The Great Lakes Beyond-Standard-Model Workshop

Report of Contributions

https://indico.global/e/15931

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

The Price of a Large Electron Yukawa

Tuesday 2 December 2025 12:00 (30 minutes)

The electron–positron phase of the Future Circular Collider (FCC-ee) will offer an opportunity to significantly improve measurements of the Standard Model parameters. One possible measurement is the Higgs–electron coupling, which requires a year of dedicated run time. In this talk, I will first summarize the experimental strategy and projected sensitivities for this program at FCC-ee, and how close such measurements can approach the Standard Model prediction. I will then explore the implications for new physics in scenarios where the electron Yukawa coupling is enhanced by factors of a few, using the framework of SMEFT. Comparing FCC-ee's reach with complementary bounds helps clarify the landscape in which an enhanced electron Yukawa could be the first observable sign of physics beyond the Standard Model.

Presenter: ROCHA, Duncan (University of Chicago)

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

Cosmological Aspects of Axion-Monopole Interactions

Tuesday 2 December 2025 12:30 (30 minutes)

We propose a minimal and natural dark-sector framework in which dark matter is composed of magnetic monopoles coupled to a light axion field. Through the Witten effect, the axion background induces electric charge on the monopoles, turning them into dyons that in turn modify the axion potential. This monopole-dependent axion mass provides a simple, radiatively stable mechanism for dark-sector interactions and allows the axion to act as a dynamical dark-energy component. The resulting slow evolution of the axion field at late times can naturally produce the polarization rotation associated with the reported CMB cosmic birefringence signal and may also accommodate the evolving dark-energy behavior suggested by recent DESI data. This framework offers a unified and economical explanation for multiple late-time cosmological hints.

Presenter: BAGHERIAN, Hengameh (University of Chicago)

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

(Non-)Perturbative Dynamics of Light QCD Axion Cosmologies

Tuesday 2 December 2025 13:00 (30 minutes)

The QCD axion, which solves the strong CP problem and constitutes a dark matter candidate, remains one of the most motivated signals of physics beyond the Standard Model. In the canonical scenario, the QCD axion mass-coupling relation fixes the interaction strength below the reach of most experiments, which target lighter or more strongly coupled axions. However, no fundamental principle demands this canonical relation. If a light QCD axion were discovered, the so-called Z_N model—invoking N exact Standard Model copies coupled by the QCD axion—would be one of the few natural explanations. Yet in a Z_N scenario only a fraction of the possible cosmological evolutions yield a solution to the strong CP problem—first assumed to be 1/N. Moreover, these scenarios are generically susceptible to non-perturbative dynamics that modify the axion relic abundance. The dynamics we uncover are expected to play a similar role in other light-axion cosmologies, including tuned Z_N models. We present the first perturbative statistical treatment of the CP-solution probability, and the first non-perturbative lattice simulations for the Z_N axion. Together, they reveal a significant reduction in the probability of solving the strong CP problem relative to the 1/N expectation, and an O(1) suppression of the axion dark matter abundance.

Presenter: LEONARD, Owen (Indiana University)

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

Effects of Lighter-than-QCD Axions no Neutron Star Tidal Deformability

Tuesday 2 December 2025 13:30 (30 minutes)

Finite density corrections to the lighter-than-QCD axion can invert the effective axion potential, sourcing a non-trivial axion field inside dense objects. In this talk, I will present the first numerical study of the complete dynamics of the lighter-than-QCD axion in a neutron star in 1+1 general relativity, extending the region of analysis of the lighter-than-QCD axion to low-mass axions with kilometer-scale Compton wavelengths. I will discuss the gravitational effects of the axion field on the neutron star and show that for a broad range of axion masses and decay constants, macroscopic neutron star properties, such as the mass, radius, and compactness, are affected at the order-1 level. This result indicates that approximate universal tidal deformability-compactness relation for neutron stars is non-trivially broken and can serve as a probe of lighter-than-QCD axions, independent of the unknown nuclear equation of state. I will highlight the potential for axion studies with future gravitational-wave observations of neutron stars and applications of this work to other new physics signatures.

Presenter: WENTZEL, Michael (University of Illinois Urbana-Champaign)

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

The cosmology of neutrinophilic ULDM and its impact on BBN

Tuesday 2 December 2025 15:00 (30 minutes)

The high densities in the early Universe provide a unique laboratory to constrain couplings between feebly interacting particles, such as dark matter and neutrinos. I will introduce a model where neutrinos get their mass from a small diagonal coupling to ultralight dark matter (ULDM), and how to consistently use cosmology, namely Big Bang Nucleosynthesis (BBN), to constrain it. In particular, I will emphasize the need for accounting for the neutrino backreaction in the ULDM evolution, which causes its energy density to scale as radiation when the neutrino interaction dominates the dynamics. Finally, I will discuss the effect of the coupled neutrino-ULDM fluid in BBN and how to use primordial element abundances to obtain competitive (and consistent) constraints.

Presenter: BERTÓLEZ-MARTÍNEZ, Toni (University of Wisconsin Madison)

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

AXIS can Access Dark Matter Decays

Tuesday 2 December 2025 15:30 (30 minutes)

As one of NASA's proposed future Astrophysics Probe missions, the Advanced X-ray Imaging Satellite (AXIS) is designed to improve the sensitivity and spatial resolution of the Chandra X-ray Observatory. AXIS aims to deliver low-background, arcsecond imaging over a broad 0.3–10 keV energy range, featuring an effective area of 3600 cm^2 at 1 keV and 830 cm^2 at 6 keV across a 450 $arcmin^2$ field of view. These capabilities open a new parameter space for exploring decaying dark matter candidates such as axion-like particles (ALPs) and sterile neutrinos through X-ray line searches. We present an initial study of AXIS's prospects for detecting dark matter decay signals, finding potential lifetime sensitivities of order $\approx 10^{30}$ seconds, surpassing current X-ray limits.

Presenter: SHAPIR, Nimrod (University of Chicago)

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

Indirect Detection of Complex Dark Sectors: Constraints and the Antinuclei Anomaly

Tuesday 2 December 2025 16:00 (30 minutes)

Complex dark sectors are models where a 'sector' of new particles with intra-sector interactions are used to extend the Standard Model. Motivated by theoretical considerations such as the Hierarchy Problem, these models generically also provide dark matter candidates. In this talk I will discuss a range of complex dark sectors and how the properties of the gauge group can effect astrophysical signals. Additionally while we can constrain these models using a variety of channels, there is still room to explain the potential antinuclei excess observed at AMS-02.

Presenter: GEMMELL, Caleb (University of Wisconsin Madison)

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

Astrophysical signatures of dark matter (DM): probing DM through AGNs

Tuesday 2 December 2025 16:30 (30 minutes)

Active Galactic Nuclei (AGNs) are among the most powerful multi-messenger sources in the universe, emitting high-energy neutrinos and electromagnetic radiation. Recent observations from IceCube and complementary gamma-ray and X-ray telescopes aid in precise modeling of these extreme environments. In this talk, I will discuss how AGNs—natural sites of intense particle acceleration—can also serve as laboratories for probing DM. In the dense DM environments surrounding supermassive black holes, DM can scatter with AGN-accelerated cosmic rays (CRs), leading to rapid CR cooling. This can suppress or modify the expected high-energy neutrino and gamma-ray fluxes. These signatures reveal how AGN multi-messenger observations can probe dark-matter interactions.

Presenter: MUKHOPADHYAY, Mainak (Fermilab)