Università degli Studi di Palermo

DiFC

# Corso di Laurea Magistrale in Fisica
*Master of Science in Physics*

# Area Teorica

CISF

# Area Teorica: Gruppi di Ricerca

## Mathematical Physics and Applied Mathematics



Fabio Bagarello

## Open Quantum Systems



Benedetto D. Militello



Anna Napoli

## Theory of Quantum Systems and Processes

qunipa



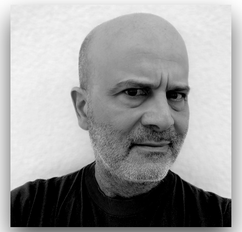
Angelo. Carollo



Francesco Ciccarello



Salvatore Lorenzo



G. Massimo Palma



M.auro Paternostro



Roberto Passante



Lucia Rizzuto

TPhQFT @unipa

## Theoretical Physics and Quantum Field Theory

# Area Teorica: Gruppi di Ricerca

## Staff


Angelo. Carollo


Fabio Bagarello


Francesco Ciccarello


Salvatore Lorenzo


Benedetto D. Militello

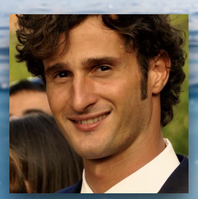

Anna Napoli


G. Massimo Palma


Roberto Passante


Mauro Paternostro


Lucia Rizzuto


Umberto DeGiovannini


Tommaso Fazio


Luca Innocenti


Gabriele Lo Monaco


Federico Roccati

## Postdocs


A. Candeloro


S. Casulleras

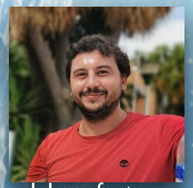

D. Chisolm


K. Chon Fai


P. Erdman



A. Anglis


L.Leonforte


D.Morrone


Z.Nie


S.Sgroi

## PhD Students

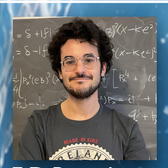

M.Arapchapzis

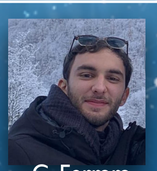

S.Artini

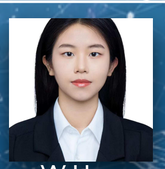

P. Barreto


A.Cammarata


L.Cammarata


E.DiBenedetto

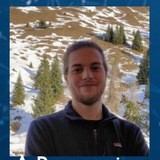

G. Ferrara


W. He


G. Ippolito


S. Pal


M.Pinto


A.Romancino


N.Segalo


G.Sferrazza


P.Spada


C.Tocchini

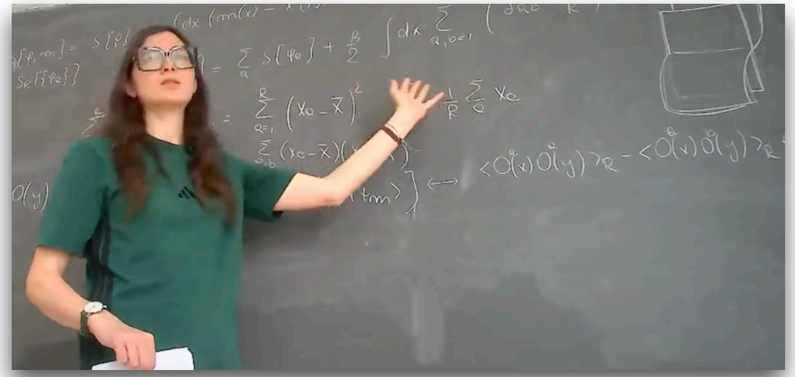

L.Valentino


M.Vetrano


S.Vijayaraj

# Opportunità didattiche/ricerca

## Weekly Group seminars



http://www.youtube.com/@QuantumUnipa

## Weekly Journal Clubs

PRX QUANTUM

...its and absence of barren plateaus

SCIENCE ADVANCES | RESEARCH ARTICLE

PHYSICAL SCIENCES

**Molecular docking with Gaussian Boson Sampling**

Leonardo Banchi[1]*, Mark Fingerhuth[2], Tomas Babej[2], Christopher Ing[2], Juan Miguel Arrazola[1]

