Chongqing University and IBS CTPU-CGA joint workshop on frontier of theoretical cosmology

Wednesday 20 May 2026 - Friday 22 May 2026

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Book of Abstracts

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Administrative Announcements

Day 1 / **80**

An On-Shell Bootstrap Program of Cosmological Correlators

We develop a new bootstrap strategy for cosmological correlators at loop level, which we call spectral dispersion. It is based on two conceptual observations that a correlator can be recovered from its on-shell data, also known as nonlocal signals, by analyticity up to local counterterms, and that the on-shell data for a loop process take the form of a discrete sum over quasinormal modes. Technically, our method combines the dS spectral decomposition with dispersion relations. Using this technique, we bootstrap new results in a simple and intuitive form for 3-point and 4-point correlators with 1-loop massive exchanges of scalar and vector bosons, either directly or derivatively coupled. Applications of this bootstrap technique to higher spins and higher-loop banana graphs are also straightforward.

Day 1 / **88**

Bootstrap for Features in Cosmological Correlators

Cosmological correlators are fundamental observables of early universe cosmology and the main targets of cosmological surveys. Despite their importance, computing them remains notoriously hard. In this talk, the speaker will show how to bootstrap several classes of correlators tied to signatures of observational interest, including large non-Gaussianities, primordial features, and parity violation.

Day 1 / **92**

Bootstrapping Inflationary New Physics

Our understanding of the primordial Universe largely depends on the information from spatial corre-

lations of cosmic-scale matter distributions. Recently, the advances of the "cosmological bootstrap" program offers new perspectives and powerful tools to study these cosmological correlators. In this talk, I will review the exciting developments along this direction, with a focus on the phenomenology and observation frontiers. I will first systematically classify the primary observational target — primordial non-Gaussianities (bispectrum) from cosmic inflation, incorporating three leading scenarios: single field inflation, cosmological colliders and multi-field inflation. Then, I will introduce the recent efforts to bootstrap graviton non-Gaussianities from massive spinning fields. In the end, I will present an up-to-date data analysis of the new predictions using the latest CMB data from Planck satellite. Via both CMB-BEST and Modal pipelines, we identify the most significant signal of cosmological collider in the current observation.

Day 1 / **57**

Role of Dark Higgs Boson in (Astro)Particle Physics and Cosmology

I will describe the landscape of a dark sector with (excited) dark matter and various force mediators controlled by dark gauge symmetry. Then I will discuss the following topics one by one: (i) Why do we have to consider the dark Higgs boson? (ii) Galactic center gamma-ray excess with dark Higgs (iii) WIMP scenario resurrected with dark Higgs boson (iv) 511 keV gamma ray excess (v) Higgs inflation assisted with dark Higgs field (vi) Other examples where dark Higgs plays crucial roles

Day 1 / **63**

Boosted dark matter and directional direct detection

We discuss a two-component dark matter model in which one component, heavier dark matter, annihilates into a lighter dark matter. The lighter dark matter is expected to generate detectable signals in detectors due to its enhanced momentum, enabling direct detection even for MeV-scale dark matter. We investigate the effectiveness of directional direct detections, especially the nuclear emulsion detector NEWSdm, in verifying these boosted dark matter particles through nuclear recoil. In particular, we focus on light nuclei, such as protons and carbon, as suitable targets for this detection method due to their high sensitivity to MeV-scale dark matter. By modeling the interactions mediated by a dark photon in a hidden U(1)D gauge symmetry framework, we calculate the expected dark matter flux and scattering rates for various detector configurations. Our results show that nuclear emulsions have the potential to yield distinct, direction-sensitive dark matter signals from the Galactic center, providing a new way to probe low-mass dark matter parameter spaces that evade conventional detection methods.

Day 1 / **52**

Black Holes as Laboratory for Dark Matter

The dark matter surrounding black hole would form dense dark environment, studying the imprint of dark matter on the observational signals from black hole via accretions and dynamical friction could be a dark matter probe. In this talk I am going to talk about how to study the nature of dark matter from radio, optics and gravitational wave channels. With these studies, black hole would be a promising laboratory for dark matter in future observations.

