Lucas Gabardos, *PhD*

Postdoctoral researcher
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29 years old

Applying for a postdoctoral researcher position

Work experience

Dec 2020 – Nov 2022 (2 years, full time) — **Postdoctoral researcher**, Université Toulouse III - Paul Sabatier, Laboratoire Collisions Agrégats Réactivité (UMR CNRS 5589), Toulouse, France
Quantum engineering group (website), Cold atoms team

- Optimal control of a ^{87}Rb BEC in a 1D optical lattice
- Nucleation of fractional momentum peaks in a Floquet system
- Transport of matter waves in a non-diffusive Hamiltonian ratchet

Education

2016 – 2020 — ***Ph.D.* in Quantum Physics**, Université Sorbonne Paris Nord, Laboratoire de Physique des Lasers (UMR CNRS 7538), Villetaneuse, France
Team: Magnetic Quantum Gases (website)
Supervisors: Bruno Laburthe-Tolra (doctoral advisor) and Laurent Vernac
Thesis title: Out-of-equilibrium dynamics of spins coupled by dipolar interactions

- Cooling and compression of ^{52}Cr atoms using gray molasses
- Spin mixing and protection of ferromagnetism in a ^{52}Cr BEC
- Out-of-equilibrium quantum magnetism in a 3D lattice system
- Spin dynamics across a superfluid to Mott insulator transition

2014 – 2016 — ***M.Sc.* in Quantum Devices**, Université Paris Diderot, Paris, France

2013 – 2014 — ***B.Sc.* in Fundamental Physics**, Université Paris Diderot, Paris, France

Internships

Mar – Jun 2016 (4 months, full time) — **Laboratoire de Physique des Lasers**, Université Sorbonne Paris Nord, Villetaneuse, France
Team: Magnetic Quantum Gases, Supervisor: Laurent Vernac
Subject: Preparation of the internal state of ^{53}Cr atoms through magnetic dipolar transitions between hyperfine levels of their fundamental state – toward spin-resolved imaging

Jun – Jul 2015 (2 months, full time) — **Laboratoire Kastler Brossel**, Université Pierre-et-Marie-Curie, Paris, France
Team: Trapped Ions, Supervisors: Jean-Philippe Karr and Laurent Hilico
Subject: Study of a 626 nm DBR diode laser for cooling beryllium ions as part of a H_2^+ metrology experiment

Jun – Jul 2014 (6 weeks, full time) — **Laboratoire Matériaux et Phénomènes Quantiques**, Université Paris Diderot, Paris, France
Team: Trapped Ions and Quantum Information, Supervisor: Luca Guidoni
Subject: Study of the heating rate of an ion trapped in a planar Paul microtrap through the analysis of its fluorescence dynamics

Contributions to national and international conferences

Jul 2017 **Young Atom Opticians (YAO)**, Paris, France (poster)

Jul 2018 **International Conference on Atomic Physics (ICAP)**, Barcelona, Spain (poster)

Jul 2022 **Congrès de la société française d'optique**, yearly conference of the French optical society, Nice, France (poster)

