Journée des nouveaux entrants 2026 : Mathematical Physics

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Orsay, 13 May 2026

Definition (from J. of Math. Phys.)

"...the application of mathematics to problems in physics, the development of mathematical methods suitable for such applications and for the formulation of physical theories."

Another (more symbolic) way to put it

$$M\Phi : M \overset{\longrightarrow}{\underset{\longleftarrow}{}} \Phi$$

where

- $M \longrightarrow \Phi$: application of existing mathematical framework/methods to theoretical Physics;
- $M \longleftarrow \Phi$: construction of the mathematical framework/methods needed to make sense of physical theories/solve problems form theoretical Physics.

N.B.: $M\Phi$ more a method than a subject $\Rightarrow$ could apply to any part of Φ

$\Rightarrow$ Overlaps with virtually every branch of Theoretical Physics!

Members of the Mathematical Physics team

- Michel Dubois-Violette
- Samuel Friot
- Valentine Maris
- Parham Radpay
- Vincent Rivasseau
- Jean-Christophe Wallet
- Robin Zegers

Main research topics

- Analytical methods for QFT:
  - Complex Analysis and Special functions
  - Constructive QFT
- Random Tensors
- Non-Commutative Geometry :
  - QFT on Quantum space-times
  - Quantum symmetries and Quantum integrability

Special functions for Feynman integrals (FI)

Dimensionally-regulated FI $\rightarrow$ Multivariable hypergeometric functions ("too complicated" objects)

Simple subclass describing many FI: Multiple polylogarithms (well-understood)

Beyond one-loop: more intricate functions also appear (elliptic polylogarithms, iterated integrals of modular forms etc). These are not fully understood $\Rightarrow$ Numerical evaluation difficult

Recent progress for the Mellin-Barnes (MB) representation computational technique

Aim

- Improve numerical evaluation by finding new analytic properties using tools such as MB technique
- Improvement of MB technique opens new research directions:
  - study of unexpected links with some aspects of computational geometry
  - direct application to multivariable hypergeometric functions
  - ...

Random Tensor theories

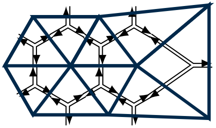
The tensor track to Quantum Gravity

A theoretical framework for Quantum Gravity

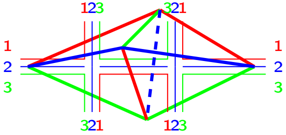
Random tensor theories

- a generalization of random matrices which describe 2d Quantum Gravity. . .

$d = 2$:



$d = 3$:



$d > 3 \ldots$

- . . . to higher rank tensors $\Rightarrow$ to higher dimensional space-times

Applications cover

- The "tensor track" to Quantum Gravity
- Random geometry and integrable models
- Signal/Image/Video analysis, Pattern recognition, Tensorial Principal Component Analysis
- Random tensors for AI and Complexity (Collaboration with CEA-LIST)

Non-commutative Geometry provides a mathematical description of "Quantum space(-time)s"

Non-Commutative Geometry

- Classically: Geometric object X dual to Commutative Algebra $\mathcal{A}$
- Question: What if $\mathcal{A}$ is replaced by a Non-commutative algebra?
- $\Rightarrow$ Non-commutative or quantized version of the Geometric object X

E.g. κ-Minkowski space-time $\simeq$ "Quantized" version of the Minkowski space-time of SR

Question: can one construct QFT on Quantum space-times?

- Motivation: an access to Quantum Gravity Phenomenology
- Construction of the 1st physically acceptable gauge theory on κ-Minkowski space-time
- Specific Phenomenology at Planck scale:
  - Modified causality
  - Modified dispersion relations
  - Modified symmetries (Lorentz, C,P,T)

Non-commutative geometry also provides a mathematical description of "Quantum Symmetries"

Non-commutative Geometry and Quantum Groups

- Classically: Lie group G dual to (co)commutative Hopf algebra $\mathcal{H}$.
- Question: What if $\mathcal{H}$ is replaced with a non-(co)commutative Hopf algebra?
- $\Rightarrow$ Quantized Lie group or Quantum Group

These can be:

- quantum symmetries of quantum spaces
  E.g. κ-Poincaré Hopf-algebra $\simeq$ Quantization of the Poincaré (universal enveloping) algebra of SR
- hidden/dynamical symmetries of quantum integrable systems (algebraic Bethe ansatz)
  E.g. Quantum affine algebras $\simeq$ Quantizations of Kac-Moody Lie algebras.

Main questions

- Construct and understand the structure of these quantum algebras
- Classify their (irreducible) representations

Thanks for your attention!