Opening Conference of the CRC 1624

Higher structures, moduli spaces and integrability

Connecting algebra and geometry to quantum field theory and string theory

Universität Hamburg
March 31 – April 2, 2025

Description

The goal of this conference is to present a panorama of research directions in mathematics and mathematical physics related to the scientific program of our **CRC 1624 „Higher structures, moduli spaces and integrability**“.

The CRC 1624 has started in April 2024. It aims to stimulate interactions between highly active topics in mathematics such as higher structures and their applications in TQFT and CFT, the geometry of moduli spaces with their applications in SUSY QFT and string theory like the swampland program, and integrability with its multitude of applications in quantum field theory and string theory. As most of the early career researchers participating in the CRC have arrived by now, we regard the first anniversary of the start of the CRC as a good time for having an opening conference.

With this conference we aim to stimulate new interactions between mathematics and theoretical physics by bringing together leading representatives of these research directions.

Organizing Committee:

Gleb Arutyunov, Vicente Cortés, Claudia Scheimbauer, Volker Schomerus, Christoph Schweigert, Jörg Teschner, Timo Weigand

Abstracts

Monday

Quantum groups from Fukaya Categories

Mina Aganagic

University of California, Berkeley

There is a family of Fukaya categories, or categories of A-branes, labeled by a choice of a Lie algebra, which categorify Chern-Simons invariants of links. I will describe how categorified quantum group symmetry, coproduct included, emerge from a certain natural set of cutting and gluing operations which these Fukaya categories posses.

A universal characterization of the curved homotopy Lie and associative operads

Vivek Shende

Centre for Quantum Mathematics, Syddansk Universitet

The A-infinity and L-infinity operads are fundamental higher structures playing key roles in mathematics and physics, ranging from deformation theory to string field theory. In all contexts, the procedure of `twisting an algebra by a Maurer-Cartan element' is fundamental. In this talk we will give universal characterizations of these structures (as initial objects in appropriate categories of decorated operads) and a universal characterization of the twisting procedure (in terms of the adjoint functor to a forgetful map). This is joint work with Guillaume Leplante-Anfossi and Adrian Petr.

Standard Extension algebras and Fukaya calculus

Catharina Stroppel

Rheinische Friedrich-Wilhelms-Universität Bonn

In this talk I will talk about an old Lie theoretic problem, namely the computation of extensions between (parabolic) Verma modules and their composition. We give a description of the corresponding algebra of extension in terms of convolution algebras and cohomology of Kazhdan-Lusztig-Deodhar-Richardson varieties. In the special example of maximal parabolic Verma modules for sl_n we give an explicit combinatorial model and connect this with Fukaya categories.

Perverse sheaves on h/W and constant terms of Eisenstein series

Mikhail Kapranov

Kavli IPMU, Tokyo

The adjoint quotient h/W of a reductive Lie algebra has a natural complex stratification "by root multiplicities". So we have the corresponding category of perverse sheaves and the problem of its description by a quiver with relations is interesting on general grounds. It turns out that the relations in such a quiver are parallel to the relations between parabolic induction and restriction in representation theory or, at one categorical level lower, between the operations of forming Eisenstein series and taking the constant term in the theory of automorphic forms.

Joint work with V. Schechtman, O. Schiffmann and J. Yuan.

Fusion category and S-matrix

Shota Komatsu

CERN

I will show that categorical symmetries --- a refined notion of symmetry that has been actively discussed in the past few years --- sometimes lead to a surprising consequence on scattering amplitudes: a modification of crossing symmetry. I will demonstrate this using example of integrable field theories in 1+1 dimensions although the argument holds more generally; namely, also for non-integrable theories. I will also present the results of S-matrix bootstrap, which constrains the space of physically consistent scattering amplitudes with categorical symmetries.

