The Future is Whispering♪♪

5th NCTS TG2.1 Future Workshop
June 25-27, 2025, Hsinchu, Taiwan

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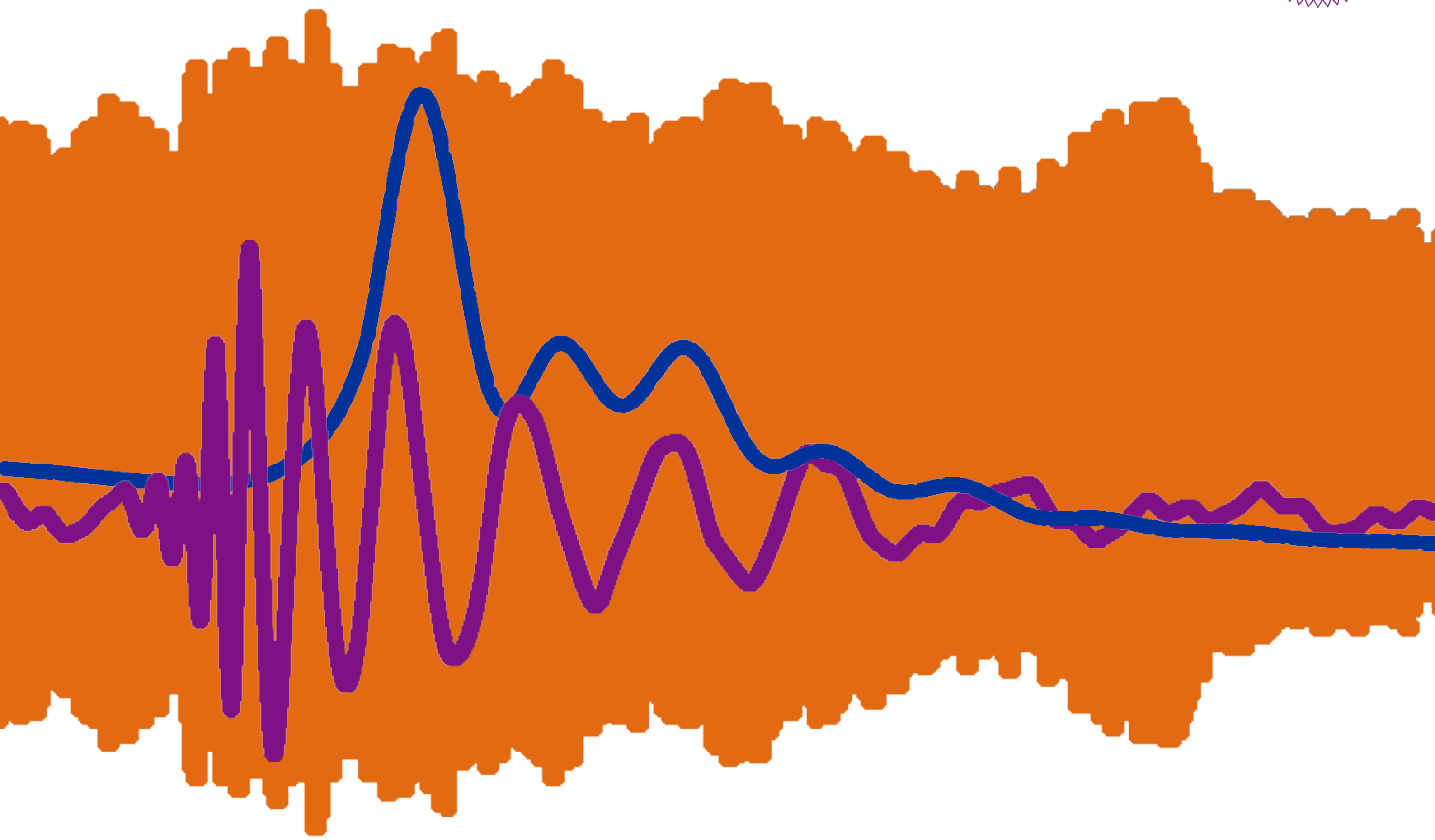

Playlist

Feeble Interactions
Gravity & Particle Physics
Dark Matter
Compact Objects & Particles

Keynote Presenters

Vedran Brdar (Oklahoma State U)
Tom Broadhurst (DIPC)
Koichi Hamaguchi (Tokyo U)
Kazunori Kohri (KEK)
Kin-Wang Ng (AS)

The Future is Whispering

5th NCTS TG2.1 Future Workshop

Wednesday, 25 June 2025 - Friday, 27 June 2025

Hosted by NYCU & NTHU and sponsored by NCTS

Contents

Practical Information

In case of problems please contact the physics secretariat at NCTS, in particular:
Jia-Yi Hsu, jyhsu@gapp.nthu.edu.tw or Renee Ho, renee.ho@gapp.nthu.edu.tw ,
Tel: +886-3-5731267

Workshop location: Room SC353 in Science Building III of NYCU. Address: No. 1001, University Road, Hsinchu, Taiwan 30010, R.O.C.

Internet access: Eduroam is broadly available on the NTHU and NYCU campuses. In case that does not work alternative access will be granted via guest accounts which will be provided on-site.

Food / store options nearby: There are a number of convenience stores, canteens and restaurants on the campuses and nearby. Please refer to the website for more information or the campus maps section at the end of this booklet.

Delivery: UberEats and Foodpanda are popular apps that provide delivery options for everything from groceries to dinner to shampoo to batteries straight to your door.

