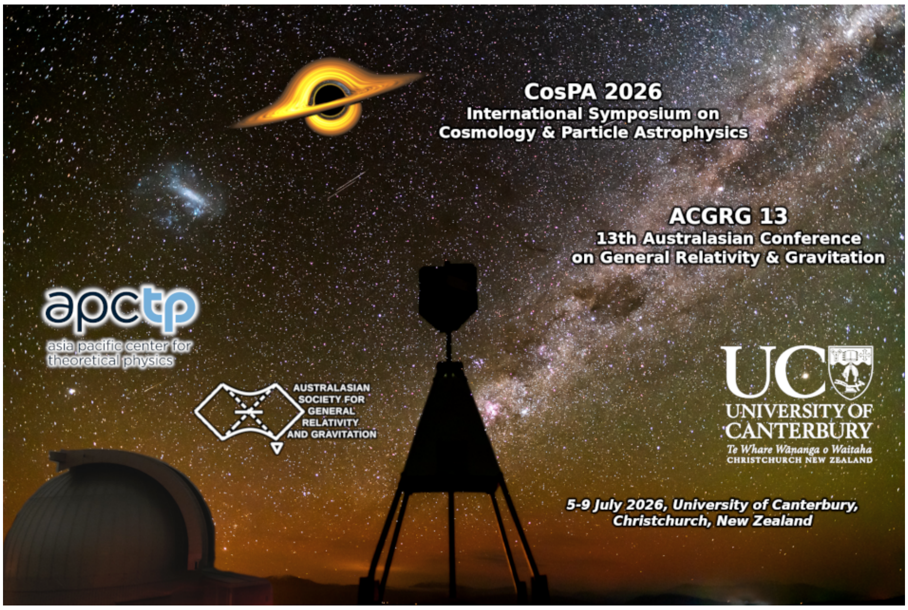
Program

Jul 5 – 9, 2026



CosPA 2026 / ACGRG 13

University of Canterbury, Rātā / Engineering Core Building
63 Creyke Road, Ilam, Christchurch 8041, New Zealand

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Sun, July 5

4:30 PM

6:00 PM

Welcome Reception

Session | **Location:** Ilam Homestead, University of Canterbury Club, 87 Ilam Road, Christchurch 8041

Description

A few hundred meters from the campus and main venue building; see https://www.ilamhomestead.co.nz/
You may register either at the Welcome Reception, or if arriving later on the following day at the main conference venue.

Mon, July 6

8:30 AM

Welcome Tea/Coffee

Session |
Location: University of Canterbury, Rātā / Engineering Core Building, 63 Creyke Road, Ilam, Christchurch 8041, New Zealand

Description

The registration desk will be open from 8:30am and in parallel with the Conference Opening.

8:45 AM

8:45 AM

Opening

Session |
Location: Rātā / Engineering Core Building, University of Canterbury, Room E8, 63 Creyke Road, Ilam, Christchurch 8041, New Zealand

9:00 AM

9:00 AM

Plenary talks: Session 1

Session | **Location:** Rātā / Engineering Core Building, University of Canterbury, Room E8

9:00 – 9:35 AM (35m)

Gravitational waves and scattering from black holes with positive cosmological constant

Speaker

Volker Schlue (University of Melbourne)

Description

This talk reviews recent advances in mathematical general relativity on the stability and scattering problem for Kerr de Sitter spacetimes. It describes several results concerning the non-linear vacuum evolution of solutions to the Einstein equations with positive cosmological constant, near the rotating black hole solutions, and outlines some of the challenges for a non-linear theory of gravitational wave experiments in the presence of expansion.

9:35 – 10:10 AM (35m)

GWTC-5.0: Observations from the second part of the fourth LIGO-Virgo-KAGRA observing run

Speaker

Jade Powell (Swinburne University of Technology)

Description

In this talk, I will present on behalf of the LIGO-Virgo-KAGRA collaborations the results from version 5.0 of the Gravitational-Wave Transient Catalog (GWTC-5.0). The updated catalog contains results from the network of observatories up to the second part of the fourth observing run (O4b). We find 161 new compact binary coalescence candidates with masses consistent with signals from the merger of binary black holes, bringing the total number of gravitational-wave candidates up to 390. We present updated population properties, tests of general relativity, and constraints on the cosmic expansion rate.

10:10 AM

10:10 AM

Morning Tea/Coffee

Break |
Location: University of Canterbury, Rātā / Engineering Core Building, 63 Creyke Road, Ilam, Christchurch 8041, New Zealand

10:40 AM

10:40 AM

Plenary talks: Session 2

Session | **Location:** Rātā / Engineering Core Building, University of Canterbury, Room E8

10:40 – 11:15 AM (35m) **Searching for Dark Matter with LHAASO**

Speaker
Kenny Chun Yu Ng (The Chinese University of Hong Kong)

Description

Abstract: I will discuss the dark matter research program of the Large High Altitude Air Shower Array (LHAASO). Located at 4410 m above sea level, LHAASO comprises three complementary detectors—KM2A, WCDA, and WFCTA—making it the most sensitive very-high-energy gamma-ray survey instrument currently operating. This unique capability establishes LHAASO as an excellent tool for indirect dark matter detection through searches for gamma-ray signatures of decay or annihilation. I will present recent constraints derived from observations of the Galactic halo and dwarf spheroidal galaxies, and discuss on the progress toward a combined, full-sky dark matter analysis using both WCDA and KM2A.

11:15 – 11:50 AM (35m) **Inferring w(z) in an inhomogeneous universe**

Speaker
Krzysztof Bolejko (University of Tasmania)

Description

The nature of dark energy remains one of the central open problems in cosmology, commonly parameterised through the equation of state w(z). The inference of the dark energy equation of state w(z) is typically performed within the homogeneous FLRW paradigm. However, cosmic structure introduces inhomogeneities that can impact both observables and their interpretation. In this talk, I discuss how cosmic inhomogeneities influence both observables and their interpretation, with particular focus on the reconstruction of w(z). I highlight mechanisms through which structure and light propagation effects can bias estimates of the expansion history, potentially mimicking signatures of dynamical dark energy or inducing apparent redshift evolution in w(z).

11:50 AM

11:50 AM

Poster Sparklers

Session |
Location: Rātā / Engineering Core Building, University of Canterbury, Room E8, 63 Creyke Road, Ilam, Christchurch 8041, New Zealand

Description

2-minute sparkler presentations of the posters which will be presented at the dedicated Poster session in the afternoon.

11:55 – 11:57 AM (2m)

Probing the Equation of State of Dense Matter in Neutron Stars

Speaker
Bao-Jun Cai (Fudan University)

Description

Understanding the equation of state (EOS) of dense matter inside neutron stars remains an important topic in modern nuclear physics and astrophysics. Recent multimessenger observations, especially gravitational-wave measurements from binary neutron-star mergers, together with X-ray timing and radio pulsar observations, have opened new opportunities for probing matter at supranuclear densities. In this talk, I will discuss recent progress in constraining the EOS of dense neutron-star matter through model-insensitive approaches based on relativistic stellar structure, including scaling properties associated with neutron-star mass, radius, and compactness. Particular attention will be given to the connection between astrophysical observables and the microscopic properties of dense matter in neutron-star cores, including the pressure, energy density, and sound-speed behavior at supranuclear densities. Possible implications for the maximum-mass configuration, the approach to the conformal limit, and the properties of matter in the innermost neutron-star core will also be briefly discussed.

11:57 – 11:59 AM (2m) **Primordial universe with vector hair on small-scale**

Speaker
Chong-Bin Chen (Nanchang University)

Description

A mechanism for generating anisotropic enhancements of the curvature perturbation through a vector field is proposed. This suggests that statistical anisotropy in primordial black hole (PBH) formation and stochastic gravitational-wave backgrounds (SGWB) may be inevitable if inflation undergoes an anisotropic inflationary phase. Our findings offer a novel approach to probe vector hair during inflation and to test the cosmic no-hair conjecture.

12:00 – 12:02 PM (2m)

The Atmospheric Muon Flux from Sub-TeV to PeV Energies with IceCube

Speaker

Pascal Gutjahr (Adelaide University)

Description

We present IceCube measurements of the atmospheric muon energy spectrum from the sub-TeV to the PeV scale, obtained by unfolding energy-sensitive observables for two complementary event classes. Stopping muons contained within the in-ice detector provide sensitivity in the few-hundred-GeV to 10 TeV range, while through-going muons extend the measurement to higher energies where the prompt contribution and cosmic-ray model dependence become relevant.
Machine-learning-based reconstructions and event selections are developed to improve energy resolution and background rejection, enabling a stable unfolding. We present the resulting unfolded spectra and discuss their implications for hadronic production models and the composition of the atmospheric lepton flux.

12:02 – 12:04 PM (2m)

A fresh look at boundary terms in Einstein-Hilbert gravity via an initial value variational principle

Speaker

Songmin Ha (Korea university)

Description

We revisit the role of boundary terms in Einstein–Hilbert gravity from the perspective of an initial value variational principle. Instead of imposing boundary conditions at both initial and final times, we employ the Schwinger–Keldysh–Galley (SKG) framework, which naturally implements an initial value formulation by doubling the degrees of freedom and imposing connecting conditions between forward and backward branches.

Within this setup, we show that the Einstein equations arise solely from the bulk part of the action, without the need to introduce additional boundary terms such as the Gibbons–Hawking–York term to ensure a well-posed variational problem. The boundary contributions that appear in the variation are instead directly related to conserved quantities, and we explicitly demonstrate their connection to the Komar current and mass.

Our analysis provides a fresh framework in which the variational principle is well-defined in an initial value setting without any additional boundary terms. This perspective sheds new light on the boundary terms of classical Einstein-Hilbert gravity.

12:05 – 12:07 PM (2m)

Perturbative unitarity bounds on field-space curvature in de Sitter spacetime: purity vs scattering amplitude

Speaker

Masataka Ishikawa (the University of Tokyo)

Description

We study perturbative unitarity bounds on the field-space curvature in de Sitter spacetime, using the momentum-space entanglement approach recently proposed by Duaso Pueyo, Goodhew, McCulloch, and Pajer. As an illustration, we perform a perturbative computation of the purity in two-scalar models and compare the resulting unitarity bounds with those obtained via a flat space approximation. In particular, we find that perturbative unitarity imposes an upper bound on the field-space curvature of the Hubble scale order, in addition to a bound analogous to the flat space result. This reflects the thermal nature of de Sitter spacetime. We also discuss generalizations to higher-dimensional field spaces. This poster presentation is based on arXiv: 2507.00850.

12:07 – 12:09 PM (2m)

Spectral Signatures of Multi-Mediator Astrophysical Neutrino Self-Interactions at Ultra-High Energies

Speaker

Ayushi Kaushik (SHIV NADAR INSTITUTION OF EMINECE DEEMED TO BE UNIVERSITY, GREATER NOIDA, INDIA)

Description

We discuss the effect of multiple mediators influencing the scattering of astrophysical neutrinos at the ultra-high energies — 100 TeV and beyond — against relic neutrinos from the Cosmic neutrino background, demonstrating unique features in the resulting spectral shape as detected at neutrino telescopes like IceCube. We specifically discuss the effect of superposition of scattering amplitudes involving interactions mediated by bosons of close but distinct masses and the importance of considering off-resonant T/U channel scattering in scenarios like these, in addition to the resonant S channels. As an example, we consider the case of L_μ – L_τ symmetry in a KK extra-dimensional scenario, leading to the existence of a tower of multiple vector bosons capable of mediating such neutrino self interactions. We show that in this specific case, the features in the flux spectrum, especially at the higher energies of the astrophysical neutrino spectrum, would be clearly distinctive from that expected in standard model scenarios.

12:10 – 12:12 PM (2m)

Interacting Phantom Dark Energy after DESI DR2 BAO Observations: New Constraints and Tension Alleviation

Speaker

Zhuochao LI (the Chinese University of Hong Kong)

Description

Abstract: Dark energy and dark matter constitute the dominant components of the universe's energy density. Nevertheless, we know very little about these dark sectors. Recent observations from the Dark Energy Spectroscopic Instrument (DESI) suggest that dark energy may be dynamical. It is natural to ask: Does dark energy interact with dark matter? In this project, we investigate and constrain the Interacting Dark Energy model using recent cosmological observations, including the Cosmic Microwave Background (CMB), Baryon Acoustic Oscillations (BAO), and Large Scale Structure (LSS).

12:12 – 12:14 PM (2m)

Quasinormal modes of scalar, electromagnetic, and gravitational perturbations in slowly rotating Kalb-Ramond black holes

Speaker

Wentao Liu (Lanzhou University)

Description

We investigate quasinormal modes (QNMs) of scalar, electromagnetic, and axial gravitational perturbations in slowly rotating Kalb–Ramond (KR) black holes, where an antisymmetric tensor field induces spontaneous Lorentz symmetry breaking. Working consistently to first order in the dimensionless spin parameter, we derive the corresponding master equations and compute the QNM spectrum using both the continued-fraction and matrix methods, finding excellent agreement. Lorentz violation modifies the oscillation and damping rates in a unified manner across all perturbative sectors: the real part of the QNM frequency increases monotonically with the Lorentz-violating parameter ℓ, while the imaginary part becomes more negative. Axial gravitational modes exhibit the strongest response, revealing an intrinsic theoretical bound $\ell < 0.5$, beyond which the spectrum approaches an extremal behavior. Our results highlight the potential of gravitational-wave spectroscopy to probe Lorentz-violating signatures in KR gravity.

12:15 – 12:17 PM (2m)

Polarization Modes of Gravitational Waves

Speaker

Yu-Xiao Liu (Lanzhou University)

Description

We establish a unified parameterized framework for analyzing the polarization modes of gravitational waves in some general gravitational theories that satisfy the following conditions: (1) Spacetime is four-dimensional; (2) The theories satisfy the principle of least action; (3) The theories are generally covariant; (4) The action describing a free particle is $\int ds$. We find that the polarization modes of gravitational waves depend on the parameter space in the framework, and a theory may allow for up to all six polarization modes. We also find that the polarization modes of gravitational waves in some general theories have some interesting universal properties.

