Workshop on Gravitational Waves, Cosmology and Fundamental Physics

Report of Contributions

https://indico.ihep.ac.cn/e/27104

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

Gravitational waves from early and late Universe

Saturday, 1 November 2025 10:00 (30 minutes)

In this talk, I will introduce recent progress on gravitational waves (GWs) from cosmological first-order phase transitions associated with primordial black hole (PBH) production, the collisions between PBHs and vacuum bubbles, sound waves and GWs from gravitational collapse, induced GWs from curvature perturbations with non-Gaussianity up to all orders.

Primary author: WANG, Shao-Jiang (I)

Presenter: WANG, Shao-Jiang (I)

Session Classification: Session 4

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

Thermal production of gravitational waves in the early universe

Friday, 31 October 2025 10:30 (30 minutes)

In this work, we systematically study gravitational wave (GW) production during both the inflationary and post-inflationary epochs. While inflationary GWs can be readily derived from tensor perturbations during inflation, post-inflationary GWs arise from a variety of processes during reheating and require detailed treatment for quantitative analysis. We consider four distinct production channels: (i) pure inflaton annihilation, (ii) graviton bremsstrahlung from inflaton decay, (iii) radiation-catalyzed inflaton-graviton conversion, and (iv) scattering among fully thermalized radiation particles. For each channel, we solve the corresponding Boltzmann equation to obtain the GW spectrum and derive a simple yet accurate analytical expression for it. By employing a consistent treatment of all production channels, our analysis yields for the first time the full spectrum of GWs produced during the inflationary and post-inflationary epochs. We find that, while inflationary GWs dominate at low frequencies, post-inflationary processes generally produce high-frequency GWs with considerably high energy densities that may significantly exceed that of inflationary GWs.

Primary author: XU, Xun-Jie

Presenter: XU, Xun-Jie

Session Classification: Session 1

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

Gravitational waves and Primordial black holes formation in a complex singlet extension of the Standard Model

Sunday, 2 November 2025 10:30 (30 minutes)

A complex singlet extension of the Standard Model not only incorporates scalar dark matter candidates but also enables the realization of a strong electroweak first-order phase transition essential for electroweak baryogenesis. This phase transition may generate gravitational waves and primordial black holes. We discuss the correlation between the strength of the phase transition and these signals, as well as their future observability.

Primary author: IDEGAWA, Chikako (Sun Yat-sen University)

Presenter: IDEGAWA, Chikako (Sun Yat-sen University)

Session Classification: Session 7

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

Gravitational waves from symmetry breaking

Saturday, 1 November 2025 10:30 (30 minutes)

In this talk, I will report our progresses on the simulation of Gravitational wave and particle productions from cosmic strings.

Primary author: 边, 立功 (重庆大学)

Presenter: 边, 立功 (重庆大学)

Session Classification: Session 4

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

Vanishing nonlinear black hole Love numbers in GR

Friday, 31 October 2025 17:00 (30 minutes)

Black hole Love numbers measure how a black hole deforms under external tidal fields, providing a window into the structure of spacetime, the dynamics of black holes, and the physics of gravitational waves. While linear analyses already suggest their vanishing, the role of non-linear effects has remained an open question. In this talk, I will explore the non-linear regime, presenting recent results that establish the vanishing of infinitely many non-linear Love numbers in the parity-even sector of general relativity, valid to all orders in perturbation theory. This striking result also unveals a hidden symmetry underlying black hole perturbations, offering new insights into the nature of black holes in general relativity.

Primary author: WONG, Sam (CityU HK)

Presenter: WONG, Sam (CityU HK)

Session Classification: Session 3

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

Gravitational Waves from the Early Universe

Friday, 31 October 2025 11:00 (30 minutes)

Gravitational waves are useful probe for the physics of the early Universe. I will discuss several sources of stochastic gravitational wave background from the early Universe and provide a historical overview of this fascinating research field.

