Conformal Field Theories: Randomness & Geometry
Abstracts

18 May 2026-29 May 2026

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Minicourse

Conformal Blocks and Modular Functor from Probability

Colin Guillarmou

Université Paris Saclay, France

We construct the conformal block of Virasoro algebra using the probabiistic construction of Liouville CFT, and describe its properties as global functions on Teichmüller space, and the action of the mapping class group on the space of conformal blocks.

Quantum Hall States at the Interface of Geometry, Probability and Physics

Semyon Klevtsov

Université de Strasbourg, France

The quantum Hall effect is a striking phenomenon in condensed matter physics, exhibiting exact quantisation in macroscopic electron systems with imprecise characteristics. Its theoretical description leads to the concept of quasiparticles with exotic exchange statistics—neither bosonic nor fermionic—known as anyons, which are of central interest for the topological quantum computation.

A key application of Conformal Field Theory is that its conformal blocks furnish trial wave functions for quantum Hall states. Following the pioneering work of Laughlin (1983), the theory of quantum Hall states developed alongside conformal field theory, introduced by Belavin, Polyakov and Zamolodchikov in 1984.

In this course, I will present a mathematical perspective on quantum Hall states, emphasizing their links with the Gaussian free field, spaces of holomorphic sections, large-N asymptotics in point processes, and geometric aspects of adiabatic transport. We develop the subject from the ground up, focusing on the unifying structures underlying these topics and their role in the modern mathematical formulation of quantum Hall phenomena. No prior background in the subject is required.

Height Functions in 2-dimensional Yang-Mills Theory

Thierry Lévy

Sorbonne Université, France

This mini-course will be devoted to the 2-dimensional Yang-Mills holonomy process, introduced in the 1990's by Bruce Driver and Ambar Sengupta. I will present this process and a explain how a combinatorial approach, based on Fourier analysis and the Schur-Weyl duality, to the computation of the fundamental numerical observables of the model, the Wilson loop expectations, naturally leads to a height function, or more precisely to an ordered tuple of height functions.

Probabilistic approach to Liouville Conformal Field Theory

Remi Rhodes

Aix-Marseille Université, France

In these lectures, I will review the probabilistic construction of Liouville CFT and explain how this construction fits into the CFT axiomatics. In particular, I will explain the Segal axioms for CFTs and how they can be implemented in Liouville CFT. Next I will explain how these concepts combine to provide a proof of the conformal bootstrap for Liouville CFT.

Fractional Quantization: the Laughlin State and its Perturbations

Nicolas Rougerie

Ecole Normale Supérieure de Lyon, France

The 1983 discovery of the fractional quantum Hall effect (FQHE) marks a milestone in condensed matter physics: systems of "ordinary particles at ordinary energies" displayed highly exotic effects, most notably fractional quantum numbers. It was later recognized that this was connected to the emergence of quasi-particles carrying a fraction of the charge of an electron and obeying fractional quantum statistics (i.e. interpolating between bosonic and fermionic behavior).

We will introduce the basic physics of the fractional quantum Hall effect and the challenges to rigorous many-body quantum mechanics emerging thereof. Most of the discussion will revolve around the Laughlin state, a well-educated ansatz for the ground state of 2D particles subjected to large magnetic fields and strong interactions. The two latter effects conspire to generate strong and very specific correlations between particles. We shall discuss mathematically the rigidity these correlations display in their response to perturbations: trapping and disorder potentials can be taken into account by generating uncorrelated quasi-particles (Laughlin quasi-holes) on top of the Laughlin state.

The Laughlin state's density can be identified with the Gibbs ensemble of a 2D one-component plasma (2DOCP). The proof of several results we mention proceed via this analogy. We shall insist on the challenges the questions inspired by the FQHE (solved and unsolved) can bring to the study of the 2DOCP.

Amplituhedra: A new geometric framework for (certain) QFTs

Ranjacob Tessler

Weizmann institute, Israel

The mini course will focus on the definition and properties of amplituhedra, certain geometric spaces discovered by physicists to encode scattering amplitudes of certain quantum field theories, including the planar N=4 SYM and ABJM theories. We will start by describing the theory of the nonnegative Grassmannian, which underlies the constructions of amplituhedra, we will then define the amplituhedra themselves, and explain how they encode the scattering amplitudes. We will then describe some of their key properties, including the BCFW triangulations and cluster adjacency phenomena. Finally we will see the main tools in the study of amplituhedra, and sketch the proofs of the key properties.