12:17 – 12:19 PM (2m)

Charged multi-sheet wormhole solutions

Speaker

Yusuke Makita (Nagoya University)

Description

We present a method to construct static regular solutions describing wormholes that connect multiple asymptotic regions, supported by a phantom scalar field. The solutions are static and axially symmetric, and are constructed using the gravitational soliton formalism, in which the equations of motion reduce to the Laplace equations on a two-dimensional sheet. However, the presence of multiple asymptotic regions necessitates the introduction of multiple such sheets. These sheets are appropriately cut and glued together to form a globally regular geometry. This gluing procedure represents the principal distinction from conventional Weyl-type solitonic solutions. We also present a charged version of these wormhole solutions.

12:20 – 12:22 PM (2m)

Magnetic Fields around Kerr Black Holes: Particle Acceleration and Jet Formation

Speaker

Myeong-Gu Park (Kyungpook National University)

Description

Magnetic fields around rotating black holes can produce diverse astrophysical phenomena. We first discuss the particle acceleration by magnetic Penrose process. Penrose process is a novel way to extract the rotational energy of the black holes, but it requires a special condition, generally not expected in typical astrophysical situations. However, magnetic Penrose process can extract the energy from the electromagnetic potential in a more generic condition. We explore the particle acceleration by the magnetic Penrose process where neutrons are produced within the hot accretion flow and then transported to the acceleration zone close to the black hole and decayed into protons which are subsequently accelerated to very high energy, especially for Sgr A*. We find a non-negligible fraction of PeV protons and TeV gamma rays observed near Earth have contribution from this process. Secondly, we explore the magnetic field configuration for the Blandford-Znajek process around Kerr black holes, incorporating the effect of force-free plasma. General relativistic Grad-Shafranov equations are solved for the combined field of split monopole and uniform vertical field with a jet-like configuration. We numerically found regular solutions suitable for the observed astrophysical jet, and the estimated electromagnetic power is consistent with that of the observed jet.

12:22 – 12:24 PM (2m)

Application of fusion-view and optimization convolutional neural network in glitch classification

Speaker

Qun-Ying Xie (Lanzhou University)

Description

The discovery of gravitational waves as a major breakthrough in 21st-century physics has provided humanity with a novel observational tool to explore the mysteries of the Universe. However, in actual detection, gravitational wave detectors are often affected by various types of noise interference, particularly transient and non-Gaussian ‘glitch’ noise. These glitches not only obscure genuine gravitational wave signals but also generate false triggers owing to their striking similarity to real signals, significantly compromising detection accuracy. Consequently, developing efficient and accurate glitch classification methods to improve the gravitational wave data quality has become a key issue that urgently needs to be addressed in this field. In this study, we present a novel classification approach that involves: (1) constructing a fusion-view dataset to fully extract valuable information from the data and (2) optimizing a convolutional neural network (CNN) model to improve the glitch classification performance in gravitational wave time-frequency representations. To further enhance the model’s capability with minority-class samples, we incorporate a long shortterm memory (LSTM) network, creating a hybrid CNN-LSTM architecture. Our experimental results show that this hybrid model achieves higher classification accuracy while demonstrating
superior feature-learning capabilities, especially for categories with limited samples. Additionally, we address the issues of class imbalance and low data quality through a data augmentation technique, effectively reducing interclass confusion and improving dataset quality.

12:25 – 12:27 PM (2m)

Trapped Surface as a Cosmic Censor

Speaker

Daisuke Yoshida (Nagoya University)

Description

We formulate a local geometric criterion for weak cosmic censorship in black hole overcharging/overspinning thought experiments.
Matter satisfying the null energy condition generically focuses the null generators of the initial Killing horizon and turns a horizon cross section into a closed trapped surface.
Thus, any candidate final spacetime that cannot accommodate this surface is ruled out.
Applying this trapped surface criterion to Reissner-Nordstrom, Reissner-Nordstrom-de Sitter, and Kerr-Newman spacetimes, we exclude the corresponding superextremal final states.
This recovers the conclusions of the Sorce-Wald formalism without using asymptotically defined conserved charges, and provides a local geometric obstruction to the formation of naked singularities.
The charge-independent nature of the criterion opens the way to applications in spacetimes where asymptotic charges are absent or where no extremality condition characterizes naked singularities.

12:27 – 12:29 PM (2m)

Effects of scalar dark matter on the merger of binary black holes

Speaker

Yu-Peng Zhang (Lanzhou University)

Description

Discrepancies between observations of galactic rotation curves and theoretical predictions suggest the existence of dark matter. Although numerous experiments have failed to detect weakly interacting massive particle (WIMP) dark matter, dark matter exhibits gravitational interactions with celestial bodies, and its high-density accumulation in strong gravitational systems such as black holes definitely leaves observable signatures. With the advancement of gravitational wave detection and black hole shadow imaging, detecting dark matter using these tools has become feasible. Scalar fields are important dark matter candidates. Theories indicate that they undergo high-density condensation near black holes under gravitational effects, making the study of their dynamical properties in the black hole background crucial. This report will introduce the impact of scalar dark matter on binary black hole mergers, calculate the corresponding gravitational wave signals, and analyze the influence of the intrinsic parameters of scalar fields on the dynamical properties of black holes, among other aspects.

12:30 PM

12:30 PM

Lunch

Break |
Location: University of Canterbury, Rātā / Engineering Core Building, 63 Creyke Road, Ilam, Christchurch 8041, New Zealand

1:30 PM

1:30 PM

Parallel sessions: Cosmology (ACGRG/NZ Gravity Student Talks)

Session |
Location: Rātā / Engineering Core Building, University of Canterbury, Room E5, 63 Creyke Road, Ilam, Christchurch 8041, New Zealand

1:30 – 1:50 PM (20m)

Numerical solutions of the Euler equations on fixed Kasner-type backgrounds with coordinate-dependent fluid-regimes

Speaker

Joshua Ritchie (University of Otago)

Description

We investigate the asymptotic behaviour of solutions to the Euler equations on fixed Kasner-type backgrounds. In particular, we focus on backgrounds with a non-constant multiplicity and non-constant fluid-type. i.e., backgrounds for which the Kasner exponents and the speed-of-sound-squared do not have a fixed ordering over the spatial manifold. The primary focus here is on developing an understanding of how the underlying geometry effects the dynamical behaviour of the fluid both in terms of the fluid flow and the density distribution. We provide an exact spatially homogenous solution of the Euler equations on a generic modified-Kasner background which is then used to provide a heuristic understanding of spatially inhomogeneous solutions of the Euler equations. In addition, we provide numerous numerical examples of fluids on spatially inhomogeneous backgrounds, exploring the various type of phenomena that can occur.

1:50 – 2:10 PM (20m)

Constraining Inflation Models with Spinning Voids

Speaker

GEONWOO KANG (Seoul National University)

Description

We present a powerful new diagnostics by which the running of scalar spectral index of primordial density fluctuations can be tightly and independently constrained. This new diagnostics utilizes coherent rotation of void galaxies, which can be observed as redshift asymmetry in opposite sides dichotomized by the projected spin axes of hosting voids. Comparing the numerical results from the AbacusSummit of cosmological simulations, we derive a non-parametric model for the redshift asymmetry distribution of void galaxies, which turns out to be almost universally valid for a very broad range of cosmologies including dynamic dark energy models with time-dependent equation of states as well as the CDM models with various initial conditions. We discover that the universality of this model breaks down only if the running of scalar spectral index deviates from zero, detecting a consistent trend that a more positive (negative) running yields a lower (higher) redshift asymmetry of voids than the model predictions. Given that non-standard inflations usually predict non-zero runnings of the spectral index and that the redshift asymmetry distribution of voids is a readily observable quantity, we conclude that this new diagnostics will pave another path toward understanding the true mechanism of inflation.

2:10 – 2:30 PM (20m)

Big Rip and inhomogeneities: can the Galaxy survive the Big Rip?

Speaker

Gawain Simpson (University of Tasmania)

Description

Dark energy drives the present accelerated expansion of the universe, yet its physical nature remains uncertain. Its properties are characterised by the equation of state $w = p/\rho$, with $w = -1$ corresponding to a cosmological constant.
Determining whether w deviates from this value is crucial, since $w < -1$ would imply a future Big Rip singularity in homogeneous cosmological models.
I present a hybrid method for reconstructing the dark energy equation of state that does not assume a predefined parametric form such as the CPL model. After validation on simulated supernova data, the method is applied to the Pantheon+SH0ES sample. While broadly consistent with $w = -1$, the reconstruction allows a region of parameter space in which w falls below -1, raising the possibility of phantom behaviour.
Motivated by this observational allowance, I then examine whether a Big Rip is inevitable once inhomogeneities are included. Using the 1+3 covariant formalism under the silent-universe approximation, I show that local shear can significantly modify the late-time dynamics. For certain parameter ranges compatible with observations, anisotropic effects stabilise the local expansion rate and prevent divergence, suggesting that the fate of cosmic structure may depend sensitively on inhomogeneous dynamics.
This talk is based on two papers that are currently under review in Phys. Rev. D, ([1, 2]):
[1] G. Simpson, K. Bolejko, and S. Walters. A hybrid method for re-construction of the equation of state of dark energy and its application to Pantheon+SH0ES data. 2026. Submitted to Phys. Rev. D.
[2] G. Simpson, K. Bolejko, and S. Walters. Big Rip and inhomogeneities: can the Galaxy survive the Big Rip? 2026. Submitted to Phys. Rev. D.

2:30 – 2:50 PM (20m)

Estimating the Cosmic Structure Backreaction: a Buchert's Averaging Approach on Halo Induced Curvature

Speaker

Che Li (The Chinese University of Hong Kong)

Description

The cosmological principle postulates that our universe is homogeneous and isotropic. Based on such assumptions, the LCDM model is proposed with its underlying FLRW metric. The structure formation in the late time universe breaks the assumption of homogeneity. From the perspective of general relativity, inhomogeneous matter distribution should also be coupled with an inhomogeneous background metric, while most of the current N-body simulations tend to solve the evolution of the background metric under the assumption of homogeneity. In the standard Newtonian N-body simulations, the cold dark matter particles' motion is calculated with the Poisson equation coupled with the homogeneous background scale factor. A caveat of such approaches is that it ignores the backreaction from inhomogeneous metric. The inhomogeneous metric induced by the inhomogeneous matter field may again backreacts on the motion of dark matter particles.

Using the Buchert's averaging scheme, one could calculate the backreaction effects of inhomogeneity by taking the average of scalar fields in space-time foliation. The backreaction effects essentially come down to two extra terms in the effective Friedmann equation: averaged curvature $\langle R \rangle$ and kinetic backreaction Q, with an additional conservation equation coupling terms $\langle R \rangle$ and Q. The effective Friedmann equation in this case is not closed. One still has the freedom to define the scaling relation for either of the terms above.

This work estimates the evolution of the magnitude of the averaged curvature induced by halos, based on N-body simulation code Gadget-2 and Uchuu's simulations. Assuming Navarro-Frenk-White density profile for each halo, an underlying Lemaître–Tolman–Bondi metric is fitted, ensuring it converges to the FLRW metric at the edge of the halo. With the inhomogeneous underlying metric, the averaged curvature term could be estimated by setting the radial peculiar velocity of the halo to zero with a variance given by its radial circular velocity. Both the EdS universe and LCDM universe are examined, yielding an averaged curvature of $\Omega_R=9.98\times10^{-4}\pm 6.69\times10^{-5}$ and $\Omega_R=9.46\times10^{-5}$ respectively at $z=0$.

2:50 – 3:10 PM (20m) **Modelling the Local Universe with Λ-Szekeres Models**

Speaker

Morag Hills (University of Canterbury)

Description

Inhomogeneous cosmological models, such as the Λ-Szekeres model, provide a fully general relativistic way of describing structures in the local Universe through exact solutions of Einstein's equations. They thus provide a natural test bed to gauge the impact of local structures on cosmological inferences. We present the results of two separate but related investigations in which we utilise the Λ-Szekeres models.

Firstly, we test the application of a covariant cosmographic framework for local structures with axially-symmetric Λ-Szekeres models. We derive the cosmographic luminosity-distance expansion to fourth order in redshift, and compare this to the exact results determined via general relativistic ray tracing. This provides important insights into the levels of approximation obtainable from cosmographic expansions, as well as their non-trivial variance across a given observer's sky.

In the second investigation, we effectively model our local Universe for redshift $z \lesssim 0.1$ through a superposition of multi-structure Λ-Szekeres patches, using the peculiar velocity and HAMLET density reconstructions of the Cosmicflows-4 observational dataset. We compute the fully inhomogeneous and anisotropic quasilocal expansion field within our model, and thus analyse variations in H_0 estimates induced by the presence of local structure. Using low-redshift Type Ia supernovae from the Pantheon+ catalogue, we ultimately determine a shift in the best-fit Hubble constant value of order $\Delta H_0 \approx 0.5\ \mathrm{km\,s^{-1}Mpc^{-1}}$, which further increases the Hubble tension.

3:10 PM

1:30 PM

Parallel sessions: Dark matter - theory

Session |

Location: Rātā / Engineering Core Building, University of Canterbury, Room E6, 63 Creyke Road, Ilam, Christchurch 8041, New Zealand

1:30 – 1:50 PM (20m) **Core-collapse supernova simulations coupled with dark photons**

Speaker

Kanji Mori (Keio University)

Description

Recent studies on the dark photon (DP) production in collapsing stars argue that the cooling effect induced by DPs can hinder supernova explosions and lead to a "failing supernova" constraint on the photon-DP mixing parameter . In order to verify the idea, we perform two-dimensional neutrino-radiation hydrodynamic simulations coupled with the DP production with the masses of 0.3 and 0.45 MeV. We find that the shock revival does not happen until the end of the simulations when $\gtrsim 3 \times 10^{-9}$. The photon-DP mixing parameter above this value can be excluded by the failing supernova argument. Interestingly, our constraint roughly coincides with the one reported by the previous studies which adopted the postprocessing framework. This result motivates one to investigate a wider parameter range of DPs with self-consistent simulations and evaluate uncertainties in the constraint.