## Visiting Professor Lectures



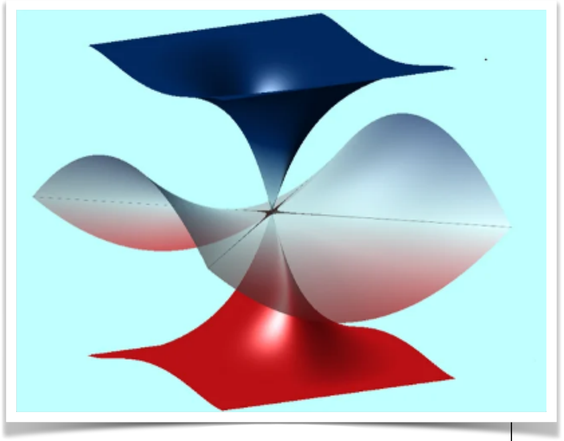
# Mathematical Physics and Applied Mathematics

Fabio
Bagarello



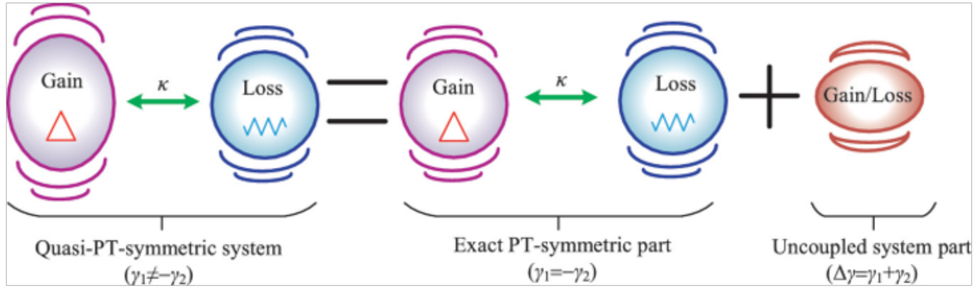
## Linee di ricerca

**Metodi matematici:**
analisi funzionale, teoria degli operatori e distribuzioni nell'analisi di sistemi quantistici



**Sistemi quantistici con Hamiltoniane autoaggiunte e non autoaggiunte:**
operatori di creazione ed annichilazione
stati coerenti e stati squeezed
elazioni di indeterminazione
teoria dei campi quantistica e regolarizzazione non perturbativa delle divergenze dei grafici di Feynman
simmetrie, dinamica e costanti del moto per sistemi quantistici con Hamiltoniane non autoaggiunte

**Tecniche quantistiche nella modellizzazione di sistemi macroscopici:**
Dinamica di sistemi complessi: dalla politica alla sociologia
Diffusione delle informazioni
Decision Making
Quantum-like finance
Sistemi biologici: dinamica di epidemie




## Collaborazioni Nazionali e Internazionali

- City, University of London, Gran Bretagna
- Université Paris Diderot, Francia
- AGH University. Cracovia, Polonia
- University of Cape Town, Sudafrica
- Tokyo University, Giappone
- Kyushu University, Giappone
- Linnaeus University, Vaxjo, Svezia
- Aston University, Gran Bretagna
- Università di Palermo – Messina -Catania
- Università di Genova – Trento – Roma
- Politecnico di Milano
- Politecnico di Bari

