

**Definition:** *Mathematical Physics involves:*

- i) *applications of Mathematics to understand/solve problems in Physics*
- ii) *developments of new Mathematics inspired by Physics*

$M \cap \Phi$

*Algebra, Topology, Differential Geometry, Complex Analysis, Functional Analysis, ...*

*almost all Mathematics Subject Classification items*



*Field Theories, Gauge theories, General Relativity, High Energy Physics, String Theory, Quantum Gravity, ...*

Examples :

- i)  $(M \rightarrow \Phi)$  : Holomorphy / Modular groups in e.g. N=2, D=4 SYM yield  $\beta$ -function from modular forms, features of phase diagram of fractional QHE, Ore-extensions in quantum gravity models
- ii)  $(\Phi \rightarrow M)$  : Topological field theories yield differential invariants, quantum gravity approaches yield new algebraic objects : e.g. "twisted" differential calculi, twisted spectral triples, ...

**Michel DUBOIS-VIOLETTE** (*emeritus*)

**Samuel FRIOT**

**Vincent RIVASSEAU**

**Jean-Christophe WALLET**

**Robin ZEGERS**

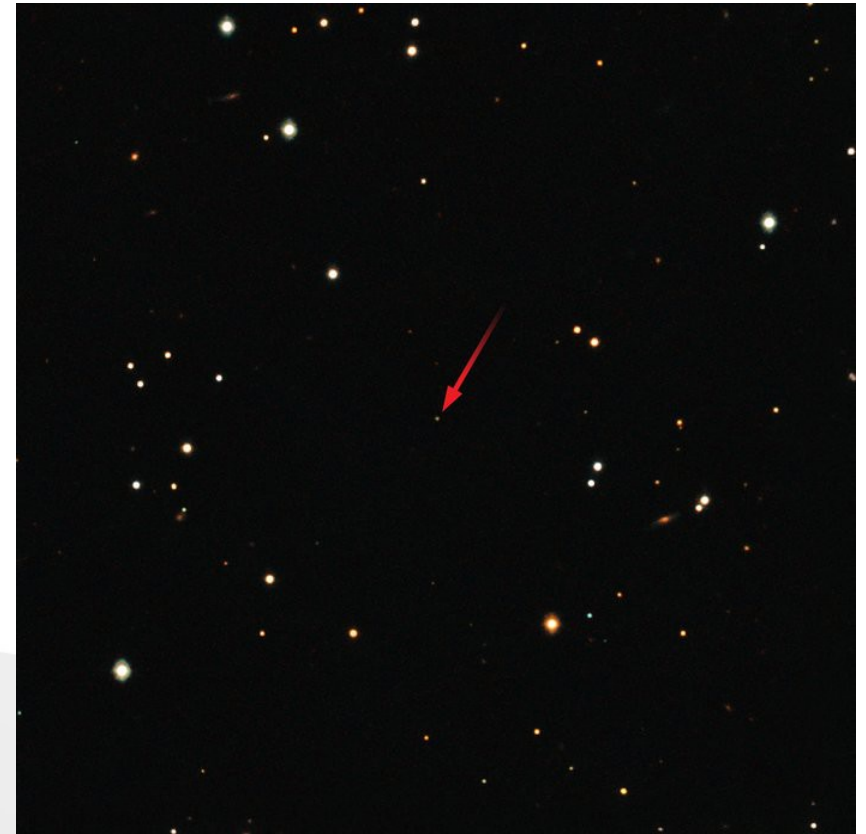
PhD students :

**Léonard FERDINAND**

**Kilian HERSENT**

**Valentine MARIS**

**Parham Radpay**



## SPECIAL FUNCTIONS FOR FEYNMAN INTEGRALS HIGHER-ORDER LOOP COMPUTATIONS

*Mellin-Barnes representation*  
*Feynman integrals and hypergeometric functions*

## QUANTUM GRAVITY AND RANDOM TENSORS

*Higher-dimensional generalisations of random matrices*

Many features:

- Random geometry approach to QG
- Tensor field theories "computable"
- Possible asymptotic freedom,...

## QUANTUM GRAVITY AND QFT ON QUANTUM SPACETIMES

*Field Theories, gauge theories on quantum spacetimes*  
*Quantum causality*

Many features:

- Causality may change at "Planck scale"
- C,P, T,... , symmetries,... are deformed
- Dispersion relations are modified,...

## QUANTUM SYMMETRIES AND QUANTUM INTEGRABILITY

*Quantum analogues of symmetries for quantum spaces*

Interesting features :

Quantum Toroidal Algebras and representation theory essential to various integrable structures : 2d CFT, SUSY gauge theories, string,...

## Recent advances and solved problems :

- ***Method to compute multiple Mellin-Barnes integrals – mixes geometry and complex functions properties***  
*Mathematica package, new properties of hypergeometric functions,...*
- ***First steps toward the construction of a theory of quantum gravity in higher dimensions ( $> 2$ )***  
*Some indications of non-perturbative asymptotic freedom ?*
- ***Construction of the first gauge theory on  $\kappa$ -Minkowski space-time***  
*Solves a 20 years old problem – extends to other deformed/quantum Minkowski space-times*
- ***Classification of the irreducible representations of quantum toroidal algebras (lowest rank)***  
*Solves a long-standing problem in representation theory*
- *... among other results...*

## Interactions/Collaborations:

- **Dept. of Maths:** *Univ. of Almeria (Spain), IHES (France), Institut for Geometry and Physics Trieste (Italy), univ. of Notre Dame Indiana (USA), univ. of Genova (Italy), Institut für Mathematik Zürich (Swiss),...*
- **Dept. of Physics:** *CPhT X, CPT Marseille (France), univ. of Napoli (Italy), univ. of Roma Sapienza (Italy), Univ. of Brussel (Belgie), Jagelonian univ. Krakow (Poland),...*

## Networks:

- **Program CA18108 “Quantum Gravity phenomenology in the Multi-Messenger approach”**

*(Investigate possible signatures predicted by quantum gravity models in the observation of different cosmic messengers, by creating the conditions for a close collaboration between theorists and the various experimental communities involved in the detection of such cosmic messengers) – 28 countries, ~150 scientists*

- **Program CA21109 “Cartan geometry, Lie, Integrable systems, quantum group theories for Applications” (CaListA)**
- ...