Looping in the Primordial Universe

Report of Contributions

https://indico.cern.ch/e/1433472

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

The Cosmological CPT Theorem (online)

Monday 28 October 2024 11:30 (20 minutes)

In the original CPT theorem, one is restricted to flat space and is unable to make converse statements. In this talk, I will show how we can reformulate the CPT theorem using a symmetry argument to make converse statements and generalise it to beyond flat space. This in turn allows us to make a non-perturbative statement of unitarity in cosmology. I will show that this applies to the wavefunction studied in the cosmology literature and how we can also express our constraints in a perturbative way at each loop order. Finally, I will comment on how these powerfully constrain properties of cosmological correlators, including determining the exact phase of the wavefunction to any loop order, as well as constraints for quantum gravity.

Work in collaboration with Harry Goodhew and Aron Wall.

Primary author: THAVANESAN, Ayngaran (University of Cambridge)

Presenter: THAVANESAN, Ayngaran (University of Cambridge)

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

One-loop infrared rescattering by enhanced scalar fluctuations during inflation

Thursday 31 October 2024 11:50 (20 minutes)

I will describe that, whenever the perturbations of some field are excited during inflation by a physical process on sub-horizon scales, they unavoidably generate, even through gravitational interactions alone, a significant resonant infrared cascade of power down to scales that are of the order of the horizon at that time. I will give general analytic one-loop results for the enhancement of the infrared power of the curvature perturbation generated by this effect, highlighting the role played by the resonance. I will also show lattice simulations result for this phenomenon, which can impact the phenomenology associated with a variety of mechanisms considered in the literature, notably concerning primordial black holes and gravitational waves.

Primary author: RENAUX-PETEL, Sébastien

Presenter: RENAUX-PETEL, Sébastien

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

IR finite correlation functions in de Sitter space, a smooth massless limit, and an autonomous equation

Thursday 31 October 2024 11:30 (20 minutes)

Currently, the study of cosmological correlation functions is extremely favored, and a large number of new techniques are being developed. I will discuss a less-fashioned but very efficient technique to calculate the loop corrections to the correlation function in the long-wavelength approximation. By employing the Yang-Feldman-type equation, we compute the two-point correlation function up to the three-loop level and the four-point correlation function up to the two-loop one. In contrast to the standard theory of a massive scalar field based on the de Sitter-invariant vacuum, we develop the vacuum-independent reasoning that may not possess de Sitter invariance but results in a smooth massless limit of the correlation function's infrared part. Our elaboration affords to calculate correlation functions of a free massive scalar field and to proceed with quantum corrections, relying only on the known two-point correlation function's infrared part of a free massless one. Remarkably, the two-point correlation function of a free massive scalar field coincides with the Ornstein-Uhlenbeck stochastic process's one and has a clear physical interpretation. We compared our results with those obtained with the Schwinger-Keldysh diagrammatic technique, Starobinsky's stochastic approach, and the Hartree-Fock approximation. At last, I will also discuss a way to generalize the obtained results to the non-perturbative case, as well as further prospects in this direction.

Based on arXiv: [2410.16226].

Primary authors: KAMENSHCHIK, Alexander; PETRIAKOVA, Polina (Bologna U.)

Presenter: PETRIAKOVA, Polina (Bologna U.)

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

Cosmological Correlators From Flat Space Feynman Integrals

Monday 28 October 2024 12:10 (20 minutes)

In this talk, I present a novel connection between cosmological correlators and flat-space Feynman diagrams in momentum space. Focusing on Witten diagrams with heavy internal lines and light external legs, I establish a **Massive Flat Space (MFS) limit**. In this limit, such heavy diagrams simplify to contact graphs with a vertex factor equal to the amputated n-point diagram in flat space. As an application of the MFS limit, I obtain **simple expressions for specific inflationary one-loop graphs, in the small sound speed regime.**

Primary authors: JAZAYERI, Sadra (Imperial College London); CESPEDES, Sebastian (Imperial College London)

Presenter: JAZAYERI, Sadra (Imperial College London)

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

Cancellation of quantum corrections on the soft curvature perturbations

Tuesday 29 October 2024 11:30 (20 minutes)

We study the cancellation of quantum corrections on the superhorizon curvature perturbations from subhorizon physics beyond the single-clock inflation from the viewpoint of the cosmological soft theorem. As an example, we focus on the transient ultra-slow-roll inflation scenario and compute the one-loop quantum corrections to the power spectrum of curvature perturbations taking into account nontrivial surface terms in the action. We find that Maldacena's consistency relation is satisfied and guarantees the cancellation of contributions from the short-scale modes. As a corollary, primordial black hole production in single-field inflation scenarios is not excluded by perturbativity breakdown even for the sharp transition case in contrast to some recent claims in the literature. We also comment on the relation between the tadpole diagram in the in-in formalism and the shift of the elapsed time in the stochastic-δN formalism. We find our argument is not directly generalisable to the tensor perturbations.

