The Fifth International Conference on Axion Physics and Experiment (Axion 2026)

Report of Contributions

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Contribution ID : **1** Type : **not specified**

Axion Dark Matter from Parametric Resonance during the QCD Phase Transition

The QCD axion cosmological abundance is usually attributed to the misalignment mechanism. We will present a complementary production channel that arises during the QCD phase transition. Primordial temperature fluctuations modulate the axion mass and can trigger parametric resonance in the axion field evolution, exciting finite-momentum modes and enhancing axion production. This effect can significantly modify the predicted axion relic abundance and shift the preferred dark-matter mass range, with implications for ongoing and future axion search experiments.

Primary author(s) : Dr ., Pirzada; Prof. YU, Gao; Prof. QIAOLI , Yang

Presenter(s) : Prof. QIAOLI , Yang

Contribution ID : **2** Type : **not specified**

Mapping the ALPs: A Naturalness Map for Axions and ALPs

The axion solution to the strong CP problem is only as robust as the Peccei-Quinn symmetry it relies on, and quantum gravity is expected to break it. We quantify the resulting axion quality problem using principled measures of fine-tuning, and show that the cost is severe. For the QCD axion to account for the observed dark matter, Planck-suppressed symmetry-breaking operators must be absent up to mass dimension $d \geq 12$; the naturalness penalty for failing to realize this protection can exceed a Bayes factor of 10^{10}. Extending the analysis to generic axion-like particles, we map the axion mass-decay constant plane by the degree of UV protection required, and find that large portions of the sensitivity reach of laboratory experiments are already fine-tuned at the part-per-million level or worse. We argue that quality, not mass, is the central naturalness question for the axion program.

Primary author(s) : FOWLIE, Andrew (XJTLU); CHEEK, Andrew (TDLI, SJTU); Dr HERRERA, Gonzalo (Harvard University)

Presenter(s) : FOWLIE, Andrew (XJTLU)

Contribution ID : **3** Type : **not specified**

New Isocurvature Constraints and its Axionic Interpretations

Although measurements of the Cosmic Microwave Background (CMB) have shown a nearly scale-invariant primordial spectrum of adiabatic perturbations, in which the energy densities of different components (radiation, baryons, and dark matter) fluctuate proportionally, there could also exist isocurvature perturbations, in which density fluctuations of the individual components differ from the adiabatic mode. Cold dark matter isocurvature (CDI) perturbations with a variety of spectral tilts generated in pre-inflationary axion models provide one such example. In this article, we present the most updated constraints on these axion CDI perturbations using the latest CMB anisotropy measurements from Planck, the Atacama Cosmology Telescope (ACT), and the South Pole Telescope (SPT).

We study both fixed spectral indices with values ranging from red- to blue-tilted spectra as well as the case with a free index. We find that the constraint on the spectral index gets moderately improved with the combined datasets compared to Planck alone, while the bounds on the isocurvature amplitudes for fixed spectral indices we consider do not get tighter.

Primary author(s) : Prof. LI, Lingfeng

Presenter(s) : Prof. LI, Lingfeng

Contribution ID : **4** Type : **not specified**

A Supersymmetric Extension of Axionic Electrodynamics: From Axions and Photons to Axinos and Photinos

In this contribution, we investigate a supersymmetric effective extension of axionic electrodynamics by adopting the superspace/superfield approach. Rather than focusing on UV-complete axion models, our goal is to analyze how supersymmetry modifies the dynamical and propagating sectors of axion electrodynamics at the effective-field-theory level. In terms of component fields, the resulting Lagrangian describes the interactions among the axion, the photon, and their respective supersymmetric partners, the axino, the saxion and the photino. Supersymmetry induces new fermionic self-interactions and a non-polynomial interaction involving the axino, the photino, and the saxion. An interesting aspect to be highlighted is the appearance of fermionic bilinear contributions involving the photino to both the permittivity and permeability tensors of the constitutive relations. We also pay special attention to the dispersion relations in both the bosonic and fermionic sectors, and analyze the effective masses of the different particles in the presence of an external magnetic background, which induces supersymmetry breaking. Finally, with the help of numerical methods, we identify a class of axionic and electromagnetic-field configurations whose profiles resemble magnetic vortex-like configurations.

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Contribution ID : **5** Type : **not specified**

Experimental signatures of Kalb-Ramond-like particles

We analyse phenomenological signatures of Kalb-Ramond-like particles, described by an antisymmetric rank-2 tensor, when coupled to fermionic matter. The latter is modelled by a tensor current coupled directly to the Kalb-Ramond field or by a pseudovector current coupled to the rank-1 dual of the field-strength tensor. We obtain limits on the coupling constants to fermions and mass of the Kalb-Ramond-like particles by investigating their impact on the hyperfine splittings of hydrogen, the tree-level unitarity of the S matrix for $e^- + e^+ \to \ell^- + \ell^+$ scattering with $\ell \neq e$ and the differential cross section for Bhabha scattering. Assuming that the couplings to fermions are independent of the fermion species, the strongest 95\%-CL bounds we find are from LEP data at $\sqrt{s} = 136.23$~GeV, namely $g_{\rm PV}/\Lambda$
$lesssim 6.3 \times 10^{-13}\,{\rm eV}^{-1}$ and $g_{\rm T}$
$lesssim 1.3 \times 10^{-12}\,(m/{\rm eV})$, both for $m \ll \sqrt{s}$ (here Λ is a characteristic energy scale). These limits can be improved in upcoming lepton colliders due to enhanced precision, as well as higher energies.

