Mathematical Physics at IJCLab

Definition: *Mathematical Physics involves: i) applications of Mathematics to (understand/solve) problems in Physics as well as ii) developments of new Mathematics inspired by Physics.*
(definition borrowed from Journal of Mathematical Physics)

Examples:

i) Math.→Phys.: *(standard!)* Group Theory → Symmetries,…, Fiber bundles → Gauge Theories,…
ii) Phys.→ Math.: *(not so standard)* ‘’Particular’’ Gauge models → Differential Invariants of manifolds, Quantum Gravity approaches → new algebraic structures,…

Summary:

Algebra, Topology, Differential Geometry, Functional Analysis,… *almost all MCS items*

←→

Field Theory, High Energy Physics, Quantum Gravity,…

Mathematical Physics at IJCLab: People

https://theorie.ijclab.in2p3.fr/en/members

Michel DUBOIS-VIOLETTE

Samuel FRIOT

Vincent RIVASSEAU

Jean-Christophe WALLET

Robin ZEGERS

Léonard FERDINAND

Kilian HERSENT

Mathematical Physics at IJCLab: Topics

RANDOM TENSORS

Higher-dimensional generalizations of random matrices

➔ Interesting features:
-- Random geometry approach to QG
-- Tensor field theories "computable"
-- Possible asymptotic freedom

A.I. ?

Image processing?

HIGHER-ORDER LOOP COMPUTATIONS

Mellin-Barnes representation
Feynman integrals and hypergeometric functions

QFT, QCD,…

QUANTUM GRAVITY

QUANTUM SPACE-TIMES

QFT and Gauge Theories on quantum space-times
Quantum causality on these space-times

➔ Modifications of:
-- Causality (quantum causality constraints)
-- C,P,T,… symmetries,
-- Dispersion relations,…

Strings

Brane models

QUANTUM SYMMETRIES

Quantum analogues of symmetry groups for quantum spaces

➔ Symmetries of integrable systems

Integrable systems

Recent results (among others)

→ **Classification of the irreducible representations of quantum toroidal algebras (lowest rank)**

Solves a long-standing problem in representation theory

→ **Construction of the first physically suitable gauge theory on κ-Minkowski space-time**

Solves a 20 years old problem in the area of field theories on quantum spaces

→ **First steps toward the construction of a renormalizable Tensor Field Theory**

Some indications of non-perturbative asymptotic freedom

→ **Powerfull method to compute multiple Mellin-Barnes integrals (mixes geometry and complex functions properties)**

Mathematica package, new properties of hypergeometric functions,…

→ **Exceptional Jordan algebra (octonionic 3x3 matrices) to describe the internal space of fermions in Standard Model**

New insight in the (Connes approach to the) Standard model

→ **Constraints from quantum causality in κ-deformed quantum space-times**

Existence of quantum generalisation of the speed of light limit; experimental impacts

→ **Review paper on Quantum gravity phenomenology in the Multi-Messenger approach**

(collab. Theory/Phenomenology/Experiment -- Prog. Part. Nucl. 125 (2022) 103948 --)

→ …

Networks
High visibility

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),…*

EU Programs:

→ **Program CA18108 ''Quantum Gravity phenomenology in the Multi-Messenger approach'' (QG-MM)**

(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)**