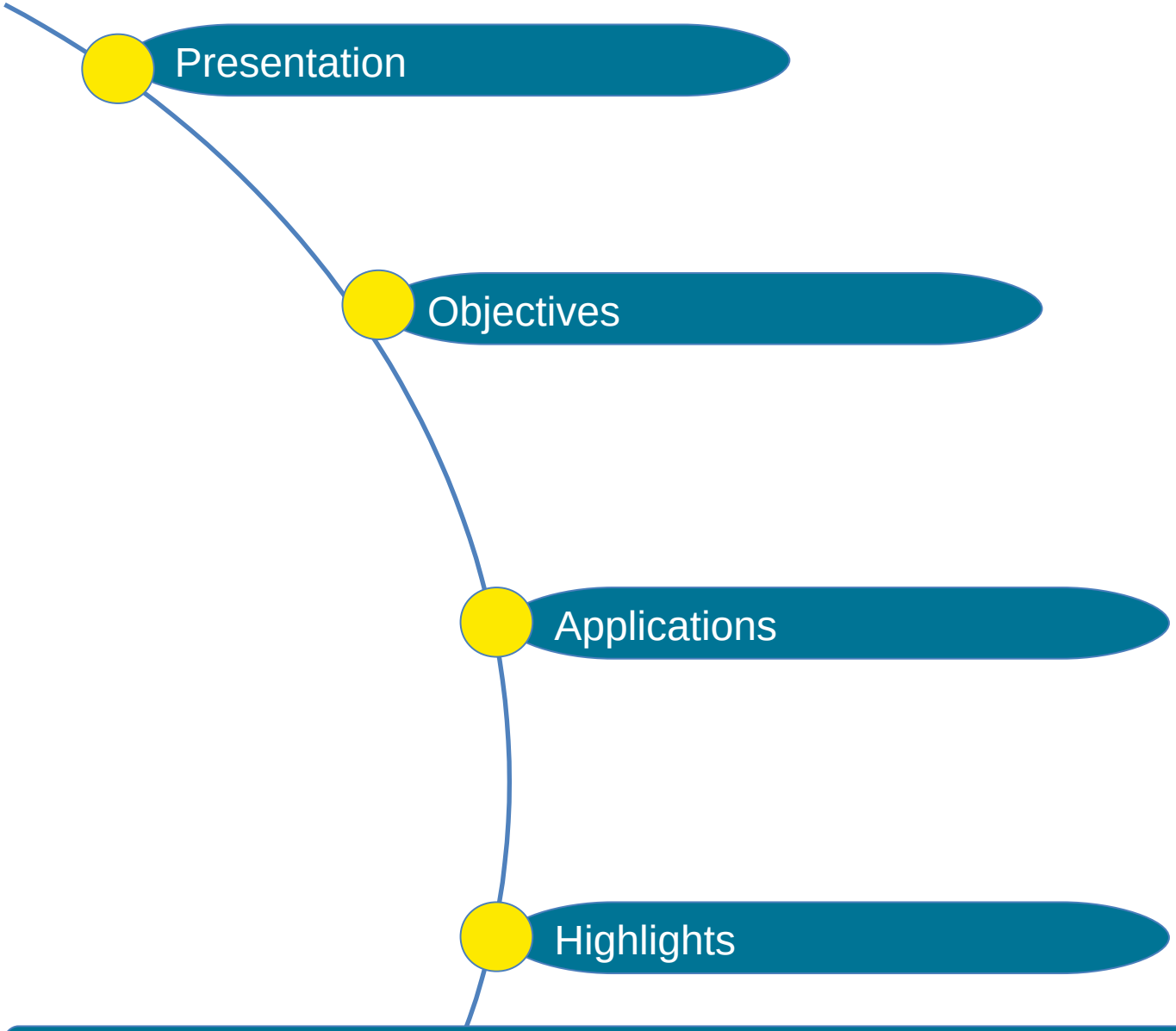
# Présentation of the Quantum Simulations axis





# Board members of the Quantum Simulations axis

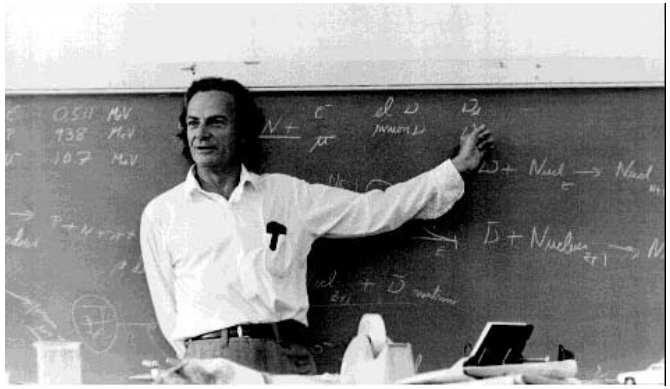


| Quantum simulations | |
|---|---|
| **Hélène Perrin** | **LPL – Paris-Nord** |
| **Pascal Simon** | **LPS – Paris-Sud** |
| Jacqueline Bloch | C2N – Paris Saclay |
| Antoine Browaeys | LCF – IOGS |
| Giuliano Orso | LMPQ – Paris Diderot |

**Members:**

**Qsim = 17 laboratories, 42/48 groups, 120/150 permanent researchers, 250/300 members in total.**

## What is quantum simulation ?



***Simulating Physics with Computers***
***Richard P. Feynman*** *1981-82*

**Initial problem:**
Classical computers are unefficient for simulating many interacting particles
→ Exponential growth of the Hilbert space

**Basic idea:**
Build a well-controlled system emulating a given Hamiltonian
Measure its properties: ground state EOS, excitation spectrum...