Primary author: TADA, Yuichiro (Nagoya University)

Co-authors: Dr TOKUDA, Junsei (Institute for Basic Science); TERADA, Takahiro

Presenter: TADA, Yuichiro (Nagoya University)

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

Curvature Perturbations Protected Against One Loop

Tuesday 29 October 2024 11:50 (20 minutes)

We examine one-loop corrections from small-scale curvature perturbations to the superhorizon-limit ones in single-field inflation models, which have recently caused controversy. We consider the case where the Universe experiences transitions of slow-roll (SR) ⟶ intermediate period ⟶ SR. The intermediate period can be an ultra-slow-roll period or a resonant amplification period, either of which enhances small-scale curvature perturbations. We assume that the superhorizon curvature perturbations are conserved at least during each of the SR periods. Within this framework, we show that the superhorizon curvature perturbations during the first and the second SR periods coincide
at one-loop level in the slow-roll limit.

Primary author: INOMATA, Keisuke (Jonhs Hopkins University)

Presenter: INOMATA, Keisuke (Jonhs Hopkins University)

Contribution ID: **26** Type: **not specified**

Simplicity of In-In correlators (online)

Monday 28 October 2024 11:50 (20 minutes)

We compute loop integrals of in-in correlators in dS for scalar theories and comment on the nature of the functions encountered and the simplicity observed compared to loops of wave functions (which can be equivalently thought of as AdS correlators).

This is based on upcoming work and 2312.13803, 2408.00074

Primary authors: LIPSTEIN, ARTHUR,ELIAS (Durham University); CHOWDHURY, Chandramouli (University of Southampton); SACHS, Ivo; MEI, JIAJIE (Durham University); MARSHALL, JOSEPH (Durham University); VANHOVE, Pierre (Institut de Physique Théorique - CEA/Saclay); CHOWDHURY, Pratyusha; MOGA, Radu-Nicolae; SINGH, kajal (Harish-Chandra Research Institute, India)

Presenter: CHOWDHURY, Chandramouli (University of Southampton)

Contribution ID: **27** Type: **not specified**

Gravitational waves in ultra-slow-roll and their anisotropy at two loops

Tuesday 29 October 2024 14:45 (20 minutes)

We use the in-in formalism to compute the non-Gaussian corrections to the energy density and anisotropies of gravitational waves induced after an ultra-slow-roll phase of inflation by using a diagrammatic approach and present the corresponding Feynman rules. Our two-loop calculation includes both the intrinsic non-Gaussianity of the inflaton perturbation $\delta\phi$ and the non-Gaussianity arising from the nonlinear relation between the latter and the curvature perturbation $\mathcal{R}$. We apply our formalism to an analytical model in which the ultra-slow-roll phase is followed by a constant-roll stage with a non-vanishing second slow-roll parameter η, and address the renormalization of the one-loop scalar power spectrum in this scenario.

Primary author: REY IDLER, Julian Leonardo

Co-author: Mr ALVAREZ, Juan

Presenter: REY IDLER, Julian Leonardo

Contribution ID: **28** Type: **not specified**

Slow-roll inflation at N3LO (as deviations from a purely de Sitter background)

Wednesday 30 October 2024 12:10 (20 minutes)

In the context of slow-roll inflation, deviations from a purely de Sitter background are expected and are both separate and complementary to the loop corrections in various inflationary scenarios. In this talk, I propose to go over some of the most up-to-date computations of the inflationary scalar and tensor slow-roll power spectra at next-to-next-to-next to leading order (N3LO), fully expanded around an observable pivot wavenumber, for all single field inflationary models having minimal and non-minimal kinetic terms. This result therefore encompasses string-inspired inflationary models having a varying speed of sound. The aim is to contribute to this workshop by highlighting the classical corrections alongside loop corrections in inflationary predictions.