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Contribution ID : **6** Type : **not specified**

WIMP Meets ALP: Coherent Freeze-Out of Dark Matter

The microscopic nature of dark matter is the major open question in science. Weakly-Interacting Massive Particles (WIMPs) and Axion-Like Particles (ALPs) are the two most theoretically motivated dark matter candidates. Thousands of papers consider them separately. We point out that if both species are present in the theory, even a tiny (Planck-suppressed) interaction between them could lead to drastic modifications of their dynamics in the early universe.

Specifically, we consider the cosmological history of a fermionic WIMP coupled to a light ALP via a quadratic coupling. Although the coupling is too feeble to thermalize the ALP, coherent forward scattering between the two sectors induces temperature-dependent mass shifts that substantially modify both WIMP freeze-out and ALP misalignment dynamics, giving rise to a novel coherent freeze-out mechanism. At high temperatures, the WIMP thermal bath spontaneously breaks the symmetry of the ALP potential, displacing the field to a new vacuum. The resulting back-reaction reduces the WIMP effective mass and significantly delays its freeze-out. Depending on the strength of the coupling, symmetry restoration occurs via either a first-order phase transition (FOPT) or a crossover. In the FOPT regime, dark matter consists solely of WIMPs, whose delayed freeze-out permits annihilation cross sections up to three orders of magnitude above the standard value, while still yielding the correct relic density. In the crossover regime, both WIMP and ALP can contribute to dark matter. Remarkably, we find an "ALP miracle": a Planck-suppressed quadratic coupling yields an ALP abundance comparable to the observed dark matter density, largely independent of its initial displacement and mass.

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Presenter(s) : Dr YU, Bingrong (Cornell University)

Contribution ID : **7** Type : **not specified**

Constraining axion couplings with the Hulse-Taylor binary system

The orbital evolution of the Hulse-Taylor binary neutron star system is described with high precision by General Relativity, in which gravity is the only long-range force and gravitational waves provide the dominant energy-loss channel. We use this precision test of relativistic binary dynamics to derive new constraints on axion couplings to stable neutron-star constituents: neutrons, electrons, and muons. In the presence of exotic long-range forces and additional radiation channels, the measured orbital decay constrains the strength of quadratic axion-fermion interactions. Axions enjoy a perturbative shift symmetry that is broken by non-perturbative effects responsible for the axion mass. Such shift symmetry breaking can induce quadratic couplings between axions and fermions. In an ambient axion dark-matter background, these couplings mediate enhanced long-range, spin-independent forces, while also allowing binary systems to lose energy through dipole and quadrupole emission of axion waves. For light QCD axions and for models in which non-perturbative effects correct lepton masses, our bounds can be recast as limits on the axion decay constant.

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Presenter(s) : YIN, Ziwen (Tsung-Dao Lee Institute & SJTU)

Contribution ID : **8** Type : **not specified**

Parametric-Resonance Production of QCD Axions

The QCD axion remains one of the most compelling dark matter candidates, yet its mass window is tightly constrained by the standard misalignment mechanism. We identify a generic new production channel: primordial temperature fluctuations during the QCD phase transition periodically modulate the axion mass, driving parametric resonance in the axion field. This resonance amplifies the axion abundance beyond the misalignment prediction and opens a new mass window for dark matter at $10^{-4} - 10^{-3}$ eV—a regime previously unexplored but now accessible to next-generation haloscopes. Our mechanism is model-independent, relying only on the thermal history of the universe, and provides a sharp new target for axion dark matter experiments.

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Presenter(s) : Mr ., Pirzada (ITP,CAS beijing.)

Contribution ID : **9** Type : **not specified**

Axion-Like Particles at the Electron-Ion Collider

We explore the searches for axion-like particles (ALPs) at the electron-ion collider (EIC) to be built at the Brookhaven National Laboratory. We propose search strategies with the production of diphoton in both coherent (elastic) and inelastic scatterings. We found the EIC embraces the possibility to extend the existing ALP searches.

Primary author(s) : XIE, Keping (TDLI/SJTU)

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Contribution ID : **10** Type : **not specified**

Supernova Constraints on Lepton Flavor Violating Axions

We discuss supernova cooling limits and low-energy supernova constraints on lepton flavor violating axions.

