

## Personal data

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**Languages:** Spanish (Native), French (Proficient), English (Proficient),  
Catalan (Native), German (B1)



## Profile

Since my PhD, I have been captivated by the potential **Machine Learning** techniques offer to study **Classical** and **Quantum Physics**. For instance, I pioneered the use of such techniques to analyze anomalous diffusion (see [5] below, *NJP Publisher's pick of 2020*, and its application to biophysical experiments in PNAS [13]) which then led to the organization of [the AnDI Challenge](#), a scientific competition I co-organize aimed to further develop the field.

Recently, I have tackled the critical problem of quantum circuit synthesis with denoising diffusion models (see [21], *cover of May 2024's Issue in Nature Machine Intelligence*), as well as understanding how reinforcement learning can help understanding animal behavior and optimal foraging strategies (see [19], [20] and [25]).

Personally, I believe that Science is not only about publishing papers. That is why I have endeavored multiple **outreach** and **education** projects. For instance, I had the pleasure of collaborating in the citizen science experiment NightUp! ([covered](#) in the main national Spanish newspaper). I was also very lucky to collaborate in the creation of quantum inspired music, which resulted in an incredible performance by Reiko Yamada at the [Sonar Festival 2021](#) and a subsequent LP!

## Education

**19/11/2020: Phd in Theoretical Physics**, Institute of Photonic Sciences ICFO (Spain)

Thesis: Anomalous diffusion: from life to machines (cum laude)

**01/09/2016: Master in Photonics**, Universitat Politècnica de Catalunya UPC (Spain)

Thesis: Nonergodic Subdiffusion of a Random-walker from Interactions with Heterogeneous Partners

**15/07/2015: Bachelor in Physics**, Universitat Autònoma de Barcelona UAB (Spain) and Université de Laval (Canada).

Thesis: Light propagation in nanowires: from theory to experiments

## Research experience

**01/02/2023 - present: Marie Skłodowska-Curie Fellow**

Quantum Information and Computing group at Innsbruck University (Austria), led by Prof. Hans J. Briegel.

**01/10/2021 - 03/02/2023: Postdoctoral Researcher**

Quantum Information and Computing group at Innsbruck University (Austria), led by Prof. Hans J. Briegel.

**20/11/2020 - 31/09/2021: Postdoctoral Researcher**

Quantum Optics theory group at ICFO (Spain), led by Prof. Maciej Lewenstein.

#### [12/09/2016 - 19/11/2020: LaCaixa PhD Fellow](#)

Quantum Optics theory group at ICFO (Spain), led by Prof. Maciej Lewenstein.

#### [01/06/2015 - 01/07/2015: SURF Summer Fellow](#)

Institute of Physics and Complex Systems (IFISC, Spain) under the supervision of Prof. Roberta Zambrini.

#### [01/06/2014 - 15/07/2015: Undergraduate student](#)

Joint project between the UAB and IMB-CNM (Spain), under the supervision of Prof. Verónica Ahufinger and Dr. Andreu Llobera.

## Publications

You can always find an updated list of my publications in my [Google Scholar](#) profile.

### 2025

#### [25] Quantum Random Number Generators: Benchmarking and Challenges

G. Muñoz-Gil, H. J. Briegel and M. Caraglio, [arXiv:2503.11330](#).

### 2024

#### [24] Quantum Random Number Generators: Benchmarking and Challenges

D. Cirauqui, M. Á. García-March, G. Guigo-Corominas, T. Graß, P. R. Grzybowski, G. Muñoz-Gil, J. R. M. Saavedra, M. Lewenstein, [APL Quantum 1, 036125 \(2024\)](#).

