Multifield Cosmology: Inflation, Dark Energy and More: February 5-9, 2024

Events for:
Monday, February 5th - Friday, February 9th

Monday, February 5th

8:30am **Workshop: Breakfast - SCGP Cafe**

Title: Breakfast

9:30am **Workshop: Gonzalo Palma - SCGP 102**

Speaker: Gonzalo Palma

Title: Revisiting stochastic inflation with perturbation theory

Abstract: A long-standing problem within the study of cosmic inflation consists in fully reconciling the stochastic approach with perturbation theory. A complete connection between both formalisms has remained elusive even in the simple case of a single scalar field with self interactions determined by an arbitrary potential, in a fixed de Sitter background with a constant expansion rate. Using perturbation theory, we offer an exact calculation of the one-point probability density function for primordial fluctuations, valid to first order in the potential. We examine under which conditions our solution respects the Fokker-Planck equation encountered within the stochastic approach. We identify discrepancies and elucidate their origins, allowing us to shed light on the validity of the stochastic formalism.

10:00am **Workshop: Spyros Sypsas - SCGP 102**

Speaker: Spyros Sypsas

Title: Non-Gaussian statistics of de Sitter spectators: A perturbative derivation of stochastic dynamics

Abstract: Scalar fields interacting with the primordial curvature perturbation during inflation may communicate their statistics to the latter. This situation motivates the study of how the probability density function (PDF) of a light spectator field in a pure de Sitter space-time, becomes non-Gaussian under the influence of a scalar potential V. One approach to this problem is offered by the stochastic formalism introduced by Starobinsky and Yokoyama. It results in a Fokker-Planck equation for the time-dependent PDF describing the amplitude statistics. We study the derivation of the PDF using quantum field theory tools. Our approach yields an almost Gaussian distribution function distorted by minor corrections consisting of terms proportional to powers of DN DV, where DN is the number of e-folds succeeding the Hubble-horizon crossing of scalar modes and DV a derivative operator acting on V. This general form is obtained perturbatively and remains valid even with loop corrections. Our solution satisfies a Fokker-Planck equation that receives corrections with respect to the one found within the stochastic approach, allowing us to comment on the validity of the standard equilibrium solution for generic potentials. We posit that higher order corrections to the Fokker-Planck equation may become important towards the equilibrium.

10:30am **Workshop: Coffee Break - SCGP Cafe**

Title: Coffee Break

11:00am **Workshop: Lucas Pinol - SCGP 102**

Speaker: Lucas Pinol

Title: Multifield inflation (with or) without models

Abstract: Since the discovery of the Higgs boson 12 years ago, terrestrial particle collider experiments have encountered a slowdown in the quest for physics beyond the Standard Model. Arguably, the upcoming decade promises a paradigm shift towards exploring high-energy physics through cosmological observations. With an abundance of data, independent datasets, and improved systematics, a new era of exploration unfolds. Theorists now strive to attain the precision level demanded by upcoming experiments. In the realm of candidate UV completions to the Standard Model, single-field realizations of inflation appear unlikely. Multifield inflation, nearly as old as inflation itself, is often perceived as having a model-dependent phenomenology, challenging predictability and falsifiability. In this presentation, I will present a modern, model-independent approach to multifield inflationary fluctuations, bypassing the traditional model-by-model exploration. I will delineate the strengths and weaknesses of these effective field theories, comparing their predictions to those of the generic class of non-linear sigma models of multifield inflation.