Primary author(s) : Prof. LIU, Zuowei

Presenter(s) : Prof. LIU, Zuowei

Contribution ID : **11** Type : **not specified**

Discovering the Axiverse via Fifth Forces

If the Universe is described by string theory or other extensions of the Standard Model, several light, axion-like states are predicted to exist. However, most experiments only search for one of these states. We show that searches for fifth forces can't assume a non-relativistic potential induced by a single axion field. We discuss the strength of the non-relativistic spin-dependent and spin-independent potentials in the most general case of N_a different axions and show how the shape of the potentials can be used to distinguish between different axiverse scenarios.

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Presenter(s) : Mr EBERHART, Alexander (Durham University)

Contribution ID : **12** Type : **not specified**

Search for axionlike particles with ferromagnetic system.

Ferromagnetic materials offer the unique advantages of an exceptionally high spin density and large remanent magnetization. When levitated, a ferromagnet can serve as an ultrasensitive magnetometer, while soft ferromagnetic materials with low remanence provide efficient magnetic shielding. In this talk, I will introduce a hybrid ferromagnetic platform that combines these complementary functionalities. The resulting system achieves ultrahigh magnetic sensitivity together with a broad detection bandwidth.

Primary author(s) : Prof. JI, Wei; Mr PENG, Chenhao; Prof. LIU, Jia

Presenter(s) : Prof. JI, Wei

Contribution ID : **13** Type : **not specified**

Laser wakefield based axion-like particle generation and detection

The axion, a theoretically well-motivated particle, has been searched for extensively via its hypothetical interactions with ordinary matter and fields. In this talk, an axion detection approach utilizing the ultra-intense electromagnetic fields produced by laser–plasma interactions will be reported. We have developed particle-in-cell (PIC) simulation method that incorporates the axion field, the electromagnetic fields, and their interactions. By using such code we proposed a new scheme for axion generation and detection. A laser pulse firstly drives a nonlinear bubble structure inside a gas plasma and a tailor pulse propagates inside the bubble. The coupling between the laser field and the wakefield can generate axions, which then interact with both of the two fields and generate secondary electromagnetic fields. The radiated EM fields show high order frequency and spatial mode compared with the laser pulse, which gives a possible way to detect the axions. In further, to increase the detection ability, we propose a seeded photon scheme to enhance the conversion from axions to photons and it could be used in the light shinning through a wall scheme for axion detection.

Primary author(s) : Prof. CHEN, Min (Shanghai Jiao Tong University)

Presenter(s) : Prof. CHEN, Min (Shanghai Jiao Tong University)

Contribution ID : **14** Type : **not specified**

New limits on muon-philic dark matter searches and other recent progresses from PKMu

The PKMu experiment uses a resistive plate chamber (RPC) muon tomography system to study cosmic-ray scattering as a probe of both secondary cosmic-ray composition and new physics. During a 63-day data-taking campaign, 1.18 million scattering events were recorded and analyzed. Template fits to the scattering-angle distribution enable precise measurements of secondary cosmic-ray components, including the electron fraction at approximately 2% precision. The same dataset is also used to search for elastic scattering between cosmic-ray muons and muon-philic dark matter. Assuming a slow dark matter component captured and thermalized within the Earth, PKMu sets a 95% confidence level upper limit of $1.61\times10^{-17}\ \mathrm{cm}^2$ on the muon–dark matter elastic scattering cross section for 1 GeV dark matter. This contribution presents these new dark matter constraints together with other recent experimental developments from PKMu.

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Contribution ID : **15** Type : **not specified**

In-situ axion-conversion of a gamma-ray burst

Gamma-ray bursts (GRB) are the most powerful cosmic events, observed up to the multi TeV range with modern instruments like LHAASO. The brightest one ever detected, GRB221009A, challenged the frontier of known physics. As an extragalactic source estimated at about z~0.15, its transparency at multi-TeV energies poses a serious challenge to conventional models of the Extragalactic Background Light. Physics beyond the standard model has subsequently been invoked to explain the observation, notably axions acting as a weakly-interactive particle mediating the propagation across the intergalactic medium. In this talk, I propose a mechanism for in-situ axion conversion in the source's plasma, built upon the so-called "reverse-shock" model of B. Zhang et al.

Primary author(s) : ABOUNNASR, Théo (Irap, Toulouse)

Presenter(s) : ABOUNNASR, Théo (Irap, Toulouse)

Contribution ID : **16** Type : **not specified**

Probing Ultralight Dark Matter with Gravitational Waves

Ultralight bosons are promising dark matter candidates that can leave observable imprints in gravitational waves. In this talk, I will discuss several complementary ways to probe ultralight scalar fields with gravitational wave observations. I will focus on black hole superradiance and the resulting stochastic gravitational wave background, including the impact of higher modes, current LIGO–Virgo constraints, and the prospects for next-generation detectors. I will also discuss how self-interactions modify these signals, and how extreme-mass-ratio inspirals in scalar-cloud environments can develop resonant features that may be detectable by future space-based detectors. These results show that gravitational waves provide a powerful multi-band probe of ultralight dark matter.