Primary author: YOKOYAMA, Jun\'ichi (Kavli IPMU)

Presenter: YOKOYAMA, Jun\'ichi (Kavli IPMU)

Session Classification: Session 1

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

A tantalizing hint of cosmological parity violation in the polarized light of the cosmic microwave background

Saturday, 1 November 2025 14:00 (30 minutes)

The polarized light of the cosmic microwave background is sensitive to new physics that violates parity symmetry. In this presentation, we present a tantalizing hint of parity violation from the polarization data of two satellite missions, WMAP and Planck, with a statistical significance of 3 sigma. This signal has also been observed in recent data from the Atacama Cosmology Telescope. Taken together, there is evidence for a cosmological parity violation with a statistical significance of 4 sigma. If confirmed in the future with higher statistical significance, this finding would have profound implications for the elusive nature of dark matter and dark energy.

Primary author: Prof. KOMATSU, Eiichiro (Max Planck Institute for Astrophysics)

Presenter: Prof. KOMATSU, Eiichiro (Max Planck Institute for Astrophysics)

Session Classification: Session 5

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

Darkogenesis via Supercooled Phase Transition

Sunday, 2 November 2025 10:00 (30 minutes)

We discuss the intriguing possibility that the recently reported nano-Hz gravitational wave signal by Pulsar Timing Array (PTA) experiments is sourced by a strong first-order phase transition in a dark sector. The phase transition has to be strongly supercooled to explain the signal amplitude. However, such strong supercooling exponentially dilutes away any pre-existing baryon asymmetry and dark matter, calling for a new paradigm of their productions. We then develop a mechanism of cold darkogenesis that generates a dark asymmetry during the phase transition from the textured dark SU(2) Higgs field. This dark asymmetry is transferred to the visible sector via neutron portal interactions, resulting in the observed baryon asymmetry. Furthermore, the mechanism naturally leads to the correct abundance of asymmetric dark matter. Collider searches for mono-jets and dark matter direct detection experiments can dictate the viability of the model. We also discuss another scenario of darkogenesis where the number asymmetry is generated from the decay of a mother particle produced via parametric resonance during the phase transition induced due to its coupling to the order parameter scalar. It is shown that the correct baryon asymmetry and dark matter abundance can be realized for a dark phase transition at O(1) GeV. The scenario will be tested further in neutron-antineutron oscillation experiments.

Primary author: NAKAI, Yuichiro (Shanghai Jiao Tong University)

Presenter: NAKAI, Yuichiro (Shanghai Jiao Tong University)

Session Classification: Session 7

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

Probing Light Dark Matter with Cosmic Gravitational Focusing

Saturday, 1 November 2025 16:15 (15 minutes)

We investigate the possibility of using the cosmic gravitational focusing (CGF) to probe the minor light dark matter (DM) component whose mass is in the range of $(0.1 \sim 100)$\,eV. Being a purely gravitational effect, the CGF offers a mode-independent probe that is complementary to the existing ways such as Lyman-α and $\Delta N_{\rm eff}$. Such effect finally leads to a dipole density distribution that would affect the galaxy formation and hence can be reconstructed with galaxy surveys such as DESI. Both the free-streaming and clustering limits have been studied with analytical formulas while the region in between is bridged with interpolation. We show the projected sensitivity at DESI with the typical phase space distribution of a freeze-in DM scenario as illustration.

Primary author: TAN (谭), Liang (亮) (Tsung-Dao Lee Institute)

Presenter: TAN (谭), Liang (亮) (Tsung-Dao Lee Institute)

Session Classification: Session 6

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

Gravitational waves in thermal enviornments

Saturday, 1 November 2025 15:00 (30 minutes)

In this presentation, I will talk about a framework for analysing gravitational waves in thermal environments, such as the radiation-dominant early universe, from a symmetry perspective. I will focus on the effective dynamics of gravitational waves in the interaction picture of quantum field theory and discuss the symmetry constraints on the theory.