1:50 – 2:10 PM (20m)

Spherically Symmetric Fluid Simulations of Black Hole Accretion in Self-Interacting Dark Matter Halos

Speaker

Tan Chen (Beijing Normal University)

Description

We present spherically symmetric fluid simulations of black hole accretion in self-interacting dark matter (SIDM) halos, focusing on how collisional heat transport and gravothermal evolution regulate the central inflow. The black hole is modeled as a growing central point mass, and its accretion rate evolves self-consistently with the inner halo structure. Varying the SIDM halo parameters, we identify distinct accretion regimes set by the competition between dynamical inflow and conductive heat transport. In regimes where inflow outpaces conduction, the black hole can grow rapidly, accreting a substantial mass on a short timescale. These results provide a framework for assessing when SIDM can substantially alter seed black hole growth and for linking accretion histories to constraints on SIDM models.

2:10 – 2:30 PM (20m)

TeV-scale unification of light dark matter and neutrino mass

Speaker

Shu-Yu Ho (Academia Sinica)

Description

We demonstrate that TeV-scale heavy neutral leptons (HNLs) responsible for inverse-seesaw neutrino mass generation can simultaneously fix the cosmological abundance and decay properties of dark matter (DM). The spontaneous breaking of lepton number gives rise to a pseudo-Nambu-Goldstone boson that serves as a light DM candidate, whose mass originates from a small explicit breaking term. The same HNLs that generate neutrino masses produce the DM via freeze-in and mediate its decay into neutrinos, leading to a tight correlation among neutrino masses, DM relic abundance, and DM lifetime. For collider-accessible TeV-scale HNLs, the observed relic density and lifetime constraints point to sub-GeV DM, yielding observable neutrino signals at next-generation detectors such as Hyper-Kamiokande and DUNE. This framework establishes a predictive and experimentally testable link between neutrino mass generation and dark matter.

2:30 – 2:50 PM (20m)

Stone-Skipping Orbits: Resonant Dynamics in ULDM Solitons

Speaker

Yourong Frank Wang (University of Göttingen)

Description

The solitonic core is a prediction of ultralight dark matter (ULDM), yet its dynamical response to perturbations from orbiting compact objects remains poorly understood.

The orbit of a black hole embedded within a ULDM soliton is naively expected to decay due to dynamical friction. However, simulations have shown that single black holes can instead undergo “stone skipping”, in which the orbital radius varies quasi-periodically.

In Zhang et al. (arxiv:2602.11512), we show that this behaviour is driven by dipole excitation of the soliton. Using fully nonlinear simulations together with a pipeline for eigenmode decomposition, we identify the dipole mode as the dominant channel mediating the interaction. A complementary forced, damped oscillator description provides a useful interpretation of the resonant energy exchange, demonstrating that the coherent response of the soliton can significantly modify the orbital dynamics.

These results extend linear eigenmode analyses into the nonlinear regime and reveal a dynamical coupling between compact objects and ULDM cores. I will discuss the physical mechanism underlying this resonance, its dependence on mass ratio and damping, and its implications for supermassive black hole dynamics in ULDM halos.

2:50 – 3:10 PM (20m)

Testing ultralight dark matter with pulsar timing arrays

Speaker

Chris Gordon (University of Canterbury)

Description

Pulsar timing arrays have detected a nanohertz gravitational-wave background, most naturally associated with supermassive black hole binaries. The low-frequency shape of this signal may also probe the environments in which those binaries evolve, including possible interactions with ultralight dark matter. I will discuss recent work using PTA data to test this possibility, focusing on predictive model comparison. An earlier analysis found that a ULDM interpretation of the low-frequency suppression can prefer particle masses and dark-matter fractions compatible with existing constraints, motivating a closer comparison with non-ULDM explanations. In the current work, we compare simplified and realistic ultralight-dark-matter implementations with phenomenological environmental and gravitational-wave-only models using leave-one-out cross-validation. Current PTA data are compatible with ultralight-dark-matter-induced suppression, but do not yet decisively prefer it over more generic environmental descriptions of supermassive black hole binary evolution.

3:10 PM

1:30 PM

Parallel sessions: Gravitational waves

Session |

Location: Rātā / Engineering Core Building, University of Canterbury, Room E7, 63 Creyke Road, Ilam, Christchurch 8041, New Zealand

1:30 – 1:50 PM (20m)

Careless Whispers: Sub-threshold post-merger gravitational waves constrain the hot nuclear equation of state

Speaker

Fiona Panther (University of Western Australia)

Description

We show how to coherently combine information from a population of sub-threshold, gravitational-wave binary neutron star post-merger remnants to constrain the hot nuclear equation of state. Although no individual event in our synthetic population can be claimed as a confident detection, we show how to statistically determine the fraction of merger events that promptly collapse to form a black hole, compared to those for which a neutron star survives the merger for at least tens of milliseconds. This fraction, when combined with information about the neutron star mass distribution gleaned from the inspiral portion of the signals, provides an indirect measure of the neutron star maximum mass. Using conservative measures of the post-merger waveforms, we show that 50-70 events with binary neutron star inspiral measurements can be combined to give an 11−20% fractional uncertainty on the maximum mass of rapidly rotating, hot neutron stars, which can potentially be turned into a 12−21% fractional constraint on the Tolman-Oppenheimer-Volkoff mass. This measure of the hot nuclear equation of state can be combined with information of cold neutron stars to see the effect of temperature on physics in the densest regions of the Universe.

1:50 – 2:10 PM (20m)

Probing ultra-dense matter with gravitational waves from binary neutron star coalescences

Speaker

Luca Baiotti (The University of Osaka)

Description

I will briefly review recent progress in numerical simulations of binary neutron star mergers, and discuss how these signals can help distinguish among different classes of equations of state, including hadronic models, quark–hadron crossover scenarios, and first-order phase transitions.
We also investigate uncertainties in post-merger gravitational-wave emission using a non-parametric Bayesian approach to the equation of state, without assuming a specific microphysical model. This framework may enable robust predictions for post-merger signals and their sensitivity to the presence of quark matter.

2:10 – 2:30 PM (20m)

Neural Posterior Estimation for BBH Foreground Subtraction in 3G SGWB Searches

Speaker

Zhenwei Lyu (Leicester International Institute, Dalian University of Technology)

Description

The subtraction of compact-binary foregrounds is a central challenge for stochastic gravitational-wave background searches with third-generation detector networks. In particular, it remains unclear whether imperfect removal of individually resolved binary black hole signals could produce a residual foreground that limits sensitivity to cosmological or astrophysical stochastic backgrounds. Previous studies have reached differing conclusions, in part because population-scale analyses have often relied on Fisher-level approximations, while full Bayesian parameter estimation for $\mathcal{O}(10^5)$ events is computationally prohibitive. In this work, we develop a scalable full-posterior foreground-subtraction framework based on neural posterior estimation. Using a normalizing-flow parameter-estimation pipeline as a tractable surrogate for full Bayesian inference, we propagate event-level posterior uncertainty through the subtraction procedure at realistic population scale. We find that the residual from resolved binary black hole subtraction is reduced to a level well below the sensitivity of a third-generation detector network, indicating that such residuals do not constitute a sensitivity floor for stochastic-background searches in the scenarios considered. Our results demonstrate that neural posterior estimation can retain the essential posterior information required for realistic foreground subtraction while remaining computationally viable for next-generation observing campaigns. This framework provides a general methodological foundation for binary black hole foreground mitigation in future stochastic gravitational-wave background analyses.

2:30 – 2:50 PM (20m)

Dynamics of a binary system around SMBH and gravitational waves

Speaker

Kei-ichi MAEDA (Waseda University)

Description

We study the dynamics of a binary system orbiting a rotating supermassive black hole (SMBH) and the resulting gravitational-wave signatures from such hierarchical three-body systems. To describe the motion in curved spacetime, we construct a local inertial frame using Fermi–Walker transport and treat the binary as a Newtonian system in this frame.
For a binary whose center of mass follows a circular orbit around a Kerr black hole, we find that von Zeipel–Lidov–Kozai (vZLK) oscillations appear when the initial inclination exceeds a critical angle. This mechanism is characterized by a periodic exchange between the eccentricity of the inner binary and the relative inclination. Because large eccentricity enhances gravitational-wave emission, this mechanism is important in gravitational-wave astronomy. Hard binaries show regular oscillations, while soft binaries exhibit irregular but stable behavior, sometimes accompanied by orbital flips.
We extend the analysis to spherical orbits in Kerr spacetime, where latitudinal libration significantly modifies the oscillations, shortening their period and increasing the maximum eccentricity. The SMBH spin can even reduce the oscillation timescale to the dynamical one. We then analyze typical properties of gravitational waves produced by these effects, especially the vZLK mechanism, which may be detectable by future space-based interferometers. We also discuss eccentric orbits, including binary scattering events.

2:50 – 3:10 PM (20m)

Efficiency of current gravitational wave microlensing searches using isolated compact object lenses

Speaker

Uddeepta Deka

Description

Current searches for microlensing signatures in the detected gravitational wave (GW) events assume an isolated point mass lens (PML) model. However, the assumption of the lenses being isolated is overly simplistic, as these lenses are typically embedded within more complex structures, such as galaxies. In this paper, we extend the current lens model to incorporate external influences that better reflect the environment in which these lenses reside. Specifically, we consider microlenses perturbed by singular isothermal sphere (SIS) galaxy potentials. We find that neglecting host galaxy effects may lead to reduced sensitivity in microlensing searches.

3:10 PM

3:10 PM

Afternoon Tea/Coffee

Break |

Location: University of Canterbury, Rātā / Engineering Core Building, 63 Creyke Road, Ilam, Christchurch 8041, New Zealand

3:40 PM

3:40 PM

Parallel sessions: Gravity - foundational aspects

Session |

Location: Rātā / Engineering Core Building, University of Canterbury, Room E7, 63 Creyke Road, Ilam, Christchurch 8041, New Zealand

3:40 – 4:00 PM (20m) **Black hole superradiance of interacting multi-fields**

Speaker

Jun Zhang (International Centre for Theoretical Physics Asia-Pacific)

Description

Ultralight bosonic fields can undergo exponential amplification around rotating black holes through black hole superradiance. This process can result in black hole spin-down, continuous gravitational-wave emission, and many other observable consequences, providing a powerful probe of dark particles in the strong-gravity regime. In particular, the LVK Collaboration has placed constraints on dark scalars with masses around 10^{-12} eV.

While most existing studies assume a single field, the dark sector may contain multiple particle species with nontrivial interactions. In this work, we investigate black hole superradiance in the presence of multiple interacting fields. In particular, we compute the corrections to the superradiant growth rates induced by interactions with other fields, study the nonlinear evolution of the superradiant system, and discuss the observational implications.

We find that interactions can significantly suppress black hole superradiance and modify the superradiant evolution, even if the coupled field is not itself superradiant. We demonstrate that multi-field interactions can qualitatively alter superradiance phenomenology and should be incorporated when deriving robust constraints on the dark sector from black hole spin measurements and gravitational-wave observations.

4:00 – 4:20 PM (20m)

A New Definition of Horndeski Theory and the Possibility of Multiple Scalar Field Extensions

Speaker

Tomoki KATAYAMA

Description

The Horndeski theory represents the most comprehensive framework within scalar-tensor theories, comprising a single scalar field whose equations of motion are closed up to second-order derivatives. Nonetheless, systematic extensions involving multiple scalar fields remain incomplete: while the general form of the equations of motion for two fields (bi-Horndeski) is established, the overarching action remains undefined; furthermore, for three or more fields, neither the general action nor the equations have been fully elucidated.

This presentation introduces a novel “definition" that characterizes the Horndeski theory independently of the specific form of the action. Specifically, it stipulates the theory through two conditions: (i) closure under invertible pure disformal transformations, and (ii) the inclusion of the minimal (anchor) theory. From this standpoint, the standard single-field Horndeski (i.e., generalized Galileon) action is recovered, excluding boundary terms.

Subsequently, this methodology is extended to encompass multiple fields. By incorporating reversible bi-disformal transformations and minimal multiple theories, a practical pathway for the construction of multi-field models is provided. As a concrete example, the action involving two fields up to the $\mathcal{L}_4$ sector (with the $\mathcal{L}_5$ coupling set to zero) is derived, demonstrating that the additional term aligns with the antisymmetric structure characteristic of the Allys–Akama–Kobayashi (AAK) model. This signifies that structures inherent to multi-field systems, which are challenging to obtain via straightforward multi-Galileon extensions, naturally arise from the perspective of disformal closure. Additionally, the correspondence with established bi-Horndeski equations and prospects for extending to $N\geq3$ are examined.

This is based on 2511.15423.

4:20 – 4:40 PM (20m)

Application of Solving Inverse Scattering Problem in Holographic Bulk Reconstruction

Speaker

Run-Qiu Yang (Tianjin University)

Description

We investigate the problem of bulk metric reconstruction in holography by leveraging the inverse scattering framework applied to boundary two-point correlation functions. It shows that the bulk metric of a planar/ spherically /hyperbolically symmetric asymptotically anti-de Sitter static black brane/hole can be reconstructed from its boundary frequency 2-point correlation functions by solving Gel’fand-Levitan-Marchenko integral equation. In addition, we analyze the method's robustness under measurement noise and propose filtering strategies to improve reconstruction accuracy. This work advances data-driven bulk reconstruction by providing a concrete, experimentally viable pathway to recover spacetime geometry from field-theoretic observables.

