SwissMAP Annual General Meeting

September 7 – September 10, 2025

Les Diablerets
(Hôtel Les Sources)

Andrea AGAZZI (UNIBE)

Title: Clustering Dynamics in Mean-Field Models of Transformers

Abstract: *Transformers are a central architecture in modern deep learning, forming the backbone of large language models such as ChatGPT. In this talk, I will present a mathematical framework for studying how information—represented as "tokens"—evolves through the layers of such neural networks. Specifically, we consider a family of partial differential equations that describe how the distribution of tokens—modeled as particles interacting in a mean-field way—changes with depth. Numerical experiments reveal that, under certain conditions, these dynamics exhibit a metastable clustering phenomenon, where tokens group into well-separated clusters that evolve slowly over time. A rigorous analysis of this behavior uncovers a range of open questions and unexpected connections to various fields of mathematics.*

Anton ALEKSEEV (UNIGE)

Title: Horn problems and multiple Horn problems

Abstract: *The Horn problem is a classical Linear Algebra problem asking to determine possible eigenvalues of a sum of two Hermitian matrices with given eigenvalues. The multiple (or tetrahedral) Horn problem is motivated by the Quantum Information Theory, and it is asking to determine possible eigenvalues of Hermitian matrices* $(A+B)$, $(B+C)$, *and* $(A+B+C)$ *if the eigenvalues of* A, B, *and* C *are fixed. The eigenvalues of* $(A+B)$ *and of* $(B+C)$ *have non-vanishing Poisson brackets with each other, and their quantum counterpats are non-commuting operators. This leads to new interesting phenomena in comparison to the classical Horn problem. In this talk, we will review Horn problems for Hermitian matrices, for non-singular complex matrices, and for planar networks, and we will report on new results for multiple Horn problems.*

Marco AMBROSINI (UNIGE)

Title: Operator Krylov Complexity and its bulk dual

Abstract: *We explore the notion of operator Krylov complexity of a particular class of single-particle operators in double-scaled SYK, where this quantity can be computed using chord-diagrammatic technology. In particular, we find an analytical expression for the semi-classical limit of operator K-complexity, and study how the size of the operator encodes the scrambling dynamics upon the matter insertion in Krylov language. We show that operator complexity is a sum of the number of chords in a left and right sectors separated by the matter insertion, which is an essential feature underpinning its emergent geometrical interpretation. Indeed, by leveraging this property, in a triple-scaled low-energy limit, we find that the bulk dual of operator K-complexity is a geodesic length in JT gravity perturbed by a shockwave, corresponding to the operator insertion in DSSYK. This allows us to update with the matter details the holographic dictionary of the JT-DSSYK duality. [based on [arXiv:2412.15318] and upcoming work].*

Meer ASHWINKUMAR (UNIBE)

Title: Dualities and Discretizations of Integrable Quantum Field Theories from 4d Chern-Simons Theory

Abstract: *We elucidate the relationship between 2d integrable field theories and 2d integrable lattice models, in the framework of the 4d Chern-Simons theory. The 2d integrable field theory is realized by coupling the 4d theory to multiple 2d surface order defects, each of which is then discretized into 1d defects. We find that the resulting defects can be dualized into Wilson lines, so that the lattice of discretized defects realizes integrable lattice models. Our discretization procedure works systematically for a broad class of integrable models (including trigonometric and elliptic models), and uncovers a rich web of new dualities among integrable field theories. We also study the anomaly-inflow mechanism for the integrable models, which is required for the quantum integrability of field theories. By analyzing the anomalies of chiral defects, we derive a new set of bosonization dualities between generalizations of massless Thirring models and coupled Wess-Zumino-Witten (WZW) models.*

Johannes BROEDEL (ETH Zurich)

Title: Polylogarithms, Zeta values and Associators: a versatile language for mathematical physics

Abstract: *Numerous calculations in physics can be phrased in terms of iterated integrals conveniently: polylogarithms and corresponding zeta values have been the language of choice for the last decade. I will review the general construction of those special functions and comment on the role of associators in finding functional relations among them. I suggest that associators could be the key concept to finding a unifying formulation for physics algorithms ranging from recursion relations and expansion by regions to the so-called double-copy formalism.*

Nicolas BRUNNER (UNIGE)

Title: Quantum Bell nonlocality

Abstract: *Quantum physics allows for distant observers sharing entangled particles to observe strong correlations, which cannot be explained by any physical theory satisfying a natural notion of locality, as e.g. in classical physics. This effect, termed quantum Bell nonlocality, has deep implications for the foundations of quantum physics, but also leads to applications in the context of quantum information processing. This talk will review these developments and discuss recent progress in the context of quantum cryptography and quantum networks.*

Carla FERRADINI (ETH Zurich)