NTHU Guesthouse: Address: No. 101, Section 2, Kuang-Fu Road, Hsinchu City, Taiwan 30013, R.O.C. (80 on the NTHU map), Tel: +886-3-5742100, Check in: after 14:00 and check out: before 12:00 (please confirm after arrival),
website: https://affairs-guesths.vm.nthu.edu.tw/en/index.php

The Ho Hotel: Address: No. 16, Daxue Road, East District, Hsinchu City, 30013 Taiwan, R.O.C. (highlighted on the NYCU map), Tel: +886-3-5715888, Check in: after 15:00 and check out: before 11:00 (please confirm after arrival),
website: https://www.thehohotel.com.tw/

Welcome and Motivation

Hsinchu, June 2025

We are glad to provide this unique opportunity that experts from astrophysicists and particle physicists can get together to discuss the most profound puzzles of our Universe. With different perspectives, this process will stimulate new ideas and help us to gain a deeper understanding of the fundamental nature.

In the past decades, scientists poured tremendous efforts into generating new particles and understanding the interactions among them, from both experimentalists and theorists. With the synergy of the results and the discovery of the Higgs boson, we converge to the Standard Model as holy grail of particle physics, but satisfying answers for the neutrino masses and dark matter candidates are yet to come. On the other hand, the progresses of astrophysical measurements, such as gravitational wave interferometers, pulsar-timing arrays, and sky surveys, open up new windows for cosmological observations. Furthermore, extreme astrophysical viroments give stringent tests for the established theories and foresee the new one. Standing on the intersection with mist, the navigating sound shall lead us to the direction.

This workshop aims to bring together astrophyscists and particle physicists from Taiwan and abroad to address the current anomalies and prepare for the upcoming problems.

This event, “The Future is Whispering”, is the fifth instalment of the wrokshop series “The Future is ...” initiated in 2021. This year we decided to cover four topics: feebly interacting particles, gravitational aspects of particle physics, Dark Matter, and particle physics from compact objects. Hopefully, we can reach a the coherent resonance to make this workshop a success and ultimately convert the whispering into signals.

We warmly welcome you to our workshop and wish you a productive and inspiring time.

Po-Yen Tseng (on behalf of the organisers)

Timetable

On the following pages you can find the program as the time of compiling of this booklet. But since there might be some changes on short notice, please check also our indico page **here**.

The Future is Whispering

Wednesday, 25 June 2025

Welcome & Farewell: Welcome - Science Building III/SC353 (09:10 - 09:30)

-Conveners: Po-Yen Tseng

Keynote Talks: Searching for cosmological parity violation - Science Building III/SC353 (09:30 - 10:30)

-Conveners: Jan Tristram Acuña

time	title	presenter
09:30	Searching for cosmological parity violation	NG, Kin-Wang

Coffee Break - Science Building III/SC353 (10:30 - 11:00)

Gravitational aspects of particle physics - Science Building III/SC353 (11:00 - 12:00)

-Conveners: Jan Tristram Acuña

time	title	presenter
11:00	2-step FOEWPT in G2HDM	YUAN, TC
11:30	Refining Gravitational Wave and Collider Physics Dialogue via Singlet Scalar Extension	TRAN, Van Que

Lunch Break - Science Building III/SC353 (12:00 - 13:30)

Keynote Talks: Neutron Star Eclipses as Axion Laboratories - Science Building III/SC353 (13:30 - 14:30)

-Conveners: Martin Spinrath

time	title	presenter
13:30	Astrophysical Probes of New Physics: From Neutron Stars to High-Energy Neutrinos	BRDAR, Vedran

Particle physics from compact objects - Science Building III/SC353 (14:30 - 15:00)

-Conveners: Martin Spinrath

time	title	presenter
14:30	Gravitational-Wave Signatures of Nonstandard Neutrino Properties in Collapsing Stellar Cores	EHRING, Jakob

Coffee Break - Science Building III/SC353 (15:00 - 15:30)

Dark Matter - Science Building III/SC353 (15:30 - 17:00)

-Conveners: Chrisna Setyo Nugroho

time	title	presenter
15:30	Constraining Fuzzy Dark Matter Mass with Gravitationally Lensed High-z Galaxies	ZHANG, Jiashuo
16:00	Phenomenology of Neutrino-Dark Matter Interaction in DSNB and AGN	YEH, Yu Min

16:30	Shimmering darkness: Mapping the evolution of supernova-neutrino-boosted dark matter across the sky	LIN, Yen-Hsun

Thursday, 26 June 2025

Keynote Talks: Exploring Physics Beyond the Standard Model via Temperature Observations of Neutron Stars - Science Building III/SC353 (09:30 - 10:30)

-Conveners: Po-Yen Tseng

time	title	presenter
09:30	Exploring Physics Beyond the Standard Model via Temperature Observations of Neutron Stars	HAMAGUCHI, Koichi

Coffee Break - Science Building III/SC353 (10:30 - 11:00)

Particle physics from compact objects - Science Building III/SC353 (11:00 - 12:00)

-Conveners: Po-Yen Tseng

time	title	presenter
11:00	Neutrino Beacons: Illuminating New Physics with Cosmic Messengers	KANDASAMY ARUNACHALAM, Shivasankar
11:30	Flavor Equilibration of Supernova Neutrinos: Exploring the Dynamics of Slow Modes	CHEN, Heng-Hao

Lunch Break - Science Building III/SC353 (12:00 - 13:30)

Keynote Talks: Uncovering "Taiwanese Dark Matter" (ultra-light bosons) with JWST and Implications for High Energy Physics - Science Building III/SC353 (13:30 - 14:30)

