectic flavor symmetry. After briefly reviewing the consistency conditions of eclectic flavor symmetry models, including those with generalised (g)CP, we perform a comprehensive bottom-up study of eclectic flavor symmetry models based on $\Omega(1)$, consisting of the flavor symmetry $\Delta(27)$ in a semi-direct product with the modular symmetry T'. The modular transformations of different $\Delta(27)$ multiplets are given by solving the consistency condition. The eight nontrivial singlets of $\Delta(27)$ are related by T' modular symmetry, and they have to be present or absent simultaneously in any $\Omega(1)$ model. The most general forms of the superpotential and Kahler potential invariant under $\Omega(1)$ are discussed, and the corresponding fermion mass matrices are presented. Based on the eclectic flavor group $\Omega(1)$, two concrete lepton models which can successfully describe the experimental data of lepton masses and mixing parameters are constructed. For the two models without gCP, all six mixing parameters vary in small regions. A nearly maximal atmospheric mixing angle θ_{23} and Dirac CP phase δ_{CP} are obtained in the first model. After considering the compatible gCP symmetry and the assumption of $\Re\tau = 0$ in the first model, the $\mu - \tau$ reflection symmetry is preserved in the charged lepton diagonal basis. As a consequence, the atmospheric mixing angle and Dirac CP phase are predicted to be maximal, and two Majorana CP phases are predicted to be π.

Parallel / **73**

Visible in the lab and invisible in cosmology: decaying sterile neutrinos

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We explore possible mechanisms of suppressing the production of keV scale sterile neutrinos, which is the target parameter space of several current/upcoming laboratory experiments such as KATRIN,

HUNTER or MAGNETO-nu. These alternative scenarios include universes with a nontrivial cosmic lepton number, new neutrino interactions with light bosons, late-time neutrino mass generation, low reheating temperature universes, or phase transitions in the early universe. We analyze which theoretical models could explain the first detected remnant from the untested pre-BBN era in the Universe. Particularly within a low reheating Universe, a dark decay through a Z? or a new scalar, can lead to 3-body or 2-body decay to relativistic particles which doesn't violate any existing cosmological constraints and moreover provides a solution to the Hubble tension.

Parallel / **74**

Excited Q-balls

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Complex scalars in U(1)-symmetric potentials can form stable Q-balls, non-topological solitons that correspond to spherical bound-state solutions. If the U(1) charge of the Q-ball is large enough, it can support a tower of unstable radial excitations with increasing energy. Previous analyses of these radial excitations were confined to fixed parameters, leading to excited states with different charges Q. In this work, we provide the first characterization of the radial excitations of solitons for fixed charge, providing the physical spectrum for such objects. We also show how to approximately describe these excited states analytically and predict their global properties such as radius, energy, and charge. This enables a complete characterization of the radial spectrum. We also comment on the decay channels of these excited states.

Plenary / **75**

Stasis, Stasis, Stasis

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Parallel / **76**

Simulating Heavy Neutral Leptons at Forward Collider and Fixed Target Experiments

Author: Alec Hewitt[None]

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Heavy Neutral Leptons (HNLs) are among the leading examples of long-lived particles. For masses in the MeV to GeV range, HNLs are light enough to be produced at many collider and accelerator facilities, but also heavy enough to decay to visible particles on length scales that can be observed in particle detectors. We discuss the FORESEE simulation package to include the production and decay of HNLs, providing a user-friendly, relatively fast, and highly flexible tool to evaluate the prospects for HNL discovery at ongoing and proposed experiments. The framework accommodates a large range of HNL masses and arbitrary couplings to e, μ, and τ leptons. As examples, we present sensitivity reaches for five benchmark scenarios with coupling ratios $U_e^2 : U_\mu^2 : U_\tau^2$ = 1:0:0, 0:1:0, 0:0:1, 0:1:1, and 1:1:1 for FASER and proposed experiments at the Forward Physics Facility.

Plenary / **77**

Searching for New Physics with NANOGrav

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Pulsar timing array experiments aim to detect nHz-frequency gravitational waves using high-precision timing of millisecond pulsars. Of particular interest is a stochastic gravitational wave background (SGWB), which is expected to arise predominantly from a population of inspiraling supermassive black hole binaries, but there may also be contributions from exotic cosmological sources, such as inflation, first-order phase transitions, and topological defects. On behalf of the North American Nanohertz Observatory for Gravitational Waves (NANOGrav) collaboration, I will present the search for a SGWB using the latest NANOGrav data and show the results of our analyses for various early universe physics scenarios. I will also discuss searches for signatures of dark matter models that impart deterministic signals in the timing data.