4:40 PM

3:40 PM

Parallel sessions: Late universe cosmology

Session |

Location: Rātā / Engineering Core Building, University of Canterbury, Room E5, 63 Creyke Road, Ilam, Christchurch 8041, New Zealand

3:40 – 4:00 PM (20m)

Directional variations of cosmological parameters from the Planck CMB data

Speaker

Ming Chung Chu (The Chinese University of Hong Kong (HK))

Description

In an earlier work, we performed a statistical analysis of the angular distribution of the cosmological parameters by adding hemispherical masks in different directions to the Planck 2018 CMB temperature and polarization data. We found that the standard ΛCDM parameters Ωbh2, Ωch2, ns, 100θMC, and H0 closely follow a dipole form, with 2-3 σ-level directional variations. The dipole axes all generally align around a direction that is about 45° away from that of the CMB kinematic dipole. In this talk, we show that the directional variation of the CMB angular acoustic angle calculated with the fully asymmetric Bianchi Type I metric cannot account for the observed dipole-like anisotropy. Rather, we argue that local structures are likely to be the cause. If confirmed, our result implies that future CMB analyses should account for this foreground effect.

4:00 – 4:20 PM (20m)

Gauge-invariant perturbation cosmology

Speaker

Malcolm Anderson (Universiti Brunei Darussalam)

Description

Many of the predictions of theoretical cosmology are generated by perturbing around a background FLRW space-time. This procedure is problematic, because the dependence of observables on the perturbations of the metric tensor varies with the choice of coordinates (or gauge) in the perturbed space-time. Moreover, the gauge choice is rarely uniform, as for example luminosity distances and peculiar velocities are usually calculated in the Newtonian gauge, whereas matter densities and fluctuations in the CMB temperature are conventionally calculated in the synchronous gauge.

In this talk, I will explain how the correct gauge-invariant formulas for a number of important observables can be derived, and use them to revise the two-point correlation functions for the local density and peculiar velocity fields, as well as the spectrum of anisotropies induced in the CMB by perturbations in the gravitational potential on the surface of last scattering (i.e. the Sachs-Wolfe effect).

4:20 – 4:40 PM (20m)

Measuring backreaction and spatial curvature in the local Universe

Speaker

Pierre Mourier (University of Canterbury)

Description

The late-time Universe features nonlinear local deviations from strict homogeneity and isotropy as matter structures develop. These inhomogeneities may have a non-negligible impact on the cosmological expansion at the largest scales. Such "backreaction" effects from the presence of structures, including the growth of spatial curvature over large regions, can partially mimic the dynamical contributions of dark energy or dark matter depending on the scale considered. They can be described, in a general-relativistic picture, by explicitly coarse-graining the local inhomogeneous fields using a spatial averaging scheme.

We evaluate the local density, expansion rate, shear, and spatial intrinsic scalar curvature fields within a 300 Mpc/*h* comoving distance of our Galaxy ($z \sim 0.1$) using the CosmicFlows-4++ reconstruction of the associated peculiar velocity and density contrast fields. This allows us to compute the averaged energy balance over a range of scales in the cosmic neighbourhood, including the contributions from backreaction terms.
I will present these results, which show large (*O*(10%)) regional deviations in the energy budget from the flat $ \Lambda$CDM background, with a significant role played by the spatial curvature. These variations extend all the way to the edge of the surveyed volume, where they point to a vast underdense shell roughly compatible with the proposed Local Hole.

4:40 PM

3:40 PM

Parallel sessions: Neutrino physics

Session |

Location: Rātā / Engineering Core Building, University of Canterbury, Room E6, 63 Creyke Road, Ilam, Christchurch 8041, New Zealand

3:40 – 4:00 PM (20m)

Status and Prospects of the RELICS Experiment

Speaker

Jingqiang Ye (The Chinese University of Hong Kong, Shenzhen)

Description

Coherent Elastic Neutrino-Nucleus Scattering (CEvNS) is a well-understood Standard Model (SM) process with an enhanced cross section for MeV neutrinos. The CEvNS from solar B-8 neutrinos and atmospheric neutrinos define the so-called neutrino fog for dark matter direct detection, which motivates the measurement of its cross section. The large cross-section also makes CEvNS a promising method of reactor monitoring. The RELICS (REactor neutrino LIquid xenon Coherent Scattering) experiment aims to measure CEvNS using reactor neutrinos with a liquid xenon time projection chamber (LXe TPC). This technology features low threshold, ultra-low backgrounds, and large exposure, which will not only enable measurement of CEvNS but also exploration of new physics signals from reactors. In this talk, I will give an overview of the experiment, present its current status, and discuss its scientific potential.

4:00 – 4:20 PM (20m)

Direct Neutrino Mass Measurements: Status, Recent Advances, and Future Prospects

Speaker

Khushbakht Habib (Karlsruhe Institute of Technology)

Description

The determination of the absolute neutrino mass scale remains one of the central open questions in particle physics and cosmology. Several complementary approaches address this question, including direct kinematic measurements, searches for neutrinoless double-beta decay, and constraints from cosmological observations. Neutrinoless double-beta decay experiments aim to uncover whether neutrinos are their own antiparticles while probing the effective mass, whereas cosmological surveys provide independent constraints on the sum of neutrino masses. The KArlsruhe TRItium Neutrino (KATRIN) experiment currently provides the most sensitive direct kinematic probe of the neutrino mass by measuring the endpoint region of the tritium β-decay spectrum with high precision. The experimental setup employs a high-luminosity gaseous molecular tritium source in combination with a large high-resolution electrostatic spectrometer. Using the first 25% of its total dataset, KATRIN has achieved the most stringent direct upper limit of $0.45\,\mathrm{eV}/c^{2}$ at a 90% CL on the neutrino mass[[1]]. With the full planned dataset, KATRIN aims to reach a final design sensitivity of better than $0.3\,\mathrm{eV}/c^{2}$ (90% CL). Building on this success, the proposed upgrade, KATRIN++ aims to further improve the sensitivity and probe neutrino masses below the degenerate mass regime. Complementary efforts include the cyclotron radiation–based Project 8 and Quantum Tritium Neutrino Mass (QTNM) experiments, as well as calorimetric HOLMES and ECHo experiments using ^{163}Ho electron capture. Collectively, these efforts aim to reach the ultimate sensitivity required to explore the mass scale suggested by neutrino oscillation data. This talk will summarize the current global status of direct neutrino mass searches, highlight recent experimental progress, and discuss the prospects for future measurements aimed at determining the absolute neutrino mass scale.

4:20 – 4:40 PM (20m)

Galactic Point Source Searches with IceCube in the Multi-Messenger Era

Speaker

Ankur Sharma (University of Canterbury)

Description

Following IceCube's recent detection of Galactic plane emission, resolving individual Galactic neutrino sources has become an important objective. In this talk, I will present an overview of ongoing efforts to search for Galactic point sources using IceCube, with a focus on how multi-messenger observations can enhance sensitivity and interpretation. In particular, I will discuss the potential role of radio and very-high-energy gamma-ray data in guiding and complementing neutrino searches. I will also touch upon prospects for joint analyses with KM3NeT, especially in improving coverage of the Southern sky.
The presentation will outline general strategies, challenges, and future directions in combining neutrino and electromagnetic observations for Galactic source studies.

Subcontributions

20m **Neutrino detection**

4:40 PM

4:40 PM – 6:10 PM

Poster session

Session |

Location: University of Canterbury, Rātā / Engineering Core Building, 63 Creyke Road, Ilam, Christchurch 8041, New Zealand

Description

Dedicated poster session. Posters will remain on display on the following days of the conference. Poster of sizes up to A1 can easily be accommodated on the poster boards.

5:00 PM – 5:45 PM

ASGRG Biennial General Meeting

Session |

Location: University of Canterbury, Rātā / Engineering Core Building, 63 Creyke Road, Ilam, Christchurch 8041, New Zealand

7:30 PM – 8:30 PM

Public lecture: Scanning the Darkest Skies (Richard Easther, U Auckland)

Session |

Location: The Arts Centre Te Matatiki Toi Ora, Great Hall, 2 Worcester Boulevard, Christchurch Central City

Description

https://www.artscentre.org.nz/whats-on/public-astronomy-lecture-scanning-the-darkest-skies/

7:30 – 8:30 PM (1h) **Scanning the Darkest Skies**

Speaker
Richard Easther (The University of Auckland)

Location
The Arts Centre Te Matatiki Toi Ora, Great Hall, 2 Worcester Boulevard, Christchurch Central City, Christchurch 8013

Description

Matariki reminds us that astronomy begins with humanity's shared view of the night sky. Yet today's astronomers often explore invisible features of the cosmos – dark matter, gravitational waves, and black holes. Drawing connections between these two perspectives, Richard Easther will shine a light on how our small country can play a key part in answering the biggest questions.

Tue, July 7

9:00 AM

Plenary talks: Session 3

Session | **Location:** Rātā / Engineering Core Building, University of Canterbury, Room E8

9:00 – 9:35 AM (35m)

Bustling Universe Radio Survey Telescope in Taiwan (BURSTT): Status and Prospect

Speaker

Jiwoo Nam (National Taiwan University)

Description

Fast Radio Bursts (FRBs) represent one of the most intriguing frontiers in modern astrophysics, yet their origins and physical mechanisms remain elusive. The Bustling Universe Radio Survey Telescope in Taiwan (BURSTT) project is a dedicated radio interferometer designed to address these fundamental challenges. By prioritizing an ultra-wide "fisheye" field of view, BURSTT compensates for its moderate sensitivity by focusing on a systematic census of bright, nearby FRBs (median redshift z ~ 0.04), which are prime targets for multi-wavelength and multi-messenger follow-up observations.

The project has successfully completed its first phase (2023–2026). The Fushan main station, featuring an upgraded wide-band (300–800 MHz) array of 256 Log-Periodic Dipole Antennas (LPDAs), operates in conjunction with outrigger stations in Nantou and Green Island to provide essential sub-arcsecond localization. Following successful system fine-tuning and the initiation of reliable FRB detections, we are now launching an ambitious expansion phase. This includes a fourfold increase in experimental capacity and the ongoing development of an international outrigger network, including stations in Jinmen, Ogasawara (Japan), and Pyeongchang (Korea). Furthermore, we are actively conducting site surveys and prototyping for additional international nodes in Hawaii, India, Vietnam, Thailand, and Mongolia. This presentation outlines the current operational status of the BURSTT infrastructure and our long-term roadmap to transform FRB science through high-cadence, wide-field monitoring.

9:35 – 10:10 AM (35m)

New Measurements in the Era of Precision Neutrino Physics

Speaker

Nicole Bell (The University of Melbourne)

Description

Neutrino physics is entering an era of precision measurement, offering unprecedented opportunities to probe neutrino properties. This talk will discuss three examples. First, we present a new approach to measuring the CP-violating phase in neutrino mixing. This involves an up-down flux ratio for sub-GeV atmospheric neutrinos. For the example of Hyper-Kamiokande --- the first experiment with sufficient atmospheric-neutrino statistics in this energy range --- this approach can surpass the sensitivity of accelerator long-baseline experiments near the maximally CP-violating values $\delta = \pi/2$ and $3\pi/2$. Second, we show that DUNE can make a precise measurement of the total flux of ^{8}B solar neutrinos via neutral-current interactions with argon. Combined with charged-current measurements, this would enable the most precise measurements of the solar neutrino mixing parameters using neutrino from the Sun. Finally, we discuss the ability to probe light dark matter via its annihilation to neutrinos.

10:10 – 10:45 AM (35m)

Timescape versus ΛCDM — precision tests of emerging spatial curvature

Speaker

David Wiltshire (University of Canterbury)

Description

The timescape cosmology returns to first principles, to explain apparent cosmic acceleration in the statistical regime of general relativity. As inhomogeneities in density and expansion grow, they back react on the average cosmic expansion, which differs from conventional FLRW models. Crucially, dynamical spatial curvature arises as time-varying gradients of the kinetic energy of expansion, depending directly on the volume fraction of cosmic voids.

The timescape expansion history is close to ΛCDM, but with differences at a precision which we are now finally probing. Whereas ΛCDM is increasingly challenged, independent observational tests now favour timescape. In particular, the recent DESI evidence for "evolving dark energy" gives a dark energy "equation of state" w(z) consistent with timescape's non-FLRW evolution, as predicted in 2009. Projections made in 2014 for the Euclid mission showed that Euclid will distinguish FLRW expansion histories from those with emerging spatial curvature, including timescape, by the definitive Clarkson-Bassett-Lu (CBL) test. The CBL test consists of two parts: the first parts requiring over 1000 precise type Ia supernova luminosity distance measurements was completed in our recent analysis of the Pantheon+ data, finding very strong Bayesian evidence ($\ln B > 5$) in favour of timescape over ΛCDM. The second part involving Euclid BAOs over a redshift range, $0.7 < z < 2.0$, requires geometric new tools.

In this talk I will outline results to date, and discuss the remaining challenges to test a fundamentally new paradigm for cosmology with the same precision as ΛCDM by 2030.

10:45 AM

10:45 AM – 11:15 AM

Morning Tea/Coffee

Break |
Location: University of Canterbury, Rātā / Engineering Core Building, 63 Creyke Road, Ilam, Christchurch 8041, New Zealand

11:15 AM – 12:30 PM

Plenary talks: Session 4

Session | **Location:** Rātā / Engineering Core Building, University of Canterbury, Room E8

11:15 – 11:50 AM (35m) **PandaX: Deep Underground Xenon Observatory in China**

Speaker

Jianglai Liu (Shanghai Jiao Tong University)

Description

The PandaX (Particle AND Astrophysical Xenon Experiments) project is a staged xenon-based deep experiment at the China Jin-Ping Underground Laboratory. Using a dual-phase liquid xenon time projection chamber (TPC) technology, the PandaX-4T detector features a sensitive volume of about 4 tons to search for rare events, including the detection of dark matter, solar neutrinos, and neutrinoless double-beta decay. In parrel with the PandaX-4T operation, a multi-ten-tonne experiment is being actively pursued. The immediate next stage is PandaX-20T, scheduled to be under commissioning in late 2027. In this talk, I will highlight the latest results from the PandaX-4T experiment and provide an update on the progress of PandaX-20T.