-Conveners: Sut-Ieng Tam

time	title	presenter
13:30	Uncovering "Taiwanese Dark Matter" (ultra-light bosons) with JWST and Implications for High Energy Physics	BROADHURST, Tom

Dark Matter - Science Building III/SC353 (14:30 - 15:00)

-Conveners: Sut-Ieng Tam

time	title	presenter
14:30	Constraints on extended axion structures from the lensing of fast radio bursts	CHOU, Kuan-Yen

Coffee Break - Science Building III/SC353 (15:00 - 15:30)

Feebly interacting particles - Science Building III/SC353 (15:30 - 16:00)

-Conveners: Priyanka Sarmah

time	title	presenter
15:30	Probing Terrestrial Relic Neutrino Charge with Mach-Zehnder Interferometer	OTERO, Vincent Gene

Gravitational aspects of particle physics - Science Building III/SC353 (16:00 - 17:00)

-Conveners: Priyanka Sarmah

time	title	presenter
16:00	Gravitational Dressing Operators and Radiative Observables from Binary Systems	FERNANDES, Karan

16:30	The possibility of detecting dark matter with gravitational wave interferometers	HSU, Hsiang-Chieh

Friday, 27 June 2025

Special session - Science Building III/SC353 (09:30 - 10:30)

-Conveners: C.-J. David Lin

time	title	presenter
09:30	Probing the heart of the matter with supercomputers	LIN, Huey-Wen
10:00	A Search for Planet Nine with IRAS and AKARI Data	GOTO, Tomo

Coffee Break - Science Building III/SC353 (10:30 - 11:00)

Keynote Talks: New open window for dark matter with Memory Burden Effect in evaporating black holes - Science Building III/SC353 (11:00 - 12:00)

-Conveners: C.-J. David Lin

time	title	presenter
11:00	New open window for dark matter with Memory Burden Effect in evaporating black holes	KOHRI, Kazunori

Lunch Break - Science Building III/SC353 (12:00 - 13:30)

Dark Matter - Science Building III/SC353 (13:30 - 14:30)

-Conveners: KINGMAN CHEUNG

time	title	presenter
13:30	Probing the Gauge-boson Couplings of Axion-like Particle at the LHC	WANG, Chen
14:00	JUNO sensitivity to resonance-enhanced MeV dark matter annihilation in the galactic halo	VAN, Thi Dieu Hien

Coffee Break - Science Building III/SC353 (14:30 - 15:00)

Particle physics from compact objects - Science Building III/SC353 (15:00 - 15:30)

-Conveners: KINGMAN CHEUNG

time	title	presenter
15:00	Probing Jet Composition in Extreme Mass Ratio Black Hole Binaries through Periodic Emission Features	PU, Hung-Yi

Welcome & Farewell: Farewell - Science Building III/SC353 (15:30 - 16:00)

-Conveners: Sut-Ieng Tam

List of Abstracts

Keynote talks

Searching for cosmological parity violation

Author: Kin-Wang Ng[1]

[1] *Academia Sinica*

Axions are naturally coupled to photons through the Chern-Simons term. This coupling would open a window for us to probe the dark components and the inflation by their imprints on the visible sector. Over the past years, we have explored the cosmological signatures of axionic dark energy, dark matter, and inflaton. The axionic dark energy and dark matter can rotate the plane of polarization of propagating photons, thus converting CMB E-mode polarization into parity-odd B-mode polarization (the so-called birefringence B-mode or cosmic parity violation). In axion monodromy inflation, the backreaction to inflation induced by copious photon production due to the axion-photon coupling in a later stage of inflation beyond the slow-roll regime may lead to large non-Gaussian density fluctuations that seed primordial black holes (PBHs) and simultaneously generate gravitational waves (GWs). In particular, because of the Chern-Simons axion-photon coupling, the produced photons are one-handed; as a result, the generated GWs are chiral and the four-point function of density fluctuations is parity-violating. This chirality manifests a distinct signature of the cosmic parity violation in axion cosmology. The PBHs can be a candidate for dark matter and the chirality of the GWs can be detected by on-going and future GW experiments, such as LIGO, Virgo, KAGRA, LISA, and pulsar-timing arrays. We will discuss parity violation in axion cosmology, paying attention to on-going and future measurements of the density four-point function in CMB observations and galaxy surveys.

Astrophysical Probes of New Physics: From Neutron Stars to High-Energy Neutrinos

Author: Vedran Brdar[1]

[1] *Oklahoma State University*

Axion-like particles (ALPs) appear in many beyond-the-Standard-Model theories, either as candidates for dark matter or as partners of the axion that explains the apparent conservation of charge-parity symmetry, known as the strong CP problem. In the first part of the talk, I will present a novel method for probing ALPs using eclipsing binary systems which can serve as an astrophysical realization of light-shining-through-walls experiments. Such systems are composed of a neutron star that is bright in X-rays and a larger companion star, through which ALPs produced via conversion in the neutron star's magnetosphere can pass during the eclipse. The ALPs then partially reconvert into photons in the interstellar medium on their way to Earth, and the resulting X-rays are detectable by space observatories such as XMM-Newton.

In the second part of the talk, I will focus on the recently reported KM3-230213A neutrino event reported by the KM3NeT collaboration, which is nearly an order of magnitude more energetic than the highest-energy neutrino in IceCube's catalog. Despite its larger effective area and longer data-taking period, IceCube has not observed events of similar energies, which implies a 2-3σ tension, depending on the type of neutrino source. The 220 PeV neutrino, detected at KM3NeT, traversed approximately 150 km through rock and sea, whereas neutrinos from the same location in the sky would cross only about 10 km of ice to reach IceCube. I will show how this difference in propagation distance

helps to resolve this tension in the framework of a model containing a light sterile neutrino.