Primary author: OTA, Atsuhisa (Chongqing University)

Presenter: OTA, Atsuhisa (Chongqing University)

Session Classification: Session 5

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

Probing spin-2 ultralight dark matter with PTA and space-based GW Detectors

Sunday, 2 November 2025 14:00 (30 minutes)

Spin-2 ultralight dark matter (ULDM) is a viable dark matter candidate, and it can be constrained using gravitational wave (GW) observations. The pulsar timings are sensitive to both the nanohertz gravitational-wave background and the oscillation of ultralight dark matter. We study the angular correlation of the timing residuals induced by spin-2 ultralight dark matter, which differs from the usual Hellings-Downs correlation for stochastic gravitational-wave backgrounds. We also investigate the detectability of spin-2 ULDM by space-based GW interferometers. By considering a direct coupling between spin-2 ULDM and ordinary matter, we derive the corresponding response functions and sensitivity curves for various time-delay interferometry channels and calculate the optimal sensitivity curves for future millihertz GW detectors. Thus, the GW detectors can serve as powerful tools not only for detecting GWs but also for probing fundamental properties of ultralight dark matter.

Primary author: Dr ZHANG, Yun-Long (NAOC (National Astronomical Observatories, CAS))

Presenter: Dr ZHANG, Yun-Long (NAOC (National Astronomical Observatories, CAS))

Session Classification: Session 8

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

Teleparallel gravity models with parity violations

Saturday, 1 November 2025 14:30 (30 minutes)

It is not easy to have a healthy parity violating gravity models within Riemannian geometry. The famous Chern-Simons modified general relativity and its extensions are pathological due to the ghost modes appeared at high energy scales. In this talk, I will introduce some parity violating models within the framework of teleparallel gravity, especially the Nieh-Yan modified teleparallel gravity model, which is healthy and robust. It predicts the velocity birefringence phenomenon in gravitational waves and has more interesting applications in cosmology.

Primary author: LI, Mingzhe (University of Science and Technology of China)

Presenter: LI, Mingzhe (University of Science and Technology of China)

Session Classification: Session 5

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

High Reheating Temperature without Axion Domain Walls

Saturday, 1 November 2025 16:00 (15 minutes)

We investigate a cosmological scenario in which the Peccei-Quinn (PQ) symmetry remains broken in the entire history of the Universe, thereby avoiding the formation of axion strings and domain walls. Contrary to the conventional expectation, it is demonstrated that appropriately chosen scalar
interactions are able to keep the PQ symmetry broken at arbitrarily high temperatures. We carefully examine the finite-temperature effective potential in a model with two PQ breaking scalar fields. The existence of flat directions plays a vital role in suppressing axion isocurvature perturbations
during inflation by stabilizing a PQ field at a large field value. The viable parameter space consistent with theoretical and observational constraints is identified. Our scenario provides a minimal path for PQ symmetry breaking that addresses both the axion domain wall and isocurvature problems
while permitting arbitrarily high reheating temperatures accommodating high-scale baryogenesis scenarios such as thermal leptogenesis.

Primary authors: Ms WANG, Lingyun (Wuhan University); Dr NAKAGAWA, Shota (TDLI); Dr QIU, Yu-Cheng (Hong Kong, City U.); NAKAI, Yuichiro (Shanghai Jiao Tong University); 王 (WANG), 耀铎 (Yaoduo) (李政道研究所 (TDLI))

Presenter: 王 (WANG), 耀铎 (Yaoduo) (李政道研究所 (TDLI))

Session Classification: Session 6

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

Beyond general relativity: gravitational waves in non-minimally coupled theories

Friday, 31 October 2025 16:00 (30 minutes)

Non-minimal matter-curvature couplings arise in many different contexts, and modify solutions of general relativity. If dark matter (DM) experiences non-minimal couplings, the imprint can be see in gravitational waves (GWs) emitted from binary black hole mergers, where DM densities are expected to be large. In this talk, we explore effects of various non-minimal couplings on GWs by working with a model-independent parameterization for left- and right-handed GW strains. We will write down the general solution assuming slowly-varying matter fields, and then systematically apply our results to three models: Kalb-Ramond dark matter with dimension-four operators, axion-dilaton-Chern-Simons-Gauss-Bonnet dimension-five operators, and dimension-six couplings to a (dark) vector field.

