Dark Side of the Universe 2025

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Book of Abstracts

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Gravitational production in the early universe

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We will review different mechanisms for dark matter production in the early Universe, with gravitational sources. From the graviton exchange, to the perturbation during inflation and the PBH decay.

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Reliable effective theory of warm inflation in the light of CMB data

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This study investigates the alignment of theoretical and observational Cosmic Microwave Background (CMB) power spectra, focusing on the high-dissipative regime of the most reliable effective theory of inflation. Using marginalized posterior distributions, we analyze parameter spaces constrained by our model and compare them to observational data from the Planck 2018 results. The diagonal plots of marginalized distributions reveal the most probable values for each parameter, providing insights into the model's consistency with empirical evidence. We parametrized the model with an accelerated cosmology solution instead of a specific potential for the model. A comparative analysis of the theoretical power spectrum (f = 0.186 CT = 100) and Planck 2018 data highlights a close match, particularly at the first acoustic peak $\ell \approx 220$ and subsequent higher-order peaks. These results emphasize the robustness of the proposed model and its potential for accurately describing the early universe's dynamics.

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MUSE-DARK: Dark matter halo properties of intermediate-z star-forming galaxies

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Disk-halo decompositions of star-forming galaxies (SFGs) at redshifts z > 1 typically focus on massive galaxies with stellar masses exceeding log(M⊠/M⊠) > 10.
In this study, we analyse the dark matter (DM) halo properties of 127 intermediate-redshift (0.3 < z < 1.5) SFGs down to low stellar masses (7 < log(M⊠/M⊠) < 11). To do so, we use integral field unit observations from the MUSE Hubble Ultra Deep Field Survey, as well as photometry from the Hubble Space Telescope and James Webb Space Telescope.
We employ a 3D forward modelling approach to analyse the morpho-kinematics of our sample, enabling us to measure individual rotation curves extended up to 2 − 3 times the effective radii. We performed a disk-halo decomposition with a 3D parametric model, which includes stellar, DM and

gas components, as well as corrections for pressure support. Our methodology was validated using mock data cubes generated from idealised disk simulations. The DM halo was parameterised using six different density profiles, including the Navarro-Frenk-White, and the generalised profile of Di Cintio et al. (2014) (DC14). We use a Bayesian model comparison to select the best-fitting model.
Our Bayesian analysis suggests that the mass-dependent density profile of DC14, which accounts for the response of DM to baryonic processes such as stellar feedback, performs as well as or better than the other six halo models in ⊠ 65% of the sample. We performed consistency checks for DC14 and found that the stellar masses obtained from the disk-halo decomposition agree with the values inferred from the spectral energy distributions, and the recovered DM inner slopes, γ, agree with the theoretical expectations. For 72% of the SFGs, we infer $\gamma < 0.5$, indicating cored DM density profiles, however, we do not find any correlation between γ and the star-forming activity of the sample. We find that 89% of the galaxies have DM fractions larger than 50%, similar to what is observed in the local universe. The stellar–halo mass and concentration-halo –halo mass relations inferred from our 3D modelling align well with the theoretical expectations, but with larger scatter. Our results confirm the anticorrelation between the halo scale radius and DM density with a slope of ~ -1. We find tentative evidence of an evolution of the DM density with z, which suggests that the DM halos of $z \sim 0.85$ systems are denser than those of their local counterparts. In contrast, the halo scale radii are z-invariant. For the first time, we explore the Radial Acceleration Relation (RAR) at intermediate redshifts and uncover an offset from the $z = 0$ relation, with an a_0 value higher than that inferred for the local SPARC sample. Therefore, our results suggest that the RAR evolves with redshift, which is in qualitatively good agreement with ΛCDM simulations. Furthermore, an examination of individual RAR tracks uncovers a non-monotonic relationship between $a_{tot}(r)$ and $a_{bar}(r)$, which Modified Newtonian Dynamics theories do not predict, but which naturally arises in ΛCDM. Specifically, galaxies with cored dark matter density profiles exhibit downward-bending "hooks," while those with cuspy profiles display upward-bending "hooks".
In conclusion, our results support baryonic feedback-induced core formation in the context of ΛCDM.

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Dark matter at the high mass frontier

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A number of theories predict that dark matter is a very massive particle or composite state. Discovering dark matter in this high mass regime requires different approaches. This talk covers recent developments, including composite dark matter that produces unique signatures in underground experiments and dark matter detectable through Bremsstrahlung radiation in Antarctic ice. We also survey certain experiments from the 1980s and 1990s, which still provide the best sensitivity to many varieties of high mass dark matter.

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Cold collisionless dark matter halos are consistent with observations of galaxies

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Observations of intermediate mass and dwarf galaxies are hard to reconcile with the results of numerical simulations of cold collisionless dark matter (CDM). The most notable problems are (i) the core-cusp problem, or the inability of DM-only simulations to reproduce flat density profiles, i.e., cores, in the centers of dwarf galaxies, (ii) the diversity of the central density profile slopes, and the corresponding rotation curves of intermediate mass galaxies, and (iii) the too-big-to-fail problem. Other challenges, such as missing satellites, and planes of satellites, seem to be either resolved, or in limbo. The proposed solutions for (i) and (ii) range from stellar feedback, to alternative DM particle models, such as self-interacting or ultra-light. Instead of using simulations, I will describe a theory of self-gravitating cold collisionless systems, based on statistical mechanics. The theory, DARKexp, has one shape parameter, and naturally reproduces cored density profiles, as well as the diversity of profile slopes. I will briefly comment on the apparent disagreement between DARKexp and numerical simulations.

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Cosmology in an extended parameter space: new constraints on dark energy and neutrino masses with DESI BAO

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Based on arXiv: 2409.13022 (published in ApJ Letters). We update constraints on cosmological parameters in a 12-parameter model, which extends the standard 6-parameter ΛCDM to include dynamical dark energy and massive neutrinos, along with other new parameters. We use the latest Planck PR4 (2020) likelihoods, DESI DR1 BAO, and the latest uncalibrated type Ia Supernovae (SNe) datasets. In this talk, I will discuss the implications for dynamical dark energy in such an extended model, and at the same time, provide robust bounds on neutrino masses which will be useful for the astro- and particle physics communities. I will also discuss the current status of the weak lensing tension and the Hubble tension in this extended cosmology.

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Primordial black holes in the era of Roman

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Primordial black holes (PBHs) are a well-motivated candidate for dark matter that may constitute a sub-fraction of the dark sector in the Earth-mass range. The strongest observational probe of this population is through gravitational microlensing, an effect in which the bending of light by a massive object results in the apparent transient magnification of a distant source. While ground-based observatories have produced tantalizing hints of a PBH population in this mass range, our understanding of this potential signal will be transformed with the launch of the Roman Space Telescope in 2026, whose Galactic Bulge Time Domain Survey will usher in a new era of discovery in this field. In this talk, I will discuss how by leveraging the high-statistics observations that Roman will make, we will be able to discern multiple subpopulations of non-luminous lenses and provide a new window into the existence of macroscopic dark matter.

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Gravitational Waves from Gravitational Particle Production

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The excitation of scalar dark matter during inflation may result in large isocurvature perturbations, which can be avoided by inducing a sizable effective dark matter mass during the inflationary phase. This can be achieved by a direct coupling to the inflaton, through a nonminimal coupling to the curvature, or by a large bare mass. Notably, when the isocurvature is suppressed at CMB scales, a peak arises at small scales, corresponding to modes that leave the horizon near the end of inflation. I will discuss how these large perturbations result in a stochastic gravitational wave background in the sensitivity range of existing and future gravitational wave observatories.

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Measuring Dark Energy parameters with Type Ia Supernovae in LSST

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The Vera C. Rubin Observatory will conduct the Legacy Survey of Space and Time (LSST), a synoptic astronomical survey of large étendue (more than 20000 deg2) starting in october 2025. A systematic scan of the celestial sphere will be perform for ten years, leading to the largest astronomical catalog ever compiled (83 pB) with 17 billions of stars and 20 billions of galaxies.
With a high cadence of observation and a high étendue, LSST will observe an astounding number of type Ia Supernovae (SNe Ia) - more than 900000 after ten years- including a large number (more than 200000 after ten years) of SNe Ia with accurate cosmological distances estimated from SNe Ia parameters. This "cosmology-grade"sample will be used to measure cosmological parameters with high accuracy.
In LSST SNe Ia parameters are extracted from light curve measurements using five photometric bands. The accuracy of the parameters is thus governed by the quality of the light curves in terms of sampling and signal-to-noise ratio. The LSST observing strategy is thus critical to observe a large sample of well-sampled SNe Ia: a high cadence of observation and a large number of visits are mandatory.
This talk will present the impact of observing strategy parameters on Dark Energy measurements using SNe Ia as cosmological probe. It will be shown that an optimal observing strategy is required to measure Dark Energy equation-of-state parameters with high accuracy.

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From supernovae to neutron stars: a systematic approach to axion production at finite density

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As an elegant solution to the strong CP problem and promising dark matter candidate, the QCD axion is one of the best motivated particles beyond the SM. On the phenomenological side, it is extremely predictive as all its couplings to SM particles as well as its mass is determined by a single scale, the axion decay constant. The hunt for the QCD axion, both with terrestrial experiments as well as astrophysical observables, has exploded in the last years. As of today, astrophysical observations, such as neutron star cooling and energy loss from supernovae, place the strongest bounds.
In this talk, I will show that astrophysical bounds depend on a non-trivial momentum dependence of the axion-nucleon production in zero- as well as in finite density environments. This dependence is induced by one-loop corrections to that can be systematically calculated within the framework of chiral perturbation theory, both at zero density and in thermal field theory. As a consequence, the supernova bound is strengthened and the momentum dependence further allows us to constrain large parts of parameter space of the axion neutron coupling. I will talk about the current status of this systematic calculation systematically in chiral perturbation theory and elaborate how our findings compare to more phenomenological approaches in literature.
Additionally, I will talk about the model independent axion production mechanism in supernova, leading to a orders of magnitude stricter bound than in current literature.

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Flipped rotating axion non-minimally coupled to gravity: Baryogenesis and Dark Matter

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We demonstrate that the co-genesis of baryon asymmetry and dark matter can be achieved through the rotation of an axion-like particle, driven by a flip in the vacuum manifold's direction at the end of inflation. This can occur if the axion has a periodic non-minimal coupling to gravity, while preserving the discrete shift symmetry. In non-oscillating inflation models, after inflation there is typically a period of kination (with $w = 1$). In this case, it is shown that the vacuum manifold of the axion is flipped and the axion begins rotating in field space, because it can slide across the decreasing potential barrier as in Ricci reheating. Such a rotating axion can generate the baryon asymmetry of the Universe through spontaneous baryogenesis, while at later epochs it can oscillate as dark matter. The period of kination makes the primordial gravitational waves (GW) generated during inflation sharply blue-tilted which constrains the parameter space due to GW overproduction, while being testable by next generation CMB experiments. As a concrete example, we show that such a cogenesis of baryon asymmetry and dark matter can be realized for the axion as the Majoron in the Type-I seesaw setup, predicting mass ranges for the Majoron below sub eVs, with right-handed neutrino mass above $\mathcal{O}(10^8)$ GeV.

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Production of Dark Matter during Reheating after Inflation

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Without assuming instantaneous reheating, there is an extended period
and several particle process which lead to the production of Dark Matter.
These are reviewed and compared.

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Spin-dependent scattering of sub-GeV dark matter in crystal targets

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In recent years, attention has shifted to probes of sub-GeV dark matter. In this work, we explore the direct detection prospects of crystal targets through their single (or multi) phonon response to dark matter scattering in the keV-GeV mass range, which couples effectively to protons/neutrons via spin-dependent interactions. In particular, we consider coupling the SM to the dark matter through a pseudo scalar, scalar or pseudo vector mediators, summarizing the bounds obtained from meson decays, beam-dumps, supernova SN1987A and dark matter self-interactions. Finally, we present our results for the scattering cross-section in GaAs and sapphire crystal targets.

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FAT alternative dynamics to standard cosmology

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In the era of upcoming cosmic surveys, the bright sky will be more revealing than ever, allowing us to disentangle the most intriguing mysteries of the origins, content, and evolution of the universe. In this talk, I will highlight the fundamentals of extended gravity theories, and I will focus on the quintessence, probabilistic gravity, and functors of action theories (FAT). I will emphasize the uniqueness of actionions, particles emerging from FAT frameworks, and how other extended gravity theories are connected with FAT. Then, I will discuss and present results on the dynamics of cosmologies in these 3 frameworks, in comparison to ΛCDM, with the goal to tackle cosmic tensions, such as H0. I will discuss the uniqueness of remodifying the quintessence, using 2 distinct dynamical system formalisms of the φΛCDM model. Finally, I will conclude and give some outlook.

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Study of cosmic expansion anisotropy with type Ia supernovae from Zwicky Transient Facility

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The cosmological principle assumes the isotropy of the Universe. The high coverage of the Zwicky Transient Facility survey (ZTF) makes it possible to carry out an unprecedented study of the veracity of this principle by using observation of type Ia supernovae (SNe Ia).

This unique low redshift (z<0.15) survey with more than 3000 SNe Ia in the second data release (ZTF-DR2-SNe Ia) increases by a factor 10 the current low-redshift statistics. Its sky coverage, which represents more than the Northern sky, allows to develop new cosmological analysis such as the study a possible anisotropy of H_0. In this talk, I will present a preliminary analysis attending to quantify the sensitivity of detecting anisotropies, like a dipole effect, with realistic simulation reproducing the ZTF-DR2-SNe Ia.