Day 1 / **56**

Probing Fundamental physics with extreme mass ratio inspirals

Extreme mass ratio inspirals (EMRIs) composed of a stellar-mass object inspiraling into a supermassive black hole (SMBH), emitting GWs in the milli-Hertz band, are the most promising GW sources for space-based observatories. The rich information about the spacetime geometry surrounding the SMBH is encoded in the GWs, making EMRIs an excellent source for studying black hole physics like the charges carried by black holes and the DM halos around black holes. Firstly, we use EMRIs to probe the charges carried by black holes and the fundamental fields associated with the charges. Then Using the static and spherically symmetric metric for a black hole immersed in dark matter (DM) halos with Hernquist, Burkert, and Navarro-Frenk-White density distributions, we study the possibility of the detection of DM halos and the distinction between different DM halos with the extreme mass ratio inspiral systems (EMRIs).

Day 1 / **49**

Gravitational Waves from Mergers of Asymmetric Dark Stars

A strongly self-interacting component of asymmetric dark matter (DM) particles can form compact dark stars (DSs). These objects have a broad spectrum of masses and radii, with distinct evolution histories from both neutron stars and black holes (BHs). These differences allow a population of DSs to contribute significantly to the astrophysical merger rate in unique and discernible ways. Specifically, their merger rate could dominate at low redshifts over other sources, while their mass function may populate windows outside known astrophysical processes. In this presentation, I will summarize the structure and formation of DSs within a dissipative model, and show the enhancement of their merger cross-section due to tidal deformation effects. From this, I derive the cosmological DS merger rate and discuss the DM parameter space available for observation. These findings open a new window to probe DM substructure and particle interactions through present and future gravitational wave (GW) observatories.

Day 1 / **90**

Radiation-reaction effects at 3PN order in scalar-tensor theories

With the advent of third-generation gravitational-wave detectors, it has become crucial to extend analytical frameworks used to model waveforms from compact binary systems to alternative theories of gravity. In this talk, I will present recent results on radiation-reaction effects in a class of scalar–tensor theories. Using the post-Newtonian multipolar post-Minkowskian (PN–MPM) formalism, we compute the dissipative contributions to the ten Noetherian conserved quantities, which can be classified into two types: Schott and pseudo-Schott terms. In contrast to general relativity, where only pseudo-Schott terms contribute to the waveform phasing at 4.5PN order for quasi-circular orbits, we find that Schott terms begin to contribute already at 3PN order, even in the quasi-circular case. These contributions must therefore be consistently included in the future when extending the energy flux and waveform, currently known up to 2.5PN order, to 3PN order.

Day 1 / **50**

Non-perturbative evolution of the curvature perturbation during inflation.

The statistical properties of the curvature perturbation on superhorizon scales during inflation are of significant phenomenological interest, with implications ranging from cosmic microwave background (CMB) observations to primordial black hole (PBH) formation and induced gravitational waves. In this talk, I will present and compare different techniques for computing these properties: the standard δN formalism, the stochastic δN formalism, and a novel non-perturbative equation of motion for the superhorizon curvature perturbation. I will clarify the connections between these approaches and specify the regime of validity for each.

Day 2 / **59**

Detection Capability of Multi-band Detectors for Extra Polarizations of Gravitational Waves

This report explores the detection capabilities of multi-band gravitational wave detectors for extra polarizations beyond general relativity. In the mHz–kHz band, the extended parameterized post-Einsteinian (ppE) framework is applied to space-based (e.g., LISA, Taiji, TianQin) and ground-based (e.g., LIGO, Virgo, KAGRA, ET) detectors, showing that multi-band observations effectively break degeneracies and improve constraints on vector and scalar polarizations. In the GHz band, high-frequency gravitational waves (HFGWs) from early universe sources (e.g., primordial black holes, brane worlds) are analyzed via the three-dimensional synchronous rotating (3DSR) system, which enables separation of all six polarization states using a photon–photon flux (PPF) method. Experimental prospects and sensitivity estimates are also discussed. The results highlight that future multi-band GW missions significantly enhance tests of gravity and probe high-frequency cosmological signals.