Primary author(s) : Dr CHEN, Yuan

Presenter(s) : Dr CHEN, Yuan

Contribution ID : **17** Type : **not specified**

Floquet and Sideband Dynamics of Photon–Axion Mixing in Coherent Axion Backgrounds

Coherent axion dark matter provides a periodically time-dependent background for electromagnetic propagation. In the presence of an external magnetic field, the oscillating axion field acts as a temporal pump and can drive photon–axion conversion beyond the conventional static or adiabatic level-crossing picture. A unified Floquet and sideband description of this dynamics will be presented.

Resonant photon–axion mixing can occur when the mismatch between photon and axion dispersion relations is compensated by integer harmonics of the axion oscillation frequency. This driven resonance enables efficient conversion away from the usual level-crossing regime and is missed after time averaging. It constitutes a unitary mode-conversion process, distinct from axion decay or parametric particle production, and can lead to characteristic polarization signatures relevant for astrophysical observations.

A Floquet–Bloch sideband formulation of axion electrodynamics will be discussed. The periodic axion background generates a ladder of photon and axion sidebands. Near folded degeneracies, the system reduces to universal two-mode crossings whose stability is determined by the symplectic, or Krein, signatures of the colliding modes. This framework unifies stable avoided crossings, parametric instabilities, forward conversion, stop bands, and distributed reflection within a single language.

Together, these results clarify how coherent axion backgrounds modify wave propagation and provide new theoretical tools for identifying observable signatures of axion dark matter.

Primary author(s) : YAO, Runmin (HIAS, UCAS); BI, Xiaojun (IHEP); YIN, Pengfei; HUANG, Qingguo

Presenter(s) : YAO, Runmin (HIAS, UCAS)

Contribution ID : **18** Type : **not specified**

Black hole superradiance of interacting multi-fields

Ultralight bosonic fields can undergo exponential amplification around rotating black holes through black hole superradiance. This process can result in black hole spin-down, continuous gravitational-wave emission, and many other observable consequences, providing a powerful probe of dark particles in the strong-gravity regime. In particular, the LVK Collaboration has placed constraints on dark scalars with masses around 10^{-12} eV.

While most existing studies assume a single field, the dark sector may contain multiple particle species with nontrivial interactions. In this work, we investigate black hole superradiance in the presence of multiple interacting fields. In particular, we compute the corrections to the superradiant growth rates induced by interactions with other fields, study the nonlinear evolution of the superradiant system, and discuss the observational implications.

We find that interactions can significantly suppress black hole superradiance and modify the superradiant evolution, even if the coupled field is not itself superradiant. We demonstrate that multi-field interactions can qualitatively alter superradiance phenomenology and should be incorporated when deriving robust constraints on the dark sector from black hole spin measurements and gravitational-wave observations.

Primary author(s) : Dr ZHANG, Jun (International Center for Theoretical Physics Asia-Pacific)

Presenter(s) : Dr ZHANG, Jun (International Center for Theoretical Physics Asia-Pacific)

Contribution ID : **19** Type : **not specified**

Deconstructing the Extra-Dimensional Axion

We present a four-dimensional deconstruction of the extra-dimensional axion arising from a $U(1)$ gauge theory in a five-dimensional orbifold, where the axion is identified with the Wilson line of the $U(1)$ gauge field and its coupling to QCD is generated by a 5D Chern-Simons (CS) term. We construct the corresponding 4D moose (quiver) gauge theory with link scalar fields, in which the axion emerges as a collective pseudo-Nambu-Goldstone boson. The axion-gluon coupling is described by a gauged Wess-Zumino-Witten term, providing the 4D counterpart of the 5D CS term. We further analyze non-perturbative effects from zero-mode and "fractional" instanton configurations. While the latter is exponentially suppressed in the regime corresponding to the 5D description, ensuring consistency with the higher-dimensional picture, we point out that this suppression can break down for smaller instantons whose inverse size exceeds the 5D cutoff scale, leading to a potentially significant effect. We also study axion potentials induced by bulk matter fields and boundary-localized symmetry-breaking operators, reproducing the characteristic nonlocal suppression associated with propagation in the extra dimension. Our construction provides a renormalizable 4D framework with a transparent understanding of the axion shift symmetry and its quality.

Primary author(s) : XU, Junxuan (TDLI)

Presenter(s) : XU, Junxuan (TDLI)

Contribution ID : **20** Type : **not specified**

A Natural Dark Matter–Dark Energy Interaction from Axion–Monopole Dynamics

We propose a natural framework for interacting dark matter and dark energy based on axion–monopole dynamics in a dark gauge sector. Dark matter is composed of dark 't Hooft–Polyakov monopoles, while dark energy is an ultralight axion whose coupling to the dark gauge field induces an axion-dependent dyon mass through the Witten effect. This generates a direct dark matter–dark energy interaction. We show that generic models with a significant dark matter–dark energy coupling suffer from a naturalness problem: the Coleman–Weinberg potential induced by the interaction is typically much larger than the dark-energy scale. In our model, the corrections arise from a monodromy tower of dyon states, allowing them to be exponentially suppressed. In the minimal setup, the interaction strength is predicted to be $\sim 0.1\%$, below the sensitivity of current observations. We discuss scenarios in which cosmological population of higher-charge dyons can enhance the interaction to the percent level, producing an apparent phantom dark-energy equation of state.