Exploring Physics Beyond the Standard Model via Temperature Observations of Neutron Stars

Author: Koichi Hamaguchi[1]

[1] *University of Tokyo*

I will discuss how temperature observations of neutron stars provide a unique window to explore physics beyond the Standard Model of particle physics. Neutron stars, with their extreme environments, serve as natural laboratories for testing the limits of our physical understanding. The standard cooling theory, which accounts for the cooling of isolated neutron stars through neutrino and electromagnetic radiation, generally aligns with observational data. However, the presence of hypothetical particles such as axions and dark matter, predicted by theories that extend the Standard Model, could alter this cooling behavior. Axions, for example, increase cooling rates, while dark matter interactions could lead to additional heating. By comparing revised theoretical predictions with observed temperature evolution, we might explore signs of these elusive particles.

Uncovering "Taiwanese Dark Matter" (ultra-light bosons) with JWST and Implications for High Energy Physics

Author: Tom Broadhurst[1]

[1] *University of the Basque Country and DIPC*

We show how light axions generic in String Theory provide definitive predictions that are borne out by deep lensing and galaxy formation data from JWST. This wave-like behaviour was predicted by pioneering simulations in Taiwan, with pervasive substructure on the de Broglie scale that is very distinguishable from standard heavy particle CDM. This dark matter solution reinforces the absence of heavy partner MSSM candidates at the LHC and we argue strengthens the case for unification at the EW scale.

New open window for dark matter with Memory Burden Effect in evaporating black holes

Author: Kazunori Kohri[1]

[1] *NAOJ / KEK*

I will review the current state of the theories and observations of the primordial black holes (PBHs). In particular, I will discuss how a new window for PBH to become dark matter opens when the memory burden effect acts on the evaporating PBHs.

Gravitational aspects of particle physics

2-step FOEWPT in G2HDM

Author: TC Yuan[1]

[1] *IOP, Academia Sinica*

We investigate the possibility of a strong first-order electroweak phase transition (FOEWPT) during the early universe within the framework of the gauged two-Higgs doublet model (G2HDM) and explore its detectability through stochastic gravitational wave signals. The results indicate that forthcoming detectors such as BBO, LISA, DECIGO, TianQin and Taiji could potentially detect the gravitational wave signals generated by the FOEWPT. Additionally, we find that the parameter space probed by gravitational waves can also be searched for in future dark matter direct detection experiments, in particular those designed for dark matter masses in the sub-GeV range using the superfluid Helium target detectors.

Refining Gravitational Wave and Collider Physics Dialogue via Singlet Scalar Extension

Authors: Michael J. Ramsey-Musolf[1]; Tuomas V.I. Tenkanen[2]; Van Que Tran[3]

[1] *Tsung-Dao Lee Institute and School of Physics and Astronomy, Shanghai Jiao Tong University*

[2] *University of Helsinki*

[3] *NCTS, National Taiwan University*

Employing effective field theory techniques, we advance computations of thermal parameters that enter predictions for the gravitational wave spectra from first-order electroweak phase transitions. Working with the real-singlet-extended Standard Model, we utilize recent lattice simulations to confirm the existence of first-order phase transitions across the free parameter space. For the first time, we account for several important two-loop corrections in the high-temperature expansion for determining thermal parameters, including the bubble wall velocity in the local thermal equilibrium approximation. We find that the requirement of completing bubble nucleation imposes stringent bounds on the new scalar boson mass. Moreover, the prospects for detection by LISA require first-order phase transitions in a two-step phase transition, which display strong sensitivity to the portal coupling between the Higgs and the singlet. Interestingly, signals from di-Higgs boson production at the HL-LHC probe parameter regions that significantly overlap with the LISA-sensitive region, indicating the possibility of accounting for both signals if detected. Conversely, depending on the mixing angle, a null result for di-Higgs production at the HL-LHC could potentially rule out the model as an explanation for gravitational wave observations.

Gravitational Dressing Operators and Radiative Observables from Binary Systems

Authors: Feng-Li Lin[1]; Karan Fernandes[2]

[1] *National Taiwan Normal University*

[2] *NTNU*

In recent years, classical limits of scattering amplitudes have emerged as a powerful tool for deriving state-of-the-art results for gravitational wave observables from interacting binary compact objects. In this talk, I will explore gravitational dressing operators from the worldline formalism and discuss their significance for late time radiative observables. We will first consider how fluctuations around the asymptotic trajectories of the scattered compact objects can be used to derive a gravitational dressing operator in a multiple soft graviton expansion. We will then use this operator, considered up to collinear double soft graviton terms, to find late time results for the waveform, emitted momentum and angular momentum. I will conclude with results from ongoing work that relates the gravitational dressing exponent up to double soft graviton order, and the double soft graviton factor for scattering amplitudes.