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The second Type I Supernova data release of the Zwicky Transient Facility

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The Zwicky Transient Facility (ZTF) is scanning the Northern sky since 2018 with a 1.2 m class telescope installed at the Mont Palomar Observatory. This survey detects any transient in the nearby Universe within its magnitude limit, typically up to a redshift of 0.15. In February 2025, the Cosmology working group has released a set of more than 3600 Type Ia supernovae (SN Ia) corresponding to the first phase (2018-2020). This unprecedent SN Ia data sample – about 10 times more than the current compilation at low-redshift – allows to develop new cosmological analysis in the same spirit than the historical probe leading to the discovery of the accelerated expansion of the Universe. The talk will present the main characteristics of this new SN Ia data set with a review of the first results concerning their standardization procedure with new analysis, for instance on large scale structure dependency. The cosmological perspectives will be discussed as well to emphasis the game changer that can bring ZTF in particular for the Dark Energy measurement in a very near future.

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Advancing Dark-QCD searches: Model Development, Constraints, and Novel Anomaly Detection Technique

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Strongly interacting dark sectors, colloquially referred to as dark-QCD, is becoming increasingly popular in the collider community, primarily because of the rich phenomenology and the novel signatures it offers. The author pioneered the first search for semi-visible jets in ATLAS, and is following that up with multiple studies focussing on other final states (arXiv:2207.01885), new generator setups to simulate the signals (WiP), new discriminating observables (arXiv:2209.14964, WiP), setting constraints on these models based on existing results (arXiv:2502.11237) and a novel use of anomaly detection algorithms (WiP) to aid finding these signatures. In the presentation, the lessons learnt from the ATLAS result will be discussed, and these work-in-progress results on model development, constraints of the models, as well anomaly detection method being proposed will be presented, essentially summarising the state-of-the art in the semi-visible jets.

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From symmetries to gravitational waves

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Phase transitions in the early universe provide a rich testing ground for fundamental symmetries and the generation of gravitational waves. In this talk, I will explore the connection between symmetry breaking, phase transitions, and the resulting gravitational wave signatures. I will present recent theoretical and numerical developments that shed light on the dynamics of these transitions, highlighting implications for gravitational wave observatories and beyond. Special attention will be given to the interplay between particle physics models and observable gravitational wave signals, offering new insights into the fundamental structure of the universe.

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Dark Stars, a possible solution to two recent astronomical puzzles

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Launched at the end of 2021, the James Webb Space Telescope (JWST) has already begun to revolutionize our view of the cosmic dawn era. Specifically, it discovered an unexpectedly large number of extremely bright objects in the sky from the early Universe, whose light was emitted more than thirteen billion years ago. If these objects are interpreted as some of the first galaxies ever assembled, their discovery would be in stark contrast with the expectation set by numerical simulations, which predicted such bright galaxies to have formed significantly later. For this reason, those JWST objects are sometimes mistakenly called "cosmology breakers." In fact, in view of HST data, which highly disfavors a cosmological solution to this problem, it would be more appropriate to call them "astrophysics benders." Taken at face value, the JWST data implies that the first galaxies were incredibly efficient in converting of gas to stars. In addition, a combination of IR and X-ray data data further strengthen another problem in astrophysics: the origin of the supermassive black holes that power the large number of very bright quasars observed when the Universe was younger than 900 Myrs. Combined, those two problems indicate that the current understanding of the formation of the first stars and galaxies is, at best, incomplete. This "understanding" is largely based on theoretical and numerical models that ignore the role Dark Matter can play on the formation of the first stars. However, in 2008 Spolyar, Freese, and Gondolo [Phys. Rev. Lett. 100, 051101] have shown that the heat due to the annihilation of Weakly Interactive Massive Particles (WIMPs) at the center of high redshift Dark Matter halos can halt the collapse of zero metallicity protostellar gas clouds. In other words, a new kind of star can form, powered exclusively by Dark Matter annihilations. In view of their power source, those objects are called Dark Stars, although, they can be as bright as a galaxy and grow as massive as a million Suns. In this talk I will review the theoretical and observational status of Dark Stars and show how they can be natural solutions to both of the puzzles described above. Specifically, I will demonstrate how Dark Stars can provide natural massive Black Hole seeds needed to explain the most distant quasars ever observed, such as UHZ1. I will also discuss the three Supermassive Dark Star candidates already identified with JWST (JADES-GS-z-13, JADES-GS-z12, and JADES-GS-z-11) [Ilie et al. PNAS 120 (30)]. Moreover, I will present updated results in view of recently available NIRSpec data. For instance, we find that the most distant object ever observed JADES-GS-z14-0 could be a Supermassive Dark Star that powers an ionization bound nebula. Lastly, I end with an analysis of the prospects for spectroscopic confirmation of Dark Stars. The unambiguous detection of any such object, via any of its spectroscopic smoking gun signatures (such as the

HeII1640 absorption, of which hints exist in the JADES-GS-z14-0 NIRSpec spectra) would imply the first non-gravitational confirmation of the existence of Dark Matter.

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Neutrinos from captured dark matter in galactic distribution of stars

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Sub-GeV neutrinos produced in a stellar core may emerge from main sequence stars, white dwarfs and brown dwarfs producing possible observable signals of dark matter capture. A distribution of these stars near the Milky Way galactic center will produce a neutrino flux that can be probed at Earth based neutrino observatories like Super-Kamiokande and Hyper-Kamiokande. In this talk we demonstrate that this can provide a handle to probe dark matter masses in the 200 MeV – 2 GeV mass scales that compares favourably with present day direct detection bounds

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Status and results from the XENONnT Dark Matter experiment

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The XENONnT experiment is designed for the direct detection of WIMP Dark Matter through its scattering off atomic nuclei in a liquid xenon (LXe) time projection chamber (TPC). The detector, located at the Laboratori Nazionali del Gran Sasso (LNGS) in Italy, holds a total of 8.6 tonnes of xenon, of which 5.9 tonnes actively instrumented within the TPC. Searching for extremely rare interactions, XENONnT features a record low Electron-Recoil background, and reaches a nuclear recoil energy threshold of a few keV. These capabilities also facilitate searches of other rare processes, lately manifested in the observation of solar 8B neutrinos via coherent elastic neutrino-nucleus scattering (CEvNS), where the nuclear recoil energy threshold was reduced to 0.5 keV.

We will present the current status and results of the XENONnT experiment, on Dark Matter, other BSM searches and rare SM interactions. We will conclude with the plans for this experiment and the next generation.

Parallel 3 / **37**

Primordial gravitational waves: a probe of dark matter and leptogenesis

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Primordial gravitational waves (GWs) provide a unique way to look into the early Universe, revealing the connection among inflationary reheating, dark matter (DM) and baryogenesis. I will explore how distinct GW signatures can test new physics scenarios beyond the standard model, offering insights into the fundamental nature of the DM and leptogenesis. I will first discuss how inflationary GWs can probe the co-genesis of DM and high-scale leptogenesis, both produced via gravity-mediated processes at the time of reheating. I will then explore if future GW missions like LISA, ET etc. are able to probe a specific range of DM mass along with the scale of leptogenesis, with a moderately high signal-to-noise ratio (SNR). Since a non-standard epoch at the pre-BBN has non-trivial imprints on GW spectrum, we have considered an early matter domination epoch to explore an alternative detection of annihilating DM and axionic DM. This provides a new avenue for searching annihilating and axionic DM, beyond conventional laboratory searches. Moreover, using Fisher forecasts and Markov chain Monte Carlo (MCMC) analysis with mock data from upcoming interferometry missions, I will investigate the detection prospects of such signals in those missions.

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Shining Light on Dark Matter With LZ

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The LUX-ZEPLIN collaboration operates a 7-tonne active mass, two-phase xenon Time Projection Chamber surrounded by multiple anti-coincidence vetoes. In its search for the elusive dark matter, the LZ experiment involves researchers from 6 countries and 4 continents. It is located at the Sanford Underground Research Facility in Lead, South Dakota. LZ seeks standard Weakly Interacting Massive Particles (leading dark matter candidates) as well as axion-like particles, low-mass (GeV-scale) WIMPs, nuclear recoils of non-traditional high energies made possible by Effective Field Theory operators, and potential evidence of new physics in many other channels. I will present published LZ results based upon 60 and 220 live days of exposure. LZ is continuing to operate with world-leading sensitivity to WIMPs with masses above 9 GeV/cˆ2 mass. Analysis of data for lower-mass searches that are underway will also be discussed here.

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Electroweak Multiplets as Dark Matter candidates: a brief review

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In this talk, I aim to present the phenomenology of Electroweak (EW) multiplets as potential Dark Matter (DM) candidates in the coming years. I will begin by discussing the thermal production mechanism in the early Universe and providing an overview of the current phenomenological landscape in the search for Weakly Interacting Massive Particles (WIMPs). It is worth emphasizing that WIMPs remain a compelling DM candidate with significant phenomenological implications for the foreseeable future. Next, I will outline the key properties of Electroweak multiplets as DM candidates, which

serve as prototypical examples of WIMP DM. Specifically, I will detail the computation of thermal masses, including the impact of important non-perturbative, non-relativistic effects such as Sommerfeld enhancement and the formation of DM bound states. Finally, I will conclude by discussing the phenomenology of EW multiplets, highlighting the need for synergy between cosmological probes and a future muon collider to definitively address this important class of DM candidates.

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CMB signatures of dark matter interactions beyond the power spectrum

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Dark matter (DM) might have non-gravitational interactions with the standard sector, which would leave signatures in the cosmic microwave background (CMB). Traditional searches for such interactions focus on their imprints in CMB power spectra, or 2-point functions. In this talk I will argue that there is valuable information in both the CMB monopole's *frequency* spectrum, i.e. deviations from a perfect blackbody, as well as in higher-order statistics of CMB anisotropies, such as trispectra or 4-point functions. I will consider specifically two very different DM models: accreting primordial black holes and particle-DM that can scatter elastically off nuclei or electrons.

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What we believe to be known in direct Dark Matter detection physics might be incorrect

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In this talk, I will revisit some fundamental well-known knowledge in direct Dark Matter detection physics, including: (1) the general expression for the differential event rate for elastic WIMP-nucleus scattering, (2) the minimal-required incoming velocity of incident WIMPs that can deposit the given energy in the detector, (3) the spatial distribution of the nuclear recoil angle, and provide detailed arguments from the perspective of Galactic Dark Matter particles impinging on our detectors, to show that there might be several "misunderstandings". As part of the proofs, numerical results based on our double Monte Carlo scattering-by-scattering simulation of 3-Dimensional elastic WIMP-nucleus scattering events will also be demonstrated.

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Ultralight Dark Matter and Magnetic Fields on Cosmological Scales

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We propose a mechanism for the generation of magnetic fields on cosmological scales that is operative after recombination. An essential
ingredient is an instability of the electromagnetic field driven by an oscillating pseudo-scalar dark matter field, ϕ, that is coupled to the electromagnetic field tensor via a $\phi F \wedge F$ term in the Lagrangian of axion-electrodynamics. We find that magnetic fields larger than the observational lower bounds can be generated on scales of $1\mathrm{Mpc}$.

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Probing long-range dark matter-baryon interactions in compact stellar systems

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We investigate the astrophysical consequences of an attractive long-range interaction between dark matter and baryonic matter. Our study highlights the role of this interaction in inducing dynamical friction between dark matter and stars, which can significantly influence the evolution of compact stellar systems. Using the star cluster in Eridanus II as a case study, we derive a new stringent upper bound on the interaction strength < 314.5 for the interaction range = 1 pc. This constraint is independent of the dark matter mass and can improve the existing model-independent limits by a few orders of magnitude. Furthermore, we observe that the constraint is insensitive to the mass of the stellar system and the dark matter density in the stellar system as long as the system is dark matter dominated. This new approach can be applied to many other stellar systems, and we obtain comparable constraints from compact stellar halos observed in ultrafaint dwarf galaxies.

Parallel 2 / 44

Imprints of Inflaton Fragmentation on Dark Matter Production

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We investigate the production of Weakly Interacting Massive Particles (WIMPs) in the early Universe, focusing on the reheating epoch. Using an inflationary potential approximated by a quartic power law near its minimum, we analyze how inflaton self-interactions trigger exponential growth of inhomogeneities in the field resulting in the fragmentation of the condensate. We study the impact of this fragmentation on the resulting WIMP relic abundance.

Parallel 3 / 45

Wave Interference in Self-Interacting Fuzzy Dark Matter

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In the Fuzzy Dark Matter (FDM) scenario, the dark matter is composed of an ultra-light scalar field with coherence length and wave interference on astrophysical scales. Scalar fields generically have quartic self-interactions that modify their dispersion relation and the associated evolution of density perturbations. In this talk, I will present the first dedicated analysis of the relationship between wave interference and the evolution due to self-interactions, where we first develop a perturbative treatment applicable at early times and then compare against a suite of benchmark simulations. We vary the dark matter density, interaction strength, and fiducial momentum scale, focusing on the regime where the momentum is relatively high compared to the simulation volume. This is relevant for cases where the dark matter is initially "warm"from post-inflationary production or in virialized halos and other "thermalized"cases with initially cold production. We find that in such scenarios, density perturbations are unable to grow on the expected self-interaction time scale because of interference effects, instead saturating on the much shorter de Broglie crossing time, with a dependence on the sign of the interaction. Finally, I will discuss the implications of our findings for astrophysical systems such as high-density ultra-faint dwarf galaxies, where wave interference plays a significant role.