Teachings

Lectures and tutorials

2019 – 2020 Classical mechanics *lectures: 22 hours / tutorials: 32 hours*

Vector calculus *lectures: 6 hours / tutorials: 12 hours*

Tutorials

2016 – 2019 Vibrations and waves *54 hours*

2020 – 2021 Classical mechanics *12 hours*

Electricity *12 hours*

Practical work

2016 – 2019 Vibrations and waves *36 hours*

Wave optics *63 hours*

2017 – 2018 Classical mechanics *13 hours*

2018 – 2019 Electromagnetism *12 hours*

2019 – 2020 Analogue electronics *36 hours*

Labview (interfacing and simulation) *9 hours*

Classical mechanics and electricity *9 hours*

2020 – 2022 Geometrical optics *40 hours*

Computer skills

Pictures and words

LaTeX thesis and article production

Microsoft Office Word, Powerpoint and Excel

Inkscape simple vector drawing

Scientific

Matlab numerical computation

Mathematica mainly used for analytical computation

IGOR Pro data acquisition and analysis during my PhD

Programming

Python learned at university, not used a lot since

Instrument control

Labview used for running experiments, almost no programming done

Computer assisted design

FreeCAD learned for a project in 2022

Languages

French Native language

English Fluent *TOEIC listening and reading 495/495 (2019)*

Chinese Very early beginner

Publications

2018 – PRA **_Spin mixing and protection of ferromagnetism in a spinor dipolar condensate_**
S. Lepoutre, K. Kechadi, B. Naylor, B. Zhu, L. Gabardos, L. Isaev, P. Pedri, A. M. Rey, L. Vernac, and B. Laburthe-Tolra
Abstract: We study spin mixing dynamics in a chromium dipolar Bose-Einstein condensate, after tilting the atomic spins by an angle θ with respect to the magnetic field. Spin mixing is triggered by dipolar coupling, but, once dynamics has started, it is mostly driven by contact interactions. For the particular case $\theta = \pi/2$, an external spin-orbit coupling term induced by a magnetic gradient is required to enable the dynamics. Then the initial ferromagnetic character of the gas is locally preserved, an unexpected feature that we attribute to large spin-dependent contact interactions.
Physical Review A 97, 023610 (2018)

2018 – PRL **_Collective spin modes of a trapped quantum ferrofluid_**
S. Lepoutre, L. Gabardos, K. Kechadi, P. Pedri, O. Gorceix, E. Maréchal, L. Vernac, and B. Laburthe-Tolra
Abstract: We report on the observation of a collective spin mode in a spinor Bose-Einstein condensate. Initially, all spins point perpendicular to the external magnetic field. The lowest energy mode consists of a sinusoidal oscillation of the local spin around its original axis, with an oscillation amplitude that linearly depends on the spatial coordinates. The frequency of the oscillation is set by the zero-point kinetic energy of the BEC. The observations are in excellent agreement with hydrodynamic equations. The observed spin mode has a universal character, independent of the atomic spin and spin-dependent contact interactions.
Physical Review Letters 121, 013201 (2018)

2019 – PRA **_Cooling all external degrees of freedom of optically trapped chromium atoms using gray molasses_**
L. Gabardos, S. Lepoutre, O. Gorceix, L. Vernac, and B. Laburthe-Tolra
Abstract: We report on a scheme to cool and compress trapped clouds of highly magnetic ^{52}Cr atoms. This scheme combines sequences of gray molasses, which freeze the velocity distribution, and free evolutions in the (close to) harmonic trap, which periodically exchange the spatial and velocity degrees of freedom. Taken together, the successive gray molasses pulses cool all external degrees of freedom, which leads to an increase of the phase-space density (PSD) by a factor of ≈ 250, allowing to reach a high final PSD of $\approx 1.7 \times 10^{-3}$. These experiments are performed within an optical dipole trap, in which the gray molasses works as well as it does in free space. The obtained samples are then an ideal starting point for the evaporation stage aiming at the quantum regime.
Physical Review A 99, 023607 (2019)

2019 – Nature Com. **_Out-of-equilibrium quantum magnetism and thermalization in a spin-3 many-body dipolar lattice system_**
S. Lepoutre, J. Schachenmayer, L. Gabardos, B. Zhu, B. Naylor, E. Maréchal, O. Gorceix, A. M. Rey, L. Vernac and B. Laburthe-Tolra
Abstract: Understanding quantum thermalization through entanglement build up in isolated quantum systems addresses fundamental questions on how unitary dynamics connects to statistical physics. Spin systems made of long-range interacting atoms offer an ideal experimental platform to investigate this question. Here, we study the spin dynamics and approach towards local thermal equilibrium of a macroscopic ensemble of $S = 3$ chromium atoms pinned in a three dimensional optical lattice and prepared in a pure coherent spin state, under the effect of magnetic dipoledipole interactions. Our isolated system thermalizes under its own dynamics, reaching a steady state consistent with a thermal ensemble with a temperature dictated from the systems energy. The build up of quantum correlations during the dynamics is supported by comparison with an improved numerical quantum phase-space method. Our observations are consistent with a scenario of quantum thermalization linked to the growth of entanglement entropy.
Nature Communications 10, 1714 (2019)

