

Lighting New Lampposts for Dark Matter and Beyond the Standard Model

Events for:
Monday, March 13th - Friday, March 17th

Monday, March 13th

9:00am **Workshop: Breakfast - SCGP Cafe**

Title: Breakfast

9:30am **Workshop: Marc Kamionkowski (Hopkins) - SCGP 102**

Speaker: Marc Kamionkowski (Hopkins)

Title: Some modeling clay for cosmology

Abstract: We have a pretty good cosmological model: A few simple ansatzes and a handful of parameters go a long way in terms of explaining a broad array of observations and complicated data. Still, there are possibly some gaps and plenty of questions. These include the Hubble and S8 tension, but also other, less trumpeted, possible inconsistencies, including a recently noted excess of cosmic optical photons. There are then new directions in the modeling phase space that may be intriguing: for example, I have been interested in understanding how well we can determine whether baryons trace matter. I will discuss recent work related to all of these subjects.

10:30am **Workshop: Coffee Break - SCGP 102**

Title: Coffee Break

11:00am **Workshop: Neelima Sehgal (Stony Brook) - SCGP 102**

Speaker: Neelima Sehgal (Stony Brook)

Title: Discoveries from CMB-HD, a Stage-5 CMB Facility

Abstract: CMB experiments have contributed powerful constraints on the fundamental physics of the Universe. Upcoming CMB experiments such as the Simons Observatory and CMB-S4 are poised to extend this progress even further. However, CMB experiments still have a wealth of information to offer beyond these near-term facilities regarding the properties of dark matter, inflation, light relic particles, and dark energy. In particular, a much lower-noise and higher-resolution wide-area CMB survey can cross a number of critical fundamental physics thresholds and open a relatively untapped window of late-time CMB anisotropies. Here I will discuss CMB-HD, a Stage-5 CMB facility, and the wealth of discoveries it can enable.

11:30am **Workshop: Chris Tully (Princeton) - SCGP 102**

Speaker: Chris Tully (Princeton)

Title: Looking under the Relic Neutrino Lamppost

Abstract: The PTOLEMY demonstrator under construction at LNGS is on track to surpass in measurement resolution all previous tritium endpoint experiments. Commissioning of this system will enter a new level of sensitivity to neutrino mass and future high target mass relic neutrino observables. An update will be given on the performance of the individual detector elements and the plans for the first commissioning runs and goals. Ideas for sensitivity estimates to warm-inflation-esque late universe neutrino production will be discussed.

12:00pm **Workshop: Lunch - SCGP Cafe**

Title: Lunch

1:15pm **Workshop: Read My Paper Sessions - SCGP 102**

Speaker: Participants

Title: Read My Paper Sessions

2:30pm **Workshop: Yuval Grossman (Cornell) - SCGP 102**

Speaker: Yuval Grossman (Cornell)

Title: The (bosonic) neutrino pair

Abstract: In some aspects, neutrino pairs behave like bosons. In the talk, I discuss two such cases: the neutrino force and the neutrino Larmor radiation formula. Both effects are still only theoretically realized. I will discuss the progress that was done, and ways that we might be able to push forward, to find ways to probe them experimentally.

3:30pm **Workshop: Tea - SCGP Cafe**

Title: Tea

4:00pm **Workshop: Michael Romalis (Princeton) - SCGP 102**

Speaker: Michael Romalis (Princeton)

Title: Measuring shifts in spin energy levels with pHz sensitivity

Abstract: I will talk about our efforts to improve the precision of spin precession measurements using large ensembles of noble gas atoms. These systems have hours-long spin coherence times and are ideally suited for measurements of small energy shifts. Our most recent experiment uses a co-magnetometer comparing precession frequencies of Ne-21 and He-3 atoms using an in-situ Rb magnetometer. We have developed methods to reduce interactions between the spin ensembles which can create additional frequency shifts. The fundamental physics that can be studied with such measurements includes Lorentz and CPT violation, spin-gravity couplings and spin-interacting dark matter.

Tuesday, March 14th

9:00am **Workshop: Breakfast - SCGP Cafe**

Title: Breakfast

9:30am **Workshop: Giovanni Grilli di Cortona (CERN) - SCGP 102**

Speaker: Giovanni Grilli di Cortona

Title: Muon $g-2$ anomalies and GeV scale new physics

Abstract: The 4.2 sigma discrepancy between the theoretical prediction for the muon $g-2$ and its experimental measurement is accompanied by other anomalies. Determinations of the hadronic cross section from KLOE and BaBar, a crucial input for the data-driven prediction, disagree by almost 3 sigma. Furthermore, the data-driven result disagrees with the most precise lattice determination by ~ 2 sigma. In this talk, I will discuss how all these discrepancies could be accounted for by a new boson produced resonantly around the KLOE centre of mass energy and decaying promptly in electron-positron or muon-antimuon pairs. This construction performs well also in the short, intermediate and long distance windows and does not affect the CMD-3 experimental result.