11:30am **Workshop: Sebastien Renaux-Petel - SCGP 102**

Speaker: Sebastien Renaux-Petel

Title: New particles in the sky

Abstract: Was inflation multifield? Or equivalently, how to test the presence of additional degrees of freedom during inflation beyond the unavoidable curvature perturbation? In the first part, I will concentrate on the cosmological collider signal, lying in soft limits of correlators. Often described as a robust probe of the field content of inflation, it is as robust as its assumptions are restrictive, and I will show its properties in theories involving multiple degrees of freedom, with strong mixing, in the presence of features, and with non-trivial sound speeds. In the second part, I will describe another signal that would reveal the existence of additional heavy fields in a simpler and complementary manner to the cosmological collider: the low-speed collider signal arises when the curvature perturbation propagates at a reduced speed of sound, and it is characterised by a resonance in mildly-soft kinematic configurations of correlators. It can be understood in terms of a single-field effective field theory, albeit one that breaks the usual assumption of locality. Besides, I will show that this framework can naturally accommodate parity violation when the extra field is spinning. Throughout the talk, I use the cosmological flow, a systematic approach to compute inflationary correlators, as well its numerical implementation CosmoFlow. The talk is based on 2112.05710, 2205.10340, 2302.00655, 2307.01751, 2308.11315, 2312.06559. (See also related poster at the end of this PDF by Denis Werth, PhD student under advisor Renaux-Petel)

12:00pm **Workshop: Lunch - SCGP Cafe**

Title: Lunch

2:30pm **Workshop: Perseas Christodoulidis - SCGP 102**

Speaker: Perseas Christodoulidis

Title: Enhanced power spectra from multi-field inflation

Abstract: We investigate the enhancement of the power spectra in models with multiple scalar fields large enough to produce primordial black holes. We present analytic solutions for the perturbations in the case of constant turns without the need for an effective field theory for the first time and clarify the role of the Hubble friction that has been overlooked previously. For an arbitrary number of fields we derive the criteria that can lead to an exponential amplification of the curvature perturbation on subhorizon scales, while leaving the perturbations stable on superhorizon scales. Finally, we apply our results on the three-field ultra-light scenario and show how the presence of field-space torsion can yield distinct observables compared to the two-field case.

3:00pm **Workshop: Jacopo Fumagalli - SCGP 102**

Speaker: Jacopo Fumagalli

Title: PBHs, gravitational waves & loops in multifield inflation

Abstract: I will introduce a mechanism to generate primordial black holes from multifield inflation based on a strong turn in the field-space trajectory. If the transition happened to be sharp enough, the set-up gives rise to oscillations in the power spectrum typical of sharp features. These latter, in turn, leave their imprint in characteristic oscillatory patterns in the induced gravitational wave background. That offers the opportunity to probe primordial features with future gravitational wave observatories like LISA. I will then discuss loop effects in these scenarios. In particular, how a significant resonant IR cascade may be generated that significantly modifies the (near) IR part of the power spectrum of the curvature perturbation with respect to the linear theory.

3:30pm **Workshop: Tea Time - SCGP Cafe**

Title: Tea Time

4:00pm **Workshop: Discussion - SCGP 102**

Title: Workshop Discussion

Tuesday, February 6th

8:30am **Workshop: Breakfast - SCGP Cafe**

Title: Breakfast

9:30am **Workshop: Gary Shiu - SCGP 102**

Speaker: Gary Shiu

Title: Analytic bounds on asymptotic cosmologies, part 1

Abstract: We investigate whether an accelerating universe can be realized as a late-time solution of FLRW-cosmology with multi-field multi-exponential potentials. Such potentials are commonly considered in phenomenological models of dark energy, and at the same time describe typical asymptotic regions of the moduli space of string theory. Late-time cosmological solutions exhibit a universal behavior that enables us to find a general bound on the rate of time variation of the Hubble parameter through methods typical of the study of dynamical systems. Our bound represents a simple diagnostic of whether any given multi-exponential potential holds the necessary conditions for late-time cosmic acceleration, independently of any string-theoretic assumptions. [see part 2, by F. Tonioni]

10:00am **Workshop: Flavio Tonioni - SCGP 102**

Speaker: Flavio Tonioni

Title: Analytic bounds on asymptotic cosmologies, part 2

Abstract: Any FLRW-cosmology with multi-field multi-exponential potentials exhibits a universal bound on late-time cosmic acceleration [see part 1, by G. Shiu]. We show that, in coupling space, such a bound can be formulated in terms of the distance of the origin from the convex hull of the exponential couplings. Then, we discuss the conditions under which scaling solutions are inevitable late-time cosmological attractors for this class of theories. If all field-space trajectories are known analytically, one can characterize exactly any observable of interest. As multi-exponential potentials are ubiquitous in string-theoretic constructions, we can sharpen several statements on the low-energy signatures of quantum gravity in this context. We can also see how the contraction rate of cosmologies with negative potentials can be bounded by similar methods as those for cosmic acceleration.