Primary author(s) : XIAO, Huangyu (Harvard University and Boston University)

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Contribution ID : **21** Type : **not specified**

S-matrix bootstrap bounds on self-interacting dark matter

Self-interacting dark matter turns the structure of galactic halos into a direct requirement on a low-energy scattering amplitude. We show that, for weakly coupled scalar dark matter, this requirement implies a much stronger mass bound on the dark matter particle than partial-wave unitarity alone. Using analyticity, crossing symmetry, locality and partial-wave unitarity, we compute the maximal allowed threshold amplitude with a dispersive primal S-matrix bootstrap, assuming only a weakly coupled EFT below a scale Λ and allowing arbitrary UV particle content above Λ. For the benchmark self-interaction cross section $\sigma_{\rm self} = 10^{-24}(M/\mathrm{GeV}), \mathrm{cm}^2$, the mass of a generic weakly coupled scalar satisfies $M <\approx 0.3, \mathrm{GeV}$ in the controlled EFT regime. If dark matter is a derivative-dominated pseudo-Nambu-Goldstone boson, the mass bound is lowered to the MeV scale or below, depending on the hierarchy M/Λ. The results presented here are based on recent joint work with Qing Chen and Shuang-Yong Zhou, arXiv:2607.13141.

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Presenter(s) : WANG, Zhuo-Hui (University of Science and Technology of China)

Contribution ID : **22** Type : **not specified**

Search for light WIMPs with BULLKID-DM experiment using monolithic arrays of detectors

BULLKID-DM is a cryogenic experiment designed for direct detection of WIMP-like dark matter particles with a mass below 1 GeV/c^2. The detector will consist of a stack of 16 intrinsic silicon wafers, for a total mass of 800 g, that are carved in 2320 active dice with a volume of $5.4\times5.4\times5$ mm^3. Each die will be instrumented with multiplexed Kinetic Inductance Detectors (KIDs), acting as a particle absorber with an individual energy threshold of 200 eV or better. The array design enables the volume fiducialization to improve background discrimination.
To minimize the background signals from ambient radioactivities, besides using radiopure materials, a comprehensive shielding system, including a mixture of lead, copper and neutron moderator material (⊠4⊠) that placed both inside and outside the cryostat will be implemented. A cryogenic anti-coincidence veto system is also designed to further suppress the external gamma backgrounds. The veto system will use scintillating crystals and their light output is read out by phonon-mediated KIDs. The overall background with the veto system is expected to be close to the zero-background limit of 10^{-2} counts / (keV kg day).

This work presents the first operation of a 60 g demonstrator with 180 dice, in a surface laboratory equipped with a lead and copper radiation shield. The recorded backgrounds are in line with Geant4 simulations performed by the collaboration, paving the path to the deployment of final 800 g array. Current efforts focus on the low-radioactivity detector mounting, a cryogenic scintillating veto readout with KIDs, in situ calibration techniques, and detector upgrades such as KIDs with dedicated phonon-collecting structures and germanium substrates for multi-target capabilities.
The demonstrator is intended to be installed at the Gran Sasso underground laboratory (LNGS) by late 2026, following successful validation, the full experiment is expected to be commissioned in 2027.

Primary author(s) : ZHAO, Kangkang (Gran Sasso Science Institute, INFN-LNGS)

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Contribution ID : **23** Type : **not specified**

Strong-Field Dynamics and Multimessenger Signatures of Ultralight Dark Matter

Ultralight bosons near compact objects can form gravitationally bound states, some of which grow exponentially by extracting black hole rotational energy or through relaxation from ambient waves. These states can reach field amplitudes approaching the Planck scale, leading to non-perturbative phenomena analogous to early-universe cosmology and to observational signatures far stronger than those from local dark matter detection, including electromagnetic features in black hole imaging and gravitational-wave imprints of the surrounding environment. Two examples of strong-field phenomena will be discussed. First, accreting axion clouds can enter a saturation regime in which the field approaches the decay constant, with relativistic axion emission balancing the accretion and encoding the underlying self-interactions. Second, high-energy neutrinos propagating through a dense scalar background with non-diagonal couplings can undergo parametric resonance, leading to distortions in the observed flavor ratios.