Research Talks

Liouville CFT and the Quantum Zipper

Morris Ang

University of California, San Diego, USA

Two primary approaches have emerged in the probabilistic study of Liouville quantum gravity (LQG). One rigorously constructs Liouville conformal field theory (LCFT) from the Gaussian free field, while the other studies LQG random surfaces through conformal welding and their couplings with Schramm–Loewner evolution (SLE). The starting point of the latter approach is the quantum zipper process of Sheffield. I will discuss how the quantum zipper can be interpreted as dynamics on the space of random surfaces described by LCFT: the conformal welding of an LCFT random surface to itself until some stopping time gives another LCFT random surface. This has applications to both LCFT and SLE. In particular, we obtain the boundary BPZ equation for LCFT, a key ingredient in solving boundary LCFT. With Yu we prove the reversibility of whole-plane SLE for $\kappa \geq 8$ via a novel radial mating-of-trees.

Random Jordan Curves: Overview and Recent Progress

Guillaume Baverez

Peking University, China

Conformally invariant measures on Jordan curves have an active research topic in the past 25 years, with (at least) four different approaches. I will report on past and recent results leading to the unification of all these approaches.

Toda Theories and W-algebras

Baptiste Cerclé

CNRS-Sorbonne University, France

Toda conformal field theories are generalizations of Liouville theory for which the underlying field is vector-valued. In addition to conformal invariance, these theories are assumed in the physics literature to enjoy an enhanced level of symmetry encoded by W-algebras, that originate from the vertex algebra setting.

In this talk, we will discuss how to give a precise meaning to this assumption based on the probabilistic representation Toda theories. Namely we will characterize W-algebras in terms of holomorphic currents of Toda theories and show that Toda correlation functions satisfy Ward identities, a fundamental step in the conformal bootstrap procedure. We will also discuss some implications of this statement on solvability of Toda theories.

Temperature Chaos for Polymers

Victor Ginsburg

University of California, Berkeley, USA

Polymers in disordered media are examples of random Gibbs measures on paths traversing a random environment. Such disordered systems often exhibit intricate energy landscapes rich with multiple valleys corresponding to metastable states. This generic property manifests in a system being fragile or extremely sensitive to perturbations. Namely, a slight variation in external parameters such as the disorder or the temperature causes a profound change in the system, a phenomenon known as chaos. In experimental studies of chaos, temperature is the prototypical control parameter as it is easier to vary than the disorder. However, on the mathematical side, studying disorder chaos is easier as perturbing the disorder amounts to infusing the system with extra independent randomness.

In this talk we will report the first progress in understanding temperature chaos in the Kardar–Parisi–Zhang universality class, with the Continuum Directed Random Polymer being the model of study. Time permitting, we will also touch upon a connection between temperature and disorder chaos. This is forthcoming joint work with Shirshendu Ganguly and Zoe Himwich.

Bombieri-type Inequalities and Equidistribution of Points

Haakan Hedenmalm

Royal Institute of Technology, Sweden

We extend the notion of the Bombieri inequalities from the setting of homogeneous polynomials (on projective space $\mathbb{P}^1$, the Riemann sphere) to generalized polynomials on a general compact Riemann surface. We proceed to establish a bound which applies no matter how many zeros are present. We also discuss the condition numbers of Shub–Smale and how to extend these notions to a general compact Riemann surface setting.

Stochastic Log-gases and Multiple Schramm–Loewner Evolutions

Makoto Katori

Chuo University, Japan

A critical lattice system in two dimensions is conjectured to give a conformal field theory (CFT) in a scaling limit. On the other hand, Schramm–Loewner evolution (SLE) was introduced as a scaling limit of a critical domain-interface. An expected interrelation between them was called the SLE/CFT correspondence. We think that now it would be more appropriate to call the relation a coupling rather than correspondence. Since the Gaussian free field (GFF) is a probabilistic avatar of the CFT of massless free bosons, the SLE/CFT-correspondence could be realized as a coupling between SLE and GFF. We show that coupling between chordal (resp. radial) multiple SLE and GFF occurs if and only if the chordal (resp. radial) multiple SLE is driven by the usual Dyson Brownian motion (BM) (resp. circular Dyson BM). As upgraded versions of the hydrodynamic limits of log-gases described by inviscid Burgers-like equations, we also report the deterministic limits of the corresponding multiple SLEs (the dynamical laws of large numbers), when the number of SLE curves tends to infinity. This talk is based on the joint work with Shinji Koshida (Aalto Univ.), Chizuru Soukejima (Chuo Univ.), and Raian Suzuki (Chuo Univ.).

Local Fields in Lattice Models and Conformal Field Theories

Kalle Kytölä

Aalto University, Finland

In the 1980's, physicists conjectured that scaling limits of probabilistic lattice models at criticality should be described by conformal field theories (CFT). The state space of a CFT is also its space of local fields, and the observable quantities are correlation functions of local fields. A natural analogue of local fields in probabilistic lattice models is random variables built locally from the basic degrees of freedom of the model. In certain two-dimensional models, discrete complex analysis can be used to equip spaces of lattice model local fields with the main algebraic structure of CFTs: a representation of the Virasoro algebra. This opens up the possibility of full and structured correspondence between the space of local fields of a CFT and of its lattice discretization. In the discrete Gaussian free field and Ising model, the space of local fields can be shown to be isomorphic to the state space of the corresponding CFT, and correlations of lattice model local fields converge in the scaling limit to correlation functions of the CFT, when appropriately renormalized according to the eigenvalues of the Virasoro generators corresponding to the energy in CFT.