10:00am **Workshop: Kim Boddy (Austin) - SCGP 102**

Speaker: Kim Boddy (Austin)

Title: Cosmological Bounds on Thermal Dark Matter

Abstract: TBA

10:30am **Workshop: Coffee Break - SCGP 102**

Title: Coffee Break

11:00am **Workshop: Wei Xue (U Florida) - SCGP 102**

Speaker: Wei Xue (U Florida)

Title: Probing massive gauge boson signals from axion inflation: gravitational waves and parity-odd trispectrum

Abstract: Considering a Chern-Simons coupling between gauge bosons and a pseudoscalar inflaton, one of the transverse gauge modes is efficiently produced. Its inverse decay leaves an imprint in the primordial scalar and tensor perturbations. These perturbations give rich predictions in cosmology, including cosmological collider, gravitational waves, and parity-odd trispectrum. I will show that the upcoming gravitational wave interferometers can detect the tensor part. Also, the axion inflation model gives the distinct parity odd trispectrum, which is a potential explanation for the recent observation of parity-odd galaxy trispectrum from the BOSS galaxy data.

11:30am **Workshop: Yonatan Kahn (UIUC) - SCGP 102**

Speaker: Yonatan Kahn (UIUC)

Title: Axion wind detection with the homogeneous precession domain of superfluid helium-3

Abstract: Axions and axion-like particles may couple to nuclear spins like a weak oscillating effective magnetic field, the “axion wind.” Existing proposals for detecting the axion wind sourced by dark matter exploit analogies to nuclear magnetic resonance (NMR) and aim to detect the small transverse field generated when the axion wind resonantly tips the precessing spins in a polarized sample of material. I will describe a new proposal using the homogeneous precession domain (HPD) of superfluid ^3He as the detection medium, where the effect of the axion wind is a small shift in the precession frequency of a large-amplitude NMR signal. I will show that this setup can provide broadband detection of multiple axion masses simultaneously and has competitive sensitivity to other axion wind experiments such as CASPER-Wind at masses below $1e-7$ eV by exploiting precision frequency metrology in the readout stage.

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1:15pm **Workshop: Read My Paper Sessions - SCGP 102**

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1:15pm **Workshop: Kim Boddy (Austin) - SCGP 102**

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Title: Cosmological Bounds on Thermal Dark Matter

Abstract: TBA

2:30pm **Workshop: Patrick Huber (Virginia Tech) - SCGP 102**

Speaker: Patrick Huber (Virginia Tech)

Title: Reactors, gallium and sterile neutrinos?

Abstract: There is a number of anomalies in low-energy neutrino experiments, which may or may not point towards a sterile neutrino. Neutrinos were discovered using a nuclear reactor as a source and since then much of our knowledge about neutrinos comes from experiments using reactors. I will briefly touch on the history of the use of reactors as neutrino source and motivate why they still play an important role today and in the future. An overview of the physics of how neutrinos are generated in reactors and how we can compute neutrino fluxes will follow. The developments of the past decade will be reviewed in particular. 2021 may have seen the resolution of one major riddle regarding the neutrino yield from uranium-235 and I will comment on this. I will present the current status of the sterile neutrino in electron neutrino disappearance including recent gallium results. I also will be touching on coherent elastic neutrino nucleus scattering at reactors.

3:30pm **Workshop: Tea - SCGP Cafe**

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4:00pm **Workshop: Josef Pradler (Vienna, OAW) - SCGP 102**

Speaker: Josef Pradler (Vienna, OAW)

Title: Dark multipole vectors below the GeV-scale

Abstract: In this talk, we consider the phenomenology of electrically neutral complex vector particles V with a mass below the GeV-scale, but with higher dimensional form factor interactions to the SM photon. The astrophysics, cosmology and direct detection phenomenology will be presented.

4:30pm **Workshop: Lindley Winslow (MIT) - SCGP 102**

Speaker: Lindley Winslow (MIT)

Title: D Axion Dark Matter and Quantum Measurement: ABRACADABRA to DMRadio

Abstract: The particle nature of dark matter remains one of the great open questions in physics. The axion has had a renaissance as a dark matter candidate as theoretical studies have improved our understanding of axion cosmology and advances in quantum sensing and cryogenics have opened new opportunities for detection. In this talk, I will present the current results from ABRACADABRA and our vision for the DMRadio program which aims to definitively search for GUT-scale axions throughout this 1 micro-eV space. The talk will also discuss the challenges in realizing this vision from an experimentalist's perspective.