# Open Quantum Systems

## Linee di ricerca

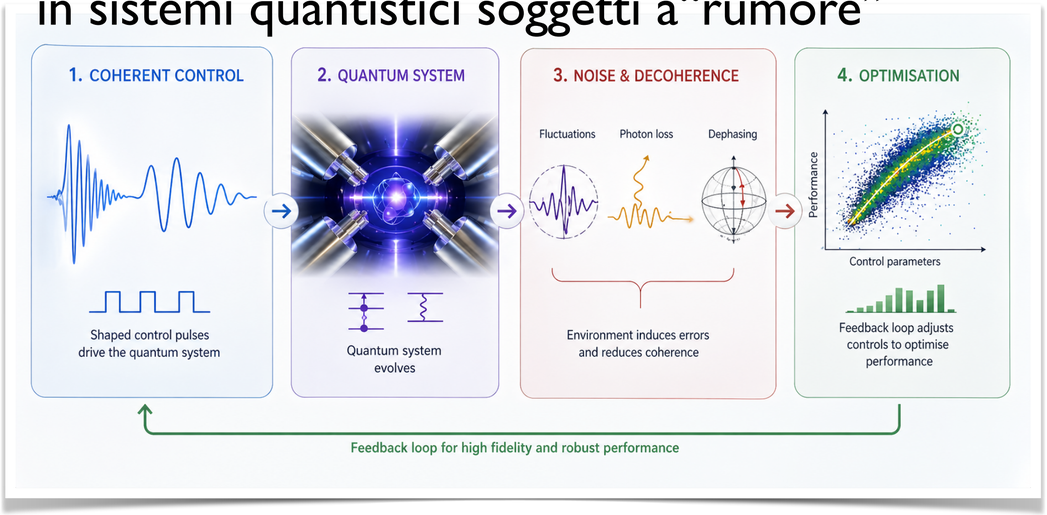
Benedetto D. Militello



Anna Napoli

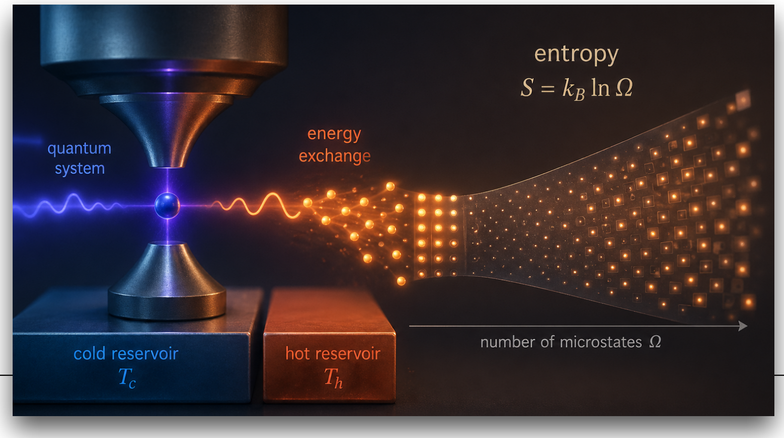


### Controllo “coerente” e ottimizzazione di processi in sistemi quantistici soggetti a“rumore”




### Processi termodinamici in sistemi quantistici

Efficienza, irreversibilità, batterie quantistiche




## Argomenti di tesi

- Correlazioni quantistiche e fenomeni di sincronizzazione
- Dispositivi superconduttivi digitali per computazione quantistica
- Tipicità di stati di non equilibrio ed evoluzioni verso l'equilibrio
- Fluttuazioni termiche e loro implicazioni
- Evoluzioni adiabatiche e debolmente non adiabatiche in presenza di rumore quantistico
- Sistemi quantistici descritti da Hamiltoniane non hermitiane