Title: Cyclic quantum causal modelling with a graph separation theorem

Abstract: *Causal modelling frameworks link observable correlations to causal explanations, which is a crucial aspect of science. These models represent causal relationships through directed graphs, with vertices and edges denoting systems and transformations within a theory. Most studies focus on acyclic causal graphs, where well-defined probability rules and powerful graph-theoretic properties like the d-separation theorem apply. However, understanding complex feedback processes and exotic fundamental scenarios with causal loops requires cyclic causal models, where such results do not generally hold. While progress has been made in classical cyclic causal models, challenges remain in uniquely fixing probability distributions and identifying graph-separation properties applicable in general cyclic models. In cyclic quantum scenarios, existing frameworks have focussed on a subset of possible cyclic causal scenarios, with graph-separation properties yet unexplored. This work proposes a framework applicable to all consistent quantum and classical cyclic causal models on finite-dimensional systems. We address these challenges by introducing a robust probability rule and a novel graph-separation property, p-separation, which we prove to be sound and complete for all such models. Our approach maps cyclic causal models to acyclic ones with post-selection, leveraging the post-selected quantum teleportation protocol. We characterize these protocols and their success probabilities along the way. We also establish connections between this formalism and other classical and quantum frameworks to inform a more unified perspective on causality. This provides a foundation for more general cyclic causal discovery algorithms and to systematically extend open problems and techniques from acyclic informational networks (e.g., certification of non-classicality) to cyclic causal structures and networks. In addition, in future work in preparation, we connect this approach to the study of emergent spacetime structure, using tensor networks to explore how spatio-temporal notions might emerge from purely information-theoretic causal models. (arXiv:2502.04168 and arXiv:2502.04171)*

Bernhard KEPKA (UZH)

Title: Modified scattering dynamics for radially symmetric solutions to the Vlasov-Poisson equation with an attractive point mass

Abstract: *The long-time behaviour of solutions to the Vlasov-Poisson equation has been a topic of interest for many years. A particular situation which has been studied recently concerns solutions with a repulsive point charge. In this work, we consider the corresponding case of an attractive point mass. We study perturbations of the point mass with radial symmetry, i.e. a gas of particles, for instance, stars in a galaxy, surrounding a central mass. Our study is based on action-angle variables in order to simplify the linearised dynamics which is given by the standard Kepler problem. Assuming that the initial distribution of the gas is localised on hyperbolic trajectories according to the linearised dynamics, we prove that the long-time behaviour is given by a modified scattering dynamics. (This is joint work with Klaus Widmayer.)*

Tsviqa LAKREC (UNIGE)

Title: The amplituhedron

Abstract: *We define the amplituhedron, discuss its connection to physics, and present ongoing reserach and open problems.*

Adrien MARTINA (EPFL)

Title: Einstein gravity from matrix integrals

Abstract: *Holography suggests that ten-dimensional quantum gravity can be described by a lower-dimensional gauge theory. We will be interested in the most reduced case, where the gauge theory is zero-dimensional. Such a theory takes the form of a matrix model, representing a remarkably simple candidate for describing gravity. In this setting, I will introduce the polarized IKKT model, explore its dual geometries, and show how the defining equations of these geometries arise from the matrix model.*

Beat NAIRZ (ETH Zurich)

Title: Beyond the Tensionless Limit

Abstract: *Turning on R-R flux in the tensionless string theory on AdS3xS3xT4 corresponds to deforming the dual symmetric product orbifold CFT. We can thus study the mixed flux background using perturbation theory in the CFT. We find an integrable structure, a dynamical spin chain, governing the perturbation for large twist. Furthermore, by studying the form of the eigenstates, we can see how the AdS3xS3 directions are contained in the orbifold of T4, away from the point with higher spin symmetry.*

Veronica SACCHI (EPFL)

Title: Dressing and Screening in Anti de Sitter spacetime

Abstract: *In this talk we will examine two features proper of Scalar QED in (Euclidean) Anti de Sitter spacetime, and we will show some explicit results specifically for 4 dimensions. The first feature involves a photon with Neumann boundary conditions: it is quite well known that with this choice of quantization, matter insertions need to be dressed with Wilson lines in order to make for gauge invariant correlation functions. The most symmetric choice, which doesn't break any additional AdS isometries, requires to send the Wilson lines along geodesics, but such dressing screens the coupling with the photon multiplet. Such effect can be understood as a consequence of conformal invariance and 1-form symmetries inherited from free Maxwell theory. Secondly, we examine a feature proper of the photon with standard quantization: whenever the boundary conditions of the matter fields break charge conservation at the boundary, gauge symmetry is spontaneously broken and the photon acquires a mass. We will compute the photon mass at order* e^2 *with two alternative methods: through bulk resummation of 1-loop bubbles, and via boundary multiplet recombination, which give a fully analytic expression of the photon mass in terms of the mass of the charged scalars.*

Antoine VUIGNIER (EPFL)

Title: Gravity from a matrix integral

Abstract: *The gauge gravity duality gives explicit examples where the geometry of general relativity emerges from more fundamental gauge theory degrees of freedom. I will describe the simplest example of gauge theories in 0+0 dimensions, i.e. matrix integrals. I will explain our current attempts to reformulate them such that the emergence of general relativity becomes manifest.*

Yineng ZHOU (UNIGE)

Title: Measuring Rényi entropy using a projected Loschmidt echo

Abstract: *We present efficient and practical protocols to measure the second Rényi entropy (RE), whose exponential is known as the purity. We achieve this by establishing a direct connection to a Loschmidt echo (LE) type measurement sequence, applicable to quantum many-body systems. Notably, our approach does not rely on random-noise averaging, a feature that can be extended to protocols to measure out-of-time-order correlation functions (OTOCs), as we demonstrate. By way of example, we show that our protocols can be practically implemented in superconducting qubit-based platforms, as well as in cavity-QED trapped ultra-cold gases.*