The possibility of detecting dark matter with gravitational wave interferometers

Authors: Chun-Hao Lee[1]; Hao-Yen Chang[2]; Henry T. Wong[2]; Hsiang-Chieh Hsu[2]; Jia-Shian Wang[3]; Martin Spinrath[4]; Miftahul Ma'arif[5]; Reinard Primulando[6]; Ting-Yi Liang[2]

[1] *Department of Physics, National Tsing Hua University*

[2] *Institute of Physics, Academia Sinica*

[3] *Academia Sinica*

[4] *NTHU*

[5] *Department of Physics, National Central University*

[6] *Parahyangan Catholic University, Indonesia*

We discuss the prospects for discovering macroscopic Dark Matter (DM) using large-scale ground-based gravitational wave (GW) detectors. Here, as an example, we consider a DM candidate with long-range Yukawa-like interactions in the kg- to tonne-scale mass range, where the analysis can potentially be further generalised for other DM models. The DM in this mass range will produce a signal that is significant enough for detection at the proposed detector. We consider the interaction range to be on the order of kilometers, thus the DM will interact with multiple GW detector mirrors simultaneously. This can lead to some interesting phenomena, such as signal enhancement or suppression and directional sensitivity. This long-range interaction also results in large cross sections for interactions between the DM and ordinary matter, compensating for the lower number density of the DM. Based on the simulation of the interaction between dark matter (DM) and the mirror suspension system, we can determine the detector response. We will further refer to this signal output from the detector as a "template." We will then attempt to search for these templates in the LIGO open data. The procedure for identifying a particular template from a noisy background is well-established for GW analysis, and is often known as "matched filtering". Through this study, we aim to explore the possibility of detecting, or setting limits on, this DM model and develop a standardised platform for analysing DM models using GW data.

Particle physics from compact objects

Gravitational-Wave Signatures of Nonstandard Neutrino Properties in Collapsing Stellar Cores

Author: Jakob EHRING[1]

[1] *Academia Sinica, Institute of Physics*

Stellar core-collapses provide formidable conditions to probe new physics. Supernovae as one possible outcome of these events are driven by the transport of energy through neutrinos. In this talk I will present the result of numerical simulations in axial symmetry show how nonstandard neutrino interactions can lead to imprints in the gravitational wave signal of supernovae.

Neutrino Beacons: Illuminating New Physics with Cosmic Messengers

Author: Shivasankar Kandasamy Arunachalam[1]

Co-authors: Arindam Das[1]; Gaetano Lambiase[2]; Takaaki Nomura[3]; Yuta Orikasa[4]

[1] *Hokkaido University*

[2] *Universit'a degli Studi di Salerno*

[3] *Sichuan University*

[4] *Czech Technical University*

The origin of tiny neutrino masses remains an open question in particle physics, prompting extensions beyond the Standard Model (SM). In this talk, I will present a study of a $U(1)$ gauge extension of the SM that incorporates three generations of Majorana-type right-handed neutrinos. This framework leads to the emergence of a neutral beyond-the-Standard-Model (BSM) gauge boson, denoted as Z', whose interactions can be chiral or flavored. We explore the potential of high-energy cosmic events, such as gamma-ray bursts (GRBs) and active galactic nuclei (AGNs), to probe Z' neutrino interactions. Specifically, we analyze the process $\nu\nu \to e^+e^-$, which can contribute to energy deposition in events like GRB221009A, the highest energy GRB observed to date. By estimating the observables of such processes, we constrain the $U(1)$ gauge coupling (g_X) and the Z' mass ($M_{Z'}$) under Schwarzschild and Hartle-Thorne scenarios. Additionally, we investigate ν-dark matter (DM) scattering mediated by Z′ bosons, utilizing data from the IceCube Neutrino Observatory. By considering high-energy neutrinos from cosmic sources such as the blazar TXS0506+056 and the active galaxy NGC1068, along with Cosmic Microwave Background (CMB) and Lyman-α data, we further constrain the g_X–$M_{Z'}$ parameter space. Finally, we compare our findings with current and prospective bounds from scattering experiments, beam-dump experiments, and measurements of the anomalous magnetic moment (g–2). This comprehensive analysis highlights the complementarity of astrophysical observations in probing chiral and flavored Z' bosons.

Flavor Equilibration of Supernova Neutrinos: Exploring the Dynamics of Slow Modes

Author: Ian Padilla-Gay[1]

Co-authors: Heng-Hao Chen[2]; Meng-Ru Wu[2]; Sajad Abbar[3]; Zewei Xiong[4]

[1] *Particle Theory Group, SLAC National Accelerator Laboratory, Stanford University*

[2] *Academia Sinica*

[3] *Max-Planck-Institut für Physik*

[4] *GSI Helmholtzzentrum für Schwerionenforschung*

Neutrinos experience collective flavor conversion in extreme astrophysical environments such as core-collapse supernovae (CCSNe). One manifestation of collective conversion is slow flavor conversion (SFC), which has recently attracted renewed interest owing to its ubiquity across different regions of the supernova environment. In this study, we systematically examine the evolution of kinematic decoherence in a dense neutrino gas

undergoing SFC, considering lepton number asymmetries as large as 30%. Our findings show that the neutrino gas asymptotically evolves toward a generic state of coarse-grained flavor equilibration which is constrained by approximate lepton number conservation. The equilibration occurs within a few factors of the inverse vacuum oscillation frequency, ω^{-1}, which corresponds to (anti)neutrinos reaching near flavor equipartition after a few kilometers for typical supernova neutrino energies. Notably, the quasi-steady state of the neutrino number densities can be quantitatively described by the neutrino-antineutrino number density ratio $n_{\overline{\nu}_e}/n_{\nu_e}$ alone. Such a simple estimation opens new opportunities for incorporating SFC into CCSN simulations, particularly in regions where SFC develops on scales much shorter than those of collisions.