#### [23] Artificial agency and large language models

M. Van Lier and G. Muñoz-Gil, [Intellectica, 81, 173-194 \(2024\)](#) (see also [arXiv:2407.16190](#))

#### [22] Learning minimal representations of stochastic processes with variational autoencoders

G. Fernández-Fernández, C. Manzo, M. Lewenstein, A. Dauphin and G. Muñoz-Gil, [Phys. Rev. E 110, L012102 \(2024\)](#).

*In this work we showed how Variational Autoencoders, an interpretable unsupervised learning architecture, can autonomously extract the degrees of freedom of physical datasets even when these are stochastic!*

#### [21] Quantum circuit synthesis with diffusion models

F. Fürrutter, G. Muñoz-Gil, H. J. Briegel, [Nature Machine Intelligence 6, 515–524 \(2024\)](#).

*Cover of the May issue! Here we propose the use of denoising diffusion models to create quantum circuits for a variety of applications, from state preparation to unitary compilation. I conceptualized the idea and led the project development.*

#### [20] Learning how to find targets in the micro-world: the case of intermittent active Brownian particles

M. Caraglio, ... and G. Muñoz-Gil, [Soft Matter, 20, 2008-2016 \(2023\)](#).

#### [19] Optimal foraging strategies can be learned and outperform Lévy walks

G. Muñoz-Gil, A. López-Incera, L. J. Fiderer, H. J. Briegel, [New Journal of Physics 26 \(1\), 013010 \(2024\)](#).

*In this work we propose a novel approach to a long standing problem in biophysics and ecology, among others. That is, the ability of agents to perform optimal strategies. Our framework, based in reinforcement learning, tackles both the optimality of those strategies as well as their learning process.*

## 2023

[18] Quantitative evaluation of methods to analyze motion changes in single-particle experiments

G. Muñoz-Gil, ... and C. Manzo, [Registered Report at Nat. Comm \(2023\)](#).

In this registered report we set the basis for the AnDi Challenge 2 scientific competition, which will run from December 2023 to July 2024. As in the previous challenge, I am a co-organizer and in charge of the framework in which the competition is run.

[17] Inferring pointwise diffusion properties of single trajectories with deep learning

B. Requena, S. Masó, J. Bertran, M. Lewenstein, C. Manzo, G. Muñoz-Gil, [Bio. Jour. 122 \(22\), 4360-4369](#).

In this paper we propose a new paradigm for single trajectory characterization: predicting diffusive properties at each frame of an input trajectory. This allows us to fully characterize diffusion at the experimental time resolution.

[16] Universal representation by Boltzmann machines with Regularised Axons

P. R. Grzybowski ... G. Muñoz-Gil and A. Pozas-Kerstjens, [arXiv:2310.14395](#).

[15] Certificates of quantum many-body properties assisted by machine learning

B. Requena, G. Muñoz-Gil, M. Lewenstein, V. Dunjko, J. Tura, [Phys. Rev. Research 5 \(1\), 0130971 \(2023\)](#).

Together with Dr. J. Tura, I conceived the core ideas of this project and proposed the resulting reinforcement learning (RL) method. Then, I supervised B. Requena in the development of the numerical tools needed to achieve the paper's results.

[14] Preface: characterisation of physical processes from anomalous diffusion data

C. Manzo, G. Muñoz-Gil, G. Volpe, M. A. Garcia-March, M. Lewenstein, R. Metzler, [J. Phys. A: Mathematical and Theoretical, \(56\) 1 \(2023\)](#).

This preface closes the Special Issue we co-edited (*Characterisation of Physical Processes from Anomalous Diffusion Data*), gathering many of the methods developed during the ANDI challenge and more.

## 2022

[13] Citizen Science to Assess Light Pollution with Mobile Phones

G. Muñoz-Gil, A. Dauphin, F. A. Beduini, A. Sánchez de Miguel, [Remote Sensing 14 \(19\), 4976 \(2022\)](#).

Publication gathering the results of the NightUp project. This study was [highlighted](#) in the biggest Spanish national newspaper (*El País*).

[12] Stochastic particle unbinding modulates growth dynamics and size of transcription factor condensates in living cells

G. Muñoz-Gil et al., [Proc. Natl. Acad. Sci. 119 \(31\) \(2022\)](#).

I designed a theoretical model describing the appearance of phase separation in the cell nucleus. The model is able to predict the features observed by single particle tracking techniques in in-vivo systems. Moreover, we showcased the validity of the use of ML for characterizing the experimental observations.