Primary authors: RINGEVAL, Christophe; AUCLAIR, Pierre (UCLouvain)

Presenter: AUCLAIR, Pierre (UCLouvain)

Contribution ID: **29** Type: **not specified**

Bispectrum at 1-loop in the Effective Field Theory of Inflation

Wednesday 30 October 2024 11:50 (20 minutes)

We compute 1-loop corrections to the Bispectrum in the decoupling limit of the Effective Field Theory of Inflation (EFToI). We employ dimensional regularization to calculate the integrals and find that final results include structures of the form $\log\left(\frac{H}{\mu}\right)$, where H is the Hubble parameter and μ is the renormalisation scale, and logarithms of ratios of comoving momenta i.e. $\log\left(\frac{k_i}{k_T}\right)$, where $k_{i=1,2,3}$ are the modes and $k_T = \sum_i k_i$. In all our calculations the unrenormalised answers feature unphysical logarithms of k/μ, which are cancelled only after renormalisation. We expect this to be a generic feature for loop corrections to higher point functions, unless there is some cancellation as in the previously computed two-point 1-loop result (arXiv:0912.2734).

Primary authors: GHOSH, Diptimoy; ULLAH, Farman (Indian Institute of Science Education and Research , Pune); BHOWMICK, Supritha

Presenter: BHOWMICK, Supritha

Contribution ID: **30** Type: **not specified**

Cosmological correlators in slow-roll violating inflation

Tuesday 29 October 2024 09:15 (45 minutes)

We present correlation functions of the curvature perturbation in single-field inflation model with violation of SR approximation up to second-order expansion of the in-in perturbation theory. We show that the soft limit of trispectrum is proportional to running of the bispectrum, which is a generalization of Maldacena's theorem. With the same cubic and quartic couplings that yields consistent trispectrum, we compute one-loop correction to the large-scale power spectrum. While we have used field redefinition approach to remove the total time derivative interactions, we show that (carefully) deriving correlation functions by accommodating the total time derivative interactions yields the same result. It means that we show equivalence between correlation function obtained by field redefinition approach and direct calculation with total time derivative interactions at second-order expansion of the in-in perturbation theory. We also discuss some issues related to one-point function of the curvature perturbation and its implication to non-1PI one-loop diagrams.

Primary author: KRISTIANO, Jason

Presenter: KRISTIANO, Jason

Contribution ID: **31** Type: **not specified**

Renormalization of the primordial inflationary power spectra

Wednesday 30 October 2024 11:30 (20 minutes)

In this talk, I will explore the effects of renormalization on the amplitude of the inflationary spectra at scales measurable in the cosmic microwave background.

Via a gauge-invariant analysis, I will explain why the standard prediction for the spectra on super-horizon scales is a late-time attractor while they are UV finite at all times. This result is independent of the equation of state after inflation, showing that the standard prediction is fully robust.

Primary authors: STEFANEK, Ben; PLA GARCIA, Silvia (King's College London)

Presenter: PLA GARCIA, Silvia (King's College London)

Contribution ID: **34** Type: **not specified**

Thematic discussion 1

Tuesday 29 October 2024 16:15 (1h 30m)

Contribution ID: **42** Type: **not specified**

Thematic discussion 2

Thursday 31 October 2024 16:15 (1h 30m)

Contribution ID: **43** Type: **not specified**

Thematic discussion 3

Friday 1 November 2024 09:45 (1 hour)

Contribution ID: **44** Type: **not specified**

Thematic discussion 4

Friday 1 November 2024 11:30 (1 hour)

Contribution ID: **46** Type: **not specified**

Renormalizing UV Divergences in the Early Universe – What can go wrong?