Parallel 1 / **46**

Searches for dark sector particles at Belle and Belle II

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The Belle and Belle II experiment have collected samples of e^+e^- collision data at centre-of-mass energies near the $\Upsilon(nS)$ resonances. These data have constrained kinematics and low multiplicity, which allow searches for dark sector particles in the mass range from a few MeV to 10 GeV. Using a 426 fb^{-1} sample collected by Belle II, we search for inelastic dark matter accompanied by a dark Higgs. Using a 711 fb^{-1} sample collected by Belle, we search for $B \to h + \text{invisible}$ decays, where h is a π, K, D, D_s or p, and $B \to Ka$, where a is an axion-like particle.

Parallel 3 / **47**

Renormalisation group improvement of dynamical symmetry breaking by dark matter

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In my presentation, I will investigate the interplay between dynamical symmetry breaking mechanisms and dark matter. More precisely, I will focus on several important details of the recently proposed Higgs-dilaton model augmented with a dark matter candidate inducing quantum corrections. In contrast to the previous studies, I will consider the effects of the renormalisation group improvement and the contributions of the Standard Model gauge bosons and the top quark. I will show that with these modifications, the parameter space of the model is still large enough to relate dynamical symmetry breaking with the properties of dark matter, such as its mass and relic abundance.

Parallel 2 / **48**

Decaying heavy DM with RHN portals and dark gauge symmetry: PAMELA/AMS02, IceCUBE and KM3

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Some cosmic ray observations such as PAMELA/AMS02 positron excesses, and high energy neutrino events reported by IceCUBE and KM3 Collaborations may be interpreted as signals of heavy decaying dark matter (DM). In this talk, I will interpret them using heavy decaying DM with right-handed neutrino (RHN) portals with dark gauge symmetry,dark photon and dark Higgs boson. Including dark gauge symmetry and dark Higgs boson make difference in phenomenology, by opening new channels for the DM decays and helping to avoid stringent constraints from various indirect detection experiments.

Parallel 3 / **49**

Light scalar dark matter stabilized by Pauli blocking in fermion background

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We study a mechanism to make dark matter stable based on the Pauli blocking in the fermion background. We examine this scenario in both Boltzmann equation and quantum field formulation and evaluate the evolution equations. We apply this mechanism to a realistic model of neutrino and dark matter.

Parallel 3 / **50**

Do Observations Prefer Thawing Quintessence?

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In light of recent observations by the Dark Energy Spectroscopic Instrument (DESI), we study evidence for thawing quintessence over a cosmological constant as dark energy, with emphasis on the effect of the choice of priors. Working with a parametrization for the equation of state parameter motivated by the theory, we analyse the DESI BAO data jointly with Planck 2018 and Pantheon+ supernovae data. I will show that a preference for thawing quintessence compared to a bare cosmological constant arises only if we use priors which are heavily informed by the data itself. Extending the priors to physically better motivated ranges, the evidence for thawing quintessence disappears.

Parallel 1 / 51

Heating the dark matter halo with dark radiation from supernovae

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Supernova explosions are extreme cosmic events that may impact not only ordinary matter but also dark matter (DM) halos. In this talk, I explore the possibility that a fraction of supernova energy is released as dark radiation, which could transform a cuspy DM halo into a cored one, potentially explaining observed cores in some dwarf galaxies. Alternatively, limits on DM core sizes provide constraints on the energy channeled into light particles beyond the Standard Model (SM). Based on evaluation of energetics, one finds that even a small fraction of the total SN energy is sufficient to change the overall shape of the DM halo and transform a cuspy halo into a cored one. We evaluate some well motivated benchmark models, e.g. the dark photon and dark Higgs, to demonstrate that significant supernova emissivity of dark radiation and large DM halo opacity are achievable in realistic particle physics model. Interestingly, couplings consistent with SN1987A observations can still have a measurable impact on dwarf galaxy halos.

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Dark plasmas in the nonlinear regime: constraints from particle-in-cell simulations

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If the dark sector possesses long-range self-interactions, these interactions can source dramatic collective instabilities even in astrophysical settings where the collisional mean free path is long. Here, we focus on the specific case of dark matter halos composed of a dark $U(1)$ gauge sector undergoing a dissociative cluster merger. We study this by performing the first dedicated particle-in-cell plasma simulations of interacting dark matter streams, tracking the growth, formation, and saturation of instabilities through both the linear and nonlinear regimes. We find that these instabilities give rise to local (dark) electromagnetic inhomogeneities that serve as scattering sites, inducing an effective dynamic collisional cross-section. Mapping this effective cross-section onto existing results from large-scale simulations of the Bullet Cluster, we extend the limit on the dark charge-to-mass ratio by over ten orders of magnitude. Our results serve as a simple example of the rich phenomenology that may arise in a dark sector with long-range interactions and motivate future dedicated study of such dark plasmas.

Parallel 1 / 54

COSINUS –A NaI cryogenic calorimeter to resolve the long standing DAMA/LIBRA dark matter claim.

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Over the past twenty-eight years, the DAMA/LIBRA experiment has observed an annual modulation signal that is consistent with a dark matter explanation. Unfortunately, the signal is contradicted by the null results of numerous experiments utilizing different target materials. In order to perform a truly model-independent investigation of the DAMA/LIBRA result, a study with the same target material is required. The COSINUS (Cryogenic Observatory for SIgnatures seen in Next-generation Underground Searches) experiment, located at the Gran Sasso underground laboratory, will use NaI crystals operated as cryogenic scintillating calorimeters to cross-check the DAMA/LIBRA result. These detectors will be cooled to milli-Kelvin temperatures and provide a measurement of both the phonon and scintillation light signals via transition edge sensors (TES). This is the first cryogenic measurement of NaI detectors, and the dual channel capability will allow particle discrimination between electron and nuclear recoils on an event-by-event basis. This talk will discuss the latest results from COSINUS prototype detectors, the status of the muon veto for the low-background facility, and the last steps of the commissioning towards starting the first physics data-taking campaign in late 2025.

Parallel 1 / 55

Reconstructing PTA measurements via early seeding of supermassive black holes

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The global network of pulsar timing arrays have recently announced the detection of a stochastic gravitational wave background (SGWB) in the nano-Hertz frequency regime. In this talk, I will discuss the implications of early seeding of supermassive black holes (SMBHs) for the observed SGWB. Assuming that these SMBHs were seeded by the collapse of supermassive, dark matter–powered stars (dark stars), I will demonstrate that the population of remnants from these sources can account for the observed SGWB. This in addition with the potential for dark stars to explain the recent JWST observations of high-redshift galaxies emphasises the role self-annihilating dark matter can play in offering solution to some of the puzzles in the high redshift Universe.

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Higgs-portal vector dark matter at a low reheating temperature

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We study vector dark matter (DM) production with Higgs-portal type interactions in the scenarios with a low reheating temperature which can be realized by a prolonged decay of the inflaton after inflation. We take the reheating temperature to be large enough to match the observations in Standard Cosmology such as Big Bang Nucleosynthesis but small enough below the DM mass for the DM production. We analyze the impact of the model parameters including the extra gauge coupling and the reheating temperature on the DM relic density, collider bounds and DM direct and indirect detection experiments.
The decay processes are generally subdominant for the DM production but they can be important when kinematically allowed and the DM mass is close to half of the Higgses mass. The DM production with DM masses below 100 GeV is driven primarily by the scatterings of the SM fermions and Higgses decay whereas the case with higher DM masses is achieved mainly due to the Higgses scatterings. The enhanced coupling for the strong freeze-in in our framework enables potential detection prospects in direct and indirect detections and collider experiments. The parameter space of the model has already been explored partly by the current direct detection experiments and it can be explored further by future experiments such as Darwin. On the other hand, the indirect detection experiments in the current and near future are not sensitive enough to test our model.

Parallel 3 / 57

Dark matter triggering decofinement phase transitions in neutron stars

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I show that the decay, self-annihilation or nucleonic scatters of dark matter can trigger phase transitions from a hadronic to a quark/hybrid phase in neutron stars. For certain high-density equations of state of nuclear matter and stellar mass-radius configurations, the phase transition would convert the neutron star to a black hole. Consequently, the observed existence of neutron stars and rates of gamma ray bursts set some of the most stringent limits on the microscopic properties of dark matter.

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Gravitational Neutrino Reheating : A minimal framework for reheating and leptogenesis

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Despite having important cosmological implications, the reheating phase is believed to play a crucial role in both cosmology and particle physics model building. Conventional reheating models primarily rely on arbitrary coupling between the inflaton and massless fields, which lacks robust predictions. In this talk, I will discuss our recently proposed novel reheating mechanism where the particle physics model, namely, the type-I seesaw model, is shown to play a major role in the entire reheating process, and the inflaton is assumed to be free from arbitrary coupling. To the best of our knowledge, this is the first reheating model of its kind that, besides being successful in resolving the well-known neutrino mass and baryon asymmetry problems, constrains a large class of inflation models, offers successful reheating and predicts a distinct primordial gravitational-wave spectrum and nonvanishing lowest active neutrino mass. Our novel mechanism opens up a new avenue of integrating particle physics and cosmology in the context of reheating.

Parallel 3 / 60

Capture, thermalisation and annihilation of Dark Matter in Compact Objects

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It is well-established that Dark Matter can be captured and accumulate in celestial objects. While this phenomenon has been extensively studied for the Sun and Earth, recent interest has shifted towards compact objects such as White Dwarfs and Neutron Stars. In this presentation, I will discuss two recent results related to these objects.

For Neutron Stars, we consider Dark Matter candidates that are capable of annihilation. The capture of Dark Matter and its subsequent annihilation can lead to the heating of old, isolated Neutron Stars. For kinetic heating to occur, the captured Dark Matter must undergo sufficient scattering to transfer its kinetic energy to the star. Our findings show that this energy transfer typically happens rapidly, and that capture-annihilation equilibrium —and hence maximal annihilation heating —can be reached without the complete thermalization of the captured Dark Matter.

For White Dwarfs, we explore a scenario where the Dark Matter is very heavy and cannot annihilate. In the heavy Dark Matter regime, multiple collisions are required for the Dark Matter to become gravitationally bound. We present an improved approach to calculate the scattering rates for these collisions, particularly when the Dark Matter interacts with the ion constituents of a White Dwarf.

Parallel 2 / 61

A Dark Photon window into GeV DM

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We study a consistent minimal Dark Abelian Higgs model as the portal to a GeV-scale DM candidate. This scenario has been previously studied in the literature and has been deemed to be ruled out by indirect detection constraints. However, we find that when taking correctly into account the production and resulting abundance of the GeV DM candidate, there is still a viable window in the parameter space in the few GeV mass range that survives the combined constraints from colliders, direct and indirect detection.

Parallel 3 / **62**

Holographic phase transitions via thermally-assisted tunneling

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We construct the thermal bounce solution in holographic models that describes first-order phase transitions between the deconfined and confined phases in strongly-coupled gauge theories. This new, periodic Euclidean solution represents transitions that occur via thermally-assisted tunneling and interpolates between the low temperature $O(4)$-symmetric configuration and the high temperature $O(3)$-symmetric critical bubble associated with classical thermal fluctuations. The exact thermal bounce solution can be used to obtain the bounce action at low temperatures which allows for a more accurate determination of vacuum decay rates. In particular, provided the phase transition is sufficiently supercooled, new predictions are obtained for the gravitational wave signal strength for critical temperatures ranging from the TeV scale up to 10^{12} GeV, which are within reach of future gravitational wave observatories.

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Jovian neutrino signatures of annihilating dark matter

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We propose the first method for water Cherenkov detectors to constrain GeV-scale dark matter (DM) below the solar evaporation mass. While previous efforts have highlighted the Sun and Earth as DM capture targets, we demonstrate that Jupiter is a viable target. Jupiter's unique characteristics, such as its lower core temperature and significant gravitational potential, allow it to capture and retain light DM more effectively than the Sun, particularly in the mass range below 4 GeV where direct detection sensitivity diminishes. Our calculations provide the first sensitivity estimates to GeV-scale annihilating DM within Jupiter using neutrino detectors, showing that these surpass current solar limits and spin-dependent direct detection results.

Parallel 2 / **64**

Ultralight Dark Matter Search with Space-Time Separated Atomic Clocks and Cavities

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We devise and demonstrate a method to search for nongravitational couplings of ultralight dark matter to standard model particles using space-time separated atomic clocks and cavity-stabilized lasers. By making use of space-time separated sensors, which probe different values of an oscillating dark matter field, we can search for couplings that cancel in typical local experiments. This provides sensitivity to both the temporal and spatial fluctuations of the field. We demonstrate this method using existing data from a frequency comparison of lasers stabilized to two optical cavities connected via a 2220 km fiber link [Schioppo *et al.*, Nat. Commun. **13**, 212 (2022)], and from the atomic clocks on board the global positioning system satellites. Our analysis results in constraints on the coupling of scalar dark matter to electrons, , for masses between 10^{-19} and $2 \times 10^{-15}\,\mathrm{eV}/^2$. These are the first constraints on ⊠⊠⊠ alone in this mass range.