[11] Modern applications of machine learning in quantum sciences

A. Dawid et al., to appear in Cambridge Press, [arXiv:2204.04198 \(2022\)](#)

This book presents some of the recent developments in the field of machine learning and quantum sciences. I participated in the chapter about reinforcement learning and in the general structure of the book.

## 2021

[10] Objective comparison of methods to decode anomalous diffusion

G. Muñoz-Gil et al., [Nat. Commun. 12, 6253 \(2021\)](#)

*I co-organized the scientific competition leading to this publication. I was in charge of the simulations and numerical analysis of the datasets used during the event. I also developed for this aim the andi-datasets Python package.*

### [9] Unsupervised learning of anomalous diffusion data

G. Muñoz-Gil, G. Guigo i Corominas and M. Lewenstein, [J. Phys. A: Math. Theor. 54 504001 \(2021\)](#)

*In this publication, we propose the use of unsupervised learning as an effective tool for the characterization of anomalous diffusion both in simulations and theory. This is the first time such techniques are used for these aims.*

### [8] Applications of Quantum Randomness: From Rabi Oscillations to Fourier Axis Controlling the Musical Timbre

R. Yamada, S. Grandi, G. Muñoz-Gil, L. Barbiero, A. Aloy, M. Lewenstein, [IJMSTA 3 \(2\): 17-25 \(2021\)](#)

### [7] Efficient training of energy-based models via spin-glass control

G. Muñoz-Gil\*, A. Pozas-Kerstjens\*, M. A. García-March, A. Acín, M. Lewenstein and P. R. Grzybowski (\* equal contribution), [Mach. Learn.: Sci. Technol. 2 025026 \(2021\)](#)

## 2020

### [6] The anomalous diffusion challenge: single trajectory characterisation as a competition

G. Muñoz-Gil, G. Volpe, M. A. García-March, R. Metzler, M. Lewenstein and C. Manzo, [SPIE 2020 Proceedings, 114691C \(2020\)](#)

### [5] Single trajectory characterization via machine learning

G. Muñoz-Gil, M. A. García-March, C. Manzo, J. D. Martín-Guerrero, M. Lewenstein, [New Journal of Physics, 22\(1\), 013010 \(2020\) \(Publisher's Pick of 2020\)](#)

*I conceived the main idea of this project, which is the first proposal for the characterization of anomalous diffusion by means of ML. The success of the proposal has translated into multiple collaborations with international theoretical and experimental groups.*

### [4] Control of anomalous diffusion of a Bose polaron

C. Charalambous, M. A. García-March, G. Muñoz-Gil, P. R. Grzybowski, M. Lewenstein, [Quantum 4, 232 \(2020\)](#)

## 2019

### [3] Diffusion through a network of compartments separated by partially transmitting boundaries

G. Muñoz-Gil, M.A. García-March, C. Manzo, A. Celi, M. Lewenstein, [Frontiers in Physics 7, 31 \(2019\)](#)

## 2017

### [2] Transient subdiffusion in Ising environments

G. Muñoz-Gil, C. Charalambous, M.A. García-March, M.F. García-Parajo, C. Manzo, M. Lewenstein and A. Celi, [Phys. Rev. E 96, 052140 \(2017\)](#)

### [1] Nonergodic subdiffusion from transient interactions with heterogeneous partners

C. Charalambous, G. Muñoz-Gil, A. Celi, M. F. Garcia-Parajo, M. Lewenstein, C. Manzo, and M. A. García-March, [Phys. Rev. E 95, 032403 \(2017\)](#)

## Supervising experience

### [PhD Supervision](#)

- **A machine learning ride in the physics theme park: from quantum to biophysics**, Borja Requena

(2019-2024)

Co-supervision together with Prof. M. Lewenstein, ICFO and UPC (Spain)

#### Master Thesis Supervision

- Generation of quantum physics experiments with diffusion models, F. Fürrutter (2023-2024)

UIBK, Innsbruck (Austria)

- Condensed matter meets deep learning: from spins to neurons, E. Piñol Jiménez (2020)