Plenary / **78**

Forecasting axionic isocurvature detectability in Euclid and MegaMapper using EFTofLSS

Author: Daniel Chung[1]

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Out of equilibrium axionic sector can generate blue isocurvature perturbations with a rich variety of spectra. Given that future galaxy surveys are probing shorter length scales with a greater accuracy, blue isocurvature perturbations are natural targets for these surveys. After a brief overview of blue axionic perturbations, a Fisher forecast for the Euclid and MegaMapper experiments in their ability to detect blue isocurvature perturbations will be presented. Some interesting features that arise in the EFTofLSS and bias expansion due to the blueness of the isocurvature spectrum will also be discussed.

Plenary / **79**

Lepton Flavor Portal Matter

Author: Lisa Everett[None]

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We discuss recent model-building directions within the general kinetic mixing/vector portal dark matter paradigm in which the portal matter is embedded together with the second and third generation Standard Model leptons in irreducible representations of a non-Abelian dark sector gauge group.

Plenary / **80**

Modular Invariance and the Strong CP Problem

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Solutions of the strong CP problem based on modular invariance are discussed in several frameworks.

Plenary / 81

A status report on the black hole information problem

Author: Daniel Harlow[1]

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In the last decade our understanding of holography has reached the point where a resolution of Hawking's black hole information problem seems to be in reach. In this talk I'll give a high-level overview of where we are now.

Plenary / 82

Enhancement of Particle Phenomena by High-Spin Black Holes

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As a black hole tends towards maximal spin the near-horizon region develops a throat-like geometry of divergent proper volume. The development of this throat has consequences on observable phenomena. Herein we will examine two such examples. First we consider adiabatic growth of a black hole within a cloud of particles. For a high-spin black hole this process results in a finite nonzero matter density within the near-horizon region. While the matter density remains finite the total mass enclosed within the near-horizon region diverges. Secondly we consider collision between infalling particles and those at the innermost stable circular orbit. These collisions can have arbitrarily high center of mass energy when they occur around a high-spin black hole. In this regime we examine the specific case of proton-electron bremsstrahlung and calculate properties of the photons that constitute the collision ejecta.

Plenary / 83

Majorana phase and matter effects in neutrino chiral rotation

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Announcing PASCOS 2024

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New physics at low redshift cannot be the sole explanation for the H0 tension

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What has everyone so excited about the H0 tension is the potential for discovering new physics. In particular, the question of new physics explanations for this tension are often divided into whether the new physics plays a role at high redshift or low redshift. In this talk, I will make the case that there can be no low-redshift solution to the H0 tension. To robustly answer this question, I used a very flexible parametrization for the dark energy equation of state, w(z), such that every cosmological distance still allowed by the data exists within this prior volume. To then answer whether there exists a satisfactory solution to the H0 tension within this comprehensive parameterization, I constrained the model using different partitions of the Planck, eBOSS/SDSS DR16 BAO, Pantheon SN and SH0ES H0 datasets. When constrained by just the CMB+H0 datasets, there exists a set of w(z) which yields high H0 values, but these w(z) functions are ruled out by the SN and BAO datasets. In other words, the constraint from CMB+SN+BAO datasets does not allow for high H0 values and converges around w(z)=-1. Thus, the search for a solution to the H0 tension should focus on high-redshift solutions. Hopefully ACT/SPTPol/CMB-S4 will be able to detect such instances of new physics on their own in order to make a convincing case for a solution to the H0 tension.

Plenary / 86

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Conformal extensions of the Standard Model

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Plenary / 88

Seesaw Light Dark Matter from Higgs Decay

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Neutron Star Heating: WIMP DM vs Others

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Weakly Interacting Massive Particles (WIMPs) in the Universe accumulate in neutron stars (NSs) through their interactions with ordinary matter and their annihilation inside the NS core causes late-time heating. It has been argued that this heating effect maintains the surface temperature of old NSs to be a few thousand K which can be regarded as a smoking gun signature of dark matter (DM) heating in NSs. However if other heating mechanisms exist they may hide this effect of the DM heating making it impossible to search for DM with this strategy. In fact recent observations suggest that there may be some heating sources in NSs. In this talk I will review such heating mechanisms and discuss their implications for the DM search using NS temperature observations.