Filzinger, Caddell, Jani, Steinel, Giani, Huntemann, Roberts, Phys. Rev. Lett. **134** 031001 (2025)

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Boosted dark matter from semi-annihilations in the galactic center

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In some scenarios, the dark matter relic abundance is set by the semi-annihilation of two dark matter particles into one dark matter particle and one Standard Model particle. These semi-annihilations might still be occurring today in the Galactic Center at a significant rate, generating a flux of boosted dark matter particles. We investigate the possible signals of this flux component in direct detection and neutrino experiments for sub-GeV dark matter masses. We show that for typical values of the semi-annihilation cross-section, the sensitivity of current experiments to the spin-independent dark matter-proton scattering cross-section can be several orders of magnitude larger than current constraints from cosmic-ray boosted dark matter. We also argue that the upcoming DARWIN and DUNE experiments may probe scattering cross-sections as low as $\mathcal{O}(10^{-37})\,\mathrm{cm}^2$ for masses between 30 MeV and 1 GeV.

Parallel 1 / **66**

Status of CRESST

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CRESST-III (Cryogenic Rare Event Search with Superconducting Thermometers) installed at Laboratori Nazionali del Gran Sasso, is looking to directly detect dark matter particles scattering off CaWO4 target nuclei in cryogenic detectors. Thanks to its energy threshold O(30 eV), CRESST-III is particularly suitable in probing sub-GeV DM masses. This contribution presents an overview of CRESST-III, reporting the latest DM results and plans for the future. Recent achievements are discussed on the Low Energy Excess (LEE), an unexplained rise of events at low energies (<200 eV). The most recent experimental campaign, using the Double TES approach to identify the origin of LEE and reject this background, is also discussed.

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From Flat to Curved: Probing Interacting Dark Energy in Light of Observations

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The standard model of cosmology, ΛCDM, has been a fundamental framework for understanding the universe from a theoretical perspective and for explaining a wide range of astrophysical and cosmological observations. Nonetheless, the increasing amount of observational data have given rise to the era of precision cosmology, revealing discrepancies in parameter values across different observables and experiments, challenging the ΛCDM's capacity to comprehensively elucidate the universe' s structure and evolution. To address these pressing gaps, I will focus on my studies on the observational signatures of various dark energy frameworks, with a primary emphasis on investigating interacting dark sector models and exploring alternatives to the standard cosmological model. I will talk about their capabilities in an attempt - to tackle significant issues such as the Hubble constant (H_0) tension and the S_8 parameter tension related to matter structure growth, combining theoretical and observational approaches.

In this talk, in particular, I will discuss about the observational data analysis of an interaction model of dark matter and quintessence dark energy. I evaluated this model using cosmological observations from
various sources like the latest observational data like CMB from Planck2018, BAO from several galaxy surveys, SN-Ia, Masers galaxy samples, cosmic chronometers (CC), growth rate ($f\sigma_8$) data, and H_0 measurements from SH0ES study and strong lensing time delay (SLTD). Due to the uncertainty involved in the dark energy physics and in the observational measurements, we found that the data constrains H_0 towards Planck CMB+ΛCDM results when SH0ES H_0 is excluded and it shifts the H_0 towards Riess et al. results with <1σ consistency when H_0 from SH0ES is included. Additionally, by freely evolving the interaction parameter, we found that while the interaction remains small, it is not disfavoured by the data at late times. These results found to be more robust in tightening constraints on H_0, S_8, and dark matter density parameter (Ω_{DM}) together at 68% confidence, and justify the reduced uncertainty and hence the parameter space. Next, I will discuss the coupled quintessence model within the framework of curved spatial geometry (Coupled+Ω_K model) and examine the
inconsistencies in spatial curvature and their implications for the H_0 and S_8 tensions. The obtained results provide evidence for an open universe in the Coupled+Ω_K model. Moreover, the results also indicate a lower value of dark energy equation of state (ω_{de}) parameter compared to the flat interacting scenario, attributable to the curvature effect. I will delve deeper into how these findings within the Coupled+Ω_K picture suggest that relaxing the flatness assumption in coupled dark sector models leads to more precise constraints on H_0 and S_8, as well as significantly better agreement between theory and observations. In the end, I will shed light on the ongoing research with DESI data, focusing on interacting dark energy models of the quintessence and phantom types.

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Picolensing as a probe of compact dark matter

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The gravitational lensing parallax of gamma-ray bursts (GRB), also known as picolensing, is a promising probe of compact dark matter, such as primordial black holes (PBH). A future space mission

consisting of two X-ray/gamma-ray detectors in the Swift/BAT class can probe PBHs in the asteroid-mass window —a range of masses that has been notoriously hard to constrain by any other means. I will discuss the robustness of the projected reach of such mission with respect to the astrophysical uncertainties, most important being the uncertainty in observed GRB angular sizes. I will show that a setup with the separation between the two detectors on the order of the Earth–L2 distance makes such a mission robust. Baselines on the order of an astronomical unit further extend the reach to higher masses with the sensitivity competitive or exceeding the existing microlensing constraints. Implications of these results to other types of compact dark matter will be briefly discussed.

Parallel 2 / **70**

Cosmological Constraints on Atomic Dark Matter from Large Scale Structure in the Nonlinear Regime

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Atomic dark matter (aDM), with a minimal content of a dark proton, dark electron, and a massless dark photon, is motivated by solutions to the Hierarchy Problem such as Mirror Twin Higgs. aDM might address the seeming tension between cold dark matter (CDM) and observations at small scales, which can be probed by Lyman-α forest and 21-cm data. The linear cosmology solver CLASS has been modified to include aDM physics. We develop a CLASS-aDM emulator to improve 21-cm constraints to drastically speed up evaluation of CMB power spectra and transfer function predictions of atomic dark matter, which will allow its use in full parameter estimation scans that utilize our new constraints on aDM from Lyman-α and UVLF data, as well as future constraints from 21cm.

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Gravitational wave symphony from (light) scalar fields in the early universe

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The stochastic gravitational wave background (SGWB) has recently emerged as a promising new probe of new particle physics and the dark side of the Universe. In this talk, we present well-motivated examples of SGWB sourced by the early Universe dynamics of light scalar fields with masses well below the electroweak scale. These include mechanisms such as post-inflation parametric resonance of oscillating scalar fields and early Universe phase transitions. Through systematic

analysis of benchmark models using lattice simulations and scanning a broad range of parameters, we show that these scenarios can generate detectable signals across a wide frequency range, potentially connecting to recent results from Pulsar Timing Array experiments. We further demonstrate that these models may simultaneously address longstanding puzzles such as dark matter and baryogenesis. Finally, we highlight how these examples reveal new complementarity between SGWB signals and laboratory searches for low-scale new physics across the frontiers of particle physics.

Parallel 3 / **72**

Could the Universe Endure a NEC Fracture?

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Recent observations suggest dark energy might have been of phantom type in the past, implying violation of the null energy condition (NEC). It is a well-known fact that quantum states can violate the NEC, but at the same time, it is a challenge to come up with theoretically robust and stable quantum field theories that could behave as phantom dark energy. In fact, there should be a theoretical limit to how much "negative energy" can accumulate over time and space. The smeared null energy condition is a quantum-inspired revision of the null energy condition, which provides such a bound. When applied to dark energy, we show how the smeared null energy condition implies different theoretical lower bounds on the dark energy equation of state. We also comment on how such bounds may be used to set better-motivated priors when doing Bayesian inference. Mainly based on arXiv:2503.19955.

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Dark Vector Splitting Functions in Proton Bremsstrahlung

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High luminosity colliders and fixed target facilities using proton beams are sensitive to new weakly coupled degrees of freedom across a broad mass range. Among the various production modes in proton-proton collisions, bremsstrahlung is particularly important for dark sector degrees of freedom with masses between 0.5 and 2.0 GeV, due to mixing with hadronic resonances. In this talk, I will revisit the calculation of dark vector production via initial state radiation in non-single diffractive scattering, using an improved treatment of the splitting functions and timeline electromagnetic form factors at the proton vertex, including the dipole coupling. Resonant enhancements impact the sensitivity above the ρ/ω mass range. The approach is benchmarked by applying an analogous calculation to model inclusive ρ-meson production. (based on 2409.09123)

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Probing dark matter annihilation through planetary airglow and internal heat flow

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The annihilation of accumulated dark matter within planetary bodies could lead to observable signatures in the form of anomalous UV airglow and excess internal heat flow. We use existing UV and IR spectral data obtained by spaceprobe flybys of Solar System planets to constrain such effects. By comparing the measured spectra to potential dark matter-induced emissions, we place limits on scenarios where dark matter annihilation could contribute significantly to planetary emissions. We consider dark matter annihilating through both short- and long-lived mediators and account for the spatial distribution of dark matter within planetary interiors. Our results highlight planetary spectroscopy as a complementary approach for probing dark matter properties.

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Dark Kinetic Heating of Exoplanets and Brown Dwarfs

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Dark kinetic heating of neutron stars has been extensively studied as a promising dark matter detection avenue. This occurs when dark matter is accelerated to relativistic speeds in the gravitational well of high-escape velocity objects, and deposits its kinetic energy after becoming captured by the object, thereby increasing its temperature. I will show how this effect can also arise in low-escape velocity objects like exoplanets and brown dwarfs if a long-range self-interaction is present. Such dark forces can lead to enhanced heating even for extremely weak couplings, opening new detection opportunities. I will discuss how different objects yield complementary heating signals across parameter space, map out future cross-section sensitivity, and show how observations of a single exoplanet already set new constraints on dark sector parameters.

Parallel 1 / 76

Constraining Dark Acoustic Oscillations with the High-Redshift UV Luminosity Function

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Many extensions of ΛCDM with additional complexity in the dark sector introduce modifications to the matter power spectrum, often appearing only at small scales. For models with interactions between a component of the dark matter and a dark radiation species at early times, the linear matter power spectrum incurs a suppression and dark acoustic oscillations (DAOs) on small scales. One probe of structure on these small scales is the UV luminosity function at high redshifts as measured by the Hubble space telescope. By comparing to these observations we compute new constraints on a generic DAO-type modification of the matter power spectrum, and interpret them in the context of the atomic dark matter model.

Plenary / **77**

Dark Matter (mass) at the extremes: reigning in the mass range of range of dark matter

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The range of possible masses of particle dark matter spans over many orders of
magnitude. The extremes of the mass range – so-called ''superheavy" and ''ultralight" dark
matter candidates – are increasingly attracting attention due to their novel phenomenology and
new developments in production mechanisms. In this talk I will discuss the complementary nature
of superheavy and ultralight dark matter, illustrated with examples from a QCD-like dark sector
and from the string theory axiverse.

Parallel 3 / **78**

Direct Collapse Supermassive Black Holes from Ultralight Dark Matter

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We investigate the possibility that parametric resonant excitation of photons in an ultralight dark matter halo could generate the required flux of Lyman-Werner photons to allow the direct collapse formation of supermassive black hole seeds. This scenario provides a plausible explanation for the origin of quasars observed at high redshifts.

Parallel 2 / **79**

Interface of Particle Physics and Cosmology: Higgs Inflation Revisited

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Cosmic Inflation provides clues to the conditions of the early universe and the highest energy scales our universe has reached. Non-thermal relics can be produced through gravitational particle production, providing dark matter candidates or unstable particles that decay into the baryon asymmetry. A minimal framework that incorporates inflation into the Standard Model is Higgs Inflation, where the Standard Model Higgs or a variant, is identified as the inflaton. In this talk, I will describe the mechanism in which particle production occurs through Higgs Inflation and the aspects of this model which distinguishes it from other inflation models. I will also discuss the implications for dark matter production and the baryon asymmetry.

Parallel 1 / **80**

Is dark energy dependent on cosmological curvature?

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Within present observational uncertainties, the time evolution of dark energy discovered by DESI (2025) is consistent with a simple model in which the dark energy density maintains a direct dependence on the $\mid \Omega - 1 \mid$ measure of spatial curvature. This, together with Bousso's (2002) conjecture that the holographic bound of the universe saturates at the observer's apparent horizon, and Gibbons & Hawking's (1977) postulate that the cosmological event horizon in de Sitter space is fully physically equivalent to an inverted event horizon of a Schwarzschild black hole of identical surface area, predicts with surprising accuracy both the strength and change in dark energy. A notable feature of this model is that ρ_{DE} remains small as long as space remains nearly flat, and ρ_{DE} acts to re-flatten space if Ω ever deviates significantly from unity.

Parallel 1 / 81

Dimming Starlight with Dark Compact Objects

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Dark compact objects can arise naturally in a variety of dark sectors. Clouds of dark matter between a source star and an observer could effectively act as a "lampshade" and dim starlight if the dark sector couples to the Standard Model photon. These dimming effects can be searched for in microlensing surveys, which measure the brightness of stars as a function of time. By considering the EROS-2 and OGLE surveys, we demonstrate how dimming effect searches could be complementary probes for extended structures of dark matter, and can be used to place constraints on dark sectors.

Parallel 1 / 82

Searches for Dark Matter with the ATLAS Experiment at the LHC

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The presence of a non-baryonic Dark Matter (DM) component in the Universe is inferred from the observation of its gravitational interaction. If Dark Matter interacts weakly with the Standard Model (SM) it could be produced at the LHC. The ATLAS Collaboration has developed a broad search program for DM candidates in final states with large missing transverse momentum produced in association with other SM particles (light and heavy quarks, photons, Z and H bosons, as well as additional heavy scalar particles) and searches where the Higgs boson provides a portal to Dark Matter, leading to invisible Higgs decays. The results of recent searches on 13 TeV pp data from the LHC, their interplay and interpretation will be presented.