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Presenter(s) : CHEN, Yifan (Tsung-Dao Lee Institute)

Contribution ID : **24** Type : **not specified**

Search for Cosmic-Ray Produced Light Dark Meson at JUNO Detector

Null results from WIMP searches motivate light sub-GeV dark sectors, whose low-mass nuclear recoils evade conventional direct detection. Cosmic-ray collisions in the atmosphere produce relativistic dark mesons that overcome this kinematic barrier. This talk focus on a confining dark sector (Dark QCD) with N_f=3 flavors coupled to the SM via a leptophobic U(1)_D vector portal. Dark quarks produced through proton bremsstrahlung, pion/eta meson decays, and Drell-Yan processes hadronize into dark mesons via a Modified Quark Combination Model. Portal-coupled K_D mesons scatter in the JUNO detector, simulated with GENIE under a conservative LES-inspired selection.

Primary author(s) : LI, jinmian; Dr PEI, Junle (Institute of Physics, Henan Academy of Sciences)

Presenter(s) : LI, jinmian

Contribution ID : **25** Type : **not specified**

Transient Bias for CP Domain Wall Decay and Dark Matter

Spontaneous CP violation (SCPV) provides an attractive solution to the strong CP problem. However, SCPV after inflation suffers from the formation of CP domain walls, requiring the maximal temperature of the Universe to lie below the CP-breaking scale. In the present work, we then propose a dynamical mechanism that removes this cosmological constraint without introducing permanent explicit CPV. We consider a new scalar field that acquires a large field value with a nontrivial phase in the early Universe and induces a transient bias among degenerate CP vacua through a higher-dimensional interaction with a CP-breaking scalar field. This bias triggers the decay of CP domain walls after they form. As the new scalar field evolves toward the origin, the bias disappears, leaving the low-energy CP structure intact. We derive the conditions for successful domain wall decay and identify the viable parameter space. Furthermore, we point out that the coherent oscillation of the new scalar field naturally survives as dark matter, linking the resolution of the CP domain wall problem to the origin of dark matter.

Primary author(s) : LIU, Fangchao (TDLI, SJTU); HAO, Sally Yuxuan (TDLI, SJTI); NAKAGAWA, Shota (Tsung-Dao Lee Institute); NAKAI, Yuichiro

Presenter(s) : LIU, Fangchao (TDLI, SJTU)

Contribution ID : **26** Type : **not specified**

Same-sign dimuon probe of charged lepton flavor violation at electron–photon colliders

Observation of charged lepton flavor violation would constitute unambiguous evidence for physics beyond the Standard Model (SM). We identify a previously unexplored same-sign dimuon signature in electron–photon collisions, $\gamma e^- \to e^+\mu^-\mu^-$, mediated by an axionlike particle (ALP) with flavor-violating e–μ couplings. The absence of irreducible SM backgrounds and the on-shell production of the ALP render this channel intrinsically clean and highly sensitive, with only small residual backgrounds arising from detector effects. Such collisions can be realized via laser Compton backscattering at e^+e^- colliders including BEPC-II with the BESIII detector, STCF, CEPC, and ILC. We find that STCF, CEPC, and ILC can probe couplings one to two orders of magnitude below existing bounds. This combination of resonant production, vanishing irreducible background, and same-sign topology would be difficult to achieve in conventional e^+e^- or hadron-collider environments, establishing electron–photon collisions as a uniquely powerful probe of charged lepton flavor violation.

Primary author(s) : □, □ (□□□□□□□)

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Contribution ID : **27** Type : **not specified**

Bias with a Timer: Axion Domain Wall Decay and Dark Matte

We explore the interplay of the post-inflationary QCD axion and a light scalar field for the axion domain wall decay and dark matter (DM). The scalar field possesses a nonzero vacuum expectation value (VEV) during inflation, so that its interaction with the axion effectively serves as an explicit Peccei-Quinn (PQ) violating term. At a temperature below the PQ phase transition, the effective PQ violating interaction generates the axion potential which generally contains multiple degenerate vacua leading to the formation of the axion string-domain wall networks. The following QCD phase transition provides another contribution to the axion potential making domain walls decay before they dominate the Universe. Later, the scalar field starts to relax to the minimum of its potential with a vanishing VEV, turning off the effective PQ violating interaction so that the axion potential is aligned with the QCD vacuum. We keep track of the evolution of the axion-scalar system and discuss the production of the axion DM through the domain wall decay and the (trapped) misalignment. We find that the string-wall network in some cases can decay due to its structural instability, rather than the volume pressure, and the correct axion DM abundance is realized with the decay constant larger than that of the conventional post-inflationary QCD axion without fine tuning.