Wednesday, March 15th

9:00am **Workshop: Breakfast - SCGP Cafe**

Title: Breakfast

9:30am **Workshop: Peter Graham (Stanford) - SCGP 102**

Speaker: Peter Graham (Stanford)

Title: Ultralight Dark Matter Detection with Trapped Electrons

Abstract: We have proposed and experimentally demonstrated a new way to search for ultralight dark matter using trapped electrons. The trapped electron serves as a high-Q resonator to search for dark photon and axion dark matter in the ~ 10 -100 GHz mass range. We carried out a proof-of-principle experiment which achieved a limit well beyond current bounds at a single frequency. Future improvements include enhancing the sensitivity of the resonator and improved cavity shape.

10:30am **Workshop: Coffee Break - SCGP 102**

Title: Coffee Break

11:00am **Workshop: Stefania Gori (UC Santa Cruz) - SCGP 102**

Speaker: Stefania Gori (UC Santa Cruz)

Title: New ALP probes from meson decays

Abstract: Rare meson decays are among the most sensitive probes of both heavy and light new physics. Among them, new physics searches using kaons and pions benefit from their small total decay widths and the availability of very large datasets. In this talk, we first give an overview of new opportunities to search for axion-like particles (ALPs) in light meson decays. Second, we revisit the theory and constraints on ALPs interacting with leptons, pointing out the relevance of charged current meson and W decays to ALPs. This is particularly prominent in models where the ALP couples in an isospin-violating way. Finally, we highlight the role of the future PIONEER experiment in probing these new charged current pion decays to ALPs.

11:30am **Workshop: Joshua Ruderman (NYU) - SCGP 102**

Speaker: Joshua Ruderman (NYU)

Title: Exponentially Growing Dark Matter

Abstract: The dark matter abundance may have experienced a period of exponential growth in the early Universe. This is a generic possibility if dark matter is non-thermal and if it experiences scattering processes converting one dark matter particle into two (or more) dark matter particles. I will show new parameter space for sterile neutrino dark matter, where active neutrinos oscillate into an initially small abundance of sterile neutrinos that then exponentially grows.

12:00pm **Workshop: Lunch - SCGP Cafe**

Title: Lunch

1:15pm **Workshop: Mark Vogelsberger (MIT) ZOOM - SCGP 102/ZOOM**

Speaker: Mark Vogelsberger (MIT) (ZOOM)

Title: Simulations of Cold Dark Matter and Beyond

Abstract: I will give an overview of recent simulation successes of cold dark matter simulations with and without baryons. After that, I will focus on simulations of alternative dark matter models with a focus on self-interacting dark matter. I will discuss different models of self-interacting dark matter and what kind of predictions simulations can make for these dark matter models.

1:45pm **Workshop: Daniel Gilman (Toronto) - SCGP 102**

Speaker: Daniel Gilman (Toronto)

Title: Quadruply-imaged quasars as testbeds for self-interacting dark matter

Abstract: Dark matter halos with masses down to 10^7 solar masses impart measurable perturbations to the relative magnifications among images in quadruple-image strong lens systems. The image magnifications provide a highly sensitive, purely gravitational probe of dark matter structure, including the internal structure of dark matter halos. The sensitivity to halo concentration and internal structure makes quadruple-image lenses ideal testbeds for detecting populations of core-collapsed halos predicted to form in models with self-interacting dark matter. I will explain how current observations of strong lenses with data from HST constrain the self-interaction cross, and how forthcoming data from JWST will enable new bounds on velocity-dependent self-interaction cross sections that reach large ($> 100 \text{ cm}^2 \text{ g}^{-1}$) amplitudes at relative velocities below 20 km/sec.

2:30pm **Workshop: Manoj Kaplinghat (UCI) - SCGP 102**

Speaker: Manoj Kaplinghat (UCI)

Title: Self-interacting Dark Matter: current status and future tests

Abstract: This talk will provide a summary of the astrophysical constraints on self-interacting dark matter (SIDM) models and motivate the idea of gravothermal collapse as a necessary part of the phenomenology. We will discuss some promising future astrophysical tests and end with an outlook on the small-scales issues.