Parallel 2 / 83

Cosmological gravitational particle production: Starobinsky vs Bogolyubov, uncertainties, and issues

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Gravitational particle production provides an ever-present background in non-thermal dark matter studies. I discuss the correspondence between the Starobinsky and Bogolyubov approaches to the problem of inflationary particle production, and derive strong constraints on frameworks with scalar dark relics.

(Based on D. Feiteira, O. Lebedev, arXiv:2503.14652)

Parallel 1 / 84

The SABRE South Experiment at the Stawell Underground Physics Laboratory

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SABRE is an international collaboration that will operate similar particle detectors in the Northern (SABRE North) and Southern Hemispheres (SABRE South). This innovative approach distinguishes possible dark matter signals from seasonal backgrounds, a pioneering strategy only possible with a southern hemisphere experiment. SABRE South is located at the Stawell Underground Physics Laboratory (SUPL), in regional Victoria, Australia.
SUPL is a newly built facility located 1024 m underground (~2900 m water equivalent) within the Stawell Gold Mine and its construction has been completed in 2023.
SABRE South employs ultra-high purity NaI(Tl) crystals immersed in a Linear Alkyl Benzene (LAB) based liquid scintillator veto, enveloped by passive steel and polyethylene shielding alongside a plastic scintillator muon veto. Significant progress has been made in the procurement, testing, and preparation of equipment for installation of SABRE South. The SABRE South muon detector and the data acquisition systems are actively collecting data at SUPL and the SABRE South's commissioning is planned to be completed by the end of 2025. This presentation will provide an update on the overall progress of the SABRE South construction, its anticipated performance, and its potential physics reach.

Parallel 1 / 85

Dark matter direct detection and constraints on non-relativistic effective operators

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The initiative to detect dark matter directly has been prominent for decades after the WIMP miracle was proposed. Following this, many institutions have come forward with a variety of dark matter direct detection experiments, each trying to find the possible missing particle of the universe. Most prominently, the DAMA collaboration published their results during the end of the last century, giving rise to a possible yearly modulation of dark matter. On the other hand, most of the other experiments report null results, such as COSINE and ANAIS which both feature a Sodium Iodine scintillator. Apart from that, experiments that feature Xenon such as XENONnT, LUX-ZEPLIN or PandaX obtain the lowest limits for the DM-SM cross sections, with yet no dark matter event observations. The aim of this work is to determine the compatibility of DAMA with other null experiments such as LUX-ZEPLIN, PICO-60 and CDMSlite. The analysis in this work uses the non-relativistic effective field theory. We classify the effective operators using an expansion scheme based on the dark matter velocity and momentum transfer. Furthermore, we investigate the posterior of the dark matter mass and the respective couplings and analyse key features. Ultimately, we are able to determine the compatibility of DAMA and other experiments and compare these results to previous literature.

Parallel 3 / **86**

Axions from magnetized plasma: effects of plasma dispersion

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Some of the most stringent constraints on axions arise from considerations of it's emission from astrophysical plasmas. However, many studies assume that particle production occurs in an isotropic plasma environment. This condition is rarely (if ever) met in astrophysical settings, for instance due to the ubiquitous presence of magnetic fields. The effects of the magnetic fields are only taken into consideration for writing down the coupling g^2B^2 while their impact on plasma dispersion are less explored in the context of axion production. In magnetized plasmas, the equations of motion are not diagonal in the usual polarization basis of transverse and longitudinal modes, causing a mixing of these modes and breaking the degeneracy in the dispersion relation of the two transverse modes. This behavior is captured by projecting the response tensor of the plasma $\Pi^{\mu\nu}$ into mode space, whose eigenvectors and eigenvalues are related to the normal modes and their dispersion relations. In this talk, I will discuss a general formalism for determining the normal modes of propagation that are coupled to axions in an anisotropic magnetized plasma. I will provide analytic approximations for the normal modes and their dispersion relations assuming various plasma conditions that are relevant to astrophysical environments. Finally, I will briefly discuss how these modified dispersion properties affect the axion production rate in a magnetized plasma.

Parallel 2 / **87**

Connecting the baryons to the dark matter of the Universe

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The existence of dark matter in our Universe and the existence of an asymmetry between nucleons and antinucleons are two of the most solid evidences for physics beyond the Standard Model. Many mechanisms have been proposed to explain these two phenomena. On the other hand, these mechanisms typically involve different particles and different energy scales, therefore the observed similarity between the dark matter abundance and the nucleon abundance is merely coincidental. In this talk we will propose a scenario that can accommodate the observed nucleon-antinucleon asymmetry without fulfilling the Sakharov conditions. Further, our scenario predicts a stable dark matter candidate without invoking new ad-hoc symmetries, and with an abundance which is in the ballpark of the observed value.

Parallel 3 / 88

DREAMS of Dark Matter Annihilation Signals

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The detection of dark matter presents one of the greatest challenges of modern astronomy.
Possibly one of the most promising avenues is via high energy particles created by dark matter self-annihilation events.
These annihilation events, naturally, depend strongly on the particle physics of the dark matter, but also on the astrophysics of the Universe.
More specifically, the small changes to your assumptions of the density of dark matter within the Milky Way can have a significant impact on the predicted annihilation signal.
In this poster, I will present work done in the DREAMS simulation suite of Milky Way mass galaxies making theoretical predictions for these annihilation signals.
The DREAMS suite is particularly well suited for this analysis as it has systematic variations in astrophysical and dark matter particles.
With these variations, we present a systematic study on the impact of astrophysics variations on your predicted dark matter annihilation signal.
We find that (i) increased supernova feedback can lower your expected annihilation signal, (ii) increased AGN feedback can actually increase your expected signal, and that (iii) warm dark matter does not significantly change your expected signal from cold dark matter.

Parallel 1 / 89

Refining the sensitivity of new physics searches with ancient minerals

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Paleodetection has been proposed as a competitive method for detecting dark matter and other new physics interactions, complementing conventional direct detection experiments. In this work, we utilise \trim simulations to improve the modelling of track length distributions. Our findings suggest

that previous studies have overestimated the number of tracks caused by weakly interacting particles, and that the lowest observable dark matter mass should be higher than previously predicted. These differences are mainly attributed to the fact that (a) the recoil energy-track length relation is not one-to-one, (b) at low recoil energies, a substantial fraction of recoils do not yield any tracks, and (c) at high energies, electronic stopping becomes dominant, resulting in a track length barrier at ~ 200 nm. In addition to WIMPs, we also modelled tracks from generalised coherent elastic neutrino nucleus scattering (CEνNS) via new light mediators and estimated the projected sensitivity for these interactions.

Parallel 3 / 90

Phase Transition and Gravitational Wave in Strongly Coupled Dark Sectors

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We go beyond the state-of-the-art by combining first principal lattice results and effective field theory approaches as Polyakov Loop model to explore the non-perturbative dark deconfinement-confinement phase transition and the generation of gravitational-waves in a dark Yang-Mills theory. We further include fermions with different representations in the dark sector. Employing the Polyakov-Nambu-Jona-Lasinio (PNJL) model, we discover that the relevant gravitational wave signatures are highly dependent on the various representations. We also find a remarkable interplay between the deconfinement-confinement and chiral phase transitions. In both scenarios, the future Big Bang Observer and DECIGO experiment have a higher chance to detect the gravitational wave signals. Most recently, via Quark-Meson model, we find the phase transition and thus gravitational wave signals will be significantly enhanced when the system is near conformal. In addition, we find that this effective field theory approach can be implemented to study the glueball dark matter production mechanism and for the first time provide a solid prediction of glueball dark matter abundance. Our prediction is an order of magnitude smaller than the existing glueball abundance results in the literature.

Parallel 3 / 92

Searching For Heavy Dark Matter with LMC Modeling

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As the search for dark matter progresses, it is useful to refine past and future searches for heavy dark matter, including for dark matter masses well above a TeV. I demonstrate the importance of properly modelling the local dark matter velocity distribution, beyond the standard Maxwellian halo model, and in particular how accurate modeling of the Large Magellanic Cloud and Milky Way impact heavy dark matter searches. As a specific example, I examine the effect of the LMC on heavy dark matter bounds obtained from a 1991 experiment searching for supermassive magnetic monopoles using plastic etch detectors at the Ohya Mine.

Parallel 2 / 93

Static Planck stars as a dark matter candidate

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I will explain how corrections motivated by loop quantum gravity can be included in the Tolman-Oppenheimer-Volkoff equation for spherically symmetric static stars. The quantum-corrected equation has new star solutions with a Planck mass, Planck radius, and no horizon. These bound objects could form in the early universe, be an end state for an evaporating black hole, and could potentially contribute to dark matter.

Parallel 1 / 94

Why the DESI results should not be a surprise

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The recent DESI results provide increasing evidence that the density of dark energy is time- dependent. I will recall why, from the point of view of fundamental theory, this result should not be surprising.

Parallel 2 / 95

Thermal effects on dark matter particle production

Authors: Hugo Schérer[1]; Katelin Schutz[None]; Nirmalya Brahma[1]; Saniya Heeba[1]

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Particles properties in an ambient medium are very different from those in vacuum. Their masses and lifetimes change, and new processes even become possible. For example, in the Standard Model, photons in a plasma (plasmons) acquire an effective mass and can decay into neutrinos, a process forbidden in vacuum. These kinds of thermal effects are especially relevant for dark matter phenomenology, since dark matter production always happens inside a medium of particles, or even from this medium. Examples of these environments include the early universe and the inside of stars. Yet, many calculations of dark matter production still rely on a vacuum-based treatment, and miss key in-medium effects.

In this talk, I will present a systematic formalism to quantify the thermal corrections to particle dynamics. Using this approach, I will demonstrate how qualitatively new amplitudes that have no vacuum analog arise in a medium, and how such amplitudes can significantly impact dark matter production. I will show how these effects can alter dark matter predictions in ways that have been mostly overlooked, and why they are essential for accurate dark matter phenomenology.

Parallel 3 / 96

Hunting axions with the James Webb Space Telescope

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Axions with a mass around 1 eV can decay into near-infrared photons. Using blank-sky observations from the James Webb Space Telescope, I search for a narrow emission line due to decaying dark matter and derive leading constraints on the axion-photon coupling in the eV-scale mass range.

Parallel 2 / **97**

Comprehensive Phenomenology of the Dirac Scotogenic Model: Novel Low-Mass Dark Matter

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The Dirac Scotogenic model provides an elegant mechanism for generating small Dirac neutrino masses at the one-loop level. A single abelian discrete $\mathcal{Z}_6$ symmetry simultaneously protects the "Diracness" of the neutrinos and the stability of the dark matter candidate. This symmetry originates as an unbroken subgroup of the so-called *445* $U(1)_{B-L}$ symmetry.
Here, we thoroughly explore the phenomenological implications of this construction, including an analysis of
electroweak vacuum stability, charged lepton flavor violation, and the dark matter phenomenology. After considering all constraints, we also show that the model allows for the possibility of novel low-mass scalar and fermionic dark matter, a feature not shared by its canonical Majorana counterpart.

Parallel 2 / **98**

ASTRA: Mapping the Cosmic Web's Dark Side with DESI DR2

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I present ASTRA (Algorithm for Stochastic Topological RAnking), a new method for classifying cosmic web structures, designed to explore the dark universe. While traditional approaches struggle to map both dense regions and cosmic voids—critical tracers of dark matter and cosmic acceleration—ASTRA leverages probabilistic reconstruction of underdense regions using random catalogs. This allows us to trace void cores, filaments, and sheets with unprecedented completeness, even in sparsely sampled volumes.
Using DESI Data Release 2 (DR2, not yet public), I show how ASTRA's cosmic web classifications provide high-precision constraints on large-scale structure. These maps reveal subtle spatial correlations in the distribution of voids and filaments, giving new ways to probe dark matter halo assembly and dark energy's influence on cosmic expansion. The method's computational efficiency makes it particularly powerful for next-generation surveys, enabling cosmological parameters exploration beyond standard two-point analyses.

Parallel 1 / 99

What happens when supercooling is terminated by curvature flipping?

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The nature of a certain type of supercooled phase transition, where the supercooling is guaranteed to end due to the curvature of the potential at the origin experiencing a sign flip at some temperature. As the potential barrier is quickly vanishing at the temperature scale of the phase transition, is not immediately clear if critical bubbles are able to form. This clearly can have large implications for gravitational wave signals in such models. As such models are able to generate PBHs or dark matter in various ways, it's important to understand their possible tests.

To address this question, we perform lattice simulations of a scalar potential exhibiting supercooling, with a small barrier around the origin, and qualitatively determine the fate of the phase transition.

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Supernova Bounds on Neutrinophilic Dark Matter

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Supernova cooling has long been used to constrain physics beyond the Standard Model, typically including new mediators or dark matter particles that couple to protons or electrons. The large density of neutrinos inside supernovae also makes supernovae powerful laboratories to study non-standard neutrino interactions. In this work, we consider supernova production of dark matter that couples dominantly to neutrinos. We show that, for a wide range of unconstrained parameter space, neutrino annihilation within a supernova could copiously produce dark matter, at a large enough rate to cause noticeable anomalous cooling. We thus set novel constraints on dark matter-neutrino interactions based on the non-observation of such anomalously high cooling.