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Contribution ID : **28** Type : **not specified**

Test

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Contribution ID : **29** Type : **not specified**

Semiconductor Spin-Qubit Arrays for Axion Dark Matter Search

Axions and axion-like particles are compelling dark-matter candidates whose derivative couplings to fermion spins generate an oscillatory, spin-dependent effective field, often referred to as the axion wind. This talk explores semiconductor quantum-dot spin qubits as frequency-resolved quantum sensors for axion-induced spin dynamics and, more broadly, as a platform for weak-field detection at the nanoscale. By mapping the axion–spin interaction or other weak effective-field perturbations onto controlled phase accumulation in coherent spin-qubit protocols, semiconductor devices provide a tunable architecture in which coherence time, control bandwidth, sensor filter functions, and readout fidelity can be engineered for narrowband sensing. I will discuss how spectral engineering of spin-qubit control sequences can enhance sensitivity within targeted axion-mass windows while suppressing charge noise, magnetic noise, and control-induced backgrounds. Particular emphasis will be placed on realistic noise spectra, quantum-control filter functions, weak field sensitivity limits, and the resulting coupling reach. Beyond sensitivity optimization, I will show how the motion of the terrestrial laboratory through the Galactic dark-matter halo produces characteristic sidereal and annual modulation signatures, leading to structured sideband responses that provide a robust discriminator against stationary instrumental backgrounds. Finally, I will outline prospects for hybrid electronic–nuclear spin architectures, where long-lived nuclear coherence can be combined with fast electronic-spin initialization and readout through hyperfine-mediated transduction, offering a scalable and CMOS-compatible route toward chip-integrated weak field sensing, axion searches, and broader quantum-enabled dark-matter detection.

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Contribution ID : **31** Type : **not specified**

Discussion K to pi a decay within large N_C chiral perturbation theory

The decay $K \to \pi a$ provides the most stringent particle-physics constraints on ALPs with masses below 300 MeV. Previous studies have been performed within SU(3) chiral perturbation theory, where the η_0 is integrated out. However, the explicit η_0 may play an important role, since the ALP and the η_0 belong to the same flavor-singlet sector. In this talk, we discuss the $K \to \pi a$ decay in U(3) chiral perturbation theory, focusing on the explicit η_0 contribution, the new weak operator, and the large-N_C behavior of the decay amplitude.

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Contribution ID : **32** Type : **not specified**

Axion Magnetic Resonance and the Enhanced Axion Signal

It is well-known that axions and photons can coherently convert into each other in a background magnetic field, a phenomenon commonly observed in a mixed two-level quantum system such as neutrino oscillations and nuclear spin processions. Similar to the nuclear magnetic resonance and spin flips in a qubit system, we point out that an periodic (in time or space) background magnetic field can significantly enhance the axion-photon conversion. We denote this resonance as the Axion-Magnetic Resonance (AMR).

In this talk, I will illustrate the theoretical and experimental implications of the AMR, in particular in the context of laser-based axion searches and solar axion experiments (helioscopes). I will show its relevance for interesting some ALPs models and its capability in distinguishing different QCD axion models (KSVZ and DSFZ), independent of the axion relic abundance or cosmological history.

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Contribution ID : **33** Type : **not specified**

Constraints on Axion-Like Particles with the Silicon Detector at a Nuclear Reactor

Axion and axion-like particles (ALPs), predicted in various extensions of the Standard Model, can be abundantly produced in nuclear reactors via the Primakoff process. In this work, we explore the detection of ALPs in silicon detectors through plasmon excitations. Owing to their relativistic nature, reactor-produced ALPs can efficiently excite plasmon resonances, while the accompanying energetic photon typically escapes from the thin detector without depositing an appreciable amount of energy. Utilizing the data from the Connie and Atucha-II experiments, we set the 90% confidence level upper limits on the ALP-photon coupling $g_{a\gamma\gamma}$ over the axion mass range $0.1-100$ keV. We further show that, for an exposure of 30 kg·yr, the projected sensitivity of vIOLETA exceeds the current NEON limit by a factor of three in the same mass range. This improvement would expand the explored region of the QCD axion and ALP parameter space.

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Contribution ID : **34** Type : **not specified**

Detecting Axion Dark Matter by Artificial Magnetoelectric Materials

Axions are considered a key component of dark matter, characterized by very weak couplings to fermions and Chern-Simons couplings to gauge fields. We propose a novel detection mechanism based on symmetry-breaking magnetoelectric materials with a linear axionic coupling between magnetization and ferroelectric polarization. The focus is on a strain gradient Sr_2IrO_4 film, where the breaking of space-inversion symmetry results in an emergent polar phase and an out-of-plane magnetic moment, exhibiting a flexomagnetoelectric effect. In this material, the linear $\mathbf{P}||\mathbf{M}$ enables a direct coupling between the external axion field and the intrinsic axion-like field, which amplifies the weak electromagnetic signals induced by axions, paving the way for pioneering axion detection. In contrast to conventional detection techniques, this mechanism is expected to enhance the sensitivity of the axion-electron and axion-photon coupling, providing a novel platform for axion detection and advancing the study of dark matter through the magnetoelectric effect.

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Contribution ID : **35** Type : **not specified**

Cosmological Collider Physics with Axions

We introduce the basics and recent developments of cosmological collider physics and cosmological correlators, with an emphasis on their applications to axions.