Day 2 / **83**

Tunneling in cosmology

We discuss several aspects of tunneling in cosmology.

Day 2 / **64**

Generalized Entropy Induces Varying-G

I will review the recently proposed GEVAG (generalized entropy and varying-G) theory. This theory gives a consistent treatment of how the field equation of gravity should be changed if the area law of horizon entropy is modified, namely that gravitational constant G is now area-dependent, the functional form of which depends on the specific modifications of the entropy. Specifically, GEVAG was able to prevent the violation of the Bekenstein bound, known to plague various generalized entropies like Tsallis entropy. When applied to the quantum gravity logarithmic correction, the framework managed to derive a modified Hawking temperature that was previously obtained in the GUP (generalized uncertainty principle) literature, but now without explicitly utilizing GUP. This circumvents the known problems in the GUP literature that heuristic derivations are often unreliable. I will briefly mention how these affect early time cosmology.

Day 2 / **91**

Extensions of scalar-tensor theory: Parity violation and multiple fields

This talk presents recent progress in the construction of scalar-tensor theories, with a focus on parity violation and multiple scalar fields. I will first review the relation between generally covariant scalar-tensor theories and spatially covariant gravity in the unitary gauge, emphasizing how this correspondence provides an efficient way to control higher-order time derivatives and avoid Ostrogradsky ghost degrees of freedom. Using this framework, I will discuss the systematic construction of the most general parity-violating scalar-tensor theory up to d=4 that is ghost-free in the unitary gauge, including the resulting "Qi-Xiu" Lagrangians and their relation to known examples such as Chern-Simons and chiral scalar-tensor theories. I will then describe a new geometric approach to multiple scalar-tensor theories, in which each scalar field defines a foliation of spacelike hypersurfaces and the theory is built from the corresponding hypersurface geometric quantities. This multiple-foliation construction provides a systematic route toward ghost-free multi-field scalar-tensor theories beyond the traditional Horndeski/DHOST framework.

Day 2 / **89**

Rethinking Gravity: From Torsion and Nonmetricity to Black Holes and Cosmology

Einstein's theory describes gravity through spacetime curvature, but more general gauge-theoretic frameworks allow spacetime to carry torsion and nonmetricity as well. I will first introduce metric-affine gravity as a framework in which curvature, torsion, and nonmetricity have distinct geometric roles, and discuss the theoretical consequences of these structures, including their relation to hypermomentum and intrinsic properties of matter such as spin, dilation, and shear. I will then turn to black holes in theories with torsion and/or nonmetricity, including scalarised black holes and the gravitational spin-orbit effect. Finally, I will discuss cosmological models with non-Riemannian geometry, focusing on FLRW backgrounds and the propagation of an additional massive spin-2 mode associated with torsion.

Day 2 / **73**

Primary black-hole scalar charges and kinetic screening in K-essence-Gauss-Bonnet gravity

Black holes beyond General Relativity may carry non-standard charges that impact their phenomenology. I will present the scalar charge that is induced by the scalar-Gauss-Bonnet coupling and how it is affected by the presence of a nontrivial kinetic term K(X). I will discuss the corresponding kinetic screening in the asymptotically flat, static solution first. I will then turn to the case where self-accelerating cosmology is driven by K(X), finding that the time-dependence of the scalar field opens up the parameter space, turning the black-hole scalar charge from secondary to primary. I will provide a stability analysis and a measure of the intensity of the kinetic screening from the quartic dispersion relation of the mixed scalar and gravitational modes.

Day 2 / **68**

BSM-enhanced PBH dark matter

In this talk I will give an overview of several beyond Standard model theories predicting a large number of additional degrees of freedom. The corresponding softening in equations of state can be significant. I will show that, within these models, it is then possible to achieve a large enhancement in PBH abundance on scales relevant for PBHDM; namely, the asteroid mass and memory burden windows.

Day 2 / **69**

On the survival of strong nuggets in the early Universe

Strong nuggets with a baryon number of A=10^10-10^30 could be able to survive from the cosmic separation of the QCD phases, provided the transition from strange quark matter to strangeon matter is accounted for, thereby evading evaporation in the early Universe. Such strangeon nuggets may serve as a dark matter candidate within particle standard model. We formulate the corresponding phase transition of cosmic strange matter, establishing a parameter space which reasonably accommodates observational constraints on the dark-to-luminous matter ratio and the mass-radius relation, as well as tidal deformability of compact objects.