10:30am **Workshop: Coffee Break - SCGP Cafe**

Title: Coffee Break

11:00am **Workshop: Timm Wrase - SCGP 102**

Speaker: Timm Wrase

Title: Asymptotic accelerated expansion from spatial curvature

Abstract: Obtaining cosmological solutions that undergo accelerated expansion has been a long-standing challenge for string theory. In this talk I will focus on asymptotic limits of moduli space where the Strong Asymptotic dS Conjecture constrains the behavior of the scalar potential. I will show that this conjecture holds even in a compactification of type IIB string theory without Kahler moduli. Then I discuss how asymptotically accelerating cosmological solutions are less constrained when the curvature of space is negative. I will discuss explicit string theory realizations that can lead to an infinite number of e-folds of asymptotic accelerated expansion.

11:30am **Workshop: Marco Scalisi - SCGP 102**

Speaker: Marco Scalisi

Title: Towers of species and cosmic acceleration

Abstract: Towers of species can drastically affect the properties of gravitational effective field theories. They naturally appear in string theory and lead, among the effects, to a renormalization of the scale at which gravity becomes strongly coupled. In this talk, we discuss some of the implications for cosmic acceleration of the presence of large number of species. We show that this leads to stringent constraints both on scalar field variations and on multi-field trajectories. Finally, we discuss some of the implications for Starobinsky inflation.

12:00pm **Workshop: Group Photo - SCGP Lobby**

Title: Group Photo

12:00pm **Workshop: Lunch - SCGP Cafe**

Title: Lunch

1:15pm **SCGP Weekly Talk: Ana Achucarro - SCGP 102**

Speaker: Ana Achucarro

Title: Cosmic inflation, reloaded

Abstract: Inflation is the currently favoured explanation for the origin of the primordial density fluctuations that seeded all large-scale structures in the universe. It turns the birth of the universe into a "cosmological collider" event whose products are still imprinted in the sky today and can be detected with telescopes, provided we know what to look for. The precise connection of inflation and particle physics is still pending, after decades, but now also its connection to quantum gravity is posing new and unexpected challenges. After a general introduction, I will discuss some recent, surprising insights into inflation scenarios involving multiple fields with curved field space geometries (such as moduli).

2:30pm **Workshop: Ivonne Zavala - SCGP 102**

Speaker: Ivonne Zavala

Title: Multifield inflation in supergravity and string theory: phenomenology and UV constraints

Abstract: I will discuss interesting phenomenological implications arising from multifield inflation models within the frameworks of string theory and supergravity. Additionally, I will discuss UV/swampland constraints that may impact these classes of models.

3:00pm **Workshop: Osmin Lacombe - SCGP 102**

Speaker: Osmin Lacombe

Title: Hybrid inflation and waterfall field in string theory from D7-branes

Abstract: We present an explicit string realisation of a cosmological inflationary scenario we proposed recently within the framework of type IIB flux compactifications in the presence of three magnetised D7-brane stacks. Inflation takes place around a metastable de Sitter vacuum. The inflaton is identified with the volume modulus and has a potential with a very shallow minimum near the maximum. Inflation ends due to the presence of "waterfall" fields that drive the evolution of the Universe from a nearby saddle point towards a global minimum with tunable vacuum energy describing the present state of our Universe.

3:30pm **Workshop: Tea Time - SCGP Cafe**

Title: Tea Time

4:00pm **Workshop: Discussion - SCGP 102**

Title: Workshop Discussion

Wednesday, February 7th

8:30am **Workshop: Breakfast - SCGP Cafe**

Title: Breakfast

9:30am **Workshop: Fernando Quevedo - SCGP 102**

Speaker: Fernando Quevedo

Title: De Sitter from Supergravity and F-theory?

Abstract: Explicit dS solutions from classical 6D supergravity are reviewed as well as their potential uplift to F-theory.