11:50 AM – 12:25 PM (35m) **Status and perspectives of KAGRA**

Speaker

Hirotaka Takahashi (Tokyo City University)

Description

KAGRA is a large cryogenic gravitational wave telescope located at the Kamioka Mine in Gifu Prefecture, Japan. KAGRA was constructed under the ground and it is operated using cryogenic mirrors that help in reducing the seismic and thermal noise. KAGRA has performed its observation runs. In this talk, we will report on the current status and the prospects of KAGRA.

12:30 PM – 1:30 PM

Lunch

Break |
Location: University of Canterbury, Rātā / Engineering Core Building, 63 Creyke Road, Ilam, Christchurch 8041, New Zealand

1:30 PM

5:30 PM

Conference Excursion: Christchurch Gondola

Session |

Location: University of Canterbury, Departure 1:30pm from Rātā / Engineering Core Building, 63 Creyke Road, Ilam, Christchurch 8041, New Zealand

Description

https://www.christchurchattractions.nz/christchurch-gondola/

Coaches depart UC immediately after lunch. At the summit station refreshments will be served in the Pinnacles Room.

Wed, July 8

9:00 AM

Plenary talks: Session 5

Session | **Location:** Rātā / Engineering Core Building, University of Canterbury, Room E8

9:00 – 9:35 AM (35m) **Black Holes Trapped by Ghosts**

Speaker

Bin Wang (Shanghai Jiao Tong University / Yangzhou University)

Description

Violent cosmic events, from black hole mergers to stellar collapses, often leave behind highly excited black hole remnants that inevitably relax to equilibrium. The relaxation is usually understood in linear perturbation theory and observed in gravitational wave. We disclose a distinct nonlinear regime exists before the linear ringdown. This intrinsic nonlinear regime is a long-lived bottleneck dominating the evolution. This stage is controlled by a saddle-node ghost in phase space, which traps the remnant and delays the onset of linearity by a timescale obeying a universal power-law. This new nonlinear dynamical behavior is a new target for future observations.

9:35 – 10:10 AM (35m) **Long-Baseline Neutrino Experiments: Oscillations and Beyond**

Speaker

Seon-Hee (Sunny) Seo (Fermilab, USA)

Description

Neutrinos are still the most mysterious particles of the Standard Model. Our knowledge of leptonic CP violation and the neutrino mass ordering remains limited; the current long-baseline experiments NOvA and T2K provide only first hints. The next generation of long-baseline experiments, DUNE and Hyper-Kamiokande, is designed to resolve these questions, while the JUNO medium-baseline reactor experiment offers an independent determination of the mass ordering. Beyond oscillations, these flagship detectors are also neutrino telescopes for astrophysics — galactic supernova bursts, the diffuse supernova neutrino background, and solar neutrinos. In this talk I will review DUNE, Hyper-K, and JUNO, focusing on leptonic CP violation, the neutrino mass ordering, and their astrophysical-neutrino programs.

10:10 AM

10:10 AM

Morning Tea/Coffee

Break |

Location: University of Canterbury, Rātā / Engineering Core Building, 63 Creyke Road, Ilam, Christchurch 8041, New Zealand

10:40 AM

10:40 AM

Plenary talks: Session 6

Session | **Location:** Rātā / Engineering Core Building, University of Canterbury, Room E8

10:40 – 11:15 AM (35m) **Inflation — my personal perspective**

Speaker

Misao Sasaki (Asia Pacific Center for Theoretical Physics)

Description

Thanks to the rapid progress in observational cosmology, we have begun to understand the physics of the very early Universe, the inflationary universe. However our knowledge is still far from complete. Based on my personal perspective, I will first review what inflation is and what we currently know about it. Then I will discuss some recent topics that may improve our understanding of the early Universe.

11:15 – 11:55 AM (40m)

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

Speaker

Sebastian Bahamonde (Institute for Basic Science, Daejon)

Description

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 and gravitational waves in theories with torsion and/or nonmetricity, including scalarised black holes and spin-orbit effects. 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.

11:55 AM

11:55 AM – 12:10 PM

Group photo

Session |

Location: University of Canterbury, Rātā / Engineering Core Building, 63 Creyke Road, Ilam, Christchurch 8041, New Zealand

12:10 PM – 1:30 PM

APCosPA Council Meeting (over lunch)

Session |

Location: Rātā / Engineering Core Building, University of Canterbury, Room 119, 63 Creyke Road, Ilam, Christchurch 8041, New Zealand

12:10 PM – 1:30 PM

Lunch

Break |

Location: University of Canterbury, Rātā / Engineering Core Building, 63 Creyke Road, Ilam, Christchurch 8041, New Zealand

1:30 PM

Parallel sessions: Dark matter - detection

Session |

Location: Rātā / Engineering Core Building, University of Canterbury, Room E6, 63 Creyke Road, Ilam, Christchurch 8041, New Zealand

1:30 – 1:50 PM (20m)

Searching for ultralight dark matter from terrestrial magnetic fields

Speaker

Kimihiro Nomura (Kyoto University)

Description

We present a novel search for ultralight dark matter using terrestrial magnetic field measurements at frequencies below 100 Hz, focusing on dark photon dark matter as a representative candidate. Coherently oscillating dark photon dark matter can induce a monochromatic magnetic field via kinetic mixing with ordinary photons. Notably, for dark photon masses around 3 \times 10^{-14} eV, the signal can be resonantly amplified within a cavity formed by the Earth's surface and the ionosphere. We compute the expected signal incorporating the effect of atmospheric conductivity, and derive new upper limits on the kinetic mixing parameter from long-term geomagnetic data. These limits improve upon previous ground-based constraints in the mass range of 1 \times 10^{-15} — 2 \times 10^{-13} eV. We would also like to touch on the results of axion dark matter searches based on similar ideas.

1:50 – 2:10 PM (20m)

WimPyDD and WimPyC: Python codes exploiting the complementarity between WIMP direct detection and indirect detection

Speaker

Sunghyun Kang (CQUeST, Sogang University)

Description

I introduce WimPyDD and WimPyC which are object-oriented and customizable Python codes that calculate accurate predictions for the expected rates in WIMP direct detection experiments and WIMP capture rate in celestial bodies as indirect detection within the framework of Galilean invariant non-relativistic effective theory. Due to the experimental threshold direct detection can not explore signals at low WIMP incoming speed range, while capture in celestial bodies is favored for low or even vanishing WIMP speed. This complementarity can be analyzed using WimPyDD and WimPyC so that one can obtain bounds on WIMP-nucleus scattering which do not depend on the WIMP velocity distributions or WIMP-nucleus interactions.

2:10 – 2:30 PM (20m)

First Bubbles in the SBC-LAr10 Detector

Speaker

Russell Neilson (Drexel University)

Description

The Scintillating Bubble Chamber (SBC) Collaboration develops noble liquid bubble chambers for the detection of low-mass (GeV-scale) particle dark matter and coherent neutrino scattering (CEvNS) at nuclear reactors. Like other bubble chamber dark matter detection efforts, SBC relies on the intrinsic background discrimination seen in superheated fluids: nuclear recoils from WIMP and neutrino interactions in the superheated target of the bubble chamber nucleate a single bubble, while electronic recoils from background beta decays and gamma rays do not. By using a noble liquid target, SBC extends this discrimination to much lower thresholds than achievable in other liquids while also adding a scintillation signal for event-by-event energy reconstruction. SBC-LAr10 is the collaboration's first physics-scale device, operating at Fermilab and designed to superheat a 10-kg argon target to bubble nucleation thresholds as low as 40 eV. SBC-LAr10 saw its first bubbles in October 2025, beginning a calibration campaign to evaluate the physics reach of this new detector technology. This talk will provide an overview of the SBC experiment and report on early results from the calibration campaign.

2:30 – 2:50 PM (20m)

Development of A Novel Compton Camera for MeV Gamma Ray Measurement

Speaker

Mengjiao Xiao (Shanghai Jiao Tong University)

Description

The astrophysical observations of gamma rays at MeV energies have not yet been well-explored due to the limitation of detection technology. The so-called “MeV-gap” exists. Opening the window of MeV gamma ray is not only critical for gamma astronomy but also key for many frontier researches in astro-particles, such as looking for the light dark matter, probing the primordial black hole and better understanding of the cosmic-ray propagation.

With the novel scintillation materials, a Compton camera with good energy resolution and angular resolution is under developing. This presentation will first review the MeV gamma-ray searches, and then focus on the development of the Compton camera, including the simulation, design as well as the construction of the functional prototype.

2:50 – 3:10 PM (20m)

The SABRE South Experiment at the Stawell Underground Physics Laboratory

Speaker

Daniel Marcantonio (University of Melbourne)

Description

SABRE is an international collaboration that will operate similar particle detectors in the Northern (SABRE North) and Southern Hemispheres (SABRE South). This innovative approach aims to distinguish potential dark matter signals from seasonal backgrounds: a pioneering strategy only feasible with a Southern Hemisphere experiment. SABRE South is located at the Stawell Underground Physics Laboratory (SUPL), in regional Victoria, Australia. SUPL is a newly constructed facility situated 1024 metres underground (~2900 metres water equivalent) within the Stawell Gold Mine. Its construction was completed in 2023.

SABRE South employs ultra-high purity NaI(Tl) crystals immersed in a linear alkyl benzene (LAB)-based liquid scintillator veto, surrounded by passive steel and polyethylene shielding, and topped with a plastic scintillator muon veto. Significant progress has been made in the procurement, testing, and preparation of equipment for the installation of SABRE South. The assembly of the experiment at SUPL will take place this year. The SABRE South muon detector and data acquisition systems are already operational and actively collecting data at SUPL, and full commissioning of SABRE South is planned this year. This presentation will provide an update on the overall progress of the SABRE South construction, its anticipated performance, and its potential physics reach.

3:10 PM

1:30 PM

Parallel sessions: Gravitational waves (ACGRG/NZ Gravity Student Talks)

Session |

Location: Rātā / Engineering Core Building, University of Canterbury, Room E5, 63 Creyke Road, Ilam, Christchurch 8041, New Zealand

1:30 – 1:50 PM (20m)

Standard Siren Cosmology in the Era of the Next-generation Gravitational Wave Detectors

Speaker

SHANGJIE JIN (University of Western Australia)

Description

In recent years, with the improvements of the measurement precisions of cosmological parameters, some puzzling tensions appear. The tension between the values of the Hubble constant inferred from the Planck CMB observations (0.8% precision, assuming the standard LambdaCDM model) and obtained through distance ladder measurements have reached 5σ, known as the Hubble tension. Gravitational wave (GW) standard siren observations provide an independent method to obtain the distance information of the GW source waveform. In this presentation, I will introduce the potential role of standard siren observations of future GW detectors in helping to solve the Hubble tension.

1:50 – 2:10 PM (20m) **PBH Flybys of SMBHs: Say Hello, Wave Goodbye**

Speaker
Laura Burn (University of Auckland)

Description

Primordial black holes (PBHs), assumed to form in the early Universe, remain a viable dark matter candidate. Since dark matter is expected to be concentrated toward galactic centres, a significant population of PBHs would reside near a supermassive black hole (SMBH), creating a promising environment for gravitational wave emission. We consider a population of PBHs with masses in the range $10^{-15} - 10 \, \mathrm{M_{\odot}}$ on hyperbolic trajectories near a SMBH, producing bursts of gravitational radiation during periastron passage. We focus on Sagittarius A* due to its proximity, and also consider M87*, with results that generalise to other scenarios. We compute the density of PBHs required to give rise to a popcorn gravitational wave background within the sensitivity range of future space-based detectors, including LISA and the proposed next generation μAres detector.

2:10 – 2:30 PM (20m) **The Hunt for the next Galactic supernova**

Speaker
Tarin Eccleston (The University of Auckland)

Description

There have only been a few recorded observations of supernovae in the Milky Way. The earliest was seen by Han-dynasty astronomers in 185 CE, while the most recent is thought to be in the late 1600s. Supernovae have appeared as unexpected guests in the sky throughout history, and we have not yet observed them in detail. But well before the star dies, it releases invisible messengers – gravitational waves – that allow us to track down the incoming explosion. Casting a wide net across the cosmos, my research explores using machine learning to locate the star before it explodes.

2:30 – 2:50 PM (20m) **Massive black holes in binary solitons**

Speaker
Russell Boey (University of Auckland)

Description

Ultralight dark matter (ULDM) is a dark matter candidate composed of light axion-like particles and is a promising alternative to cold dark matter. A feature unique to ULDM is the formation of soliton cores at the centre of galaxies, whose interactions with supermassive black holes may affect their merger dynamics. We present high-resolution numerical simulations of merging binary solitons containing supermassive black holes, and compare these to simulations of binary black holes in a single soliton of similar mass. We see novel behaviours in the orbital evolution of the black holes that are not seen with two black holes inside a single soliton or a comparable cold dark matter halo, which are likely to modify merger timescales and the resulting gravitational wave signals.

2:50 – 3:10 PM (20m)

Light, Gravity and Coffee (Astrophysical Implications of Non-linear Gravitational and Electromagnetic Scattering)

Speaker
Jesse Satherley (University of Canterbury)

Description

The interaction between GWs and EWs is interesting, but it has only been explored in the vacuum case.
Theory for the non-vacuum case does exist, but it has not been implemented numerically.
We extend current initial value boundary problem numerical simulations to include an arbitrary energy-momentum tensor, which is then used to prescribe electromagnetism.
However, adding electromagnetism introduces two new propagating modes associated with the EWs.