Day 2 / **76**

Observable Gravitational Wave Strain at Second-order

The definition of second-order gravitational wave (GW) strain in cosmological perturbation theory is traditionally ambiguous due to its dependence on spacetime slicing. This issue is particularly critical for secondary GWs induced by primordial fluctuations. This talk introduces a gauge-invariant formalism that defines GW strain via the time-delay of electromagnetic signals exchanged between geodesic observers. Our results confirm that this observable strain aligns with the transverse-traceless components in the Newton gauge, providing a robust physical foundation for interpreting secondary GWs and resolving the gauge-dependence controversy.

Day 2 / **81**

Superhorizon curvature perturbations in hybrid inflation

We utilize the δN formalism within a parameter space formed by the e-folding number N and its transverse subspace to explicitly account for the geometry of the final hypersurface in multi-field inflation. Applying this framework to hybrid inflation, we identify an enhancement mechanism of the curvature perturbation driven by the growing isocurvature perturbation due to the tachyonic instability of the waterfall field. This amplification occurs during the trajectory's turn in field space, a process qualitatively distinct from the background deceleration in single-field non-attractor models such as ultra-slow-roll. The resulting power spectrum features a broad peak with a characteristic k^3 infrared growth and a ultraviolet spectral tilt that uniquely determines the nonlinear parameter $f_{\rm NL}$ of a logarithmic non-Gaussianity, all of which are primarily governed by the waterfall dynamics. The enhanced curvature perturbation can simultaneously account for primordial black hole dark matter and a stochastic gravitational wave background detectable by LISA, Taiji, and TianQin.

Day 2 / **96**

Massive Inflationary Amplitudes: Differential Equations and Complete Solutions for General Trees

We construct and solve a complete system of differential equations for general tree-level inflation correlators with an arbitrary number of massive scalar exchanges and time-dependent couplings. Any massive tree correlators can be uniquely fixed by solving this system of equations with appropriate boundary conditions. We take a hybrid approach to solve this system, using the differential equation to get the inhomogeneous solution and the bulk time integrals to determine the homogeneous solution. Altogether, we obtain analytical results for all tree-level massive inflation correlators with generic kinematics, expressed as multivariate hypergeometric series of energy ratios. The result can be neatly organized as a sum of the completely inhomogeneous solution, which we call the massive family tree, and all of its cuts. As simple applications, we provide full analytical expressions for tree correlators with one, two, and three massive exchanges.

Day 2 / **97**

Massive Inflationary Amplitudes: Family-Tree Decomposition of Loop Integrands

Cosmological correlators with massive loop exchanges appear frequently in cosmological collider model building as promising sources of oscillatory signals. However, their computations remain challenging. In this work, we apply the family-tree decomposition to correlators at loop level and derive rules to directly write down analytic answers for arbitrary massive loop integrands in terms of dressed family-tree functions. We also derive a complete set of differential equations satisfied by arbitrary loop integrands. Finally, we demonstrate how to perform loop momentum integrals and extract the complete nonlocal cosmological collider signals for a few examples, among which the results for 1-loop triangle graph and multiloop melon graph are new.

Day 2 / **98**

TBA

TBA

Day 3 / **51**

Learning Gravity from Data: Model-Independent Reconstruction of the Cosmic Expansion and Modified Gravity Theories

The standard cosmological model is under increasing observational pressure. Persistent tensions in the Hubble constant and the growth of structure suggest either unaccounted systematics or genuine new physics beyond ΛCDM — and distinguishing between these possibilities demands data analysis methods that do not smuggle in theoretical priors through the back door. In this talk, I present a programme of model-independent reconstruction of late-time cosmology using machine learning to probe both the expansion history of the Universe and the underlying theory of gravity.