Probing Jet Composition in Extreme Mass Ratio Black Hole Binaries through Periodic Emission Features

Author: Hung-Yi Pu[1]

[1] *National Taiwan Normal University*

Largerly due to the spectral degeneracy in high-energy observations, the composition of black hole jets, wheter lepton-dominated or baryon-loaded, remains a longstanding open question. We propose that extreme mass ratio (EMR) black hole binaries, particularly systems involving a secondary microquasar interacting periodically with the accretion flow of a primary supermassive black hole, can serve as natural laboratories for disentangling jet composition. The periodic jet–accretion collisions in the system can result in distinct emission signatures shaped by underlying leptonic or hadronic processes. By modeling how these periodic features vary with jet composition, we explore that multi-frequency observations can effectively discriminate between jet compositions. These electromagnetic imprints offer a complementary probe to the emerging multi-messenger approaches for uncovering the nature of black hole relativistic jets.

Dark Matter

Constraining Fuzzy Dark Matter Mass with Gravitationally Lensed High-z Galaxies

Author: Jiashuo Zhang[1]

Co-authors: Jeremy Lim[1]; Tom Broadhurst[2]

[1] *University Of Hong Kong*

[2] *Donostia International Physics Center*

Ultra-light axions are well-motivated fuzzy/wave cold dark matter (CDM) candidates that provide potential resolutions to various small-scale problems faced by conventional heavy particle CDM. Being wavy on astronomical scales, galaxy formation is suppressed below the respective de Broglie wavelength scale, resulting in a sharp turnover in galaxy luminosity functions (LF) at the faint end. Such features, however, have yet to be confirmed and have only a few hints from Hubble Frontier lensing fields (e.g. Leung et al, 2018; Atek et al, 2018). Without the supplement of deep observations at longer wavelength (covering Balmer breaks of high-z galaxies), however, the high redshift sample for these lensing fields was shown to be severely contaminated, with contamination level reaching ~60% over 3.5<z<5.5 (Zhang et al, 2025). To achieve a more robust test, we here combine existing HST observations with recent deep JWST observations by the PEARLS team on field MACS J0416, and construct a photometric redshift catalog reliable up to

the redshift of z~10. By measuring the surface number density of gravitationally lensed high-z galaxies behind this massive galaxy cluster, we found no evidence of faint end turnover over redshifts 6<z<10. With this, we place a constraint on the fuzzy dark matter mass to above 2.76×10^{-22} eV at 95% confidence. We will also discuss the implication of this bound if the dark matter budget is composed of multiple copies of axions, a scenario more theoretically motivated from the perspective of String Axiverse. Using linear perturbation analysis, we argue different copies of axions may resemble an equivalent copy (with mass in between the highest and lowest axion mass, depending on relative contributions to total density) in terms of suppression (i.e. where turnover occurs in UV LFs) on large-scale structure. Hence the mass constraint we obtained (likewise for the stronger constraints from Lyman alpha forest) still allows for light (e.g. 10^{-22} eV) axion to dominate individual galaxies, subject to the existence of heavier copies.

Phenomenology of Neutrino-Dark Matter Interaction in DSNB and AGN

Authors: Yu Min Yeh[1]; Po-Yen Tseng[2]

[1] *National Tsing Hua University*

[2] *National Tsing Hua University, Department of Physics*

We investigate a neutrino-scalar dark matter (DM) $\nu\phi$ interaction encountering distinctive neutrino sources, namely Diffuse Supernova Neutrino Background (DSNB) and Active Galactic Nuclei (AGN). The interaction is mediated by a fermionic particle F, in which the scattering cross section characterizes different energy dependent with respect to the kinematic regions, and manifests itself through the attenuation of neutrino fluxes from these sources. We model the unscattered neutrino flux from DSNB via core-collapse supernova (CCSN) and star-formation rate (SFR), then incorporate the present Super-Kamionkande and future DUNE/Hyper-Kamiokande experiments to set limits on DM-neutrino interaction. For AGNs, NGC 1068 and TXS 0506+056, where the neutrino carries energy above TeV, we select the kinematic region $m_F^2 \gg E_\nu m_\phi \gg m_\phi^2$ such that the $\nu\phi$ scattering cross section features an enhancement at high energy. Furthermore, taking into account the DM spike profile at the center of AGN, we constrain on m_ϕ and scattering cross section via computing the neutrino flux at IceCube, where the $\phi\phi^*$ annihilation cross section is implemented to determine the saturation density of the spikes.

Shimmering darkness: Mapping the evolution of supernova-neutrino-boosted dark matter across the sky

Author: Yen-Hsun Lin[1]

[1] *Academia Sinica*

Supernova-neutrino-boosted dark matter (SNν BDM) has emerged as a promising portal for probing sub-GeV dark matter, offering the distinctive capability of DM mass differentiation via time-of-flight information. In this work, we randomly generate the spatial locations and ages of core-collapse supernovae (CCSNe) in the Milky Way (MW) over the past one hundred thousand years by Monte Carlo simulation and estimate their cumulative contribution to the present-day BDM flux at Earth. This study aims to address two crucial aspects for DM detection: *where* and *when* to search for BDM signatures. We systematically demonstrate that a spatial and temporal averaging of the total BDM signal is valid only when the duration of the BDM flux from an individual CCSN greatly exceeds the average time interval between two successive CCSNe in the MW. Particularly in a region when the ratio of BDM kinetic energy to DM mass is less than 5. Otherwise, the BDM signal must be resolved on a per-source basis. For completeness, we also discuss the results obtained using the observed supernova remnant data.