To do this, we use the conformal field equations.
They are a reformulation of the Einstein field equations using conformal compactification to include infinity within a finite domain.
The conformal field equations can then be posed as a initial value boundary problem.

To simplify the system, we implement the boundary adapted evolution system for GWs.
This modification adapts the GW evolution to the boundary of the computation domain.
Alongside this, a new boundary adapted gauge is found.
This new system simplifies the boundary data and analysis for the arising initial value boundary problem and removes two propagating modes associated with the GWs.

3:10 PM

1:30 PM

Parallel sessions: Gravity - foundational aspects

Session |

Location: Rātā / Engineering Core Building, University of Canterbury, Room E7, 63 Creyke Road, Ilam, Christchurch 8041, New Zealand

1:30 – 1:50 PM (20m)

Pseudospectrum and (in)stability of black hole total transmission mode

Speaker

Yu-Sen Zhou (University of Science and Technology of China)

Description

Total transmission modes (TTMs) are modes with complex frequencies that propagate across a black hole spacetime without reflection. Recently, it is found that suitably tailored time-dependent scattering can excite these complex modes and suppress the reflected signal for the entire duration of the process, a phenomenon referred to as virtual absorption. Motivated by this, we present a study of the spectrum stability of TTMs using pseudospectrum and condition numbers. We focus on perturbations of d-dimensional Tangherlini black holes and recast the TTM problem as a generalized eigenvalue problem by utilizing the Eddington-Finkelstein coordinates. The results show that TTMs are generically spectrally unstable, with sensitivity increasing for higher overtones, in close analogy with quasinormal modes. A notable exception is the purely imaginary TTM in the positive imaginary axis in higher dimensions. Its pseudospectrum contours are nearly concentric, and its condition number is orders of magnitude smaller than those of the overtones, indicating enhanced spectral stability. Although its four-dimensional counterpart is spectrally unstable, it becomes stable rather quickly as the spacetime dimension increases. Additionally, we confirm that purely imaginary TTMs occur for gravitational vector perturbations, whereas genuinely complex TTM families appear only in sufficiently high dimensions, $d \geqslant 8$, extending earlier claims that placed the onset at $d \geqslant 10$.

1:50 – 2:10 PM (20m)

The Teukolski equation for the Baines-Visser spacetime

Speaker

Joshua Baines (The University of Melbourne)

Description

Testing the Kerr hypothesis via gravitational wave data requires tools sensitive to potential deviations from general relativity. The Baines-Visser (BV) spacetime provides a well-motivated, maximally general parametrisation of axisymmetric stationary black hole spacetimes, encoding departures from classical Kerr via three radial functions: $\Phi(r)$, $\Delta(r)$, and $\Xi(r)$. In this talk I introduce the BV spacetime, impose separability of the Teukolsky equation and derive the associated Teukolsky equation, which enables analytical computation of post-merger ringdown modes. Comparing these modes to those observed in gravitational wave data offers a direct pathway to constraining the three free functions, providing a systematic framework for black hole spectroscopy beyond GR.

2:10 – 2:30 PM (20m)

Black hole interior and complexity of homogeneous holographic solids under shear strain

Speaker

Wei-Jia Li

Description

Guided by the spirit of effective field theory, we construct homogeneous holographic models to describe strongly correlated phases with broken translational and rotational symmetry. These holographic systems retain background homogeneity, thereby enabling controllable and efficient computations. In this talk, I will introduce how these models capture key features of solids, including collective modes at finite temperatures and nonlinear elastic behavior under finite shear. Particularly, I will show how shear deformation influences the global geometry of the black hole as well as the quantum complexity of the dual system.

2:30 – 2:50 PM (20m) **A photon cloud induced from an axion cloud**

Speaker

Zi-Yu Tang

Description

It is known that the axion-photon coupling can lead to quantum stimulated emission of photons and classic exponential amplification of electromagnetic (EM) fields at half the axion mass frequency, when the axion density or the coupling constant is sufficiently large. In this work, we studied the EM photon cloud induced from an axion cloud around a Kerr black hole in the first order of the coupling constant classically. In the presence of a static EM background (such as the extended Wald solution motivated by astrophysical environments), we found that an EM photon cloud emerges, oscillating at the same frequency as the axion cloud and growing exponentially in accordance with the axion cloud when the superradiant condition for the axion field is satisfied. The evolution of the EM photon cloud with time and azimuthal angle is obtained analytically while the cross-sectional distribution is solved numerically. The induced EM field exhibits symmetries that are markedly different from those of the background EM field. Consequently, the induced photon cloud forms an unstable bound configuration that emits EM waves to spatial infinity while being replenished by the axion cloud, providing a potential observational signature of both the presence of an axion cloud and axion-photon coupling.

2:50 – 3:10 PM (20m) **Gravity with torsion and matter–antimatter asymmetry**

Speaker

Nikodem Poplawski (University of New Haven)

Description

The conservation law for the orbital plus spin angular momentum of a free Dirac particle in curved spacetime requires that the affine connection has the antisymmetric part: the torsion tensor, which extends general relativity to the Einstein–Cartan theory of gravity. In the presence of torsion, the Dirac equation becomes a nonlinear, cubic equation in the spinor wave function. We show that the energy eigenvalues of the corresponding Hamiltonian as functions of the momentum are different for the fermion and antifermion components of the spinor, violating charge conjugation symmetry, and also depend on the helicity. Consequently, particles of matter and antimatter have different effective masses. This mass difference increases with density and becomes significant at extremely high densities in the early Universe. Because antimatter particles were more massive than matter particles, they were also slower during pair production in the early Universe and therefore had higher cross sections for gravitational capture by primordial black holes. This difference might have led to the matter–antimatter imbalance in the observable Universe.

3:10 PM

3:10 PM

Afternoon Tea/Coffee

Break |

Location: University of Canterbury, Rātā / Engineering Core Building, 63 Creyke Road, Ilam, Christchurch 8041, New Zealand

3:40 PM

3:40 PM

Parallel sessions: Astroparticle and relativistic astrophysics

Session |

Location: Rātā / Engineering Core Building, University of Canterbury, Room E6, 63 Creyke Road, Ilam, Christchurch 8041, New Zealand

3:40 – 4:00 PM (20m)

Magnetic field in low-mass X-ray binaries and Dark Matter signals

Speaker

Stefano Scopel (CQUeST, Sogang University)

Description

Recent studies suggest that the intensity of the magnetic field in low-mass X-ray binaries (LMXBs) is much smaller that its equipartition value. If the black hole in the binary is surrounded by a DM spike this would strongly suppress the strength of synchrotron emission from Dark Matter (DM) induced electron--positron pairs. We analyze the issue in detail and conclude that, instead, the data do not rule out the possibility that the intensity of the magnetic field can approach its equipartition value. This confirms that LMXBs are potentially promising systems to search for DM.

4:00 – 4:20 PM (20m)

UHECRs Beyond the GZK Limit as Magnetic Monopole Candidates

Speaker

Michael Padgett (Vanderbilt University)

Description

A recent event in Ultra High Energy Cosmic Rays (UHECRs) known as the Amaterasu particle is the foundation of a possible glimpse into beyond the standard model physics. The particle was detected by the Telescope Array Project in 2021 and later identified in 2023 with an energy exceeding 240 EeV. There exists a limit that applies to protons as UHECRs known as the GZK limit. It is derived by calculating the mean free path of interactions between a proton and the CMB. The GZK limit is approximately 50 EeV with a mean free path of approximately 6 Mpc. Every time one of these collisions occur, the proton loses approximately 20% of its energy. Another fact that makes the Amaterasu particle interesting is that its arrival direction was calculated to be coming from the local void, a region of space with an under-density of galaxies relative to the rest of the Universe. This makes it unlikely for the Amaterasu particle to have been produced anywhere in the local void since there are no obvious sources. This also means that if we consider the Amaterasu particle to be a proton which crossed the local void, the energies with which it would have to be produced would be above ~10^23 eV. This is extremely unlikely given known acceleration mechanisms. We hypothesize that the Amaterasu particle is not a proton/nucleus, but a Magnetic Monopole (MM).

4:20 – 4:40 PM (20m)

Testing the Leptogenesis from Observable Gravitational Waves

Speaker

Yongcheng Wu (Nanjing Normal University)

Description

Leptogenesis provides an elegant mechanism to explain the observed baryon asymmetry of the Universe (BAU), yet its experimental verification remains challenging due to requirements of either extremely heavy right-handed neutrinos or precisely fine-tuned mass splittings. We adapt a solution by introducing an extra scalar field that significantly enhances CP asymmetry through loop-level contributions. This scalar extension not only facilitates successful leptogenesis but also enables a strong first-order electroweak phase transition, generating potentially observable gravitational waves (GWs). We demonstrate a strong correlation between the generated BAU and the GW signal strength, establishing a unique way to test the leptogenesis. We show that when the model achieves a successful BAU, the resulting GW signal from EWPT can have signal-to-noise ratio of $\mathcal{O}(10^3)$ and $\mathcal{O}(10^6)$ at the upcoming LISA and DECIGO experiments, respectively. This work presents a concrete connection between successful leptogenesis and detectable GWs, offering a promising method for experimental testing of the leptogenesis mechanism through future GW observations.

4:40 – 5:00 PM (20m)

Search for galactic gamma-ray hotspots using IceTop and IceCube

Speaker

Sebastian Vergara Carrasco (University of Canterbury (UC))

Description

Over the past few decades, gamma-ray observations at TeV energies have significantly advanced our understanding of extreme processes in our galaxy. However, key questions about cosmic-ray acceleration remain, particularly regarding their maximum energy and their connection to features like the "knee" and "ankle" in the cosmic-ray spectrum. Extending gamma-ray observations to higher energies is essential as gamma rays, unlike cosmic rays, are not deflected by magnetic fields and can directly trace back to their sources.

The IceCube Observatory, located at the South Pole, is uniquely equipped to address these questions with its sensitivity to PeV gamma rays. As the only experiment of its kind in the Southern Hemisphere, IceCube has a field of view not covered by any other high-energy gamma-ray observatories.

Using simulations for supervised learning, we apply multiple machine learning techniques to improve background rejection and to estimate the uncertainty of our directional reconstructions on an event-by-event basis. Using these developments, we report the resulting improvements to IceCube’s sensitivity using data from the 2012 observation period. This motivates a multi-year point-source search to identify potential PeV gamma-ray sources or, in the absence of significant hotspots, to set upper limits on their flux.

5:20 PM

3:40 PM

Parallel sessions: Early universe cosmology

Session |

Location: Rātā / Engineering Core Building, University of Canterbury, Room E7, 63 Creyke Road, Ilam, Christchurch 8041, New Zealand

3:40 – 4:00 PM (20m) **Non-Markovian effects in stochastic inflation**

Speaker

Diego Cruces Mateo (Institute of Theoretical Physics - Chinese Academy of Sciences (ITP,CAS))

Description

Stochastic inflation is a fully non-perturbative approach that allows us to study rare, large inhomogeneities generated during inflation. These inhomogeneities are phenomenologically very interesting because they can lead to the formation of primordial black holes, which are a candidate for dark matter. In this talk, after giving a pedagogical introdution to the stochastic approach to inflation, I will explain why such an approach is inherently non-Markovian, which makes its practical implementation highly challenging. I will then present a novel perturbative approach able to tackle these non-Markovian effects.

4:00 – 4:20 PM (20m)

On the Fate of Inflaton after Inflation: Fragmentation, Oscillon Formation and Decay

Speaker

Swagat Saurav Mishra (Centre for Theoretical Physics of the Universe, Institute for Basic Science)

Description

The transition from cosmic inflation to the hot Big Bang phase, known as reheating, remains a key open question in inflationary cosmology. During its early 'preheating' stage, the inflaton field is expected to decay explosively via parametric resonance into lighter bosonic offspring fields. However, when such external couplings are very weak, strong enough self-interaction causes the oscillating inflaton condensate to fragment, forming extremely long-lived scalar-field lumps, known as Oscillons. In this talk, we discuss the conditions for oscillon formation during preheating, particularly in the presence of an external coupling, within the class of inflationary potentials favored by the latest CMB observations. Using high-resolution (3+1)-dimensional lattice simulations performed on the CosmoLattice platform, we systematically map the parameter space that supports oscillon formation. Our results suggest that preheating may have proceeded through both oscillon decay and the conventional decay of the inflaton condensate, offering new insights into this early preheating dynamics. The talk will conclude by highlighting some of the open problems in the field, and discussing possible future directions.

4:20 – 4:40 PM (20m)

A Unified Axion Framework for Dark Sectors and Early Structure Formation

Speaker

Cindy Gulis (Department of Astronomy & Astrophysics, The Pennsylvania State University)

Description

The standard Lambda–Cold–Dark–Matter (LambdaCDM) cosmological model has been remarkably successful in describing the large-scale Universe, yet it faces growing challenges from observations, including the persistent Hubble tension, emerging evidence of evolving dark energy, and the unexpectedly abundant population of massive galaxies discovered by JWST at redshift z>10. These observations collectively suggest that the LambdaCDM may be incomplete, motivating physically motivated extensions to the current model.

I will present Harmonic Axion Unified Cosmology (HAUC), a multi-axion model in which axion-like fields spanning different mass scales naturally generate the universe's fundamental components. In this framework, an ultra-light axion drives a time-evolving dark-energy density, a light axion produced via the misalignment mechanism forms wave-like dark matter, and overdensities of heavy axions during inflation produce primordial black holes. Using cosmological simulations incorporating the HAUC model, we find that primordial black holes provide early gravitational seeds that accelerate the formation of the first galaxies and supermassive black holes. The results suggest that the HAUC framework can naturally enhance early structure formation while remaining broadly consistent with current cosmological constraints. I will discuss the physical mechanisms of the model, simulation results, and observational tests with current and upcoming multi-band surveys of galaxies and black holes at the cosmic dawn.