3:30pm **Workshop: Tea - SCGP Cafe**

Title: Tea

4:00pm **Workshop: Hai-Bo Yu (UCR) - SCGP 102**

Speaker: Hai-Bo Yu (UCR)

Title: Signatures of strong dark matter self-interactions

Abstract: If dark matter particles have strong self-interactions, dark matter halos could experience gravothermal collapse, resulting in an extremely high density. In this talk, I will discuss recent work on high-resolution cosmological simulations that capture this process, and a mechanism that the collapsed halo provides a massive seed for supermassive black holes. I will further discuss observational tests with data from satellite galaxies of the Milky Way and high-redshift galaxies discovered by JWST.

4:30pm **Workshop: Mike Boylan-Kolchin (Austin) - SCGP 102**

Speaker: Mike Boylan-Kolchin (Austin)

Title: High-redshift structure formation and the Lambda-CDM model

Abstract: Once the six parameters of the base Lambda-CDM cosmology are specified, so too is a wide variety of phenomena, from statistical properties of the cosmic microwave background to the growth of structure to the evolution of the expansion rate of the Universe. While the base Lambda-CDM model is in excellent agreement with the vast majority of observations, I will consider the possibility that high-redshift galaxy candidates revealed with JWST may be in tension with its predictions. Possible extensions to Lambda-CDM that produce more structure at high redshift also have intriguing implications for the Hubble tension. I will discuss how this might be tested in the near future, including the use of precision stellar age measurements in the local Universe.

6:00pm **Workshop: Banquet Dinner - SCGP Cafe**

Title: Banquet

Thursday, March 16th

9:00am **Workshop: Breakfast - SCGP Cafe**

Title: Breakfast

9:30am **Workshop: Kathryn Zurek (Caltech) - SCGP 102**

Speaker: Kathryn Zurek (Caltech)

Title: CM for DM

Abstract: We review strategies, materials, and novel condensed matter systems for light dark matter detection.

10:30am **Workshop: Coffee Break - SCGP 102**

Title: Coffee Break

11:00am **Workshop: Ben Safdi (UC Berkeley) - SCGP 102**

Speaker: Ben Safdi (UC Berkeley)

Title: Gamma-ray probes of higgsino dark matter

Abstract: WIMP dark matter remains a well-motivated paradigm to explain the observed relic abundance of cold dark matter. The higgsino and the wino are arguably the two simplest implementations of this paradigm, with the dark matter placed either in the fundamental or the adjoint representation of $SU(2)_L$, respectively. The wino, however, is in tension with indirect detection constraints. Thus, the higgsino remains one of the last minimal dark matter candidates that has yet to seriously be probed experimentally. In addition to being a minimal dark matter candidate, higgsino dark matter would not be unexpected from the point of view of, for example, mini-split type theories of supersymmetry near the electroweak scale. In this talk I will discuss how gamma-ray data from the Fermi Large Area Telescope may already be used to search for evidence of higgsino dark matter annihilation. I will present results of the most sensitive search to-date for higgsinos with Fermi data, which tantalizingly shows a small fluctuation over the null hypothesis that could consistently arise from higgsino dark matter with the expected annihilation cross-section. I will discuss how existing data from the H.E.S.S. telescope could potentially already be used to verify this signal, if analyzed in the correct way, and how the higgsino model will be more definitively tested with data from the upcoming Cherenkov Telescope Array (CTA).

11:30am **Workshop: Neal Weiner (NYU) - SCGP 102**

Speaker: Neil Weiner (NYU)

Title: Nu Physics in the LCDM Desert

Abstract: LCDM has a “desert” from the MeV scale down to the eV scale. Because the universe is radiation dominated in this era, the evolution of density perturbations is especially sensitive to the presence and properties of additional radiation. An eV to MeV dark sector fermion with self-interactions which mixes with SM neutrinos will naturally come into equilibrium in this era and generically after BBN, even for exponentially small mixings and couplings. Via this particle, other dark sector particles can equilibrate and then decouple from the SM. Upcoming CMB experiments and LSS surveys directly probe the scales that came inside the horizon in this era, and should provide a robust test of whether a late dark sector equilibration occurs.

12:00pm **Workshop: Lunch - SCGP Cafe**

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1:15pm **Workshop: Read My Paper Sessions - SCGP 102**

Speaker: Participants

Title: Read My Paper Sessions

2:30pm **Workshop: Philip Schuster (SLAC) - SCGP 102**

Speaker: Philip Schuster (SLAC)

Title: New Ideas about Long Distance Physics

Abstract: Quantum Mechanics and Relativity suggest that long-distance physics is governed by the interactions of massless particles. From symmetry considerations alone, the polarization states of massless particles can transform covariantly under boosts, with a degree of mixing determined by a dimensional quantum number ρ . The case of Lorentz-invariant helicities corresponds to $\rho=0$, which is what we find in familiar gauge theories and general relativity. In this talk, I will introduce the core elements of a new gauge theory describing massless particles of the more general type, as well as basic aspects of their interactions with matter. As an illustration of the physics in a simple yet relevant example, I'll describe electromagnetism with nonzero ρ and discuss novel corrections to the Lorentz force law and Larmor radiation with testable predictions. I will also discuss ideas for how this physics might relate to dark matter, cosmology, and other aspects of phenomenology in the Standard Model.