10:00am **Workshop: Filippo Revello - SCGP 102**

Speaker: Filippo Revello

Title: String Theory and the First Half of the Universe

Abstract: We perform a detailed study of stringy moduli-driven cosmologies between the end of inflation and the commencement of the Hot Big Bang, including both background and cosmological perturbations: a period that can cover half the lifetime of the universe on a logarithmic scale. Compared to the standard cosmology, stringy cosmologies motivate extended kination, tracker and moduli-dominated epochs involving significantly trans-Planckian field excursions. As conventional effective field theory is unable to control Planck-suppressed operators, such epochs require a stringy completion for a consistent analysis. Perturbation growth is substantially enhanced compared to conventional cosmological histories. The transPlanckian field evolution results in radical changes to Standard Model couplings during this history and we outline potential applications to baryogenesis, dark matter and gravitational wave production.

10:30am **Workshop: Coffee Break - SCGP Cafe**

Title: Coffee Break

11:00am **Workshop: Alexander Westphal - SCGP 102**

Speaker: Alexander Westphal

Title: Gravitational Axiverse Spectroscopy: Seeing the Forest for the Axions

Abstract: The presence of axions coupled to U(1) gauge fields during inflation, a rather generic outcome of string theory, can drive a spectrum of multiple peaks of induced gravitational waves. We will discuss two rather typical scenarios - several axions directly driving narrowly interrupted periods of inflation, and light spectator axions active during a period of high-scale inflation.

11:30am **Workshop: Evangelos Sfakianakis - SCGP 102**

Speaker: Evangelos Sfakianakis

Title: Probing the Axiverse with CMB Birefringence

Abstract: I will revisit the evidence for CMB birefringence in the context of a rich Axiverse. Using probability density functions (PDFs) for various axion parameters, such as the mass and axion decay constant, I will construct the PDF for the cosmic birefringence angle and investigate its properties. By relating the observed value of the birefringence angle to the mean or standard deviation of the constructed PDF, one can constrain the shape of the input PDFs, providing insights into the statistical distribution of the Axiverse. The focus will be on three different types of axion potentials: cosine, quadratic, and asymptotically linear axion monodromy. I will describe the potential of cosmic birefringence in constraining the distribution of axion parameters and uncovering possible correlations among them. I will additionally derive predictions for "birefringence tomography," anticipating future measurements of birefringence from lower multipoles, and show how it can be used to rule out simpler versions of the Axiverse.

12:00pm **Workshop: Lunch - SCGP Cafe**

Title: Lunch

2:30pm **Workshop: Kuver Sinha - SCGP 102**

Speaker: Kuver Sinha

Title: The String Landscape, SUSY Breaking, and Axions

Abstract: Axions, and more general axion-like-particles, have become a central topic in our field. On the other hand, the question of supersymmetry and its breaking continues to have deep implications for the collider program. I will discuss both these questions from the point of view of statistical analyses of the string landscape. Specifically, I will focus on the question of statistics after taking into account the stabilization of Kahler moduli. We will find that depending on the moduli stabilization scheme, the statistical predictions can be very different: KKLT features a power-law pull towards high-scale SUSY and heavy axions, while LVS features a log distribution of the SUSY-breaking scale, as well as the axion decay constant and masses. These findings, performed under lamppost stabilization schemes at small $h(1,1)$, complement the findings of other groups, which focused on the statistical behavior in the limit of large numbers of Kahler moduli.

3:00pm **Workshop: Rouzbeh Allahverdi - SCGP 102**

Speaker: Rouzbeth Allahverdi

Title: Moduli and Postinflationary Thermal History

Abstract: I will discuss the important role of string moduli in the evolution of the early universe paying particular attention to the implications for dark matter. Then I will give some explicit examples that give rise to the correct dark matter abundance in agreement with observational bounds.

3:30pm **Workshop: Tea Time - SCGP Cafe**

Title: Tea Time

4:00pm **Workshop: Discussion - SCGP 102**

Title: Workshop Discussion

6:00pm **Workshop: Banquet - SCGP Cafe**

Title: Banquet Dinner

Thursday, February 8th

8:30am **Workshop: Breakfast - SCGP Cafe**

Title: Breakfast

9:30am **Workshop: Cliff Burgess - SCGP 102**

Speaker: Cliff Burgess

Title: The Gravity of Light Scalars (Naturally)