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Contribution ID : **36** Type : **not specified**

Axion Dark Matter Induced Modulation in Ferromagnetic Resonance and Spin Wave Interferometry

We propose a novel asymmetric sensitive spin wave interferometer to detect ultralight axion dark matter, which modulates spin wave properties through a weak effective magnetic field in ferromagnets. By splitting a spin wave source into two paths of different lengths and setting them to interfere destructively, the interferometer converts the axion induced phase shift into a measurable magnetization oscillation, which can radiate electromagnetic waves and also generate electrical signals via Faraday induction. The signal to noise ratios have been evaluated for three detection schemes: the linear amplifier, the single photon detector and the electrical signal detection approach, with both magnetization fluctuation noise and thermal noise taken into account. Limited by the conditions of spin wave propagation distance and the relaxation time, the accessible axion mass range is approximately 10^{−8} eV to 10^{−6} eV.

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Contribution ID : **38** Type : **not specified**

Search for ultralight scalar dark matter with quadratic interactions

In this talk, I will discuss about my recent work on the searches for the ultralight scalar dark matter with quadratic interactions with SM fields. This will lead to the effective interactions between the ultralight dark matter and the nucleon fields phi^2 N N/f below the QCD confinement scale, which can be thought as potential barrier for the dark matter wind in the presence of ordinary matter. When the potential barrier is large enough compared with the kinetic energy of the dark matter, the dark matter flux will bounce back from the ordinary object, as a result inducing a pressure force on the object. After taking into the constraints from Supernova cooling, BBN and gravitational inverse square law test, there exists parameter spaces in our model which can be searched for by utilizing this force effect on the experiment for the test of the weak equivalence principle.

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Contribution ID : **39** Type : **not specified**

Resonant enhancement of axion dark matter decay

The axion is a particularly well-motivated candidate for the dark matter comprising most of the mass of our visible Universe, leading to worldwide experimental and observational efforts toward its discovery. As is well known, resonant cavities are a primary tool in this search, where they are used to enhance the conversion rate of axions into photons in a background electromagnetic field. What is perhaps less well appreciated is that resonant cavities can also enhance the rate at which axions decay to two photons, a manifestation of the Purcell effect. We examine this possibility and show that it offers a previously unexplored method to search the axion parameter space in a way that is competitive and complementary to other approaches, with the capability to probe a well-motivated region for QCD axion dark matter. Furthermore, we establish that this method can be implemented via preexisting axion heterodyne detection schemes, enabling such experiments to perform these searches with minimal modification.

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Contribution ID : **40** Type : **not specified**

Paths to Solving the Strong CP Problem and the Footprints Left Behind

We explore two major approaches to the strong CP problem, the axion solution and spontaneous CP violation (SCPV). We first focus on composite axion models, which provide a compelling realization of the axion solution but face serious cosmological challenges, in particular the domain wall problem. We present a new framework based on a special embedding of gauge symmetries, where the domain wall number is reduced to unity in the ultraviolet theory, and small instanton effects induce a controlled bias term that lifts the vacuum degeneracy and allows domain walls to decay without spoiling the axion solution. We then turn to the axionless approach based on SCPV, where CP is an exact symmetry of the Lagrangian and is broken only spontaneously. In supersymmetric theories, SCPV can be realized along flat directions and stabilized by supersymmetry-breaking and non-perturbative dynamics, and the framework is compatible with viable cosmology including Affleck–Dine baryogenesis. These mechanisms provide distinct paths to resolving the strong CP problem with testable implications.

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Contribution ID : **41** Type : **not specified**

Majoron Potential by Majorana fermion Loops

We present a diagrammatic framework for radiative Majoron potentials induced by an explicit Majorana mass M. Classifying one-loop diagrams by the number of fermion-number-violating (N_{FNV}) and fermion-number-preserving (N_{FNP}) propagators yields a heavy-mass scaling rule: pure FNV amplitudes behave as M^{4-n}, while mixed diagrams receive additional suppression from momentum numerators. After removing the dominant tadpole by a matching condition, the bubble diagram provides the leading Majoron mass $\propto y^2 M^2$. The mixed FNV/FNP triangle supplies the complete next-to-leading $\mathcal{O}(yv/M)$ correction through a $\cos\theta$ harmonic after vacuum alignment. We analyze the one-loop Coleman-Weinberg potential for the full two-field space $V_{\mathrm{eff}}(r,\theta)$, derive the quantum-shifted vacuum and scalar Hessian, and identify the parameter conditions required for local stability. The heavy Majorana fermion decouples from irrelevant operators but leaves non-decoupling threshold corrections to relevant symmetry-breaking operators. At finite temperature, the explicit breaking spurion M induces a thermal tadpole $\propto MT^2 r\cos\theta$. This term prevents the origin from ever being a stationary point, ensuring that the radial vacuum expectation value remains non-zero at all temperatures. Consequently, the system undergoes a smooth crossover rather than a true symmetry-restoring phase transition, and the pseudo-Goldstone description remains rigorously valid across all temperature regimes. The resulting effective potential is a periodic non-linear sigma model whose Wilson coefficients follow a two-parameter lattice classification.

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Contribution ID : **42** Type : **not specified**

Constraints on axions from neutrino experiments

Constraints on axions from neutrino experiments

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