3:30pm **Workshop: Tea - SCGP Cafe**

Title: Tea

4:00pm **Workshop: Vera Gluscevic (USC) - SCGP 102**

Speaker: Vera Gluscevic (USC)

Title: What does cosmology tell us about dark matter mass and interactions?

Abstract: Cosmological observables, from the CMB anisotropy to the census of galaxies in the early and local universe, offer the most direct and broad tests for the nature of dark matter, including a number of scenarios that are challenging or even impossible to test in a laboratory setting. I will review the status of the recent early-universe and late-universe searches for the identity of dark matter, summarizing the best current limits on scattering between dark matter and baryons, the non-thermal production mechanisms for sterile neutrinos, and mass bounds on thermal-relic dark matter. I will highlight the interplay between complementary probes of dark matter physics, using the example of the 21-cm signal from the Cosmic Dawn, the CMB primary anisotropy, and substructure in the Milky Way. Finally, I will discuss the prospects for unveiling the physics of dark matter in the coming decade.

4:30pm **Workshop: Julian Munoz (Austin) - SCGP 102**

Speaker: Julian Munoz

Title: What does the 21-cm signal really measure?

Abstract: The 21-cm line of hydrogen has a wealth of information about the dark sector of our universe. Its depth during cosmic dawn depends on the thermal state of gas, so it is sensitive to dark-matter annihilation/decays or scattering. Meanwhile, its timing is due to the first galaxy formation, and thus depends on dark-matter clustering at very small scales. In this talk I will demystify the 21-cm signal during cosmic dawn. I will describe a new effective approach to calculating the signal and how it enables us to understand each of the components analytically, highlighting the use of 21-cm for beyond-SM cosmology. If time allows, I will work through a tutorial of the Zeus21 Python package where this model is implemented. It takes seconds to run on a laptop, and does not require any simulation knowledge.

Friday, March 17th

9:00am **Workshop: Breakfast - SCGP Cafe**

Title: Breakfast

9:30am **Workshop: Tracy Slatyer (MIT) - SCGP 102**

Speaker: Tracy Slatyer (MIT)

Title: Where Next for Indirect Dark Matter Searches?

Abstract: I will review current results in indirect searches for dark matter, outline the landscape of upcoming experiments, and survey some key scientific goals for indirect detection over the next decade. I will discuss case studies including searches for light DM and primordial black holes with MeV-band experiments, and prospects for theoretical and experimental advances in indirect searches for heavy WIMPs

10:30am **Workshop: Coffee Break - SCGP 102**

Title: Coffee Break

11:00am **Workshop: Masha Baryakhtar (U Washington) - SCGP 102**

Speaker: . Masha Baryakhtar (U Washington)

Title: Precision astrometry with intensity interferometry

Abstract: I will present a proposal for a modification to optical intensity interferometers that allows for microarcsecond astrometry at angular separations as large as several arcseconds. The modification introduces an additional, adjustable path length into the optics, which creates a primary interference fringe for widely separated sources. Combined with other recent technological advances in spectroscopy and fast single-photon detection, this design could allow for unprecedented precision in angular resolution of stars. Promising applications include astrometric microlensing of stars, binary-orbit characterization, exoplanet detection, and Galactic acceleration measurements.

11:30am **Workshop: Dan Hooper (Fermilab) - SCGP 102**

Speaker: Dan Hooper (Fermilab)

Title: The Status of the Galactic Center Gamma-Ray Excess

Abstract: The Galactic Center Gamma-Ray Excess has a spectrum, angular distribution, and overall intensity that agree remarkably well with that expected from annihilating dark matter particles in the form of a 50 GeV thermal relic. Previous claims that these photons are clustered on small angular scales or trace the distribution of known stellar populations once appeared to favor interpretations in which this signal originates from a large population of unresolved millisecond pulsars. More recent work, however, has overturned these conclusions, finding that the observed gamma-ray excess does not contain discernible small scale power, and is distributed with approximate spherical symmetry, not tracing any known stellar populations. In light of these results, it now appears significantly more likely that the Galactic Center Gamma-Ray Excess is produced by annihilating dark matter.

12:00pm **Workshop: Lunch - SCGP Cafe**

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