Tuesday

The arithmetic of non-perturbative effects

Claudia Rella

Institut des Hautes Études Scientifiques, IHES

Perturbative expansions in quantum theory, particularly in quantum field theory and string theory, are typically factorially divergent due to hidden non-perturbative sectors. First developed in the 1970s and 80s, the theory of resurgence provides universal machinery to extract non-perturbative effects, which are encoded in exponentially small corrections, from the perturbative series itself. Very recently, it has been observed that, under special assumptions, non-perturbative data accessed via resurgent methods exhibit intrinsic number-theoretic properties, which appear to be rooted in symmetries of the geometry underlying the quantum theory. The framework of modular resurgence aims to formalise this observation. In this talk, I will first introduce the systematic, algebraic approach of resurgence to the problem of divergences. I will then describe the emerging bridge between non-perturbative effects and arithmetic structures and conclude with a concrete example from topological string theory.

A microscopic realization of dS_3

Beatrix Mühlmann

Institute for Advanced Study (IAS), Princeton

I will discuss a recent proposal of a precise duality between pure (2+1)-dimensional de Sitter quantum gravity and a double-scaled matrix integral. There are two main aspects of this correspondence. First, by discussing the canonical quantization of the gravitational phase space, I will arrive at a novel proposal for the quantum state of the universe at future infinity, which differs from the usual no-boundary proposal. I will then discuss the computation of cosmological correlators of massive particles in the universe specified by this wavefunction. Remarkably, these integrated cosmological correlators are precisely computed by the string amplitudes of the recently-introduced complex Liouville string (CLS), thereby establishing a direct connection between the cosmological correlators and resolvents of the matrix integral dual of CLS. The second aspect of the duality involves the Gibbons-Hawking entropy of the cosmological horizon of the de Sitter static patch. I will show that the de Sitter entropy can be reproduced exactly by counting degrees of freedom in the matrix model dual.

Dijkgraaf-Witten TQFT with defects

Catherine Meusburger

Friedrich-Alexander-Universität Erlangen-Nürnberg

We give a gauge theoretical construction of 3d (untwisted) Dijkgraaf-Witten TQFT with defects of all codimensions à la Freed-Quinn. This defines a symmetric monoidal functor from a category of stratified surfaces and stratified 3d cobordisms into the category of finite-dimensional vector spaces. It is formulated in terms of graded quivers that describe the stratifications, spans of groupoids and certain groupoid representations. It does not require choices of triangulations, allows an easy computation of examples and can be applied to describe defects in Kitaev's quantum double model.

This is joint work with João Faria Martins, arXiv: 2410.18049

Counting curves with Calabi-Yau gerbes

Thorsten Schimannek

Utrecht University

To start the talk, I will recall the beautiful relationship between topological strings, enumerative geometry and variations of Hodge structure via mirror symmetry.
I will then discuss a recent proposal for the interpretation of the A-model topological string partition function on nodal Calabi-Yau threefolds that carry a flat but topologically non-trivial B-field.
From an enumerative perspective, this is conjectured to encode a refinement of the usual Gopakumar-Vafa invariants with respect to a torsion curve class that only exists in small resolutions that have a trivial canonical class but are not Kaehler. After illustrating the phenomenon at the hand of the quintic, my focus will be on the relation under mirror symmetry to variations of Hodge structure that have an atypical integral structure. This integral structure can be interpreted in terms of the singular geometry and the non-trivial B-field topology.

Counting BPS black hole micro-states with (mock) modular forms

Boris Pioline

LPTHE, Sorbonne Université and CNRS

A central problem in quantum gravity is to get a quantitative microscopic interpretation of the Bekenstein-Hawking entropy of black holes. In type II strings compactified on a Calabi-Yau manifold, BPS black hole microstates are realized by bound states of D-branes wrapped along complex submanifolds, or in mathematical terms by stable objects in the derived category of coherent

sheaves. String dualities predict that suitable generating series of indices counting such stable objects (known as Donaldson-Thomas invariants) possess strong modular properties.
I will explain recent progress in computing these BPS indices on compact Calabi-Yau manifolds such as the quintic threefold, using wall-crossing and relations to topological string theory and present strong evidence that modularity is indeed at work. Conversely, by assuming modularity one may compute topological string amplitudes at higher genus than before.