Abstract: We live in remarkable times: the recent advent of gravitational-wave observations allows testing gravity in a strongly relativistic regime. We also have plausible candidates for UV physics that reconciles General Relativity with Quantum Mechanics. But there is also Bad News: Decoupling - which beautifully explains why low-energy measurements are largely insensitive to UV details - seems a central organizing feature of Nature that thwarts the extraction of fundamental insights about UV physics from astrophysical or cosmological observations. This talk argues that all is not lost because some UV features can penetrate the decoupling barrier in interesting ways. In particular, generic accidental symmetries can robustly point to the existence of scalars in the low-energy effective theory (and these are not just axions). Normally we are taught that naturalness arguments preclude these scalars from being light enough or too weakly coupled to be important for tests of gravity, but I argue that the additional information that the observed Dark Energy is so small puts us in a regime where some scalars are pseudo-dilatons (i.e., naturally light with Brans-Dicke couplings to matter). The question of why these scalars are not already detected motivates more detailed studies of whether screening mechanisms exist that could have hidden them from present-day tests of gravity. Crucially they must do so in a way consistent with other properties of UV completions of gravity (in a way that standard screening mechanisms - like Chameleons - are not). The talk describes new proposals for such UV-consistent screening mechanisms and why they thread a blind spot in current theoretical approaches to testing gravity. If time permits I will also explore other implications these models might have, including possible relevance to other problems like the Hubble tension.

10:00am Workshop: Oksana Iarygina - SCGP 102

Speaker: Oksana Iarygina

Title: Non-Gaussianity in rapid-turn multi-field inflation

Abstract: Primordial non-Gaussianity is a powerful tool to discriminate between models of inflation by probing the dynamics and field content of the very early Universe. In this talk, I will show that theories of inflation with multiple, rapidly turning fields can generate large, potentially observable amounts of non-Gaussianity. I will discuss a novel, analytical formula for bispectrum generated from multi-field mixing on super-horizon scales for a general theory with two fields, an arbitrary field-space metric and potential. I will explain why the detection of local non-Gaussianity with an amplitude of order one would rule out all attractor models of single-field inflation and discuss what would such detection tell us about multiple-field inflation.

10:30am Workshop: Coffee Break - SCGP Cafe

Title: Coffee Break

11:00am Workshop: Xingang Chen - SCGP 102

Speaker: Xingang Chen

Title: Primordial features as probes of the primordial universe and high energy physics

Abstract: Primordial features are components of the primordial density perturbations that significantly depart from scale invariance. We review how observing such signals could help us understand the nature of the primordial universe and the realms of particle physics beyond the reach of human-made colliders.

11:30am **Workshop: Robert Rosati - SCGP 102**

Speaker: Robert Rosati

Title: Searching for Early-Universe Multifield Dynamics with LISA

Abstract: By the time I give this talk, the LISA mission will hopefully have been formally adopted by ESA and NASA. This future space-based gravitational wave detector will open a new window into the gravitational wave spectrum and the early universe. I will discuss the prospective LISA sources from early multifield dynamics, including during- and post-inflationary sourced scalar-induced gravitational waves, as well as the data analysis pipelines in development at NASA and in the LISA Cosmology Working Group for detecting or placing upper limits on these processes in the LISA data.

12:00pm **Workshop: Lunch - SCGP Cafe**

Title: Lunch

2:30pm **Workshop: Nemanja Kaloper - SCGP 102**

Speaker: Nemanja Kaloper

Title: Falsifying Anthropics

Abstract: We discuss implications of observation of superradiance from supermassive black holes, primordial gravity waves and exclusion of ultralight fuzzy dark matter for the anthropic principle.

3:00pm **Workshop: Katy Clough - SCGP 102**

Speaker: Katy Clough

Title: The impact of modifications to gravity on inhomogeneous cosmologies

Abstract: I will describe recent developments in numerical relativity that permit us to simulate non trivial scalar-tensor theories of gravity, which represent the next order corrections in an effective field theory approach. I will discuss how they can be applied to cosmology, in particular to the non linear dynamics of preheating and the initial condition problem for inflation (the question of whether inflation can start from strongly inhomogeneous initial conditions).