Plenary / 90

HEFT, SMEFT and Higgsing—the on-shell way

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Dark Energy with a Little Help from its Friends

Author: Susha Louise Parameswaran[1]

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It has proven surprising difficult to obtain a microscopic understanding of Dark Energy within string theory. The two main paradigms, a landscape of de Sitter vacua or slow-roll quintessence, seem to require working at the boundaries of control, which has led to much fruitful debate. I will discuss alternative scenarios for Dark Energy within string theory, in which interacting Dark Sectors – including Dark Radiation, Dark Matter or mutual-aid Dark Energy – can source a late-time, transitory accelerated expansion. These scenarios require no fine-tuning of initial conditions, only mild fine-tuning for light masses, have potentially observable consequences, and are consistent with recent string theory 'swampland conjectures'.

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Cosmic Probes of the Dark Sector

Author: Chanda Prescod-Weinstein[1]

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In this talk, I will motivate why in the 2020s so many of us are focusing on astrophysics and cosmology as an important tool for studying one of the most challenging questions in all of particle physics: determining what exactly dark matter is comprised of. I will focus most especially on questions relating to large-scale structure an axion-like particle models, as well as on asymmetric dark matter in neutron stars as valuable exemplars of interesting work that is underway.

Plenary / 93

Quantum transitions in the string landscape and detailed balance

Author: Fernando Quevedo[None]

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Plenary / 94

Light Scalars at FASER

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FASER, the ForwArd Search ExpeRiment, is a currently operating experiment at the Large Hadron Collider (LHC) that can detect light long-lived particles produced in the forward region of the LHC interacting point. In this paper, we study the prospect of detecting light CP-even and CP-odd scalars at FASER and FASER 2. Considering a model-independent framework describing the most general interactions between a CP-even or CP-odd scalar and SM particles using the notation of coupling modifiers in the effective Lagrangian, we develop the general formalism for the scalar production and decay. We then analyze the FASER and FASER 2 reaches of light scalars in the large tan beta region of the Type-I two Higgs double model as a case study, in which light scalars with relatively long lifetime could be accommodated. Both FASER and FASER 2 can probe a large part of the parameter space in the large tan beta region up to 10ˆ7, extending beyond the constraints of the other existing experiments.

Plenary / 95

Perspectives in Particle Physics

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Disentangling the flavor puzzle with strings

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Semi-realistic string models offer a plausible path to uncover the flavor structure of particle physics, which improves over models based on pure traditional or pure modular flavor symmetries. Interestingly, the eclectic flavor picture they exhibit, leads to realistic patterns of fermion masses and mixings, which depend on a modulus and matter-field configuration. Further, string models display all the right ingredients to arrive at a dynamic mechanism to stabilize such configurations.

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Magnetic Monopoles: Scattering Amplitudes, QFT, Group Theory and Topology

Author: Ofri Telem[1]

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Magnetic monopoles and dyons are unique beasts in the zoo of Quantum Field Theory. The long range interaction between monopoles and electric charges generates an extra electromagnetic angular momentum, fundamentally changing the S-matrix for their scattering.

Though the effective field theory of Dirac monopoles and charges has been known since the '70, its Hilbert space has only been explored recently. As matter of fact, the quantum states spanning the charge-monopole Hilbert space are dressed multiparticle states that do not factorize into the tensor product of single-particle states. For charge-monopole states, the electromagnetic dressing is not just the means to get a finite S-matrix, but is also the source of the extra angular momentum in the system. For half-integer charges, this dressing can even alter the quantum statistics of the state, effectively making fermions out of bosons.

In the second half of the talk we present a novel alternative description for a system of monopoles and charges. In this description, spacetime is divided into duality frames separated by duality defects. Each particle sees itself as a charge (rather than a monopole), while seeing the particles in the other frames as monopoles/dyons, similarly to locally-flat coordinate patches in GR. We show how QED+duality defects can reproduce all of the unique features of the charge-monopole system. Finally, we present some long standing open problems in the Quantum Field Theory concerning the famous monopole catalysis of nucleon decay.

Plenary / 98

BSM physics in the far-forward region of the LHC

Author: Sebastian Trojanowski[None]

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The ongoing LHC Run 3 has initiated a novel BSM and neutrino physics program at the LHC in its far-forward region. While dedicated detectors FASER and SND@LHC are already taking data this could be further significantly extended during the HL-LHC era with the proposed Forward Physics Facility (FPF). In the talk I will summarize the physics opportunities of this new research direction with an emphasis of BSM searches.