Master in Photonics, UPC-UAB-UB-ICFO, Barcelona (Spain)

- Unsupervised learning of single trajectory characterization in anomalous diffusion, G. Guigó (2020)

Master of Multidisciplinary Research in Experimental Sciences, BIST-UPF, Barcelona (Spain)

#### Bachelor Thesis Supervision

- A graph neural network approach to Projective Simulation, M. di Re (2024)

UIBK, Innsbruck (Austria)

#### Undergraduate Project Supervision

- Using Quantum Machine Learning to Recognize Handwritten Numbers, J. Zingel (2019)

Barcelona Youth Summer Camp, ICFO, Barcelona (Spain). Winner of the '[New Zealand Future Scientist Prize 2020](#)' and the 'BIYSC project award 2019'.

## **Selected Conference Attendances**

**15/09/2024 - IEEE International Conference on Quantum Computing and Engineering 2024 (Montreal, Canada)**

Invited talk: Quantum Circuit Synthesis with Diffusion Models

**26/05/2024 - AIM - Artificial Intelligence in Imaging 2024 (Tarragona, Spain)**

Invited talk: Actions in representation learning: discovering the world with your hands

**26/02/2024 - Quantum Optics Obergurgl 2024 (Obergurgl, Austria)**

Poster: (Best Poster Award) Quantum circuit synthesis with diffusion models.

**09/04/2023 - Machine Learning and (Quantum) Physics Workshop (Obergurgl, Austria)**

Invited talk: Machine learning, randomness and Physics.

**19/10/2022 - Physics in Biology and Medicine 2022 (Maó)**

Invited talk: Machine learning approaches to anomalous diffusion

**19/09/2022 - ML in Sciences: from Quantum Physics to Nanoscience and Structural Biology (Hamburg)**

Invited talk: Creating community driven challenges to advance Science.

**05/09/2022 - Venice meeting on Fluctuations in small complex systems VI (Venice)**

Invited talk: Learning physics and optimal strategies with artificial agents.

**01/12/2021 - ANDI Workshop (Barcelona)**

Organizer: event gathering the participants of the ANDI challenge as well as international leading experts of the field of anomalous diffusion.

**03/10/2021 - Venice meeting on Fluctuations in small complex systems V (Venice)**

Invited talk: Machine learning approaches to anomalous diffusion data.

**24/08/2021 - Summer School: Machine Learning in Quantum Physics and Chemistry (Warsaw)**

Tutor: Responsible for the practical sessions of the school.

**01/08/2021 - SPIE Photonics. Emerging Topics in Artificial Intelligence (San Diego, virtual)**

Invited talk: The anomalous diffusion challenge: Objective comparison of methods to decode anomalous diffusion.

**15/04/2021 - Initial Training on Experimental Methods for Active Matter (Gothenburg, virtual)**

Assistant lecturer: ‘Characterization of Ergodicity Breaking and Anomalous Diffusion from Single Trajectories’

**01/12/2019 - NEURIPS, Machine Learning for the Physical Sciences Workshop (Vancouver)**

Poster: RAPID – Training Boltzmann Machines without sampling

**11/2019 - 09/2020 - ANDI seminars (virtual)**

Organizer: Series of online talks on the topic of anomalous diffusion from leading experts of the field.

## Other (selected) activities

**2020 - Present - Co-organizer of the AnDi Challenge**

The AnDi challenge is a series of scientific competitions aimed to advance the field of single-trajectory characterization in biophysical experiments. You can find all the info in our [webpage](#). I am personally one of the main co-organizer, together with Prof. Carlo Manzo (Universitat de Vic) and have been in charge of developing all the computational resources (see the [andi\\_datasets](#) Python library).

**01/04/2023 - Co-organizer of the Qiskit Hackaton Barcelona**

I was part of the organizing team of the hackaton, in collaboration with researchers of IBM, UAB, ICFO, BSC and Quantum Barcelona. The event was directed to undergraduate students, which had to solve typical quantum problems with IBM’s Qiskit interface. [Highlighted in the national press](#).