Primary authors: Prof. ALEXANDER, Stephon (Brown University); Dr DANIEL, Tatsuya (McGill University); MANTON, Tucker (HIAS-UCAS)

Presenter: MANTON, Tucker (HIAS-UCAS)

Session Classification: Session 3

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

Dynamics of coherent vacuum domains from axion fragmentation

Sunday, 2 November 2025 13:30 (30 minutes)

In this talk we will present the formation of multiple vacuum states in axion models with non-degenerate vacua, which originate from vacuum fluctuations amplified via parametric resonance. The domains are classified as sub-horizon, cross-horizon, or super-horizon on their scale upon formation, leading to the different cosmic evolution as well as gravitational wave spectrum

Primary authors: FAN, Qiqi; Dr 蒋, 🄵 (Sun Yat-Sen (Zhongshan) University)

Presenter: Dr 蒋, 🄵 (Sun Yat-Sen (Zhongshan) University)

Session Classification: Session 8

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

Nearly Monochromatic Primordial Black Holes as total Dark Matter from Bubble Collapse

Saturday, 1 November 2025 11:00 (30 minutes)

We propose a two-field model where the inflaton χ is non-minimally coupled to the instanton ϕ. By choosing an appropriate coupling function, we realize the scenario where the difference of the values of potential between false vacuum (FV) and true vacuum (TV) is maximized during inflation. Most of the bubbles are created at this time. After inflation ends, the potential value of FV drops below that of TV so that these bubbles collapse to form primordial black holes (PBHs). By tuning the parameters of our model, we analyze the Coleman-de Luccia (CDL) and Hawking-Moss (HM) process, finding that the corresponding mass function of PBHs is sharply peaked, implying that we can realize either PBHs as cold dark matter, sub-solar PBHs, or supermassive PBHs in this scenario without enhancement of primordial curvature perturbations.

Primary authors: Dr WANG, Haonan (Tongji University); Prof. ZHANG, Ying-li (Tongji University); Prof. SUYAMA, Taruaki (TITECH)

Presenter: Prof. ZHANG, Ying-li (Tongji University)

Session Classification: Session 4

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

Scalar wave emission from particles radially infalling in a Schwarzschild black hole

Friday, 31 October 2025 16:30 (30 minutes)

I present an analytical computation of the energy emitted by a scalar particle radially infalling into a Schwarzschild black hole spacetime within the framework of the gravitational self-force. The results are expressed in Post-Newtonian expanded form, as is customary.

Primary author: DI RUSSO, Giorgio (Hangzhou Institute for Advanced Study)

Presenter: DI RUSSO, Giorgio (Hangzhou Institute for Advanced Study)

Session Classification: Session 3

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

The TianQin Project and its Implication to Astronomy

Friday, 31 October 2025 15:00 (30 minutes)

The TianQin mission is a proposed space-borne gravitational wave detector, aiming to detect gravitational waves in the milli-Hertz frequency band. In this talk, I will give a brief overview of the concept of the mission, as well as its general progress and status. Furthermore, I will also briefly cover how the operation of TianQin can help deepen our understanding of the Universe.

Primary author: Prof. 胡, 一鸣 (中山大学)

Presenter: Prof. 胡, 一鸣 (中山大学)

Session Classification: Session 2

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

δn formalism and non-perturbative curvature perturbation during inflation.

Saturday, 1 November 2025 13:30 (30 minutes)

Contrary to what it is typically done in the literature, we re-formulate the δN formalism by using the e-folding number n counted forward in time. Taking advantage of the complete (anti-)correlation of the initial field perturbation $\delta\phi 0$ with its conjugate momenta $\delta\pi 0$, we find a simple formula to calculate the non-linear curvature perturbation as well as its PDF by using the δN method reformulated in terms of n, the δn formalism. We will also explore the connection of the δn formalism with the non-linear equation of motion for the curvature perturbation at superhorizon scales.

Primary author: CRUCES, Diego (ITP-CAS)

Presenter: CRUCES, Diego (ITP-CAS)

Session Classification: Session 5

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

Constraining the Primoridal Black Hole Abundance with Space-Based Detectors

Saturday, 1 November 2025 16:30 (15 minutes)

Primordial black holes, hypothesized to form from the collapse of large density fluctuations in the early universe, remain a compelling candidate for dark matter and a powerful probe of primordial cosmological physics. In this work, we explore the capabilities of future space-based gravitational wave detectors, including LISA, Taiji, and TianQin, to constrain the PBH abundance. We focus on the stochastic background of scalar-induced gravitational waves associated with PBH formation, and derive upper bounds on the PBH abundance across a wide mass range. We systematically account for the width of the primordial curvature power spectrum and determine the mass windows in which PBHs can be excluded as the dominant component of dark matter under null detection scenarios. Notably, we find that the exclusion window is narrowest for a power spectrum width of $\Delta \sim 0.28$, yet PBHs with masses in the range 10^{-17}–$10^{-9} M_\odot$ can still be robustly ruled out. This implies that if PBHs constitute the majority of dark matter, the associated SIGW signal must be detectable by upcoming space-based interferometers.