# Theory of Quantum Systems and Processes

## Linee di ricerca (Argomenti di Tesi)

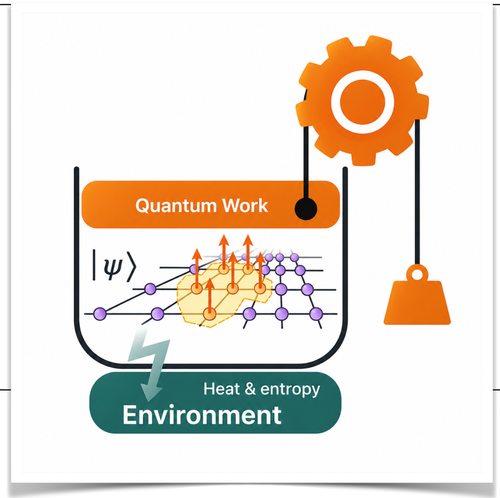

A. Carollo 

F. Ciccarello 

S. Lorenzo 

G. M. Palma 

M.Paternostro 

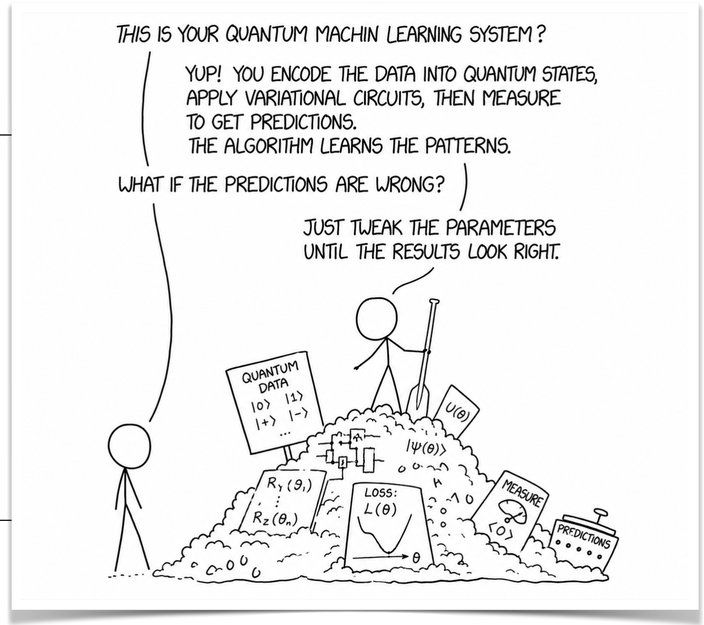



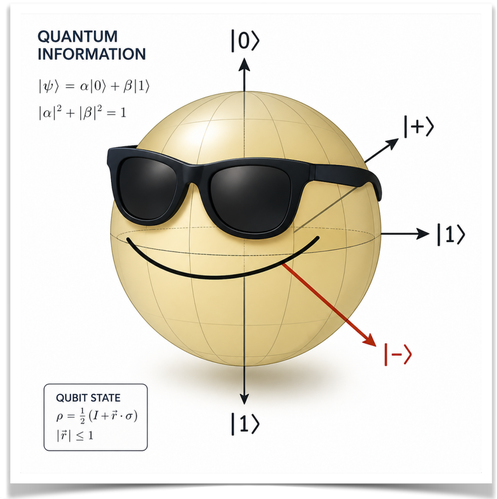

### Quantum Thermodynamics:

Characterising the role of quantum resources in thermodynamics

### Quantum Machine Learning:

deploying machine learning to the control of quantum processes



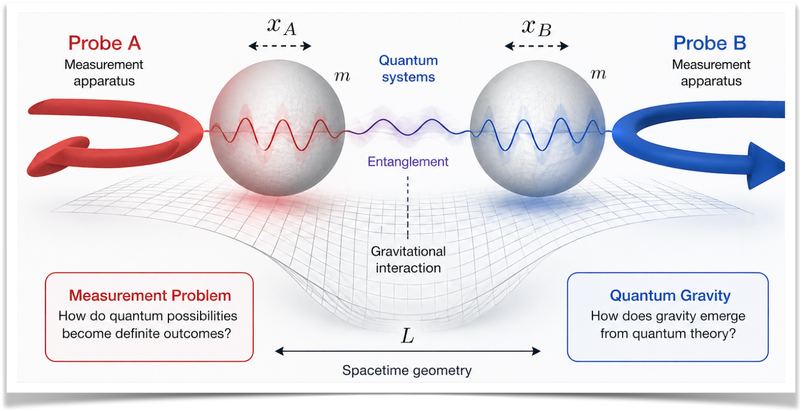

### Quantum Information Theory:

Representation and manipulation of information encoded in quantum states, where superposition and entanglement enable processing capabilities beyond classical limits.

https://quantum.unipa.it/

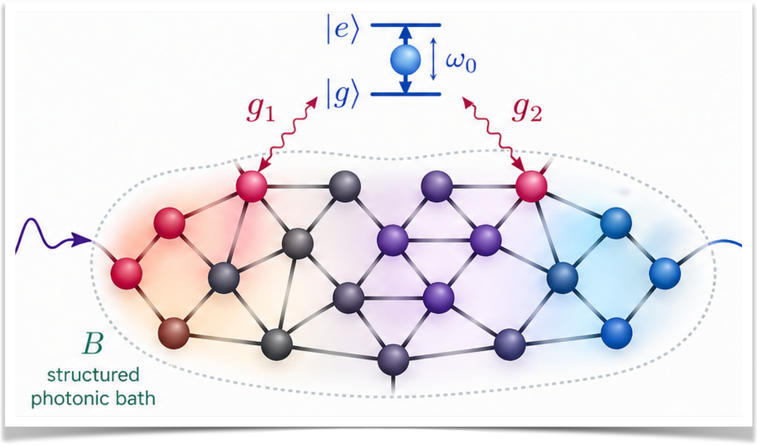
# Theory of Quantum Systems and Processes