Constraints on extended axion structures from the lensing of fast radio bursts

Authors: Jan Tristram Acuña[1]; Kuan-Yen Chou[1]; Po-Yen Tseng[2]

[1] *Department of Physics, National Tsing Hua University*

[2] *National Tsing Hua University, Department of Physics*

Axions are hypothetical pseudoscalar particles that have been regarded as promising dark matter (DM) candidates. On the other hand, extended compact objects such as axion stars, which are supported by gravity and axion self interactions, may have also been formed in the early Universe and comprise part of DM. In this work, we consider the lensing of electromagnetic signals from distant sources by axion stars as a way to constrain the properties of axion stars and fundamental axion parameters. Accounting for the effect of the finite size of the axion star, we study the lensing effect induced by gravity and by axion-photon interactions. The latter effect is frequency dependent, and is relevant in the low frequency band, which motivates the use of fast radio burst (FRB) signals as a probe. We calculate the predicted number of lensed FRB events by specifying the fundamental axion parameters, axion star radial profile, fraction of DM residing in axion stars, and imposing lensing criteria based on the flux ratio and time delay between the brightest images from lensing. Assuming an optimistic case of 10^4 observed FRB events, and a timing resolution of $1\,\mu$s, the lack of observed FRB lensing events in CHIME allows us to probe axion stars with mass $\gtrsim 10^{-2} M_\odot$, corresponding to axion masses $\lesssim 10^{-10}$ eV and for negligible axion-photon couplings. Even lighter axion stars up to $\sim 10^{-3} M_\odot$ can be probed, assuming axion-photon couplings of at least 10^{-6} GeV^{-1}. Our results indicate that while FRB lensing by axion stars leads to sensitivities that are competitive with conventional microlensing searches operating in the optical band, it remains a challenge to probe axion-photon induced lensing effects.

Probing the Gauge-boson Couplings of Axion-like Particle at the LHC

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In this work, we calculate the sensitivities on the gauge-boson couplings g_{aZZ}, $g_{aZ\gamma}$, and g_{aWW} of an axion-like particle (ALP) that one can achieve at the LHC with $\sqrt{s} = 14$ TeV and integrated luminosities of 300 fb^{-1} (current run) and 3000 fb^{-1} (High-Luminosity LHC). We focus on the associated production processes $pp \to Za \to (l^+l^-)(\gamma\gamma)$ and $pp \to W^\pm a \to (l^\pm\nu)(\gamma\gamma)$. We show that better sensitivities on these gauge couplings can be achieved at the LHC for $M_a = 1 - 100$ GeV, down to the level of 10^{-4} GeV^{-1}. In conclusion, this study emphasizes the significance of the investigated channels in constraining the ALP couplings at the LHC, offering valuable insights for future experiments dedicated to ALP detection.

JUNO sensitivity to resonance-enhanced MeV dark matter annihilation in the galactic halo

Authors: Guey-Lin Lin[1]; Thi Dieu Hien Van[1]

[1] *NYCU-IOP*

JUNO sensitivity to the annihilation cross section of MeV dark matter (DM) into neutrinos in the galactic halo (A. Abusleme *et al.* [JUNO], JCAP 09, 001 (2023)) constrains the

DM-extended $U(1)_{L_\mu - L_\tau}$ model, characterized by the Z' boson with mass m_Z, the coupling g_Z between Z and the second and third generations of leptons, and the coupling g_χ between DM and Z. Focusing on light DM with masses below 100 MeV, we study the annihilation channel $\chi\chi \to Z' \to \nu_{\mu,\tau}\overline{\nu}_{\mu,\tau}$ in the galactic halo with $m_Z \approx 2m_\chi$. We impose the condition that the DM relic density matches the observed value $\Omega_\chi h^2 = 0.12$, which fixes the value of $\langle\sigma v\rangle$ in the early universe. Under this condition, we predict the value of resonance-enhanced $\langle\sigma v\rangle$ in the present-day universe as a function of the coupling product $g_Z \cdot g_\chi$. We discuss the possibility of testing this resonance-enhanced annihilation by JUNO detector.

Feebly interacting particles

Probing Terrestrial Relic Neutrino Charge with Mach-Zehnder Interferometer

Author: Chuan-Ren Chen[1]

Co-authors: Vincent Gene Otero[1]; Chrisna Setyo Nugroho[1]

[1] *National Taiwan Normal University*

We propose a novel mechanism to detect terrestrial cosmic neutrino background's (CNB) limit of electric charge by employing Mach-Zehnder interferometer with asymmetrical arm placement –one at the Earth's surface and the other is placed underground. Assuming that relic neutrinos possess a small but nonzero charge, their coherent forward scattering with photons induces measurable phase shift in a laser beam. From the terrestrial CNB overdensity resulting from weak interaction induced by neutrino-antineutrino asymmetry near the surface of the earth, we formulate the quantum interaction Hamiltonian and analyze the induced phase shift under realistic interferometric constraints. The projected sensitivity reaches of our setup are evaluated under three operation regimes: the standard quantum limit (SQL), the Heisenberg limit, and the super-Heisenberg limit. For neutrino masses $m_\nu = 0.05$ eV, our scheme can probe fractional electric charges ϵ_ν as small as 9.3×10^{-11}, 1.6×10^{-16}, and 2.9×10^{-22}, respectively. The proposed interferometric strategy surpasses existing laboratory bounds and even astrophysical constraints when operating in the Heisenberg or super-Heisenberg mode.

Special Session

Probing the heart of the matter with supercomputers

Author: Huey-Wen Lin[1]

[1] *Michigan State University*

Nucleons (that is, protons and neutrons) are the building blocks of all ordinary matter, and the study of nucleon structure is a critical part of frontier research to unveil the mysteries of the universe and our existence. Gluons and quarks are the underlying degrees of freedom that explain the properties of nucleons, and fully understanding how they contribute to the properties of nucleons (such as mass or spin structure) helps to decode the last part of the Standard Model that rules our physical world. After more than half a century of large-scale experimental efforts, there are still many unknowns concerning the theory quantum chromodynamics (QCD), the branch of the Standard Model describing how gluons strongly interact with themselves and with quarks, binding both

nucleons and nuclei. Using supercomputers and a theoretical tool called "lattice QCD", we can simulate the theory that dominates the universe at the femtoscale and unveil its diverse phenomenology, including some properties that are hard to determine in experiments. Few selected recent Lattice-QCD examples and their impacts will be briefly discussed.