Non universal → easier than the universal quantum computer

***Learn more****: DIM SIRTEQ + GDR Atomes Froids organize the International Conference on Quantum Simulation, Paris 13-17 November 2017*

www.sirteq.org

## Relevant topics that can be simulated

**Equilibrium quantum systems, bulk or lattice**
Phase diagrams, eq of state, superconductivity and spin imbalance, superfluidity

**Out-of-equilibrium systems and quantum quenches**
Transport and dissipation, Kibble-Zurek scenario, many-body localization

**Quantum magnetism**
Individual particle detection, lattices systems, frustration, impurity problems

**Topological systems**
Quantum Hall effect, spin-orbit coupling, gauge fields, Majorana fermions, link with quantum computation

**Simulation of lattice gauge theories**
Abelian or non-Abelian Higgs mechanism

**Theory**
Preparation, measurements, dissipation and entanglement
Thermalization of isolated Q-systems, quenches, entanglement growth

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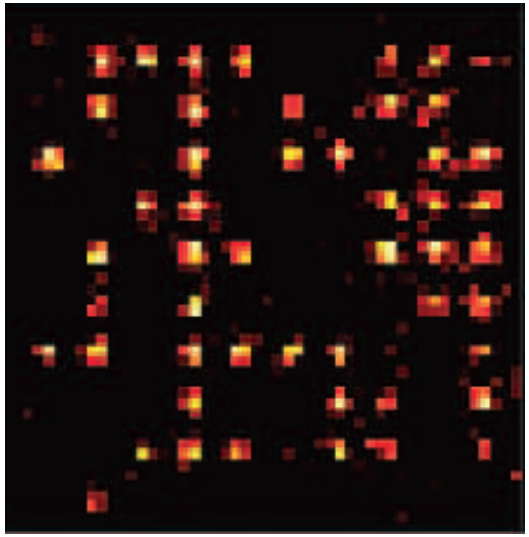
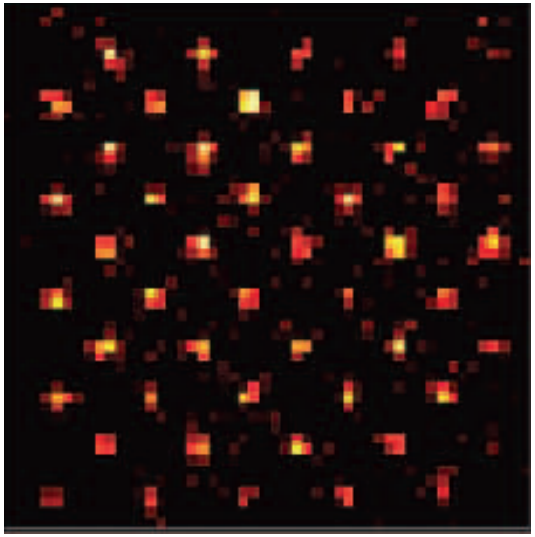
*Rydberg atoms – Quantum Simulation with arrays of coupled qubits*

→ Single atoms in configurable optical traps
→ Addressed, manipulated individually
→ Switchable interaction using Rydberg states
→ Up to 50 atoms, in 2D ans 3D



sorting atoms with an optical tweezer

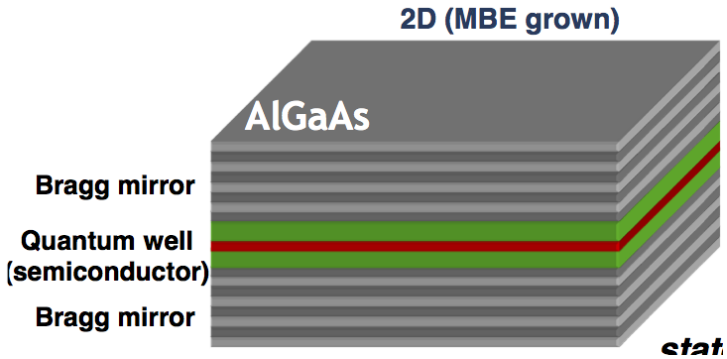


LCF (see also LKB)