Wednesday 30 October 2024 09:15 (45 minutes)

In this talk, we examine some of the challenges that can arise when renormalizing UV divergences in cosmological settings. One fundamental step of renormalization is regularization. Hence, we start by introducing two of the most commonly used regularization schemes: hard cutoffs and dimensional regularization. Specifically, we demonstrate that in the case of finite inflationary background evolution, physical "preferred" scales corresponding to the beginning and end of inflation do not regulate UV divergences. We show that dimensional regularization can be used to regulate these UV divergences, and is, in general, preferable to hard cutoffs, since it allows divergences to be absorbed by counterterms that preserve the symmetries of the background. Furthermore, we discuss how the potential errors can arise when UV divergences are not carefully managed, focusing on the example of the energy density of primordial vacuum gravitational waves, $\rho_{\rm gw}$. In particular, in the literature, constraints on primordial vacuum gravitational waves – the tensorial counterpart of scalar quantum fluctuations that seed galaxies – are derived by connecting $\rho_{\rm gw}$ to the effective number of species, $N_{\rm eff}$. We examine this derivation and illustrate how careful renormalization of UV divergences is crucial for drawing accurate conclusions.
This talk is based on: AN and S. P. Patil, Riv.Nuovo Cim. 47 (2024) 3, 179-228

Primary author: NEGRO, Anna

Presenter: NEGRO, Anna

Contribution ID: **47** Type: **not specified**

On adiabatic renormalization with an infrared cut-off

Thursday 31 October 2024 12:10 (20 minutes)

We describe a new approach to renormalize physical quantities in curved space-time introducing a comoving infrared cut-off in defining the adiabatic counterpart of the physical quantity under consideration. This infrared cut-off is fundamental to avoid unphysical divergences that can be generated by a pathological behavior of the adiabatic subtraction extended to the infrared domain. Applying such formalism to symptomatic case of U(1)-axion inflation model, we evaluate properly the expectation value of gauge contribution setting the cut-off by the conformal anomaly.

Primary author: CONZINU, Pietro

Presenter: CONZINU, Pietro

Contribution ID: **48** Type: **not specified**

Absence of one-loop effects on large scales from small scales

Tuesday 29 October 2024 12:10 (20 minutes)

I will discuss loop corrections to the large-scale primordial power spectrum induced by short-wavelength modes. In transient non-slow-roll dynamics, the relevance of these corrections has been recently the subject of intense debate. This underscores that in models with enhanced scalar fluctuations, many of the standard procedures employed in single-field slow-roll inflation may require reconsideration.
I begin by showing how these potentially threatening corrections, which are scale-invariant relative to tree level, do arise in general. I then review how to express one-loop diagrams as three-point functions, emphasizing the crucial role played by quartic interactions. By using a series of explicitly proven consistency relations, I will thus rewrite the one-loop corrections, obtained by including contributions from the relevant cubic and quartic interactions, as a total derivative term over comoving momenta. The role played by boundary terms to equal time correlators will also be emphasized and discussed.
All this leads me to conclude that one-loop corrections to long-wavelength modes are unaffected by the physics of short and enhanced modes in non-slow-roll dynamics. More specifically, theoretical scenarios related to primordial black holes and gravitational waves do not pose a threat to CMB physics.
If time permits, I will mention differences in both procedure and results compared to other works in the literature.

Primary author: FUMAGALLI, Jacopo

Presenter: FUMAGALLI, Jacopo

Contribution ID: **49** Type: **not specified**

Weyl Fermion Creation by Cosmic Perturbations at 1-loop

Tuesday 29 October 2024 14:00 (45 minutes)

Weyl spin 1/2 fermions, when minimally coupled to Einstein's gravity, cannot be produced purely gravitationally in an expanding universe at tree level. However, this picture changes at the gravitational 1-loop level in the presence of cosmic perturbations, leading to a new and unavoidable mechanism for gravitational particle production. In this talk, I will explore the theory and phenomenological implications of this new effect.

Primary author: MALEKNEJAD, Azadeh

Presenter: MALEKNEJAD, Azadeh

Contribution ID: **50** Type: **not specified**

Soft Metric Fluctuations during inflation

Wednesday 30 October 2024 10:00 (45 minutes)

We use EFT techniques to show the all orders conservation of the super-horizon scalar and tensor modes during inflation. The EFT is built in analogy with Soft de Sitter EFT. Power counting and symmetry arguments are used to directly constrain the time evolution. We also introduce Mellin representation as an advantageous scheme to connect the UV and EFT descriptions.