Parallel 2 / 101

Boosted dark matter driven by cosmic rays and diffuse supernova neutrinos

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Direct detection of light dark matter can be significantly enhanced by upscattering of dark matter with energetic particles in the cosmic ambient. This boosted dark matter flux can reach kinetic energies up to tens of MeV, while the typical kinetic energies of GeV mass dark matter particles in the Milky Way halo are of the order of keV. Dark matter boosted by energetic diffuse supernova background neutrinos can be detected only through nuclear or electron scattering in ground-based detectors requiring a nonzero interaction of dark matter with nucleon or electron, in addition to its interaction with neutrino. However, in the presence of dark matter-nucleon (electron) interaction, the scattering of dark matter with cosmic rays is unavoidable. Thus, we consider boosted dark matter resulting from diffuse supernova neutrinos as well as cosmic protons (electrons) considering both energy-dependent and energy-independent scattering cross sections between dark matter and standard model particles. We explore this scenario in dark matter detectors such as XENONnT and neutrino detectors like Super-Kamiokande.

Parallel 3 / 102

Composite dark matter disassembly in the Earth

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Composite dark matter models, where dark matter exists in bound states formed in the early universe, have long been a source of scientific interest. In this talk, I will focus on loosely bound dark matter composite states, where the binding energy per constituent is small compared to the constituent's bare mass. If this binding energy is sufficiently small, scattering with Standard Model nuclei will disassemble composites as they pass through the Earth. I will present results from modelling composite disassembly in the Earth prior to their arrival in direct detection experiments, and begin exploring the expected detection signatures from these disassembled composites.

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Apparent w<-1 and a Lower S8 from Dark Axion and Dark Baryons Interactions

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The fundamental natures of dark energy and dark matter remain two of the biggest mysteries in modern cosmology. We show that a simple coupling between dark energy and dark matter can simultaneously address two distinct hints at new physics coming from cosmological observations. The first is the recent evidence from the DESI project and supernovae observations that the dark energy equation of state is evolving over cosmic time from an earlier value that is <-1 to a present-day value >-1. The second observation is the so-called S8 tension, describing the suppression of the growth of matter overdensities compared to that expected in the ΛCDM model. We propose a stable, technically natural particle physics implementation of this idea, in which dark matter consists of dark baryons in a strongly-coupled hidden sector, and the dark energy field is the associated dark axion. The time-variation of the dark matter mass results in an effective dark energy equation of state that exhibits a phantom crossing behavior consistent with recent results. It also results in a slight delay in matter-radiation equality, which suppresses the overall growth of density perturbations.

Parallel 2 / **104**

New Mechanism for heavy dark matter production from cosmic phase transition and beyond

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Motivated by the current status of dark matter search, we discus new production mechanism for heavy dark matter based on non-thermal processes, such as cosmic phase transition, Hawking radiation, and superradiance process. Furthermore, we explore potential signatures of this mechanism in various experiments including the gravitational wave signals. This study provides a viable pathway to understanding the origin of heavy dark matter and its cosmological implications.

Parallel 1 / **105**

Dark Matter Induced Proton Decays

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We present a novel framework for dark matter induced proton decay. This scenario arises naturally from a $U(1)_{B+L}$ symmetry, whose spontaneous breaking triggers the proton decay. This breaking leads to a residual Z_4 subgroup, which ensures dark matter stability and forbids proton decay at tree level. Consequently, proton decay occurs at the one-loop level, mediated by dark sector particles. The $\mathcal{O}$(TeV) masses of the mediators remain consistent with current proton lifetime limits, making them accessible in upcoming experiments. Notably, the proton lifetime limit constrains the dark matter mass range, resulting in a viable parameter space from 500 GeV to a few TeV. Furthermore, leptoquark mediating proton decay, carrying exotic $(B+L)$ charges, leads to a distinctive signature in collider searches. By intertwining proton decay, dark matter stability, and collider phenomenology, this framework not only sheds light on baryon number violation but also provides a promising avenue for future experimental probes.

Parallel 2 / **106**

Building black holes and dark compact objects before Big Bang Nucleosynthesis

Authors: Aaron Vincent[1]; Christopher Cappiello[None]; Joseph Bramante[2]; Leo Kim[None]; Melissa Diamond[None]; Qinrui Liu[1]

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I present a novel mechanism for creating primordial black holes and MACHOs. A heavy dissipative dark sector can come to dominate the universe, creating an early matter dominated era prior to Big Bang Nucleosynthesis (BBN). At this time the dark matter can form halos which persist after the phase transition back to radiation domination, and slowly collapse at late times. This leads to the late time formation of MACHOs and subsolar mass primordial black holes. This also leads to the formation of late forming low mass black holes which may Hawking radiate violently at late times.

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General Implications of the Froggatt-Nielsen Mechanism

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The fermion mass hierarchy of the Standard Model (SM) spans many orders of magnitude and begs for a further explanation. The Froggatt-Nielsen (FN) mechanism is a popular solution which introduces an additional $U(1)$ symmetry to the SM under which SM fermions are charged. We examine the phenomenological implications of the FN mechanism for the lepton sector in the most general way, by considering all possible charge assignments up to some maximum, assessing how naturally each charge assignment reproduces standard model masses and mixings. In this talk, we present results for the phenomenologically viable set of leptonic FN solutions. We calculate the magnitude of resulting flavor-changing observables and discuss the potential for distinguishing between different FN scenarios based on the patterns observed in flavor violation. We conclude with a discussion of the implications of this newfound understanding of the FN parameter space on mirror twin Higgs dark matter and the coincidence problem.

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Fitting the DESI BAO Data with Dark Energy Driven by the Cohen–Kaplan–Nelson Bound

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Motivated by the work of Cohen, Kaplan and Nelson (CKN) in which the authors argue that gravity restics the range of validity of a QFT, we consider a time-dependent dark energy density, scaling

proportional to the squared Hubble parameter $H(z)$.
These models are of particular interest in the light of the recent data release of the DESI collaboration, since the measurements show an increasing preference for time-depending dark energy models in comparison to the ΛCDM model.
In our work, we compare the generalized CKN models to DESI BAO, supernova datasets and model-independent Hubble measurements and find a preference of up to $2.6\,\sigma$ over the ΛCDM model.

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Searching for dark matter in Antarctica: the GAPS experiment.

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The primary science goal of the General Anti Particle Spectrometer (GAPS) is to search for light antinuclei in cosmic rays at kinetic energies below 0.25 GeV/n, as a possible indirect dark matter signature. GAPS is a balloon-borne cosmic-ray experiment expected to be launched during the Antarctic summer season 25/26. It consists of a ten-layer silicon tracker, cooled by a novel oscillating heat pipe thermal system. It is surrounded on all sides by a precision timing plastic scintillator time-of-flight (TOF) and trigger system. GAPS will measure the antiproton component with unprecedented statistics in an unexplored low-energy range and will deliver leading sensitivity to cosmic antideutereon and antiheliumun. GAPS utilizes a novel exotic-atom-based particle identification technique, in which an incoming antinucleus is trapped within the tracker and identified by the resulting annihilation topology. During the summer season 24/25, the GAPS team performed an extensive ground calibration campaign at the Long Duration Balloon facility at the McMurdo base in Antarctica. This talk will highlight some results from the Antarctic ground testing campaign and present an outlook for the next Antarctic season of 25/26 for which GAPS is scheduled to launch.

Parallel 2 / **110**

Seeking Dark matter candidates in the Alternative Left Right model

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The Alternative Left-Right Model is an attractive variation of the usual Left-Right Symmetric Model because it avoids flavour-changing neutral currents, thus allowing the additional Higgs bosons in the model to be light. We show here that the model predicts several dark matter candidates naturally, through introduction of an R-parity similar to the one in supersymmetry. Dark matter candidates can be fermionic or bosonic. This talk will summarise some of the possibilities. Both the bosonic and fermionic candidates provide promising signals, the first in LHC at 300fb^{-1}, the second at higher luminosity, 3000fb^{-1}. Signals from bosonic candidates are indicative of the presence of exotic d'

quarks, while fermionic candidates imply the existence of charged Higgs bosons, all with masses in the TeV region.

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Atomic Dark Matter Capture in the Earth

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Atomic Dark Matter (aDM) is a well motivated class of models which has potential to be discovered at ground based Direct Detection experiments. The class of models we consider contains a massless dark photon and two Dirac fermions with different masses and opposite dark charge (dark protons and dark electrons), which will generally interact with the Standard Model through a kinetic mixing portal with our photon. The dark fermions have the potential to be captured in the Earth. Due to the mass difference, evaporation efficiencies are lower for dark protons than dark electrons, leading to a net dark charge in the Earth. The captured charge has the potential to alter the incoming flux of aDM in complex ways, due to interactions between the ambient dark plasma and the dark charged earth. The altered flux modifies event rates in ground based direct detection experiments compared to the standard DM expectation. I will describe our ongoing effort to calculate aDMs interaction with, and subsequent capture in, the Earth through the dark photon portal. We identify regions of the aDM parameter space where there will be significant accumulation of aDM in the Earth, and elucidate the effect on the incoming velocity distributions of both species.

Parallel 2 / 113

Heavy dark matter in the first stars

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The capture of dark matter by astrophysical compact objects has been of great interest in recent years. In this talk, we present the capture of heavy dark matter by Population III stars at both the early and late stages of their evolution. In the early phase, we calculate dark matter capture via multiple scatterings of the dark matter with two different target species. For the late stage, we consider multiple collisions with three different target elements. Rather than using constant values for the escape velocities and target number densities, we use radial profiles obtained from MESA simulations, which include a rich core-atmosphere structure for the late star. We also incorporate attenuation effects beyond the optically thin limit and model a response function for the hydrogen target, which was unavailable in early studies.

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The Universality of Dark Matter Density Profiles for Milky Way Analog Galaxies

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For nearly five decades, the interplay between dark matter (DM) halos and baryonic (or luminous) matter has shaped our understanding of galaxy formation and evolution. Recent observational data (e.g., the latest DESI results) suggests that the standard Λ-CDM model, although remarkably successful, may need to be revisited to fully explain the Universe. This tension motivates a more detailed track of DM on galactic scales, where its gravitational imprint is more directly observable. To address the DM density in galaxies, we combine cosmological simulations with multi-wavelength observations to constrain DM profiles. The structure, extension, and mass of the Milky Way (MW) still hold observational challenges due to the fact of globally analyzing the system in which we are located. The study of MW analogs helps us with this challenge. We are interested in studying the galaxy-halo connection on a more local scale, from the center of disk galaxies up to the outskirts of those systems. In this work we present a comprehensive study of DM distribution in MW-like galaxies: we analyze a large sample of $>$100 galaxies from the state-of-the-art Illustris TNG-50 cosmological simulation, combined with 21 cm line observations of nearby MW analogs. Using both spatial and spectral high-resolution data from VLA and GMRT radio telescope arrays, we employ the 3D-Barolo algorithm to derive precise kinematic maps and rotation curves. We use Spitzer mid-IR imaging at 3.6/4.5 \textmu m, the best single-band tracer of stellar mass, to perform a careful analysis of the baryonic component–strongly dominated by the emission from low-mass stars. We decompose the rotation curves into their different mass components (stars, gas, and DM), enabling the construction of a DM radial profile for each galaxy. By using a Markov Chain Monte Carlo-based routine, we account for the DM contribution for the observed rotation curves. This allows us to test the universality of DM halo shapes and its possible deviations when taking baryonic physics into account. One of our goals is to constrain the DM density in the solar neighborhood of the MW, based on drawing analogies with the DM distribution in our MW analog sample. In general, current values in the literature rely on the study of stellar orbits in the solar neighborhood or under assumptions about the shape of the DM halo in the MW (e.g., NFW or Einasto profiles). Instead, we calculate the DM density at the corresponding location of the solar neighborhood in each of the analog galaxies. For this purpose, the galactocentric distance from the Sun of $\sim 8\ kpc$ can be translated into $1.6 \times R_{eff}$, where R_{eff} is the radius that encompasses half of the light ($R_{eff} = 5\ kpc$, for a MW reference). Our analysis yields an average local DM density of $\rho_{DM}\ \sim 0.01\ M_\odot\ pc^{-3}$ for the sample of simulated galaxies–consistent with the rotation curve results based on HI observations. This provides a critical link to direct DM detection experiments on Earth, as the local DM density is a key parameter for estimating expected interaction rates with DM particles. Such a result contributes to sharpening both the empirical basis for DM searches and our understanding of its role in astrophysical and cosmological scenarios.

Parallel 3 / 115

Detecting dark matter with atomic systems

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The mystery of dark matter (DM) is a long-standing issue in physics, with numerous dedicated experiments returning no confirmed detections. As many direct detection experiments rely on catching a signal of nuclear recoil, these types of experiments are not applicable to many DM models.

Instead, we can utilise the precision that atomic physics allows to search for potential interactions between atomic systems and DM, with possibilities spanning a large mass range. If we have a DM particle with masses just above electrons, then we can search for signals of atomic ionisation. If we move to masses just below electrons, then we look to absorption of DM on atomic electrons.

Moving much further down to where DM begins to behave like a classical field, then we can measure the effects with atomic systems, such as those in atomic clocks and variations in fundamental constants. Additionally, interactions such as these many be possible to detect with current and upcoming detection experiments.

In this work, I will discuss the prospect for DM detection with atomic systems, the tools needed to accurately assess the possibility, and potential implications for experimental searches.