Day 3 / **67**

Unified Origin of Primordial Black Hole Dark Matter and Nanohertz Gravitational Waves

Recent high-cadence observations by Subaru-HSC have identified a population of ultrashort-timescale microlensing events, providing a compelling window for planet-mass primordial black holes (PBHs) to constitute the entirety of dark matter. In this Letter, we demonstrate that this PBH population and the nanohertz stochastic gravitational-wave (GW) background reported by pulsar timing arrays (PTAs) can be naturally unified by a single primordial origin: a broad, nearly-flat enhancement of the curvature power spectrum with an amplitude of O (1 0 − 2) O(10 −2). The resulting PBH mass function spans the planet-to-solar mass range, while remaining consistent with all current observational constraints. This unified PBH–induced-GW framework makes concrete multi-messenger predictions, which can be decisively scrutinized by forthcoming microlensing surveys, next-generation PTAs, space-borne interferometers, precision astrometry, and laser ranging experiments.

Day 3 / **78**

FoPTs, PBHs, SIGWs, and SWs from early Universe

In this talk, I will first introduce our recent progress in first-order phase transitions, in particular, generations of density perturbations, formations of PBHs, associated scalar-induced gravitational waves, and productions of sound waves from gravitational instability.

Day 3 / **55**

On cosmological properties of black-hole hair in linearly coupled scalar–Gauss–Bonnet theory

We investigate the superhorizon behavior of scalar hair sourced by black holes in de Sitter spacetime in the linearly coupled shift-symmetric scalar–Gauss–Bonnet theory. This hair exhibits both spatial and temporal growth, which has been suggested to be problematic. We show that this growth is expected, as it is not a special consequence of the black hole, but instead follows from the dynamics of a minimally coupled massless scalar field in expanding de Sitter spacetime. Moreover, it is not specific to black holes, but also arises for a point scalar charge in de Sitter, indicating that a scalarized black hole acts effectively as a localized subhorizon source of scalar perturbations. Backreaction, when important, first arises on subhorizon scales and does not by itself eliminate the superhorizon profile. The time-dependent scalar hair also carries a steady outward energy flux, which helps explain the difficulties encountered in attempts to construct self-consistent static solutions.

Day 3 / **79**

The Nonlinear Tails of Black Hole Ringdown

Black hole perturbation theory is a cornerstone of gravitational wave science, providing a powerful framework to test General Relativity in the strong-field regime and to characterize the final remnant of a binary merger. The final “ringdown” phase, where the newly formed black hole settles into its

stationary state, is a particularly clean probe of its fundamental properties. In this talk, I will begin by reviewing the essential structure of the Green's function in black hole perturbation theory, which governs the response of the black hole to any disturbance. I will then present our main result on the late-time behavior of gravitational waves, demonstrating the existence of non-linearly generated power-law tails that dominate after the initial ringdown signal has decayed. We show that this late-time tail is a generic and robust feature for spinning black holes, carrying important information about the nonlinear nature of spacetime dynamics. If time permits, I will also briefly discuss the connection between these nonlinear phenomena and the behavior of tidal Love numbers during the inspiral phase.

Day 3 / **85**

Quantum Treatment of Black Hole Superradiance

Rotating black holes can form dense boson clouds through superradiant instability, making Kerr black holes a powerful probe of ultralight massive bosons. Previous studies of black hole superradiance have often treated bosonic fields classically, leaving open questions about how particles are produced and how the clouds grow over time. In this work, we canonically quantize a massive scalar field around a Kerr black hole, providing a fully quantum description of black hole superradiance. We show that the evolution of the particle number in the cloud, as well as the energy and angular momentum of the scalar field, can be consistently explained within the standard framework of quantum field theory in curved spacetime. Furthermore, we prove that the growth of the cloud occurs independently of the choice of initial state. We also explore several phenomena related to a massive scalar field in a rotating black hole spacetime, including Hawking radiation, adiabatic backreaction on the black hole spin, and the direction of level transitions in the presence of self-interactions of the field. Our analysis provides a consistent quantum-mechanical perspective that includes all these phenomena.

Day 3 / **71**

Gravity and Cosmology -my personal recollections and perspectives-

I will talk about various topics in gravity and cosmology which I have been studying through my academic life, and discuss my personal perspectives.

Closing remarks / **93**

Closing