## Linee di ricerca (Argomenti di Tesi)




**Quantum Foundations:**
tackling the measurement problem & the fundamental nature of gravity

### Quantum Optics in structured photonic baths




A. Carollo



F. Ciccarello



S. Lorenzo



G. M. Palma

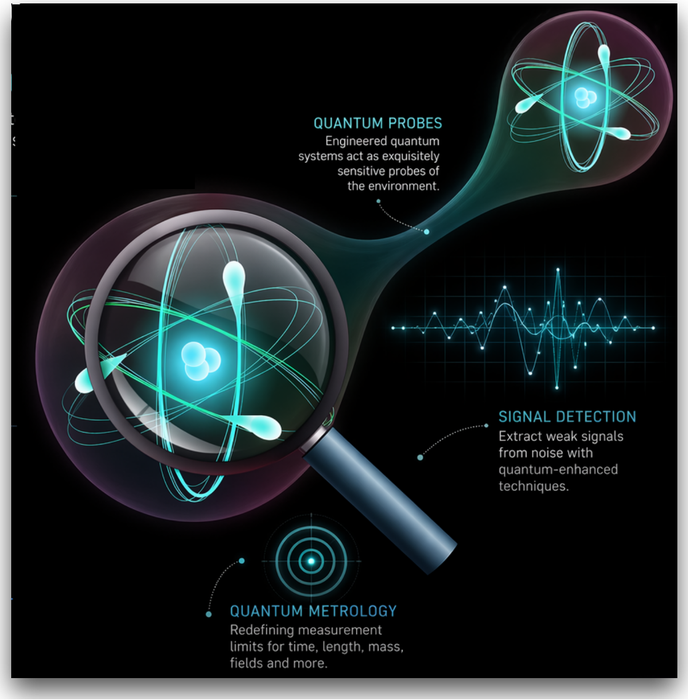


M.Paternostro



**Quantum Metrology & Sensing:**

Harnessing quantum systems to measure the world with unprecedented precision




https://quantum.unipa.it/

# Theory of Quantum Systems and Processes

A. Carollo F. Ciccarello S. Lorenzo G. M. Palma M.Paternostro

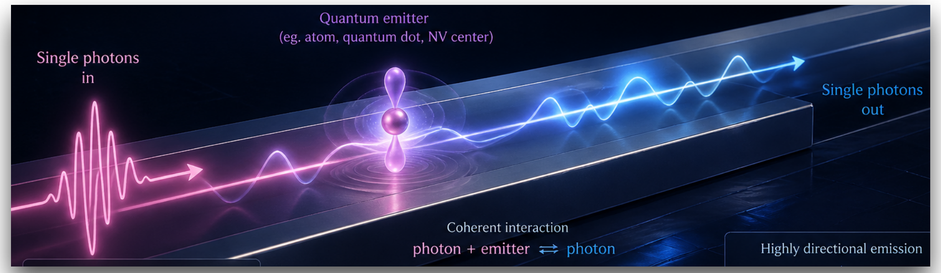






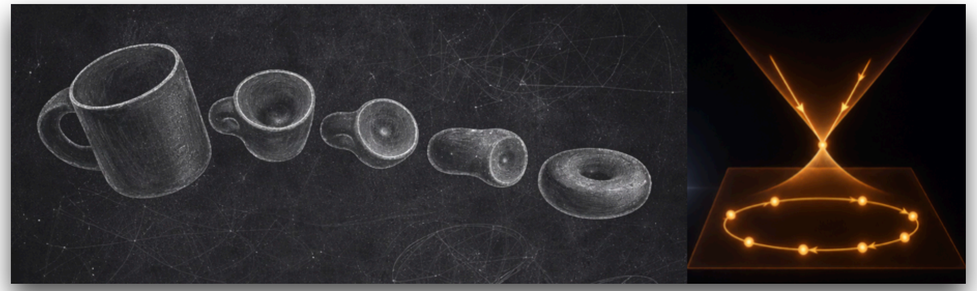
## Linee di ricerca (Argomenti di Tesi)

### Waveguide quantum electrodynamics




Exploing how photons confined in one dimension strongly interact with quantum emitters, enabling controlled light–matter interactions at the single-photon level.