4:40 – 5:00 PM (20m) **Impact of light sterile neutrino on cosmic structure formation**

Speaker

Rui HU (Chinese University of Hong Kong)

Description

Sterile neutrinos with masses on the eV scale are promising candidates to account for the origin of neutrino mass and the reactor neutrino anomalies. The mixing between sterile and active neutrinos in the early universe could result in a large abundance of relic sterile neutrinos, which depends on not only their physical mass $m_{\rm phy}$ but also their degree of thermalization, characterized by the extra effective number of relativistic degrees of freedom $\Delta N_{\rm eff}$. Using neutrino-involved N-body simulations, we investigate the effects of sterile neutrinos on the matter power spectrum, halo pairwise velocity, and halo mass and velocity functions. We find that the presence of sterile neutrinos suppress the matter power spectrum and halo mass and velocity functions, but enhance the halo pairwise velocity. We also provide fitting formulae to quantify these effects.

5:00 – 5:20 PM (20m)

Probing Small-Scale Primordial Power Spectrum with Cosmological Simulations

Speaker

Tsang Keung Chan (the Chinese University of Hong Kong)

Description

The Lambda Cold Dark Matter paradigm, with a power-law primordial power spectrum, explains successfully the large-scale (>> Mpc) structure of the Universe. However, the small-scale (< Mpc) structures are relatively unconstrained. Recently, JWST has found surprisingly early formation of massive galaxies at high redshifts. Small, dense, dark matter subhaloes have been inferred from strong gravitational lensing. Furthermore, a large number of satellite galaxies have been discovered, larger than expected from standard theoretical models. An enhancement of the small-scale (blue-tilted) primordial power spectrum could be a possible solution to these tensions.

Using cosmological simulations, we investigate how a blue-tilted primordial power spectrum affects cosmic structure formation. We find that in the blue-tilted model, dark matter structures form much earlier, potentially facilitating the early galaxy formation. We also find that blue-tilted halos develop higher central densities, possibly detectable via strong gravitational lensing. With cosmological zoom-in simulations of the Milky Way-mass dark matter halos, we find the subhalo mass function is enhanced by more than a factor of two for subhalo masses below 10^10 solar masses. Finally, we show that the blue tilted model can also produce detectable signatures on 21cm signals around cosmic dawn and reionization.

5:20 PM

3:40 PM

Parallel sessions: Mathematical Relativity (including ACGRG/NZ Gravity Student Talks)

Session |

Location: Rātā / Engineering Core Building, University of Canterbury, Room E5, 63 Creyke Road, Ilam, Christchurch 8041, New Zealand

3:40 – 4:00 PM (20m) **From Black Holes to Stars: Rigidity Beyond Einstein Gravity**

Speaker

Nitesh Dubey (Indian Institute of Astrophysics, Bengaluru)

Description

The final equilibrium stage of stellar evolution may result in either a black hole or a compact object such as a white/black dwarf or neutron star. In general relativity, both stationary black holes and stationary stellar configurations are known to be axisymmetric, and black hole rigidity has been extended to several higher curvature modifications of gravity. In contrast, no comparable result had previously been established for stationary stars beyond general relativity. In this talk, I present our work where we extend the stellar axisymmetry theorem to a broad class of diffeomorphism invariant metric theories. Assuming asymptotic flatness and standard smoothness requirements, we show that the Killing symmetry implied by thermodynamic equilibrium inside the star uniquely extends to the exterior region, thereby enforcing rotational invariance. This demonstrates that axisymmetry of stationary stellar configurations is not a feature peculiar to Einstein gravity but a universal property of generally covariant gravitational theories, persisting even in the presence of higher curvature corrections.

4:00 – 4:20 PM (20m)

Asymptotic Generation of Kerr Geometry from Schwarzschild via BMS Supertranslations

Speaker

Nihar Ranjan Ghosh

Description

The Bondi-van der Burg-Metzner-Sachs (BMS) group, as the asymptotic symmetry group of asymptotically flat spacetimes, plays a central role in connecting infrared structures of gravity with soft theorems and gravitational memory. In this work, we investigate the extent to which BMS supertranslations can relate physically distinct black hole geometries. Focusing on the Schwarzschild and Kerr solutions, we show that the asymptotic structure of the Kerr spacetime can be generated from the Schwarzschild geometry via two successive supertranslations. These transformations yield a Kerr-like geometry at null infinity and reveal two distinct classes of supertranslation functions. The first, composed of $l=1$ spherical harmonics, corresponds to center-of-mass displacements and encodes the translational sector of the BMS group. The second, characterized by an infinite series of even-parity Legendre polynomials ($l\geq 2$), captures the intrinsic mass multipole structure of the Kerr spacetime. Our result illustrates how BMS supertranslations can act as symmetry transformations linking asymptotically flat black hole geometries, and that they encode physically meaningful soft hair consistent with the multipole structure of rotating black holes. This work supports a unified description of soft degrees of freedom in black hole spacetimes and underscores the role of infinite-dimensional asymptotic symmetries in gravitational physics.

4:20 – 4:40 PM (20m)

Internal instability in charged black holes

Speaker

Travers Bloemsaat

Description

The stability of the inner structure of an irrotational charged black hole is a significant issue in relativity, serving as a prototype for the much more complicated problem of internal stability of a rotating charged black hole. Linear results suggest that the inner structure of a charged black hole is unstable under gravitational and electromagnetic perturbations. However, non-linear work on the problem has yet to reach a definitive conclusion on the stability. I aim to use a numerical approach based on Friedrich’s general conformal field equations to investigate the stability in the full non-linear picture. I will discuss previous works as well as the current status of the problem. Further, I will outline the numerical approach I am taking and the results obtained so far.

4:40 – 5:00 PM (20m)

Numerical Implementation of the Friedrich-Nagy Initial Boundary Value Problem

Speaker

Areeba Merriam (University of Canterbury)

Description

Gravitational waves, first predicted by Albert Einstein in 1916, are ripples in spacetime that travel at the speed of light. They were only recently detected directly by observatories like LIGO and are generated when massive objects, such as black holes or neutron stars, collide. They are important because they can provide information that electromagnetic radiation from surrounding matter cannot. However, studying their non-linear behaviour is extremely limited due to the complexity of the Einstein field equations.

Most numerical studies of general relativity are based on an initial boundary value problem (IBVP) for the Einstein equations. Standard numerical formulations involve second spatial derivatives and do not give a well-posed treatment of the boundary. The first well-posed IBVP was introduced by Friedrich and Nagy in 1999. The Friedrich–Nagy formulation provides a first-order, symmetric-hyperbolic IBVP with a natural maximally dissipative boundary treatment, yet it has only been explored numerically in a few simple cases.

This talk discusses a numerical implementation of the Friedrich–Nagy IBVP aimed at exploring non-linear gravitational-wave behaviour. In this framework, gravitational waves can be generated directly through boundary conditions, rather than by solving complicated elliptic PDEs to introduce them through the initial data, making it a nicer approach for future numerical studies.

5:00 – 5:20 PM (20m) **Gravitational wave simulations from past to future null infinity**

Speaker

Chris Stevens (University of Canterbury)

Description

We present fully nonlinear numerical simulations of asymptotically flat spacetimes whose computational domain includes both past and future null infinity. Using Friedrich's generalised conformal field equations, we study the scattering of gravitational waves by a Schwarzschild black hole and compute asymptotic quantities, including the Bondi energy and Bondi news, on both null infinities. This framework allows a direct numerical investigation of how incoming gravitational radiation at past null infinity is related to outgoing radiation at future null infinity. Our results demonstrate the feasibility of studying gravitational scattering in this setting and provide a step toward connecting numerical relativity with scattering problems in general relativity.

5:20 PM

6:00 PM

Conference Dinner

Session |

Location: Haere-roa, University of Canterbury, Dr Bk Ngau Tī Kōuka Room, 90 Ilam Road, Ilam, Christchurch 8041

Description

https://haereroa.org.nz/

The bar opens at 6pm for those wanting pre-dinner drinks. Dinner service will start at 6:45pm.

10:00 PM

Thu, July 9

9:00 AM

Plenary talks: Session 7

Session | **Location:** Rātā / Engineering Core Building, University of Canterbury, Room E8

9:00 – 9:35 AM (35m)

PeVatrons: The Most Extreme Particle Accelerators in our Galaxy

Speaker

Sabrina Einecke (University of Adelaide)

Description

Cosmic rays play a crucial role in the evolution of galaxies, but their origin remains one of the biggest mysteries today. Their spectrum suggests the existence of so-called PeVatrons - astrophysical objects that accelerate particles up to at least PeV energies. However, we cannot trace them back to their accelerator, as they are deflected by interstellar magnetic fields. To hunt these extreme accelerators, we therefore need alternative messengers such as gamma rays or neutrinos, which are produced in interactions involving cosmic rays. With the recent release of a catalogue of ultra-high-energy gamma-ray sources by the LHAASO observatory, we obtained a first glimpse of where these PeVatrons are located. The next - much more crucial - milestones are to identify the astrophysical objects behind them, uncover the underlying particle populations, and determine the emission and acceleration mechanisms at work.
This contribution highlights key results from the search for Galactic PeVatrons and reviews strategies for achieving these milestones, drawing on data from the next-generation gamma-ray observatory CTAO, the IceCube Neutrino Observatory, Australian radio surveys, and other facilities.

9:35 – 10:10 AM (35m)

On Dark Energy Reconstruction and Interpretation

Speaker

Arman Shafieloo (Korea Astronomy and Space Science Institute)

Description

Reconstructing the expansion history of the universe and the properties of dark energy has been a central goal in physical cosmology, with far reaching implications for our understanding of fundamental physics. In this talk, I will discuss different approaches of reconstructing dark energy properties, assess findings from the latest observational data such as DESI DR2 and discuss potential advancements in the field that may enhance our understanding of the universe’s fundamental dynamics. I will also discuss the possibility of Phantom Crossing in the equation of state of dark energy considering recent cosmological observations.

10:10 – 10:45 AM (35m)

Gravitational Wave Astronomy with the TianQin Space Observatory

Speaker

Yi-Ming Hu (Sun Yat-sen University)

Description

TianQin is a proposed space-based gravitational-wave observatory designed to explore the millihertz frequency band and to open a new window on gravitational-wave astronomy, fundamental physics, and cosmology. In this talk, I will review recent progress of the TianQin project, including its mission concept, technology roadmap, and key developments toward space-based detection, and discuss its main scientific prospects based on recent studies. TianQin is expected to observe a wide range of sources, including massive black hole binaries, extreme- and intermediate-mass-ratio inspirals, stellar-mass black hole binaries, Galactic compact binaries, and stochastic gravitational-wave backgrounds. These observations will provide new insights into black hole formation and growth, compact-object dynamics, binary evolution, and cosmic structure formation, while also enabling precision tests of general relativity, searches for new fundamental physics, and probes of the early Universe and cosmic expansion. Together with other ground- and space-based detectors, TianQin will contribute to a global multi-band gravitational-wave network and help advance gravitational-wave astronomy into a new era.

10:45 AM

10:45 AM

Morning Tea/Coffee

Break |

Location: University of Canterbury, Rātā / Engineering Core Building, 63 Creyke Road, Ilam, Christchurch 8041, New Zealand

11:15 AM

11:15 AM

Plenary talks: Session 8

Session | **Location:** Rātā / Engineering Core Building, University of Canterbury, Room E8

11:15 – 11:50 AM (35m)

Dark matter and gravitational wave signals from a phase transition in the early universe

Speaker

Torsten Bringmann (University of Oslo (NO))

Description

A strong first-order phase transition offers the intriguing possibility of explaining the stochastic gravitational wave background at nHz frequencies. In order to avoid cosmological constraints, such a phase transition must have occurred in a dark sector with non-negligible couplings to the standard model -- opening promising avenues of connecting the gravitational wave signal to the cosmological dark matter abundance. In order to illustrate this, I will consider a classically conformal dark sector with a *U(1)* gauge symmetry. The spontaneous breaking of this symmetry generates both gravitational waves and sources the mass of a fermionic sub-GeV dark matter candidate. Contact with the standard model is established through kinetic mixing of the *U(1)* gauge bosons with ordinary photons, a possibility that is actively being searched for at various collider experiments. I will discuss the rich phenomenology of such a scenario, demonstrating that it can successfully generate both the observed nHz gravitational wave background and the cosmological dark matter abundance, while at the same time avoiding all current constraints. If time allows, I will further contemplate about what a future gravitational wave signal observed by LISA may tell us about dark matter production in the early universe.

11:50 AM – 12:25 PM (35m)

The Present and Future of Neutrino Astronomy

Speaker

Naoko Kurahashi Neilson (Drexel University, USA)

Description

In the past decade, neutrino astronomy went from dream to reality with the IceCube collaboration producing observations of the very first neutrino sources in the sky and the Galactic Plane, making it the first non-electromagnetic view of our own galaxy. Fundamentally, all neutrino astronomy telescopes are particle physics detectors, and observations are only possible by teasing out an astronomical signal hidden in dominating background rates that are many orders of magnitude higher. The successes of neutrino astronomy in the past decade opened a new field, and the current state of neutrino astronomy is evolving. With more future neutrino telescopes planned, the field is poised to make more discoveries.