**Summer 2019/2020/2021 - Co-organizer of the [Barcelona International Youth Summer Camp \(BIYSC\)](#)**

Participated as an organizer and teacher of the ICFO branch of the BIYSC. In particular, I helped to organize the whole program and imparted lectures on simulations of quantum cryptography algorithms.

**01/09/2020 - Co-founder of [Quantum Barcelona](#)**

We are a team of *quantum* enthusiasts organizing activities for the dissemination of topics related to the quantum sciences. Due to the pandemic, we limited our activities to spotlight talks from experts in the field, most of them working in successful companies working on quantum hardware and software.

**04/10/2020 - Organizer of the course ‘Quantum Programming with IBM Qiskit’, Thinktic, Logroño (Spain).**

Organized and taught an extended course (20 h.) about quantum computation and quantum machine learning implemented in the IBM library, Qiskit. The course is aimed at people with little to no knowledge on quantum physics and covers the basics of Machine Learning and Quantum Physics as well as their implementation on IBM quantum computers.

## Prizes and Grants

**10/2024 - Best Poster Award - 2nd Workshop on Machine Learning for Quantum Technology (2024)**

Our poster based on the paper “Quantum circuit synthesis with diffusion models” received the best poster award.

**03/2024 - Best Poster Award - Quantum Optics Obergurgl (2024)**

Our poster based on the paper “Quantum circuit synthesis with diffusion models” received the SFB best poster award.

### **03/2023 - Marie Skłodowska-Curie Individual Fellowship**

Grant awarded to pursue a project about autonomous learning agents in Physics in the Innsbruck University.

### **02/2021 - NJP's best of 2020 selection**

The paper 'Single trajectory characterization via machine learning' was shortlisted by the editorial board of New Journal of Physics (NJP) among the most the most cited and downloaded papers from NJP in 2020

### **09/2016 - La Caixa - Severo Ochoa PhD fellowship grant.**

Grant awarded to pursue a PhD program at the Institute of Photonic Science (ICFO).

### **04/2016 - UPC Collaboration Grant**

Grant awarded to collaborate with the coordinators of the Master in Photonics (UPC) on organization tasks.

### **07/2015 - SURF Summer Fellowship, IFISC–UIB, Palma de Mallorca.**

Grant awarded to work with Prof. R. Zambrini on the study of quantum optomechanical oscillators.

### **10/2014 - UAB Collaboration Grant, UAB, Barcelona.**

Grant awarded to collaborate with 'Dinamització comunitària de la UAB', promoting and organizing all kinds of activities for the students of the Science Faculty and my university. I also worked on the improvement of the exchange programs of the UAB.

### **10/2012 - UAB Collaboration Grant, UAB, Barcelona.**

Grant awarded to collaborate with 'Àmbit de Participació de la UAB', creating platforms for students' representation in the Science Faculty, and promoting the participation of students in university activities.

## **Selected transferable skills courses**

### **01/2025 - FWF-Coaching-Workshop "Submitting Your Proposal"**

One day workshop by experts from the Austrian funding body FWF on how their funding landscape as well as hands-on exercises on how to better write a proposal for various of their grant opportunities.

### **11/2023 - p2i: In Action Obergurgl**

Two days workshop on innovation and entrepreneurship. Participants were exposed to an entrepreneurial way of thinking and learnt the process to develop ideas into potential business ventures and how to communicate these through interactive team work sessions.

### **05/2020 - BIST Leadership in action 2021**

Twelve hours course aimed at developing skills for the successful self-management and development to progress in a professional career.

### **10/2019 - Supervising Master's Research projects**

Six hours workshop aimed at developing supervision skills to meet the needs of a master's students during the progress of their Master thesis.

### **04/2018 - Becoming a Scientific Writer: Putting Why? before How?**

Six hours workshop aimed at helping publishing scientists develop a more impartial, analytical view of scientific writing, to better understand their readers as the focus for their scientific communication, and to make them more efficient writers and editors.

### **02/2017 - Effective oral presentation**

Eight hours workshop aimed at developing skills to prepare and deliver an oral presentation and convey a direct and effective message.