The talk is based on joint works with Clément Hongler (EPFL Lausanne), Fredrik Viklund (KTH Stockholm), David Adame-Carrillo, Delara Behzad, Dmitry Chelkak (Univ. Michigan), and Konstantin Izyurov (Univ. Helsinki)

Liouville Quantum Gravity: from Random Planar Maps to Conformal Field Theory

Xin Sun

Beijing International Center for Mathematical Research, China

Originating in theoretical physics, Liouville quantum gravity (LQG) has been an important topic in probability theory and mathematical physics in the past two decades. In this talk, we review two aspects of this topic. The first is that LQG describes the random conformal geometry of the scaling limit of random planar maps. We highlight the convergence of random planar maps under discrete conformal embedding, where couplings between LQG and the Schramm-Loewner evolution (SLE) play a key role. The second aspect is the connection to conformal field theory (CFT). Here we highlight the interplay between Liouville CFT and the SLE/LQG coupling, the CFT description of 2D quantum gravity coupled with conformal matter, and applications to SLE and 2D statistical physics. Based on the joint 2026 ICM proceeding with Nina Holden.

Collapsing Behavior of Two-dimensional Coulomb Gases

Ludvig Svensson

Chalmers University, Sweden

I will discuss joint work with R. Andreasson on two-dimensional Coulomb gas models. In a recent paper, we study canonical ensembles of N-particle systems on the two-sphere with logarithmic pair interactions determined by a symmetric hollow coupling matrix, via the associated Gibbs measure and partition function. Different choices of coupling matrix recover several familiar models, including one-, two-, and n-component plasmas, vortex models such as Onsager's model of turbulence, as well as models arising in R. J. Berman's probabilistic approach to constructing canonical approximations of Kähler–Einstein metrics in complex dimension one.

We derive a formula relating the critical inverse temperature, at which the partition function diverges, to a certain discrete optimization problem associated with the coupling matrix. We further show that this optimization problem governs the behavior of the Gibbs measure and the partition function as the critical inverse temperature is approached.

Our approach draws on classical ideas from complex algebraic geometry, in particular the Fulton–MacPherson compactification of configuration spaces and the analytic continuation of complex powers, originating in work of Bernstein–Gel'fand and Atiyah.

If time permits, I will briefly discuss ongoing work together with Andreasson in which, by considering a regularized two-component plasma, we extend the analysis beyond the critical temperature with the aim of describing the formation of higher-order multipoles. I will also mention connections to joint work together with Andreasson and Berman on the probabilistic approach to Kähler–Einstein metrics, where similar Gibbs measures and partition functions arise.

Mean Value Inequalities for the Coulomb Gas

Eric Thoma

Stanford University, USA

The Coulomb gas is a statistical physics model consisting of N particles interacting with electrostatic repulsion and with a global confining potential. After reviewing previous results on the model, I will show how a certain subharmonic structure associated with the k-point correlation function arises. This structure implies new bounds on quantities such as the furthest particle from the origin, generalizing bounds known for the Ginibre ensemble, and it also explains how Poissonian statistics takes over in the high-temperature regime below a rigidity length scale.

Correlation Decay in Area-Tilted Line Ensembles

Vilas Sreenivasan Winstein

University of California, Berkeley, USA

A putative scaling limit for the level curves of low-temperature 3D Ising droplets consists of non-intersecting Brownian lines above a hard wall and subject to geometrically growing area tilt potentials. Understanding the limiting object is an important step towards proving this scaling limit, and an important question is to clarify the spatial correlations of these lines. This has remained a longstanding open problem as many common algebraic and analytic tools used for other line ensembles do not apply to this one. We instead develop a novel probabilistic framework and resolve the question of spatial correlations, under the assumption that the area tilt strength is large enough.

This is forthcoming joint work with Shirshendu Ganguly.

Scaling Limits of Critical FK(4)-decorated Maps

Mo Dick Wong

University of Hong Kong, Hong Kong SAR

Fortuin–Kasteleyn (FK) maps are models of discretised two-dimensional quantum gravity with close connections to several classical models in statistical physics. In this talk, I will discuss their scaling limit (in the peanosphere sense) in the critical case q=4, and explain how a correspondence with the fully packed loop O(2) model on triangulations reveals an exactly solvable structure that underpins our analysis. This is based on joint work with William Da Silva, Xingjian Hu, and Ellen Powell.