Moduli spaces for categorification of $U_q (sl_n)$ invariants

Sergei Gukov

Caltech, Dublin Institute for Advanced Studies (DIAS)

Braiding of Verma modules for the quantum group $U_q (sl_n)$ leads to a TQFT that associates q-series invariants to 3- manifolds with knots and links. One of the main interests in these invariants is that they are expected to admit categorification, thus providing new insights into the mysterious world of smooth 4- manifolds. Building on recent works with M. Jagadale and P. Putrov, we describe what this homological lift looks like with mod 2 coefficients, and what the corresponding moduli spaces look like. Resurgent analysis and compactification divisors play important roles. We prove that the proposed categorification is invariant under Kirby moves for all weakly negative definite plumbed manifolds.

Wednesday

Factorization algebras and a chiral 6d/2d correspondence

Brian Williams

Boston University

The holomorphic twist (minimal BPS sector) of 6-dimensional N=(2,0) superconformal symmetry enhances to an infinite-dimensional symmetry algebra of exceptional type. Using the theory of factorization algebras we explain how this symmetry algebra plays an essential role in a chiral version of the famous 6d N=(2,0) /2d CFT correspondence. From the perspective of the holomorphic twist of the 6d theory, we further propose a generalization of related theorems of Nakajima and Grojnowski on the vertex algebra structure present in the cohomology of the Hilbert scheme of points.

Monodromy-free potentials and Calogero-Moser spaces

Giovanni Felder

ETH Zürich

A rational function is called monodromy-free potential if it is the potential of a one-dimensional Schrödinger equation whose solutions are meromorphic for all values of the spectral parameter. Monodromy-free potentials appear in the description of equilibrium points of Calogero-Moser systems, rational solutions of the Korteweg-de Vries equations and more recently in the IM/ODE correspondence. In the case of potentials with quadratic growth at infinity it was shown by Oblomkov that monodromy-free potentials are enumerated by partitions via the Wronskian map for Hermite polynomials. We show that they can also be identified with fixed points of a circle action on the Calogero-Moser space. As a corollary, we solve the inverse problem for the Wronskian map by showing that the set of contents of the partition is the spectrum of Moser's matrix evaluated at the poles of the potential. We also prove a conjecture by Conti and Masoero by computing the weights of the circle action at the fixed points.
In this talk I will review the classical results on the relation between monodromy-free potentials and Calogero-Moser systems, then explain the new results.

The talk is based on joint work with Alexander Veselov, with inputs of Nikita Nekrasov.

On the large charge/matrix models duality

Alba Grassi

Université de Genève / CERN

Strongly coupled regimes of quantum field theory remain notoriously difficult to access with standard analytic tools. However, certain aspects of these theories become more manageable when focusing on sectors where specific quantum numbers are taken to be large. Well known examples include the large N limit, where N denotes the rank of the gauge group or the large spin limit. More recently, a new approach based on effective field theory has gained importance for studying sectors of a theory where a given global charge is considered to be very large. In this talk, I will show how a dual description in terms of matrix models emerges in such large-charge regimes, with the matrix size directly related to the underlying global charge. I will show how this framework provides a powerful tool not only to demonstrate the predictions of effective field theory, but also to go beyond them.

Geometry of relativistic hydrodynamics and topological strings

Nikita Nekrasov

Simons Center for Geometry and Physics

New view of relativistic hydrodynamics, generalizing Euler equations of compressible ideal fluid, is proposed. Connections with topological strings and Liouville conformal blocks will be discussed. Work in progress with Paul Wiegmann.

Renormalons for the people

Marcos Marino

Université de Genève

Renormalons are the smoking guns in perturbation theory for a wide class of non-perturbative effects. They have been mostly studied in QCD phenomenology, but as I will try to argue in this talk, renormalons and their associated non-perturbative corrections are fundamental aspects of quantum field theories. I will first illustrate the existence of renormalons in simple models, review their properties, and describe some recent progress in the topic, as well as open problems.