Primary author: GUPTA, Kshitij

Presenter: GUPTA, Kshitij

Contribution ID: **51** Type: **not specified**

Physics of and from the large-scale structure of the Universe

Wednesday 30 October 2024 14:00 (1 hour)

It is expected that measurements of the large-scale structure of the Universe will soon become our leading sources of fundamental cosmological information. In this talk, I will review some of the major progress, both theoretical and data-oriented, that we have made in understanding the physics of galaxy clustering, as well as what we might hope to learn about new physics (including primordial non-Gaussianities) from these measurements. A key milestone in this direction has been the advent and development of the Effective Field Theory of Large-Scale Structure (EFT of LSS), a theoretical framework that allows for a controlled and consistent perturbative expansion (analogous to the QFT loop expansion) of cosmological observables on large scales. After reviewing galaxy clustering surveys and the theoretical underpinnings of the EFT of LSS, I will describe some recent results. Overall, we find that including higher-order predictions significantly increases the amount of information that can be reliably extracted from existing data sets. This points to even larger gains from future surveys such as DESI, Euclid, and MegaMapper, and opens the door to exploring exciting new physics with precision large-scale structure measurements.

Primary author: LEWANDOWSKI, Matthew

Presenter: LEWANDOWSKI, Matthew

Contribution ID: **52** Type: **not specified**

Perturbative unitarity bounds from entanglement

Monday 28 October 2024 14:45 (45 minutes)

When is it necessary to compute loop corrections in cosmology, or to introduce new physics in a theory? For which values of the parameters does perturbation theory break down? In particle physics, sharp bounds for the validity of the perturbative expansion are given by partial wave unitarity. Unfortunately these bounds don't extend to curved spacetime where scattering experiments are difficult or impossible to define. In this talk we propose to use the growth of entanglement as a breakdown diagnostic for perturbation theory in general field theories. This diagnostic can be readily used in cosmological spacetimes and does not require taking any flat spacetime limit. More in detail, given an EFT we trace out all Fourier modes but a single one. Then, we develop a diagrammatic technique to compute the so-called purity of the resulting density matrix in perturbation theory. Bounds on the coupling constants are then derived when the perturbative purity violates its unitarity constraints. We study these bounds on flat spacetime, where we compare them to those from partial waves showing that purity bounds can be sometimes weaker, but other times they exist when no partial wave bounds exist. We also study them in de Sitter for a variety of interactions that appear in inflationary models, and show that the breakdown of perturbation theory is parametrically different from flat space for operators of large dimension.

Primary author: DUASO PUEYO, Carlos

Presenter: DUASO PUEYO, Carlos

Contribution ID: **53** Type: **not specified**

The one-loop power spectrum of curvature fluctuations in ultra slow-roll inflation

Tuesday 29 October 2024 10:00 (45 minutes)

I will discuss the ratio of the one-loop to the tree-level power spectrum of curvature fluctuations in a toy model of USR inflation, with the aim of discerning if perturbation theory breaks in related scenarios of PBH dark matter.

Primary author: BALLESTEROS, Guillermo

Presenter: BALLESTEROS, Guillermo

Contribution ID: **54** Type: **not specified**

Stochastic inflation: key insights, latest advances and future directions

Thursday 31 October 2024 09:15 (45 minutes)

During inflation, quantum vacuum fluctuations are stretched beyond the Hubble radius, modifying the large-scale dynamics of the universe. Although typically negligible in the perturbative regime, this backreaction can become significant in regimes leading to primordial black hole (PBH) formation, where large density fluctuations arise, and which are the standard framework for addressing loop corrections. The combination of stochastic inflation and delta N formalisms provides an efficient non-perturbative framework to track these large fluctuations.

After reviewing the key results of stochastic inflation—particularly its prediction of heavy non-Gaussian tails in the curvature perturbation distribution—I will show how large fluctuations are spatially correlated in the presence of quantum diffusion during inflation, computing real-space correlation functions in the stochastic-delta N formalism.

To this end, I will show how the relationship between field values and physical distances is encoded in the recursive geometry of a stochastically inflating universe, allowing the consistent inclusion of volume-weighting effects. This approach is the first step in reconstructing the power spectrum and examining potential quantum diffusion corrections at cosmic microwave background (CMB) scales.

Primary author: ANIMALI, Chiara

Presenter: ANIMALI, Chiara

Contribution ID: **55** Type: **not specified**

Finite parts of inflationary loops

Tuesday 29 October 2024 15:05 (20 minutes)

The objective of this talk is to present a systematic approach for calculating loop corrections, including finite contributions, to the power spectrum in a cosmological setting. Particular emphasis will be placed on the renormalization procedure, comparing the results obtained using different regularization methods.