2019 – PRA ***Dynamics of an itinerant spin-3 atomic dipolar gas in an optical lattice***
P. Fersterer, A. Safavi-Naini, B. Zhu, L. Gabardos, S. Lepoutre, L. Vernac, B. Laburthe-Tolra, P. Blair Blakie, and A. M. Rey
Abstract (shortened): [...] In this work we report on our investigation of the quantum many-body dynamics of a large ensemble of bosonic magnetic chromium atoms with spin $S = 3$ in a three-dimensional lattice as a function of lattice depth. Using extensive theory and experimental comparisons, we study the dynamics of the population of the different Zeeman levels and the total magnetization of the gas across the superfluid to the Mott insulator transition. We are able to identify two distinct regimes. At low lattice depths, where atoms are in the superfluid regime, we observe that the spin dynamics is strongly determined by the competition between particle motion, on-site interactions, and external magnetic-field gradients. Contact spin-dependent interactions help to stabilize the collective spin length, which sets the total magnetization of the gas. On the contrary, at high lattice depths, transport is largely frozen out. In this regime, while the spin populations are mainly driven by long-range dipolar interactions, magnetic-field gradients also play a major role in the total spin demagnetization. [...]
Physical Review A 100, 033609 (2019)

2020 – PRL ***Relaxation of the collective magnetization of a dense 3D array of interacting dipolar S = 3 atoms***
L. Gabardos, B. Zhu, S. Lepoutre, A. M. Rey, B. Laburthe-Tolra, and L. Vernac
Abstract: We report on measurements of the dynamics of the total magnetization and spin populations in an almost unit-filled lattice system comprising about 10^4 spin $S = 3$ chromium atoms, under the effect of dipolar interactions. The observed spin population dynamics is unaffected by the use of a spin echo and fully consistent with numerical simulations of the $S = 3$ XXZ spin model. On the contrary, the observed magnetization decays slower than in simulations and, surprisingly, reaches a small but nonzero asymptotic value within the longest timescale. Our findings show that spin coherences are sensitive probes to systematic effects affecting quantum many-body behavior that cannot be diagnosed by merely measuring spin populations.
Physical Review Letters 125, 143401 (2020)

2021 – PRX Quantum ***Quantum state control of a Bose-Einstein condensate in an optical lattice***
N. Dupont, G. Chatelain, L. Gabardos, M. Arnal, J. Billy, B. Peaudecerf, D. Sugny, and D. Guéry-Odelin
Abstract: We report on the efficient design of quantum optimal-control protocols to manipulate the motional states of an atomic Bose-Einstein condensate (BEC) in a one-dimensional optical lattice. Our protocols operate on the momentum comb associated with the lattice. In contrast to previous works also dealing with control in discrete and large Hilbert spaces, our control schemes allow us to reach a wide variety of targets by varying a single parameter, the lattice position. With this technique, we experimentally demonstrate a precise, robust, and versatile control: we optimize the transfer of the BEC to a single or multiple quantized momentum states with full control on the relative phase between the different momentum components. This also allows us to prepare the BEC in a given eigenstate of the lattice band structure, or superposition thereof.
Physical Review X Quantum 2, 040303 (2021)

2022 ***Phase-space distributions of Bose-Einstein condensates in an optical lattice: optimal shaping and reconstruction***
N. Dupont, F. Arrouas, L. Gabardos, N. Ombredane, J. Billy, B. Peaudecerf, D. Sugny and D. Guéry-Odelin
Abstract: We apply quantum optimal control to shape the phase-space distribution of Bose-Einstein condensates in a one-dimensional optical lattice. By a time-dependent modulation of the lattice position, determined from optimal control theory, we prepare, in the phase space of each lattice site, translated and squeezed Gaussian states, and superpositions of Gaussian states. Complete reconstruction of these non-trivial states is performed through a maximum likelihood state tomography. As a practical application of our method to quantum simulations, we initialize the atomic wavefunction in an optimal Floquet-state superposition to enhance dynamical tunneling signals.
arXiv:2210.11112 [cond-mat.quant-gas] (submitted to NJP)

Note: We are currently writing two more papers. The first on the emergence of a crystaline order in a Floquet-Bloch system and the other on the transport of matter waves in a non-diffusive Hamiltonian ratchet.