Primary authors: HONG, Wencong (ITP-CAS); KUROYANAGI, Sachiko; PI, Shi; WANG, Ao; ZHANG, Zhenyu

Presenter: HONG, Wencong (ITP-CAS)

Session Classification: Session 6

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

Constraining reheating temperature by ACT DR6

Saturday, 1 November 2025 16:45 (15 minutes)

The latest Atacama Cosmology Telescope (ACT) Data Release 6 suggests the spectral index of the curvature perturbation n_s = 0.974 ± 0.003, about 0.01 larger than the Planck 2018 result, which revives chaotic inflation with a power-law potential V(ϕ) ~ |ϕ|p. We revisit such a model in the light of ACT DR6, and carefully takes into account the intermediate oscillatory inflation stage after slow-roll inflation when p < 1. We find that such models are consistent with ACT DR6, which also implies p < 2/3 and T_reh ≥ 10ˆ11 GeV.

Primary authors: PI, Shi; LI, Zi-Han

Presenter: LI, Zi-Han

Session Classification: Session 6

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

Constraints on Lortentz and parity symmetry with gravitational waves

Friday, 31 October 2025 14:00 (30 minutes)

Gravitational wave (GW) observations offer a powerful tool for testing the fundamental Lorentz and parity symmetries of gravity. Any violation of these symmetries could manifest as deviations in GW propagation. In this talk, I will explore how current and future GW detections can constrain Lorentz- and parity-violating effects in gravity. I will introduce a systematic parameterization framework to describe potential deviations in GW propagation from general relativity in a cosmological background. Using this framework, we can construct modified GW waveforms, incorporating the effects of Lorentz and parity violations as predicted by various alternative gravity theories. Finally, I will present the latest results from our analysis of these modified waveforms using current GW data and discuss the prospects for placing even stronger constraints from future GW detections.

Primary author: 朱, 涛 (Zhejiang University of Technology)

Presenter: 朱, 涛 (Zhejiang University of Technology)

Session Classification: Session 2

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

Space GW detection in China and progress

Friday, 31 October 2025 14:30 (30 minutes)

China's space-based gravitational wave detection projects will open a new observational window in the mid-to-low frequency band (0.1 mHz to 1 Hz), providing new approaches to understand the origin and evolution of the universe, the formation and evolution of black holes, the nature of gravity, dark energy, and dark matter. Since space-based gravitational wave detection involves a series of key technologies, the TianQin project has proposed a "0-1-2-3" development roadmap, while the Taiji program has put forward a three-step plan. Both TianQin-1 and Taiji-1 were successfully launched in 2019 and have completed their in-orbit tests with outstanding results. Supported by the National Key Program on Gravitational Wave Detection, China has achieved breakthroughs in critical technologies for space-based gravitational wave detection, with the technological levels meeting the requirements for project initiation. In this talk, I will briefly introduce recent progress in China's space-based gravitational wave detection program, especially on Taiji, and provide an outlook on future development.

Primary author: Prof. LUO, Ziren

Presenter: Prof. LUO, Ziren

Session Classification: Session 2

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

Opening

Friday, 31 October 2025 10:20 (10 minutes)

Opening remarks

Primary author: KAMADA, Kohei (HIAS, UCAS)

Presenter: KAMADA, Kohei (HIAS, UCAS)

Session Classification: Session 1

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

Closing

Sunday, 2 November 2025 14:30 (10 minutes)

Closing talk

Primary author: KAMADA, Kohei (HIAS, UCAS)

Presenter: KAMADA, Kohei (HIAS, UCAS)

Session Classification: Session 8