Primary author: RICCARDI, Flavio

Presenter: RICCARDI, Flavio

Contribution ID: **56** Type: **not specified**

Loops in the separate universe framework

Monday 28 October 2024 10:00 (45 minutes)

In this talk I will review the separate universe framework as a tool to perform loop calculations during and after inflation. I will describe recent work (with L. Iacconi and D. Mulryne) in which we use this framework to calculate loops representing a cascade of power from short scales to much longer, infrared scales. The backreaction associated with this cascade can destroy our ability to uniquely predict the subsequent evolution of a superhorizon volume based on the smoothed field values at its location, which is an essential condition for use of the separate universe method. I will discuss a personal selection of open issues in relating separate-universe type calculations to in-in type calculations using the full formulation of out-of-equilibrium field theory.

Primary author: SEERY, David

Presenter: SEERY, David

Contribution ID: **57** Type: **not specified**

On loops in inflation

Monday 28 October 2024 09:15 (45 minutes)

I will discuss several aspects of loop effects in single and multifield inflation.

Primary author: SENATORE, Leonardo

Presenter: SENATORE, Leonardo

Contribution ID: **58** Type: **not specified**

Looping with combinatorics

Monday 28 October 2024 14:00 (45 minutes)

Understanding the loop corrections to cosmological observables can have both phenomenological and theoretical implication: on the one hand, the coupling between the inflaton and fermions first appears at one-loop, and on the other hand they allow to have control on the quantum consistency of a theory in an expanding universe as well as to get a better handle on aspects of the framework underlying our current description of the primordial universe, i.e. quantum field theory in curved space-times. In this talk, I will provide an overview on recent progress on a general approach to understanding of the asymptotic behaviour of the cosmological observables as well as of their one loop corrections, based on the combinatorial features of a special integral representations for the perturbative contributions to cosmological observables.

Primary author: BENINCASA, Paolo

Presenter: BENINCASA, Paolo

Contribution ID: **59** Type: **not specified**

On the IR divergences in de Sitter: loops, resummation and the semi-classical wavefunction

Thursday 31 October 2024 10:00 (45 minutes)

Detecting local Non-Gaussianity provides valuable insights into the early universe's particle composition. Interactions between the inflaton and light particles yield distinctive signatures, potentially observable in upcoming surveys. However, addressing IR divergences in light fields on de Sitter spacetimes requires careful treatment. Stochastic inflation offers a solution, but its relationship with perturbative computations remains unclear.

In this presentation, we establish a clear connection between perturbation theory and the stochastic formalism through the wavefunction formalism. We will explain how the leading-order Fokker-Planck equation arises from the classical saddle point of the wavefunction, and how subleading terms can be interpreted as quantum corrections to the wavefunction.

Presenter: CESPEDES, Sebastian

Contribution ID: **60** Type: **not specified**

Late-time massless scalar field correlators in dS space from regions and effective field theory

Thursday 31 October 2024 14:00 (45 minutes)

I plan to discuss 1) what can be learnt from the interacting field in Euclidean dS space, 2) the method of region applied to calculate the late-time asymptotics from (IR-divergent) loop diagrams of the massless field, 3) matching to Soft dS Effective Theory.

Presenter: BENEKE, Martin

Contribution ID: **61** Type: **not specified**

New analytical results for massive inflationary correlators at tree and loop orders

Thursday 31 October 2024 14:45 (45 minutes)

I will report a few new methods and results we recently obtained on the analytical computation of cosmological correlators with massive exchanges. At the tree level, we derive a complete set of differential equations for an arbitrary number of massive exchanges. We find a straightforward way to directly write down the analytical solution in terms of multivariate hypergeometric functions. The solution has a neat interpretation as the sum of all possible cuts of a massive family tree. At the 1-loop order, we develop a new method, combining spectral decomposition and dispersion techniques, which allows us to find new and much simplified analytical expressions for massive bubble loop diagrams, which have a simple interpretation as the sum of all quasi-normal modes and their descendants.

Presenter: XIANYU, Zhong-Zhi

Contribution ID: **62** Type: **not specified**

Opening

Monday 28 October 2024 09:00 (15 minutes)

Contribution ID: **63** Type: **not specified**

Discussion session

Wednesday 30 October 2024 15:45 (1 hour)