A Search for Planet Nine with IRAS and AKARI Data

Author: Tomo Goto[1]

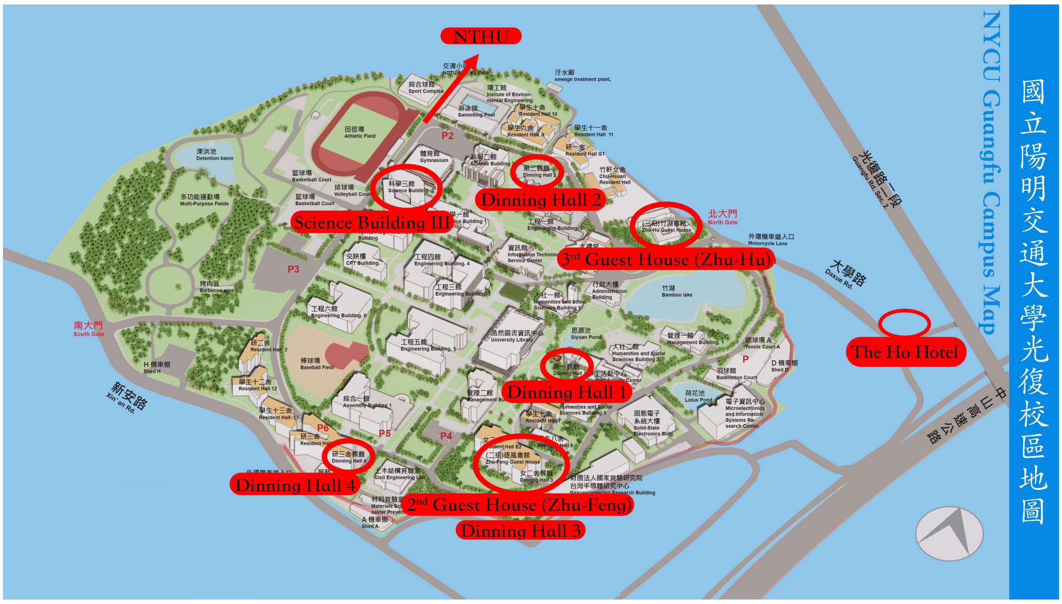
[1] *IoA*

The outer solar system is theoretically predicted to harbour an undiscovered planet, often referred to as P9. Simulations suggest that its gravitational influence could explain the unusual clustering of minor bodies in the Kuiper Belt. However, no observational evidence for P9 has been found so far, as its predicted orbit lies far beyond Neptune, where it reflects only a faint amount of Sunlight. This work aims to find P9 candidates by taking advantage of two far-infrared all-sky surveys, which are IRAS and AKARI. The epochs of these two surveys were separated by 23 years, which is large enough to detect the ~3'/year orbital motion of P9. We use a dedicated AKARI Far-Infrared point source list for our P9 search - AKARI Monthly Unconfirmed Source List, which includes sources detected repeatedly only in hours timescale, but not after months. We search for objects that moved slowly between IRAS and AKARI detections given in the catalogues. First, we estimated the expected flux and orbital motion of P9 by assuming its mass, distance, and effective temperature to ensure it can be detected by IRAS and AKARI, then applied the positional and flux selection criteria to narrow down the number of sources from the catalogues. Next, we produced all possible candidate pairs whose angular separations were limited between 42' and 69.6', corresponding to the heliocentric distance range of 500 - 700 AU and the mass range of 7 - 17 Earth masses. There are 13 pairs obtained after the selection criteria. After image inspection, we found one good candidate, of which the IRAS source is absent from the same coordinate in the AKARI image after 23 years and vice versa. However, AKARI and IRAS detections are not enough to determine the full orbit of this candidate. This issue leads to the need for follow-up observations, which will determine the Keplerian motion of our candidate.

Campus Maps

For your convenience we provide here an NYCU and an NTHU campus map with some important landmarks highlighted.

NYCU campus map



NTHU campus map

	Restaurant	Remarks	Google maps links (click in pdf)
Breakfast	Shine Mood	Waffles, drinks	at NYCU and at NTHU
	比司多 (breakfast place)	Sandwiches, burgers, tea, soymilk	at NTHU
	早餐屋 (breakfast place)	Taiwanese breakfast snacks and drinks	nearby NTHU guest house
	漢堡邦 Burger Gang	Burger and breakfast place	close to NYCU main entrance
	7-11	Convenience store	at NYCU and at NTHU
	Family Mart	Convenience store	at NYCU and at NTHU
Dinner	Lala Kitchen	Western style dishes with vegan options	at NYCU
	Wavelight restaurant	Noodles, salads, rice meals	at NTHU
	十六區和風料理	Japanese style	in front of NTHU
	NYCU & NTHU student halls	various food options	check campus maps
Coffee shops	Cama Café		in front of NTHU
	Louisa		at NYCU and at NTHU
	RD Café		in front of NTHU
	HereCafé		at NYCU
	Panda Café		at NTHU
Vegan/Halal options	A+ Indian food		just outside NYCU campus gate
	Indian Darbar		just outside NTHU campus north gate

Table 1: Food options. For additional suggestions, feel free to contact the organisers and locals.