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Axion detection with optomechanical cavities

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Off Shell Gluon Amplitudes in the CHY Formalism

Author: Alex Stewart[None]

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Cachazo, He, and Yuan (CHY) demonstrated an alternative approach for computing the tree-level S-matrix of pure Yang-Mills theories in arbitrary spacetime dimensions on shell, as a contour integral encircling solutions of the so-called "scattering equations" in their paper "Scattering of Massless Particles in Arbitrary Dimensions." Later, Dolan and Goddard analyzed the scattering equations and identified a set of N-3 Mobius covariant polynomial equations which were equivalent to the original CHY scattering equations used to compute the scattering of N particles. In the same paper, it was shown that any Mobius invariant set of equations must take the form of the scattering polynomials that had been identified. That is, the scattering polynomials used to calculate scattering amplitudes in scalar and Yang-Mills theories are specified solely by their mathematical properties related to the Mobius group; no reference to a Lagrangian is needed for these computations. This talk will focus on attempts to modify the scattering equations to allow for off shell computations, and the issues that arise off shell due to gauge invariance.

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Results from FASER

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FASER, the ForwArd Search ExpeRiment, is an LHC experiment located 480 m downstream of the ATLAS interaction point, along the beam collision axis. FASER and its sub-detector FASERnu have two physics goals: (1) to search for new light and very weakly-interacting particles, and (2) to detect and study TeV-energy neutrinos, the most energetic neutrinos ever detected from a human-made

source. FASER was designed, constructed, installed, and commissioned during 2019-2022 and has been taking physics data since the start of LHC Run 3 in July 2022. This talk will present the status of the experiment, including detector design, detector performance, and first physics results from Run 3 data.

Parallel / 102

Dark matter production out of kinetic equilibrium: the latest developments

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In this talk I will discuss some of the recent progress in understanding the impact of non-equilibrium effects on dark matter (DM) production. First I will present a framework for performing calculations beyond kinetic equilibrium and exemplify its importance on several classes of DM models. Then I will discuss the latest results regarding impact of processes distorting the momentum distribution like semi-annihilation and cannibalization as well as numerical treatment of the elastic scattering collision term relaxing some of the up to now adopted assumptions. Finally I will comment on the effect of DM self-scatterings which although have been mostly neglected in the calculation of the relic abundance in fact can have a significant impact on the evolution of DM density through the modification of momentum distribution influencing the effectiveness of annihilation processes.

Parallel / 103

Electron mass variation from dark sector interactions and compatibility with cosmological observations

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We investigate the model where electrons and dark matter interact with dark energy through the rolling of a scalar field which comes from extra dimensional theories such as the braneworld theory and Brans-Dicke theory. In this model dark energy couples to dark matter and electrons which leads to larger values of the mass energies of dark matter and electrons in the early universe. We also fit our model to the cosmological data. By analyzing the data from Planck baryon acoustic oscillation (BAO) light curves (Pantheon) and type-Ia supernovae (SH0ES) it can be seen that the Hubble tension is relieved in our model and the coupling parameter prefers a nonzero value with a significance of over 2 sigma.

Plenary / 104

All in the Family: the quintessential kinship between Inflation and Dark Energy

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A unified dynamical model of dark energy and inflation is presented, in which both phenomena are driven by axion-like fields-quintessences-of spontaneously broken global U(1)'s symmetries whose potentials are induced by instantons of the QCD gauge group SU(3)c for inflation and of a new strongly interacting gauge group SU(2)Z for dark energy. It is shown that SU(3)c and SU(2)Z fit

snugly into a unified gauge group SU(5)Z, Ischyro´s Unification Theory or IUT, which is spontaneously broken down to SU(3)c × SU(2)Z × U(1)Z. A judicious choice of SU(5)Z representations leads to the SU(3)c and SU(2)Z couplings growing strong at ΛQCD ~ 200 MeV and ΛZ ~ 10−3eV respectively. The model predicts particles carrying SU(2)Z quantum numbers which can be searched for at colliders such as the LHC and which, as a result, might indirectly reveal the nature of dark energy and perhaps inflation in a laboratory.