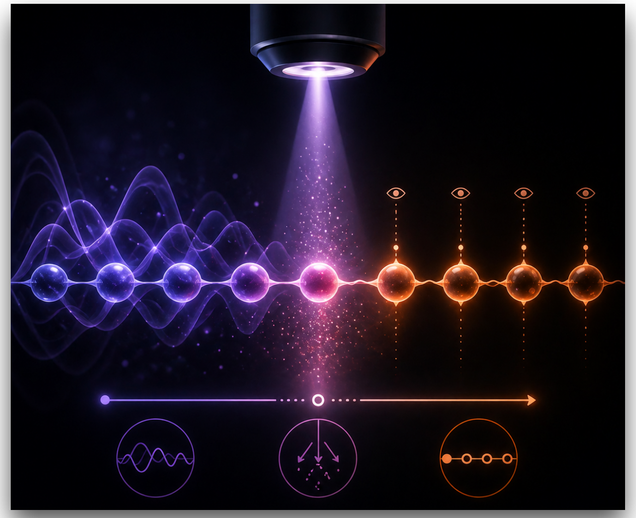
### (Non-Hermitian) topology in quantum physics



Global and robust properties of quantum systems give rise to unique phenomena such as edge states and topological phases.

### Non-equilibrium Quantum many-body physics

Analysing the interplay between many-body interaction, external driving, measurement and dissipation



https://quantum.unipa.it/

# Theory of Quantum Systems and Processes

## Collaborazioni Nazionali e Internazionali (Opportunità di Tesi in collaborazione)

- Universitat Autonoma Barcelona
- University College Dublin
- University of Helsinki
- IFISC Universitat Illes Balears
- University of Malta
- Universität Wien & TU Wien
- University of Southampton
- EPFL- Lausanne
- CNRS- College de France- Paris
- Universität Tübingen
- Sorbonne Université
- CSIC Madrid
- Max Planck Erlangen
- TUM Munich
- Università di Trieste
- Sapienza Università di Roma
- Università Statale di Milano



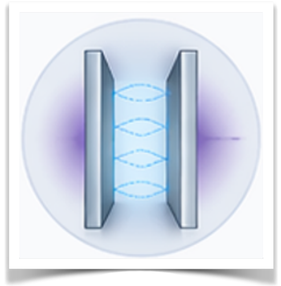

## Argomenti di tesi

- Quantum Machine Learning for biological systems
- Quantum reservoir computing
- Quantum Information in complex quantum systems
- Simulating Quantum Many-Body systems on NISQ
- Quantum Thermodynamics of mesoscopic systems
- Transport properties in chiral quantum systems
- Chiral emission in engineered photonic baths
- Atom-photon bound states in photonic lattices
- Quantum optics with giant atoms
- Non-Hermitian and topological quantum optics
- Measurement induced phenomena in Many-body
- Witnessing quantum gravity
- Falsification of quantum collapse models
- Quantum state engineering of mesoscopic systems

https://quantum.unipa.it/

# Theoretical Physics and Quantum Field Theory

## Linee di ricerca (Argomenti di Tesi)



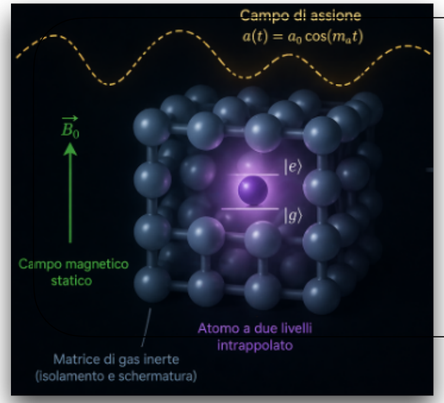
### Quantum Electrodynamics (QED)

- Quantum Electrodynamics
- Quantum vacuum fluctuations
- Casimir physics (static and dynamical Casimir effect, Casimir-Polder forces)
- Radiative processes in structured environments

### Quantum Field Theory (QFT)

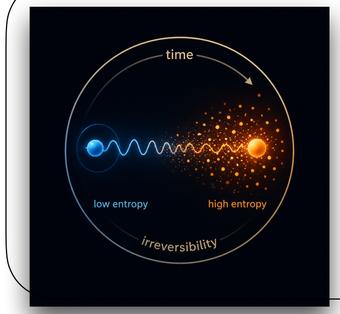
- Quantum Field Theory in curved spacetime and in non-intertial frames
- Unruh and Hawking effects
- Backreaction effects in quantum gravity models
- Quantum fields with fluctuating boundaries and horizons