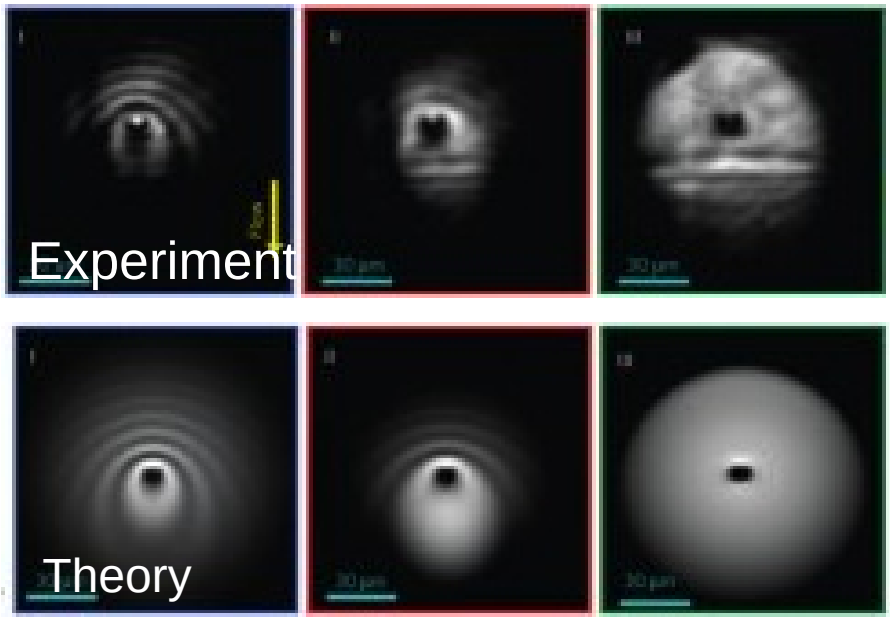
D. Barredo et al., Science 354, 1021-1023 (2016)

www.sirteq.org

*Cavity polaritons – Quantum Simulation with open quantum systems*

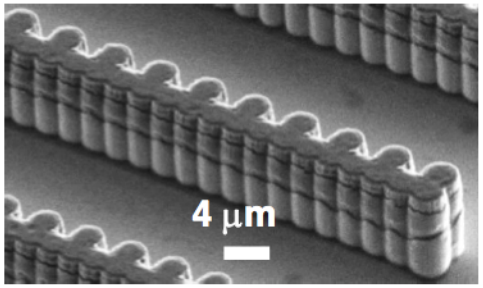


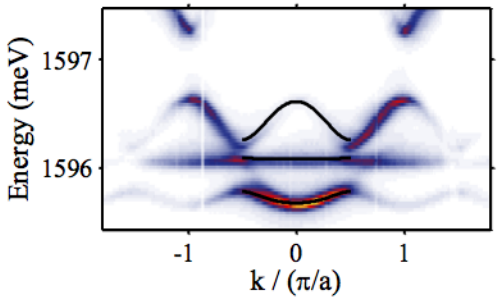

**Easy detection**




Lateral structuration:

**Flat-band physics** ➡ correlated phases



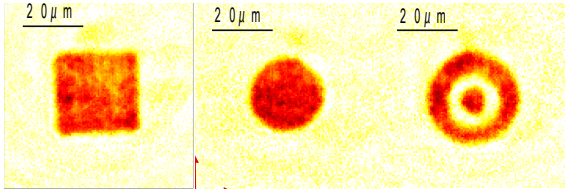

F. Baboux et al., Phys. Rev. Lett. 116, 066402 (2016)

Bulk: superfluidity

Ile-de-France is a **world leader**
C2N, LKB, MPQ

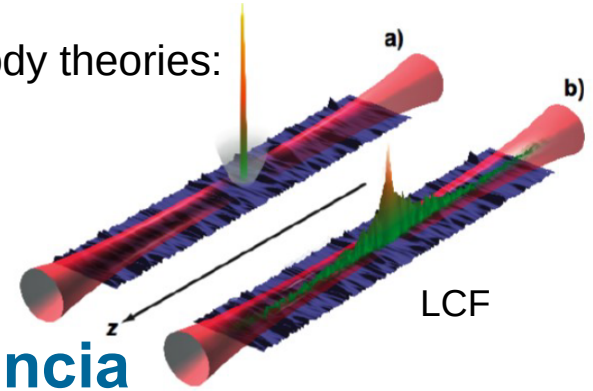
*Cold atoms – Quantum Simulation highly controllable quantum systems*

**Versatile and controllable systems :**
- Control of the sign and magnitude of **interaction**
- Control of **trapping** parameters and **dimensionality**
- Periodic potentials, « **optical lattices** »
- Effective **magnetic field** (gauge fields)
- Time dependent phenomena: **out of equilibrium** situations in 3D, 2D,1D
- Simplicity of **detection**



structured 2D quantum gas (LKB)

Quantitative Comparison with mean-field and quantum Many-Body theories:
Gross-Pitaevskii, Bose and Fermi Hubbard models,
search for exotic phases, dipolar gases,
**disorder effects, Anderson localization**, …



LCF

**See talk by Laurent Sanchez Palencia**

LPTM Cergy, LPL, LKB, LPS-ENS, LMPQ, LPTMC, Collège de France, LAC, CPhT, LCF, IPCMS, ENS-Lyon, LPTMS + GDR Atomes froids