Parallel / 105

Light Dark Matter Search with Nitrogen-Vacancy Centers in Diamonds

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Axions and dark photons are well-motivated dark matter candidates but much of their parameter space remains unexplored. We demonstrate that magnetometry with nitrogen-vacancy centers can cover a broad parameter space with masses over several orders of magnitude. Its unique advantages include a wide dynamic range and the ability to perform measurements without magnetic shielding enhancing its sensitivity to large mass ranges. The proposed method provides a new way to access unexplored regions and will impact future dark matter searches. This brand-new interdisciplinary study demonstrates how recent developments in engineering and industrial science are instrumental in solving fundamental physics problems.

Parallel / 106

How to find the Feynman Rules from any scalar-tensor theory and not collapse in the process

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The ability to represent perturbative expansions of interacting quantum field theories in terms of simple diagrammatic rules has revolutionized calculations in particle physics. However in the case of extended theories of gravity deriving this set of rules requires linearization of gravity perturbation of the scalar fields and multiple field redefinitions making this process very time-consuming and model dependent. In this talk I will motivate and present FeynMG a Mathematica extension of FeynRules that automatizes this calculation allowing for the application of quantum field theory techniques to scalar-tensor theories.

Parallel / 107

Solution to Axion Quality Problem by Non-Minimal Gravitational Coupling

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It is expected that any global symmetry is explicitly violated by gravity. In QCD axion models the effective axion potential obtains other terms than QCD contributions due to gravitational violation of the global U(1) Peccei-Quinn (PQ) symmetry and the minimum of the potential is deviated from the CP-conserving points. In general the deviation is large enough to invalidate the PQ solution to the strong CP problem. This is called ?quality problem?. In this talk assuming that the axionic wormhole

is the only source of gravitational violation of the PQ symmetry we discuss a novel solution to the quality problem in which a non-minimal gravitational coupling is introduced to suppress the gravitational violation. Moreover we show that the condition to avoid the quality problem is different between the metric and the Palatini formulations.

Parallel / 108

Affleck-Dine leptogenesis with one loop neutrino masses and a solution to the strong CP problem

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We discuss a unified model that solves four major problems of the standard model i.e. neutrino masses the origin of matter the strong CP problem and dark matter by using the framework of the Affleck-Dine (AD) mechanism. The AD field is responsible for inflation the origin of matter and neutrino masses which arise at the one-loop level. Neutrino masses are therefore intimately connected to the baryon-to-photon ratio of the Universe. The dark matter in the model is the axion field used to solve the strong CP problem. The model has a near massless Majorana fermion which contributes to Delta N_eff?0.1 in the early Universe that can be tested in the upcoming CMB-S4 experiment.

Parallel / 110

g-2 Model Building with Portal Matter

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In this talk I discuss recent work on model building for the anomalous muon magnetic moment with "portal matter" vector-like fermions charged under both SM hypercharge and a hidden Abelian gauge group U(1)D which can induce kinetic mixing at one loop. The portal matter fields are a well-motivated extension of simplified dark matter models in which the dark matter candidate interacts with the SM via the U(1)D gauge boson in which case the loop-induced kinetic mixing from the portal matter is of the appropriate magnitude to recreate the observed dark matter relic abundance for dark matter and dark gauge bosons in the sub-GeV regime. If the portal matter fields are sufficiently light they may have other phenomenological implications either from direct production or precision effects. I will outline a minimal model of portal matter that resolves the anomaly and discuss the other phenomenological probes of this construction.

Parallel / 111

Measuring neutrino dynamics in NMSSM with a right-handed sneutrino LSP at the ILC

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We study the possibility of measuring neutrino Yukawa couplings in the Next-to-Minimal Supersymmetric Standard Model with right-handed neutrinos (NMSSMr) when the lightest right-handed sneutrino is the Dark Matter (DM) candidate by exploiting a 'dijet + dilepton + Missing Transverse Energy' (MET or
$slashedE_T$) signature. We show that this extended model of SUSY offers a much lighter (bosonic)

state as DM that can then be produced at the next generation of e^+e^- colliders with energies up to 500 GeV or so. The ensuing signal energing from chargino pair production and subsequent decay is extremely pure so it also affords one with the possibility of extracting the Yukawa parameters of the (s)neutrino sector. Altogether our results serve the purpose of motivating searches for light DM signals at such machines where the DM candidate can have a mass around the Electro-Weak scale.