### Physics Beyond the Standard Model

- Dark energy
- Dark matter
- Axions




### Foundations of Quantum Mechanics

- Irreversibility and Time-symmetry breaking

TPhQFT@unipa
THEORETICAL PHYSICS AND QUANTUM FIELD THEORY GROUP



Roberto Passante



Lucia Rizzuto

# Theoretical Physics and Quantum Field Theory




TPhQFT@unipa

THEORETICAL PHYSICS AND QUANTUM FIELD THEORY GROUP

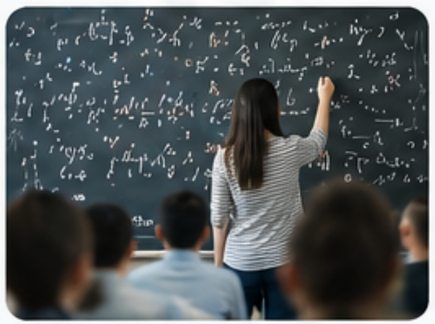
## Collaborazioni Nazionali e Internazionali (Opportunità di Tesi in collaborazione)

- INFN, Laboratori Nazionali di Legnaro (Italy)
- Università di Padova, Dip. Fisica e Astronomia (Italy)
- University of Kassel (Germany)
- Laboratoire Charles Coulomb, Université Montpellier (France)
- Dept. Phys. Science, Osaka Metropolitan University (Japan)
- Center for Complex Quantum Systems, The University of Texas at Austin (USA)
- Wake Forest University Winston-Salem, NC (USA)
- Norwegian University of Science and Technology, Trondheim (Norway)
- University of Glasgow, Glasgow (UK)
- Laboratoire de Physique – ENS Lyon (France)

# Le Opportunità di Lavoro di un Fisico in area Teorica

## I Percorsi Principali

### Didattica



Insegnamento e formazione nelle scuole e università

### Divulgazione



Comunicazione della scienza e divulgazione al grande pubblico

### Ricerca fondamentale



Esplorare le leggi fondamentali della natura e nuovi modelli teorici

### Ricerca applicata



Applicare la teoria per risolvere problemi reali e interdisciplinari

### Settore tecnologico



Sviluppo tecnologico, innovazione e trasferimento tecnologico

## Opportunità legate a Competenze Trasversali

- Problem Solving
- Abilità Matematico-Formali
- Abilità Numerico-Computazionali

### Big Data



Analisi di grandi quantità di dati e modellizzazione complessa

### Finanza Quantitativa



Modellizzazione dei mercati, gestione del rischio e strategie quantitative

### Machine Learning



Algoritmi di apprendimento automatico e intelligenza artificiale

# Le Opportunità di Lavoro di un Fisico in area Teorica

## Opportunità Emergenti: Quantum Information Industry

### Quantum Machine Learning



Algoritmi di machine learning potenziati da risorse quantistiche

### Quantum Cryptography



Comunicazioni sicure basate sui principi della meccanica quantistica

### Quantum Simulation



Simulazione di sistemi complessi in chimica, farmaceutica, scienza dei materiali, fisica…

### Quantum Processing



Sviluppo di hardware e algoritmi per calcolo quantistico

### Quantum Metrology & Sensing



Misure ultraprecise e sensori quantistici per applicazioni in navigazione, medicina e ambiente.

**1. QUANTUM COMPUTING – HARDWARE**
Building scalable quantum processors

- Superconducting Qubits
- Trapped Ions
- Neutral Atoms
- Silicon / Spin Qubits

PASQAL (France) · plangc (Germany) · QUANTUM MOTION (UK)

**2. QUANTUM SOFTWARE & ALGORTIHMS**
Enabling software, algorithms

ZAPATA AI (EU presence)

QCWARE (EU presence)

**3. QUANTUM COMMUNICATION & NETWORKING**
Secure communication and the quantum internet

- ID Quantique (Switzerland)
- KETS Quantum Secu (UK)
- Nu Quantum (UK / Spain)
- Toshiba Europe Quantum (UK)

**4. QUANTUM SENSING & METROLOGY**

BOSCH
Bosch Quantum Sensing (Germany)

**5. ITALY – KEY PLAYERS & RESEARCH NODES**

INFN Istituto Nazionale di Fisica Nucleare
Research & technology development

CINECA
HPC, simulations & quantum integration

Società Italiana di Scienze e Tecnologie Quantistiche

SISTEQ

Dottorato Nazionale in

Quantum Artificial Intelligence