Parallel 2 / **116**

Bandwidths Broadening in Ultra-light dark Matter Search with Alkali-noble-gas Apin Systems

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Alkali-noble-gas spin systems have been widely used in searches for ultra-light dark matter coupling to nucleon spins. These searches usually confronted limitations of bandwidth and sensitivity. In this talk, we demonstrated two strategies to broaden the sensitive bandwidths in dark matter searches with alkali-noble-gas spin systems. The system has been implemented in the hybrid spin-coupled regimes in the first strategy. We finally achieved leading sensitivity in the frequency range [10^{-2},10^3]Hz. In the second strategy, we effectively broadened the width of the spin resonant search by 30-fold, and finally set the most stringent limit for axion-neutron coupling in the 4.5–15.5 Hz frequency range.

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Observational scalings testing modified gravity

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We consider different observational effects to test modified gravity approach involving the cosmological constant in the common description of the dark matter and the dark energy. We obtain upper limits for the cosmological constant by studying the scaling relations for 12 nearby galaxy clusters, the radiated power from gravitational waves and the Tully-Fisher relation for super spiral galaxies. Our estimations reveal that, for all these cases the upper limits for Λ are consistent with its actual value predicted by the cosmological observations.

We involve the galactic halo observational data to test the weak field General Relativity involving the cosmological constant. Using the data for 15 hydrogen (Hi) VLA super spirals and the Tully-Fisher relation we obtain constraints for each galaxy. The results are consistent with previous results for spiral galaxies, as well as with the scaling relations for the halos, thus confirming the efficiency of the use of dark halo data and Tully-Fisher relation, including the baryonic Tully–Fisher index (BTFR), for testing modified gravity models.

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Estimation of the Hubble parameter from compact object catalogues without threshold

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Gravitational waves from compact binary coalescences offer a promising avenue for inferring the Hubble parameter independently of electromagnetic distance ladders or cosmic microwave background observations. As an independent probe of cosmic expansion, it has the potential to contribute to ongoing efforts to resolve the Hubble tension and to shed light on the properties of the dark sector. In particular, so-called dark sirens – compact binary coalescences events without electromagnetic counterparts – enable statistical inference using galaxy catalogs or population models. Recent studies using dark sirens have typically focused on high signal-to-noise ratio candidates, modelling the signal detection process as a step function in observed signal-to-noise ratio. While these methods have shown considerable utility, potential biases can still remain due to differences between the simulated analysis framework and real detection pipeline behavior.
In this work, we present a framework that estimates the Hubble parameter from a threshold-free catalogue of gravitational wave candidates. Our method makes direct use of detection-level information such as ranking statistic distributions and the probability of astrophysical origin, p(astro), allowing the detection process itself to be integrated into the cosmological inference. Furthermore, the approach avoids the need for individual parameter estimation for each candidate, significantly reducing computational cost and enabling the inclusion of a large number of sub-threshold candidates.

Parallel 2 / **119**

PBH formation during reheating

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We present the formation of Primordial Black Holes (PBHs) from the gravitational collapse of inhomogeneities in a scalar field dominated universe, featuring a code that solves Einstein Equations plus the matter evolution in spherical symmetry. We focus on prospects of reheating for the scalar field potentials. We report on threshold amplitudes for the formation of PBHs, as well as characteristic density profiles for (non-collapsing) virialized configurations. We discuss these results and future prospects, in light of previous approximations to the abundance of PBHs produced during reheating.

Parallel 2 / **120**

Simulating Free Streaming in Warm Wave Dark Matter

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We provide a framework for numerically computing the effects of free-streaming in scalar fields produced after inflation. First, we provide a detailed prescription for setting up initial conditions in the field. This prescription allows us to specify the power spectra of the fields (peaked on subhorizon length scales and without a homogeneous field mode), and importantly, also correctly reproduces the behaviour of density perturbations on large length scales consistent with superhorizon adiabatic perturbations. We then evolve the fields using a spatially inhomogeneous Klein-Gordon equation, including the effects of expansion and radiation-sourced metric perturbations. We show how gravity enhances, and how free streaming erases the initially adiabatic density perturbations of the field, revealing more of the underlying, non-evolving, white-noise isocurvature density contrast. Furthermore, we explore the effect of non-gravitational self-interactions of the field, including oscillon formation, on the suppression dynamics. As part of this paper, we make our code, Cosmic–Fields–Lite (CFL), publicly available. For observationally accessible signatures, our work is particularly relevant for structure formation in light/ultralight dark matter fields.

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Mapping the Gravitational Wave Sky from Primordial Black Holes

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Primordial black holes (PBHs) have been invoked as a component of dark matter, and PBH mergers will produce copious gravitational radiation. The future launch of the Laser Interferometer Space Antenna (LISA), an ESA/NASA gravitational wave observatory set to launch in 2035, will open a new low-frequency band of the gravitational wave sky, one that may include PBH mergers. Our work focuses on determining what LISA would observe if dark matter consisted partially of PBHs, using a high resolution cosmological n-body simulation, Romulus. Our preliminary work assumes 1% of dark matter consists of PBHs with a single mass spectrum and a binary separation distribution determined by inflationary models. We use LISAcode to calculate the signal-to-noise ratio and sky position uncertainty for each binary PBH, creating a map of the PBH sky seen by LISA. We calculate the three-point correlation function of our sky map to quantify how well PBHs trace the large scale structure of galaxies to determine how well large scale structure within LISA can probe the nature of dark matter.

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RG Improvement of the Scalar Effective Potential in Finite Temperature Quantum Field Theory

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Stochastic gravitational wave (GW) backgrounds from first-order phase transitions are a compelling target for next-generation GW observatories, offering a novel probe of dark sectors with strong phase transitions. However, reliable theoretical predictions for the GW signal strength remain challenging, particularly beyond the high-temperature regime where standard techniques like dimensional reduction become unreliable. In this talk, we present the Optimized Partial Dressing (OPD) framework, a thermal mass resummation method that uses gap equation solutions inserted into the tadpole of the potential to systematically improve perturbative calculations of the finite-temperature effective potential without relying on high-temperature expansion.

We will review how OPD controls perturbation theory at finite temperature and then introduce a self-consistent renormalization group (RG) improvement of the scalar potential within the OPD formalism. This RG improvement substantially reduces the scale dependence of physical quantities and improves the robustness of predictions for gravitational wave signals from cosmological phase transitions.

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Fast Times at SIDM High(-resolution)

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Dark matter models which admit large non-destructive self-interactions (self-interacting dark matter, or SIDM) are having a moment, for both particle physics and astrophysics reasons. Of particular interest is how halos and the galaxies within them —especially satellites —evolve. In this talk, I will discuss several approaches to modeling satellite galaxy evolution in SIDM, and connecting to different types of astronomical observables. I will show where SIDM parameter inference is more limited by theory than observational systematics, outline paths to more robust and faster predictions, and show opportunities in comparing satellite galaxies to those in the field.

Parallel 2 / **124**

Searching for heavy millicharged particles from the atmosphere

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If millicharged particles (MCPs) exist they can be created in the atmosphere when high energy cosmic rays collide with nuclei and could subsequently be detected at neutrino experiments. We extend previous work, which considered MCPs from decays of light mesons and proton bremsstrahlung, by including production from Υ meson decays and the Drell-Yan process. MCPs with masses below a GeV primarily arise from proton bremsstrahlung, while heavier MCPs predominantly originate from heavy meson decays and Drell-Yan. We analyze the resulting single scatter and multiple scatter signals at SuperK and JUNO. Searches for low energy coincident signals at JUNO will be sensitive to MCPs with millicharges up to an order of magnitude beyond current constraints for MCP masses between 2 and 10 GeV.

Parallel 2 / **125**

Hawking radiation from primordial black holes

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Low-mass primordial black holes (PBHs) have re-emerged as a promising dark matter candidate. At the lowest allowed masses (of order 10^{17} g), the leading tool for constraining PBHs is Hawking radiation, either in gamma rays or in electrons and positrons (since the peak of the Hawking graybody spectrum is at an energy of order the electron mass). Our group is carrying out a systematic computation of the photon, electron, and positron spectra from Hawking radiation to order $O(\alpha)$ (where $\alpha \approx 1/137$ is the fine structure constant), using the full machinery of quantum electrodynamics (QED), with both the electromagnetic field and the fermions quantized on the Schwarzschild spacetime background. We present results on two previously discussed processes —final state radiation and stochastic charge —that modify the particle spectra, as well as the roadmap for our ongoing calculations. We discuss the implications both for PBH searches, and what we are learning about interacting theories in the Schwarzschild spacetime.

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Probing Primordial Black Hole and Dark Matter Energy Injection Using the 21-cm Power Spectrum

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Before reionization, the universe acts as a pristine calorimeter for detecting potential energy injections from primordial black holes and decaying or annihilating dark matter. The injected high-energy particles can alter the thermal and ionization states of hydrogen, leaving imprints on the 21-cm line signal. These energy injection sources are inherently inhomogeneous, as they depend on structure formation, and the energy deposition processes can be multi-step, delayed, and non-local to the injection site.

In this talk, I will present an updated version of our simulation code, DM21cm, designed to address these challenges. I will describe our treatment of in-halo and diffuse energy injection processes, and provide forecasts for the sensitivity of upcoming HERA 21-cm power spectrum measurements to signals from primordial black hole Hawking radiation, accretion emissions, and annihilating dark matter.

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Growth Through Stasis: The Evolution of Matter Perturbations During a Stasis Epoch

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Cosmological stasis is a phenomenon wherein the abundances of multiple cosmological energy components with different equations of state remain constant for an extended period despite the expansion of the universe. This stasis phenomenon can give rise to cosmological epochs in which the effective equation-of-state parameter $\langle w \rangle$ for the universe is constant, but differs from the canonical values associated with matter, radiation, vacuum energy, etc. Indeed, during such a stasis epoch, the spatial average of the energy density of the universe evolves in precisely the same manner as it would have evolved if the universe were instead dominated by a perfect fluid with an equation-of-state parameter equal to $\langle w \rangle$. In this talk, however, I demonstrate that this equivalence is broken at the perturbation level. As an example, I show that the density perturbations associated with a spectator matter component with an exceedingly small energy density —a component which behaves like a population of frozen-out dark-matter particles —exhibit power-law growth during an epoch of matter/radiation stasis. This growth can potentially lead to significant enhancements of structure at small scales. Such enhancements are not only interesting in their own right, but may also provide a way of observationally distinguishing between a stasis epoch and an epoch of perfect-fluid domination.

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New dynamical probes of primordial black holes

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Compact objects as dark matter have historically been constrained by their dynamical effects. Since these objects can participate in hard few-body scattering processes, they can readily transfer energy to visible objects, with effects such as the disruption of wide binaries. However, binary disruption is not the only possible outcome of such few-body encounters. I will discuss recent work on dynamical capture, exchange, and perturbations to precision observables that open new avenues for compact object phenomenology across a wide range of masses. In particular, I will show how astronomical precision data offers the opportunity to detect primordial black holes in the asteroid-mass range, where compact objects can constitute all of the dark matter.

Parallel 2 / **129**

False and genuine decoherence of primordial perturbations

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Quantum fluctuations of the metric are amplified during inflation, producing the macroscopic perturbations observed in the late universe. To clarify whether these fluctuations retain their quantum coherence, we investigate the decoherence of superhorizon modes induced by gravitational nonlinearities. We show that cubic gravitational couplings, constrained by the soft theorem, lead to IR and UV divergences in the decoherence rate at one loop. These divergences originate from deep IR fluctuations, which appear as background modes to a local observer, and from violent zero-point fluctuations in the deep UV. We argue that these divergences are unobservable, as they vanish when proper observables are considered. To incorporate the observer's perspective, we propose using an effective quantum state, defined in terms of actual observables, as a more appropriate probe of quantum coherence. Based on this framework, we evaluate the finite decoherence rate induced by the superhorizon environment during inflation and in the late universe.

Parallel 2 / **131**

The GAIA impact on Dark Matter Searches

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All Dark Matter (DM) searches, both direct and indirect, are affected by our knowledge (or lack of it) of the DM density/velocities locally as well as in the entire volume of our Milky Way (MW). The GAIA satellite, with its data release 3 (DR3), has revolutionised our knowledge of the Milky Way. Using GAIA DR3 data, I will present the tightest constraint ever of the local DM density, as well as the density of DM over the entire MW up to its edge. Time permitting, I will also present the best estimate of the DM velocity distribution function to date. These can have an immediate impact on DM searches.

Parallel 2 / **132**

Ultra-relativistic freeze-out: a bridge from WIMPs to FIMPs

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We re-examine the case for cold dark matter (DM) produced by ultra-relativistic freeze-out (UFO). UFO is the mechanism by which Standard Model (SM) neutrinos decouple from the radiation bath in the early universe at a temperature $T_d \approx 1$ MeV. This corresponds to chemical freeze-out without Boltzmann suppression, such that the freeze-out (decoupling) temperature T_d is much greater than m_ν and the neutrinos are therefore ultra-relativistic at freeze-out. While UFO has historically been rejected as a viable mechanism for DM production due to its association with hot DM and the accompanying incompatibility with ΛCDM, we show that when the approximation of instantaneous reheating after inflation is lifted, UFO can produce cold DM and account for the entire observed relic density in large regions of parameter space, without invoking exotic cosmological histories. In fact, DM with masses ranging from sub-eV to PeV scales can undergo UFO and be cold before structure formation, given only a simple perturbative, post-inflationary reheating period prior to radiation domination. We demonstrate that for some interactions, such as a contact interaction between the Higgs and DM scalars, there is a seamless transition between the WIMP and FIMP regimes which excludes UFO. However, for many other interactions, such as SM fermions producing fermionic DM via a heavy scalar or vector mediator, the WIMP to FIMP transition occurs \textit{necessarily} via a large intermediate region corresponding to UFO. This mechanism is highly robust and does not require fine tuning. In particular, we find that UFO during reheating can produce the correct relic density ($\Omega_\chi h^2 = 0.12$) for DM masses spanning about 13 orders of magnitude, reheating temperatures spanning 17 orders of magnitude, and beyond the Standard Model (BSM) effective interaction scales spanning 11 orders of magnitude. Finally, we identify an important distinction between UV and IR UFO, where the relic abundance for the former is determined by the freeze-out temperature, while the latter is sensitive to T_{RH} and m_χ but not the freeze-out temperature.