12:30 PM

12:30 PM

Lunch

Break |

Location: University of Canterbury, Rātā / Engineering Core Building, 63 Creyke Road, Ilam, Christchurch 8041, New Zealand

1:30 PM

1:30 PM

Parallel sessions: Black holes - Mathematical aspects

Session |

Location: Rātā / Engineering Core Building, University of Canterbury, Room E5, 63 Creyke Road, Ilam, Christchurch 8041, New Zealand

1:30 – 1:50 PM (20m)

The (non-)uniqueness of multipole moments beyond general relativity

Speaker

Arthur Suvorov (University of Alicante)

Description

As proven by Simon, Beig, and others from the 1960s on, Einstein spacetimes are uniquely decomposable into a set of multipole moments. The Geroch-Hansen or Thorne moments are often used to categorise radiation patterns, tidal deformations, geodesics, and other phenomena associated with compact objects, and these theorems ensure such descriptions are complete in some sense. What if we drop the "Einstein" qualifier? In fact, I will argue via counterexamples that this breaks the uniqueness properties and thus it is ambiguous to describe astrophysical observables in terms of moments *unless* the theory is fixed *a priori*. This has implications for null tests of general relativity. More generally, I will discuss why these degeneracies could be important to recognise in the context of several well-studied results, like the "I-Love-Q" relations featuring a quadrupole moment (Q).

1:50 – 2:10 PM (20m) **Kerr black holes as circular polarizers**

Speaker

De-Chang Dai (National Dong Hwa University)

Description

We study the retrograde second caustics of extremal Kerr black holes, where the intensity of the light beam is infinitely magnified. We find that the caustics of different polarized beams are split by as much as 10−3 rad by an external black hole for a suitable range of parameters. A lensing black hole at several lys away separates the polarized beams about 1012 m apart. This splitting is larger than the radius of the Earth. Therefore, an observer on Earth would see different circularly polarized light according to their location. The polarization will change while the detector is wandering around. Thus, the polarization of light beams can be an important quantity in retrolensing observations.

2:10 – 2:30 PM (20m) **The hidden symmetries of slowly rotating black holes**

Speaker

Finnian Gray (Macquarie University)

Description

I will discuss a recently proposed class of Generalized Lense–Thirring spacetimes in all dimensions. The class represent an ansatz for slowly rotating black holes which can be applied to solve the equations of motion, to linear order in the rotation parameters, for a wide variety of gravitational theories including Einstein--Gravity. In this case it is equivalent to the original Lense--Thiring solution to linear order.

However, the class has the following remarkable properties which go beyond ordinary Lense--Thrring spacetimes: 1) It is regular on the horizon, 2) it can be put into Painlevé--Gullstrand (in-falling) coordinates, and most remarkably 3), it has a growing tower of hidden symmetries which in higher dimensions is greater than the number of explicit isometries. In this construction, the key ingredient is the non-commutativity of the underlying Killing vectors of the base space. It the growing rank irreducible Killing tensors are determined by the structure constants of the corresponding Lie algebra.

These hidden symmetries and the resultant constants of motion underpin the integrability and separability of test particles and fields in these spacetimes, thus allowing physical observables to be easily characterized.

2:30 – 2:50 PM (20m) **How Time-Evolving Photon Polarization Encodes Kerr Ringdown**

Speaker

Yehui Hou (Tsung-Dao Lee Institute)

Description

A key challenge in imaging supermassive black holes is disentangling gravitational effects from plasma physics in order to accurately determine spacetime properties, particularly black hole spin. In this Letter, we present a fully covariant and rigorous analysis of the synchrotron emission from accreting plasma in the equatorial plane in the stationary, axisymmetric, high-conductivity regime and identify for the first time a distinctive near-horizon polarization (NHP) pattern that remains robust across different flow patterns. This NHP arises from strong frame dragging near the event horizon, which induces a degeneracy among plasma flow and magnetic field configurations, yielding a polarization signature determined solely by the spacetime geometry and the observer’s inclination. The NHP thus offers a clean probe of black hole spin and other fundamental parameters. If space-based millimeter very long baseline interferometry observations can resolve synchrotron emission originating within approximately 1% of the event horizon radius, this universal polarization pattern may become observable.

2:50 – 3:10 PM (20m) **Physical horizons versus mathematical horizons**

Speaker

Matt Visser (Victoria University of Wellington)

Description

The event horizons, and Cauchy horizons, of mathematical General Relativity are mathematical idealisations that are not particularly well suited to questions that physicists and astronomers like to ask.
For very many purposes dynamical trapping horizons are much more suitable. I shall give a brief overview of the current situation.

3:10 PM

1:30 PM

Parallel sessions: Gravity - foundational aspects

Session |

Location: Rātā / Engineering Core Building, University of Canterbury, Room E7, 63 Creyke Road, Ilam, Christchurch 8041, New Zealand

1:30 – 1:50 PM (20m) **Gravity-Induced Entanglement in an infinite square well**

Speaker

Fu-Wen Shu (Nanchang University)

Description

Constructing a complete and self-consistent quantum gravity theory stands as one of the most significant challenges in theoretical physics. The main difficulties arise from two aspects: the theoretical difficulty stemming from the dual nature of general relativity, and the experimental observational difficulty due to the prohibitively high energy scale of quantum gravity. To this day, we still lack any conclusive experimental evidence for quantum gravitational effects. In fact, the fundamental question of whether gravity is inherently quantum remains controversial precisely because of this absence of definitive experimental proof.

In recent years, experimental proposals leveraging quantum gravity induced entanglement of masses to probe low-energy quantum gravitational effects show promise in providing a definitive resolution to this question. This report offers a brief review of relevant advances and introduces a novel scheme in an infinite square well.

1:50 – 2:10 PM (20m)

Hunting for the observational signature of universal horizon and Lorentz-violation effects

Speaker

Chao Zhang (China University of Petroleum-Beijing)

Description

Einstein-Aether theory extends general relativity by introducing a dynamical timelike vector field that breaks Lorentz symmetry/invariance, motivated by quantum gravity approaches including loop quantum gravity models. While maintaining self-consistency and passing all observational constraints, the theory permits superluminal gravitons that revolutionize black hole causal structure, namely, the universal horizon replaces the traditional event horizon as the true causal boundary, trapping particles of arbitrarily large speeds from within. This novel phenomenon modifies gravitational waves at the ringdown stage through altered boundary conditions and the resultant quasi-normal mode spectra, with latter being potentially detectable by future space-based observatories (LISA, TianQin, Taiji, etc.). In addition to phenomenological significance, the universal horizon thus serves as a distinctive fingerprint of Lorentz violation (and a probe to the structure of a black hole). Overcoming formidable technical challenges through reduced Lagrangian methods, this framework opens a theoretical laboratory for probing spacetime causal structure and revealing the nature of gravitational Lorentz-violation effects. Together with different aspects reflected from the gravitational waves at the inspiral stage, we shall build up a more comprehensive as well as systematic understanding towards the theory, serving for uncovering the dawn of quantum gravity plus an illustration of an effective treatment of tackling this sort of problems.

2:10 – 2:30 PM (20m) **Inside Black Holes, Singularity to Complementarity**

Speaker

Dingfang Zeng (Beijing University of Technology)

Description

Through two exact solutions to the Einstein equation with sources, we show that general relativity allows two complementary descriptions for the microscopic state of BHs formed through gravitational collapse: (1) an ensemble of continuously contracting collapsars with close-to-implementing but never successfully implemented horizon in the Schwarzschild time definition, and (2) over-cross oscillatory solid-balls ergodically but unpredictably crossing the singularity in the Lemaitre time definition. The necessity of ensemble in the Schwarzschild time definition is due to the uncertainty of initial status, while the ergodicity of oscillations across the singularity is due to the unpredictability of motions over-cross the singularity. The complementarity of the two descriptions emerges naturally from the general coordinate invariance of GR rather than apriori assumptions required of any unknown quantum gravitation theory. The area-law formula of Bekenstein-Hawking entropy arises from the degeneracy of the quantised wave functional of the collapsing matter configurations. Our work provides a reconcilation for the contradiction between the statistic feature BH thermodynamics and the deterministic scenario of singularity theorems. It suggests that BHs maintain extended matter distributions of their progenitors rather than developing successfully implmented singularities or event horizons. This is a remarkable prediction testable through gravitational wave spectroscopy and multi-messenger astronomy.

2:30 – 2:50 PM (20m)

Topological perspective on bulk boundary thermodynamic equivalence

Speaker

Si-Jiang Yang (Hainan University)

Description

In this talk, we establish an exact duality between the extended thermodynamics of five-dimensional charged Gauss-Bonnet AdS black holes and the thermodynamic framework of the dual boundary conformal field theory (CFT). The thermodynamics of the dual CFT involves two central charges originating from the trace anomaly. We demonstrate a precise correspondence between the extended first laws on the bulk and boundary sides. Moreover, the topological charges of the CFT thermodynamics, associated with the phase transition and critical point, coincide with those of the corresponding bulk black hole.

3:10 PM

1:30 PM

Parallel sessions: Observational cosmology

Session |

Location: Rātā / Engineering Core Building, University of Canterbury, Room E6, 63 Creyke Road, Ilam, Christchurch 8041, New Zealand

1:30 – 1:50 PM (20m)

Mapping the nanohertz gravitational-wave sky to reveal the origin of the stochastic background

Speaker

Eric Thrane (Monash University)

Description

A key question has emerged in the wake of recent observations in pulsar timing astronomy: what is the origin of the nanohertz gravitational-wave background? If the background can be firmly linked to the mergers of supermassive binary black holes, there will be important implications for cosmology: from the evolution of supermassive black holes over cosmic time to the formation of galaxies. On the other hand, if the binary black hole hypothesis can be falsified, this would imply new fundamental physics such as a phase transition in the early Universe. In this talk I argue that mapping the gravitational-wave sky is our most reliable method for understanding the origin of the nanohertz background. I describe recent advances in "phase-coherent mapping" that will help us to understand the origin of the nanohertz background.

1:50 – 2:10 PM (20m)

Do Cosmic String Segments Emit Gravitational Waves?

Speaker

Akifumi Chitose (Institute for Cosmic Ray Research, University of Tokyo)

Description

Cosmic strings are predicted in various extensions of the Standard Model, including grand unified theories. Depending on the symmetry-breaking pattern, they can be either topologically stable or metastable. Intriguingly, metastable strings have been proposed as a possible origin of the gravitational wave (GW) background observed by recent pulsar timing array experiments. When metastable strings decay, they fragment into segments with monopoles and antimonopoles attached at their endpoints. The monopole and antimonopole are strongly pulled by the string tension. Violent oscillations of these segments have been considered as a potential GW source, in addition to contributions from string loops. We show that, in realistic situations, the monopoles frequently collide with thermal fluctuations on the string segments, which act as a resistance and prevent the oscillation. As a result, we find that the contribution from string segments to the GW background is negligible.

2:10 – 2:30 PM (20m) **Observed Evidence for the Primordial Origin of Galaxy Sizes**

Speaker
Jounghun Lee

Description

We present an observational evidence supporting the scenario that the protogalactic angular momenta play an important role in molding the optical sizes of present galaxies. Analyzing the NASA-Sloan Atlas catalog in the redshift range of 0.02≤z<0.09, we observationally determine the probability density distributions, p(r50) and p(r90), where r50 and r90 denote the galaxy sizes enclosing 50% and 90% of their r-band luminosities, respectively. Both of the distributions are found to be well described by a bimodal Gamma mixture model, which is consistent with the recent numerical results. Classifying the local galaxies by their ratios, r50/r90, we also show that for the case of late-type galaxies with r50/r90≥0.45 both of p(r50) and p(r90) exhibit no bimodal feature, following a unimodal Gamma model. Assuming the existence of a linear causal correlation between {r50,r90} of the late-type galaxies and the primordial spin factor, τ, defined as the degree of misalignments between the initial tidal and protogalaxy inertia tensors, we reconstruct the probability density distributions, p(τ), directly from the observationally determined p(r50) and p(r90) of the late-type galaxies. It is shown that the reconstructed p(τ) is in an excellent agreement with the real distribution of τ that was determined at the protogalactic stages by numerical experiments. A critical implication of our result on reconstructing the initial conditions from observable galaxy sizes is discussed.

2:30 – 2:50 PM (20m)

Testing universal pressure profile models on Sunyaev-Zel'dovich galaxy cluster data

Speaker
Denis Tramonte (Xi'an Jiaotong-Liverpool University)

Description

The electron pressure profile is a convenient tool to characterize the thermodynamical state of a galaxy cluster, with several studies adopting a "universal" functional form. In this talk, I will present a recent work aimed at testing this assumption over a population-level cluster sample, using Sunyaev-Zel'dovich (SZ) data and four different parameterizations for the cluster pressure profile: generalized Navarro-Frenk-White (gNFW), β-model, polytropic, and exponential.

A set of 3496 ACT-DR4 galaxy clusters, spanning the mass range $[10^{14},10^{15.1}]\,\text{M}_{\odot}$ and the redshift range [0,2] , was stacked on the ACT-DR6 Compton parameter y map over $\sim 13,000\, \text{deg}^2$. An angular Compton profile was then extracted and modeled using the theoretical pressure recipes, whose free parameters were constrained against the measurement via a multi-stage MCMC approach. The analysis was repeated over cluster subsamples spanning smaller mass and redshift ranges. All functional forms were effective in reproducing the measured y profiles within their error bars, without a clearly favored model. While best-fit estimates were in broad agreement with previous findings, hints of residual subsample dependency were detected favoring higher amplitudes and steeper profiles in high-mass, low-redshift clusters.

This work shows that population-level cluster studies based on SZ data alone are likely unable to accurately constrain different pressure profile models. Residual trends at population level and scatter at individual cluster level undermine the universal pressure model assumption whenever high precision is required. Finally, functional forms different from the gNFW proved equally effective while being more physically motivated.

3:10 PM

3:10 PM

Closing Remarks and Award Presentations

Session | **Location:** Rātā / Engineering Core Building, University of Canterbury, Room E8

Description

The Kerr Prize Award for the best ACGRG student talk will be presented in this session.

3:40 PM

3:40 PM

4:10 PM

Afternoon Tea/Coffee

Break |

Location: University of Canterbury, Rātā / Engineering Core Building, 63 Creyke Road, Ilam, Christchurch 8041, New Zealand