Plenary / 112

Catastrogenesis: Dark Matter ALPs PBHs and gravitational waves from cosmic string-wall system annihilation

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Parallel / 113

Extending the Discovery Potential for Inelastic-Dipole Dark Matter with FASER

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Neutral particles are notoriously difficult to observe through electromagnetic interactions. As a result, they naturally elude detection in most collider detectors. In this talk, I will point out that neutral particles that interact through a dipole interaction can nevertheless be detected in far-forward detectors designed to search for long-lived particles (LLPs). In contrast to previous analyses that focused on neutral particles with elastic interactions, we consider inelastic interactions. This naturally leads to LLPs, and we demonstrate that FASER (and future experiments at the Forward Physics Facility) will be able to probe substantial regions of the associated parameter space. In particular, we find that FASER is capable of probing the region of parameter space wherein thermal freeze-out gives rise to an O(GeV)dark-matter candidate with the appropriate relic abundance, as well as regions of parameter space that are difficult to probe at fixed-target experiments. FASER and its successor experiments may therefore play a critical role in the discovery of such a dark-matter candidate.

Parallel / 114

Conserved Currents and the Power of Enhancement: Unveiling New Bounds

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In the ever-expanding landscape of BSM model building, the ubiquitous presence of new vector bosons has led to new frontiers in probing the depths of fundamental physics. While it is widely acknowledged that non-conserved currents of these vector bosons can lead to (energy/vector mass)^2 enhancements, we diverge from standard literature and consider the realm of conserved currents. We demonstrate that conserved currents can lead to similar enhancements, provided we focus on specific energy regimes. In this talk, we focus on two common scenarios: rare Z decays and meson

decays which lead to flavor changing neutral currents. By analyzing these processes, we not only shed light on the underlying mechanisms but also establish constraints on their existence using data from a range of experiments. These experimental bounds play a pivotal role in elucidating the potential implications of these enhanced processes within the broader context of particle physics.

Parallel / 115

Probing String-Modified Gravity in Neutron Stars

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I will discuss ongoing work in studying how the combination of two modified gravity theories that are well motivated from string theory, Dynamical Chern-Simons (dCS) and Einstein-dilaton-Gauss-Bonnet (EdGB) gravity, will affect the gravitational waveforms emitted from a binary neutron star system, as well as observed neutron star relations such as the mass-radius relation and universal relations. The combination of these two modified gravity theories introduces a non-trivial coupling between the axion and the dilaton, and furthermore we consider a coupling between the dilaton and matter fields, as opposed to the neutron stars being in vacuum.

Special talk / 116

What happened before the big bang & other big questions about the universe

Big ideas and powerful instruments have allowed us to reconstruct the history of universe from its big-bang beginning 13.8 billion years ago through an early state of quantum fluctuations to a soup of quarks and other particles, from the formation of nuclei and atoms to the emergence of stars and galaxies, and finally to its accelerating expansion today driven by dark energy. I will share what we know, what we are trying to figure out,
the biggest questions we asking, and most of all, the excitement of this grand adventure to understand our cosmic origins.

Special talk / 117

Local and Global aspects of JEDI (justice, equality, diversity and inclusion) in Science

Author: Fernando Quevedo[None]

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Talent in science is uniformly distributed among regions, nationalities, gender, race and social origin. However, opportunities are not. An overview is presented of the challenges we are facing to reach a balance regarding access to scientific education and for developing a scientific career for underrepresented sectors of the society, either locally within a given country or globally from country to country. Some initiatives to address this lack of justice, equality, diversity and inclusion will be briefly mentioned.

Fernando Quevedo is a Professor of Theoretical Physics at the University of Cambridge, UK. He was the Director of the Abdus Salam International Centre for Theoretical Physics (ICTP) from 2009 to 2019.

He received his B.Sc. in 1979 in his country, Guatemala and his Ph.D. in 1986 from the University of Texas under the supervision of Nobel Laureate Steven Weinberg. He has made many contributions to formal, phenomenological and cosmological aspects of field and string theories.

He has received several awards and honorary degrees, including the 1998 Guggenheim Fellowship, the 2003 Wolfson Merit Award from the Royal Society, the 2019 Salam Medal from the World Academy of Sciences (TWAS) and the 2021 Wheatley Award from the American Physical Society (APS).

Special talk / 118

Welcome to PASCOS

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Special talk / 119

Welcome to the Department of Physics and Astronomy at UCI

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