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An effective theory for violent relaxation in cold dark matter halos: origin of the universal halo profiles

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Cold dark matter halos are known to harbor universal density profiles such as the NFW, Einasto and prompt cusp profiles in cosmological N-body simulations. Despite decades of research, the origin of these profiles has remained elusive. I will present a first principles kinetic theory calculation based on the Vlasov-Poisson equations that, for the first time, provides a microscopic description of the emergence of universal profiles from the violent relaxation of dark matter halos. First, I will present a quasilinear theory that yields the NFW profile as a quasi-steady state attractor of collisionless relaxation of accreted matter. Next, I will present an effective theory for violent relaxation that yields both NFW and prompt cusps as quasi-steady attractors. The halo gets stuck in these quasi-steady states for a long time before Maxwellianizing into an isothermal sphere.

Plenary / **135**

Gravitino Dark Matter and Neutrino Masses

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In MSSM with a global U(1) symmetry, the gauginos are psuedo-Dirac particles. The psuedo-Dirac bino can play the role of right-handed neutrinos and generate the light neutrino masses through an inverse seesaw mechanism. In this scenario, the lightness of the neutrino masses is governed by the ratio of the gravitino mass and the messenger scale between the SM and the supersymmetric sector. For low messenger scales at O(100 TeV), the gravitino is expected to be about O(keV-MeV) in mass. I will discuss how this gravitino can be a dark matter candidate.

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Ion Traps as Quantum Detectors for Millicharged Dark Matter: A Quantum-Mechanical Description

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Detection of millicharged dark matter with trapped ions has emerged as a powerful technique. Millicharged particles scatter off the ions, producing detectable signals either through individual quantum jumps or via an increase in the ions'overall heating rate. Prior studies have shown that this approach can probe a vast parameter space for superheavy mCPs in the $10^2 \sim 10^9$ GeV mass range. By treating the ion-mCP interaction fully quantum mechanically, the sensitivity can be extended even further. In what follows, I present the quantum-mechanical framework for this scenario and project the resulting improvement in reach.

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Dark-Matter Mass from Angular Scanning

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We propose a novel method to determine the mass scale of ambient dark matter that can be generally applied to the (at least effectively) two-dimensional direct detection experiments allowing for directional observables. Due to the motions of the solar system and the Earth relative to the galactic center and the Sun, the dark-matter flux carries a directional preference. We first formulate that dark-matter event rates have a non-trivial dependence on the angle between the associated detection plane and the overall dark-matter flow and that the curvature of this angular spectrum encrypts the mass information. For proof of principle, we take the recently-proposed Graphene-Josephson-Junction-based superlight dark-matter detector (named as GLIMPSE) as a concrete example and demonstrate these theoretical expectations through numerical analyses.

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Testing heavy WIMPs at the Cherenkov Telescope Array Observatory

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Upcoming gamma-ray telescopes offer the prospect of sensitivity to the canonical thermal-relic annihilation cross section up to mass scales of tens of TeV. I will discuss new precise predictions for high-energy gamma-ray signals from the classic "minimal dark matter" benchmark models, including bound-state formation and resummation of large logarithms, in the case where the dark matter inhabits a real representation of the Standard Model SU(2) group. I will show that under conservative assumptions on the dark matter density profile, the Cherenkov Telescope Array Observatory (CTAO) should be capable of detecting or excluding almost all these scenarios.

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Running a Dark Matter Experiment on a Galaxy

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The hypothesis of Cold Dark Matter (CDM) has been confirmed on the largest scales of the Universe and must now be stress-tested on sub-galactic scales. Many well-motivated and generic alternatives to CDM can leave spectacular signatures on precisely these scales, affecting the evolution of galaxies as well as their population statistics. Excitingly, over the course of the next decade, a flood of astrophysical data will open the possibility of searching for these distinctive imprints and shedding light on key questions about dark matter. I will review the promise of upcoming data as well as recent theory advancements for modeling dark matter physics on these scales.

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Searching for New Physics with Stars, Near and Far

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Stars are large, plentiful and the Universe provides them to us for free. They provide us with unique laboratories to test fundamental physics at high densities and temperatures, and their large volumes potentially give us access to very rare processes. While stars have been used for decades to probe fundamental physics, they still offer new exciting avenues to search for beyond-the-standard-model physics. I will discuss some recent work including possible hints of dark matter, but also subtle caveats when it comes to applying particle physics to astronomical observables.

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Probing Dark Matter with Liquid Xenon Detectors

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The fundamental nature of dark matter remains one of the central open questions in physics. A leading hypothesis is that dark matter consists of new elementary particles, whose masses and interaction cross sections span a vast parameter space. Among the various detection technologies, liquid xenon detectors have emerged as the most sensitive for dark matter particles with masses above a few GeV, offering unprecedented discovery potential. In this talk, I will present recent results from the latest generation of multi-tonne liquid xenon detectors currently operating deep underground. I will also highlight advances in detector technology, ongoing R&D efforts, and the prospects for next-generation experiments to further expand our reach in the search for dark matter.

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Cracks in the Standard Cosmological Model: Anomalies, Tensions, and Hints of New Physics

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The ΛCDM model has long served as the standard paradigm in cosmology, offering a remarkably successful description of the Universe's evolution. Yet, as observational precision continues to improve, persistent tensions have emerged across a range of probes, including the well-known Hubble constant discrepancy. While individual datasets may each align with ΛCDM, their collective interpretation reveals significant discordances that challenge the model's internal consistency. In this talk, I will review the most prominent tensions in modern cosmology and assess their implications. I will present recent results pointing to hints of dynamical dark energy and interactions within the dark sector. I will also reflect on the growing influence of methodological choices, such as dataset selection and model assumptions, in shaping our cosmological conclusions.

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Narrowing down the mass range of ultra-light dark matter

Author: Elisa Gouvea Mauricio Ferreira[1]

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The nature of dark matter remains one of the biggest mysteries in cosmology. Among the many possible candidates, one of the most well-motivated class of models and leading candidate is the ultra-light dark matter (ULDM). ULDM represents the lightest possible dark matter candidates and exhibits wave-like behavior on galactic scales, offering a unique opportunity to probe its properties through distinctive astrophysical signatures. In this talk, I will discuss the latest efforts to constrain the mass of ULDM, focusing on the fuzzy dark matter (FDM) model. I will show how we can use the different predictions of this model and different astrophysical systems to put the strongest bounds to date on the mass of this ultra-light axion, and possibly other quantities like the fraction, spin, and axion-photon coupling. I will focus more on the current developments in using interference patterns as a way to probe the FDM model. In particular using gravitational lensing and pulsar timing data as a powerful probe to measure this wave behaviour.

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The Devil is in the (Axion) Details

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Over the last decade, one of the most popular solutions to the dark matter problem has been a hypothetical class of particles known as axions or axion-like particles. In this talk, I will discuss why the axion is such an attractive candidate and also explain the challenges we face in determining whether axions are the dark matter and which axion(s) are the dark matter. I will highlight results from my research group that indicates: the devil is in the details.

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Fundamental Physics with Pulsar Timing Arrays

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Pulsar timing array (PTA) experiments aim to detect nHz-frequency gravitational waves using high-precision timing of millisecond pulsars. Multiple PTA collaborations have recently reported evidence for a stochastic gravitational wave background (SGWB), expected to arise predominantly from a population of inspiraling supermassive black hole binaries. In this talk, I will discuss how PTA experiments characterize the expected signal of the SGWB and present a new analysis technique, which may better facilitate tests of general relativity with future data.

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Present and future of dark matter detection with skipper-CCDs

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To be completed

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Entanglement between pair-created universes bridged by a Euclidean wormhole

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What happens if our universe was created from an Euclidean instanton? The no-boundary proposal is not the unique choice; instead, a more natural option is to introduce Euclidean wormholes, but as a result, we need to accept that our universe was indeed an outcome of a pair creation. Invoking the Klebanov-Susskind-Banks Euclidean wormhole as a bridge, we investigate the power spectrum and the entanglement between two pair-created universes. We construct a suitable global vacuum for the perturbations of the inflaton field in the Euclidean regime, which becomes a mixed state when restricted to one of the paired universes. This mixed state leads to an enhancement of the power spectrum for long-wavelength modes. In addition, entanglement between the two universes is realized by the existence of the wormhole. Thus, the power spectrum enhancement in the long-wavelength regime might be evidence of our universe being created from a Euclidean wormhole that was entangled with a partner universe, and hence our universe does not begin with a pure state.

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TBA

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TBA

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TBA

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TBA

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Dark dimension boundary or shiny bulk? - Modular invariant quintessence

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UV Priors with a Dark Energy (Naturally)

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This talk describes recent progress in the Highland Program: an effort to identify useful non-swampy UV clues guiding a low-energy understanding of the Dark Sector.

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Results from the Atacama Cosmology Telescope Data Release 6

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The Atacama Cosmology Telescope recently published results from the sixth data release (DR6). I will present these DR6 data and the implications for several cosmological models beyond the standard picture.

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Listening to the Dark Universe: Experimental Searches for Axion Dark Matter

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The axion is a highly motivated hypothetical particle that could simultaneously address two major fundamental questions in modern physics—the strong CP problem and the dark matter mystery. A large class of experimental searches exploit the axion-photon coupling, aiming to detect axion-induced photons in the presence of strong magnetic fields. These efforts have advanced significantly in recent years, with several searches, particularly in the micro-eV (GHz) mass range, now reaching sensitivity levels that probe well-motivated theoretical models. Ongoing developments aim to broaden the accessible mass range and improve detection capabilities through advanced technologies and innovative experimental strategies. This talk will review the current status of axion dark matter experiments and discuss future prospects across the global search program.

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TBA

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Simple quintessence models in light of DESI-BAO observations

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Recent analyses from the DESI collaboration suggest that the dark energy density of the Universe may be decreasing with time, slowing the acceleration of the scale factor a. Typically these studies are performed assuming an ansatz for the equation of state $w(a)$. In this talk, we present simple models of a scalar quintessence potential with linear and quadratic behavior, which could be more representative of real models than particular parametrizations of $w(a)$. We observe a significant preference for dynamical dark energy when using supernova data from DESY5 along with DESI BAO and Planck data, at the cost of slightly exacerbating the Hubble tension. However, when using supernova data from Pantheon+ or Union3, we find only a mild preference for dynamical dark energy.

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Solid State Detectors for Low-Mass Dark Matter Searches

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We are faced with convincing evidence that approximately a quarter of the universe is composed of something whose gravitational effects can be seen in a variety of astrophysical phenomena, but which we have been unable to detect and identify in the laboratory. The majority of physicists agree that this "dark matter" (DM) consists of as-yet-undiscovered subatomic particle(s) that are not included in our Standard Model of particle physics; the quest to discover its exact nature is among the foremost missions in modern physics and the greatest treasure hunts in history. Direct DM searches over the past few decades have been largely focused on Weakly Interacting Massive Particles with masses much greater than that of the proton. The absence of any conclusive discovery, along with various theoretical developments and certain astrophysical observations, has recently motivated the direct detection community to broaden our experimental program to search for DM candidates in lower mass ranges. Solid-state detectors provide many advantages for such searches. This talk will summarize recent advances in phonon- and ionization-based semiconductor crystal experiments, cryogenic scintillating calorimeter experiments, Charge-Coupled Device experiments, and R&D for future new solid-state detector technologies. It will also discuss future prospects and discovery potential for solid-state detectors with respect to various low-mass DM candidates, including dark photons, axion-like particles, and lightly-ionizing particles.

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Unveiling Imprints from Dark Symmetries: Signatures of Axion Portal to Scalar Dark Matter

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If dark matter is blind to standard model gauge interactions, the dark sector might not be totally secluded but connect to the visible sector via the introduction of portal interactions. In this talk, I will discuss a novel scenario where an axion-like particle acts as mediator between the SM and a complex scalar singlet dark matter candidate. The identification of physical couplings crucially incorporates a profound connection to the underlying symmetry that stabilizes the dark matter particle. In particular, I will examine the case of non-Abelian discrete symmetries and show how these prevent dark matter portal interactions to be removed via field redefinitions. This choice leaves peculiar imprints on both cosmological evolution and late times phenomenology. I will discuss how dark matter relic abundance is solely determined by freeze-out of semi-annihilations and is independent of portal couplings to the visible sector. While naturally evading direct detection constraints, rich and peculiar indirect detection spectra are uniquely determined by the one-step cascade DM semi-annihilation rate, with visible decay channels of the mediator only affecting the spectral shape.

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