3:30pm **Workshop: Tea Time - SCGP Cafe**

Title: Tea Time

4:00pm **Workshop: Discussion - SCGP 102**

Title: Workshop Discussion

Friday, February 9th

8:30am **Workshop: Breakfast - SCGP Cafe**

Title: Breakfast

9:30am **Workshop: Krzysztof Turzynski - SCGP 102**

Speaker: Krzysztof Turzynski

Title: Preheating and gravitational waves from geometrical destabilization

Abstract: Multi-field models of inflation with negative field-space curvature may lead to geometrical destabilization of non-adiabatic, or spectator, scalar perturbations. This phenomenon can occur at the end of inflation, e.g. in alpha-attractor models of inflation, or during inflation. Recent numerical lattice simulations shed light onto dynamics of the coupled scalar perturbations when such geometrical destabilization occurs. In the end-of-inflation geometrical destabilization, a rapid growth of the spectator perturbations can lead to preheating and associated production of gravitational waves, to the extent that alpha attractor T-models can be constrained or even ruled out by present observations. The middle-of-inflation geometrical destabilization turns out a short-lived phenomenon and a negative feedback loop prevents field fluctuations from growing indefinitely. As a result, fields undergoing geometrical destabilization are merely shifted to a new classical configuration corresponding to a uniform value of the spectator field within a Hubble patch.

10:00am **Workshop: Diederik Roest - SCGP 102**

Speaker: Diederik Roest

Title: Black hole binaries in more general relativity: perihelion precession and hidden symmetries

Abstract: As beautifully illustrated by Mercury's orbit, general relativistic corrections break the hidden symmetry of the Kepler system and introduce a perihelion precession. We will discuss whether this can be remedied by the introduction of additional charges, and find that extensions of GR with vectors and scalars allow for closed orbits. The resulting theories are related to Kepler systems in an interesting manner, involving null geodesics in higher-dimensional space-times.

10:30am **Workshop: Coffee Break - SCGP Cafe**

Title: Coffee Break

11:00am **Workshop: Calin Lazaroiu - SCGP 102**

Speaker: Calin Lazaroiu

Title: Slow-roll rapid-turn metrics in two-field cosmology and contact Hamilton-Jacobi theory

Abstract: I show that the PDE which characterizes scalar field metrics that are likely to admit rapid turning cosmological trajectories with sustained slow roll for a fixed scalar potential is a geometric contact Hamilton-Jacobi equation defined on the total space of the first jet bundle of the determinant line bundle of the Riemann surface which forms the scalar field manifold. I also discuss some aspects of this highly nonlinear PDE, which can be studied mathematically using the theory of viscosity solutions.

11:30am **Workshop: Matteo Licheri - SCGP 102**

Speaker: Matteo Licheri

Title: Higher derivative corrections to string inflation

Abstract: In this talk I will estimate the leading higher derivative corrections to $N = 1$ supergravity derived from IIB string compactifications and study how they affect moduli stabilisation and inflation model building within the LVS framework.

12:00pm **Workshop: Lunch - SCGP Cafe**

Title: Lunch

3:30pm **Workshop: Tea Time - SCGP Cafe**

Title: Tea Time

4:00pm   **Denis Werth (PhD Student of Renaux-Petel) - Poster presentation - For Reference Only**

Title: The Cosmological Flow

Abstract: Cosmological correlators hold the key to high-energy physics as they probe the earliest moments of our Universe. However, even at tree-level, perturbative calculations are limited by technical difficulties absent in flat-space Feynman diagrammatic. As a result, a complete dictionary mapping the landscape of inflationary theories and the corresponding observable signatures is not yet available.

This poster presents the cosmological flow: a complete formalism to compute tree-level inflationary correlators. The method is based on following their time evolution from their origin as quantum zero-point fluctuations to the end of inflation. From first principles, the structure of the bulk time evolution imposes a set of universal differential equations in time satisfied by equal-time correlators. We automatise the process of systematically solving these equations. To this end, we introduce CosmoFlow: a new accurate open source Python code that is specifically designed to offer a simple, intuitive and flexible coding environment to theorists, primordial and late-time cosmologists. Our numerical implementation of the cosmological flow allows any new user to quickly become familiar with this approach and obtain immediate high-resolution results for correlators that were previously out of reach.

This poster is based on 2302.00655, 2312.06559, and an upcoming paper code.

Copies available during workshop week in lecture room and lobby table.