UNIVERSITÀ DI TRENTO

Corso di dottorato in Fisica / PhD in Physics
Ciclo 38 / Cycle 38
A.Y. 2022-2023

Borse a tematica vincolata / Reserved scholarships

A - Molecular astrophysics: challenging reactivity beyond the second period elements via ion-molecule reactions
B - Relaxation dynamics of glasses and supercooled liquids
C - Theory of ultrafast photoinduced phases in technology relevant materials
D – Kinetics of soft matter systems: from statistical mechanics to machine learning
E - Photonic neural network
F - Theory of ultrafast phase transitions
G - Quantum simulators with atoms or photons
H - Quantum-classical hybrid algorithms for real-world inspired application problems using qudits
I-J - Particle, astroparticle, nuclear, theoretical physics, related technologies and applications, including medical Physics
K - Development of a payload for differential flux measurement of low energy particles in space
L - Deep Learning for event selection at the LHC

Scholarship A

PhD Scholarship Title	**Molecular astrophysics: challenging reactivity beyond the second period elements via ion-molecule reactions**
Research group link	https://www.physics.unitn.it/98/fisica-atomica-e-molecolare
Contacts:	Daniela Ascenzi (daniela.ascenzi@unitn.it), Paolo Tosi (paolo.tosi@unitn.it) lab. FAM, Ines Mancini (ines.mancini@unitn.it) - lab. Chimica Bioorganica
Synthetic description of the activity and expected research outcome	The number of molecules detected in space is increasing at a fast pace thanks to the improved sensitivities of telescopes. The presence of complex molecules in regions with extreme temperature and pressure conditions is a great challenge to the comprehension of chemical reactivity. By using an interdisciplinary approach (physics/chemistry/astronomical observations) the project aims at unveiling the formation routes of molecules containing atoms beyond the second period of the Periodic Table (e.g. S, P, Si and Cl). The research will focus on the reactivity of charges species with neutrals using guided ion beam mass spectrometry (also carried out at SOLEIL synchrotron radiation facility). Contact: Daniela Ascenzi (daniela.ascenzi@unitn.it)
Ideal candidate (skills and competencies):	

Scholarship B

PhD Scholarship Title	**Relaxation dynamics of glasses and supercooled liquids**
Research group link	https://www.physics.unitn.it/105/struttura-e-dinamica-dei-sistemi-complessi
Contacts:	prof. Giacomo Baldi Giacomo.baldi@unitn.it
Synthetic description of the activity and expected research outcome	Structural glasses are often considered as archetypes of out-of-equilibrium materials. The proposed activity will focus on the relaxation dynamics of chalcogenide and oxide glasses prepared either under normal ambient conditions or pre-densified with the application of high pressures. Relaxation processes will be monitored by a combination of experimental methods, including laboratory based spectroscopic and calorimetric techniques and advanced X-ray spectroscopies at large scale facilities. The thesis will be held in co-tutoring between the University of Trento and the University of Lyon 1 and the PhD candidate, if successful, will have a PhD degree of both institutions.
Ideal candidate (skills and competencies):	

UNIVERSITÀ DI TRENTO

Scholarship C

PhD Scholarship Title	**Theory of ultrafast photoinduced phases in technology relevant materials**
Research group link	https://webapps.unitn.it/du/it/Persona/PER0195318/Pubblicazioni https://mcalandra.github.io/
Contacts:	m.calandrabuonaura@unitn.it
Synthetic description of the activity and expected research outcome	Ultrafast lasers sources open new perspectives in exploring broken symmetry phases as it becomes possible to promote a substantial number of electrons in excited states generating a thermalized electron-hole plasma and leading to reversible or irreversible phase transitions. Light-induced charge density waves, order-disorder transitions, melting, stabilization of topological phases and laser-tunable ferroelectricity have been demonstrated. Experiments are far ahead of theory as few (if any) of the demonstrated light-induced phenomena have been predicted by theory. In this thesis we plan to develop a theoretical strategy to predict and discover photoinduced phases in materials. To accomplish this goal, we will develop quantum-chemical and molecular dynamics schemes including the effect of the thermalized electron-hole plasma on the crystal potential and accounting for light-induced non-perturbative quantum anharmonicity. We will try to answer questions such as: which systems undergo light induced phase transitions? Can we use light pulses to enhance or tune charge density wave, ferroelectric and magnetic critical temperatures, to generate new topological phases or to optimize the properties of thermoelectric materials? The proposal will impact chemistry, physics, energy and material engineering. It could lead, for example, to the development of devices with dynamical light switching on/off of magnetism or ferroelectricity, relevant for ultrafast memories, or to the stabilization of new thermoelectric compounds with photo-tunable thermal conductivity and figure of merit.
Ideal candidate (skills and competencies):	Good knowledge of quantum mechanics and theoretical solid state physics. Experience in density functional theory or GW/Bethe Salpeter calculations for excited states properties.

Scholarship D

Topic:	**Kinetics of soft matter systems: from statistical mechanics to machine learning**
Research group link	https://sbp.physics.unitn.it/raffaello-potestio/
Contacts:	Raffaello Potestio raffaello.potestio@unitn.it
Synthetic description of the activity and expected research outcome	The position is funded through the FARE Ricerca in Italia - R18ZHWY3NC HAMMOCK (CUP E64I19003120001) project supported by the Italian Ministry of University and Research. The aim of the project is to understand the relation between the kinetic properties of coarse-grained models of soft matter systems and their high-resolution counterpart. The successful candidate will apply the toolbox of statistical mechanics, information theory, and deep learning to gain greater insight into this relation, so as to comprehend the function of macromolecules and model biological systems in and out of equilibrium, and to highlight general principles to guide the design of artificial systems and materials with desired properties.

Ideal candidate (skills and competencies):	Background in physics, chemistry, mathematics, engineering Excellent programming skills (unix os, C/C++, python, matlab, tensorflow)

Scholarship E

PhD Scholarship Title	**Photonic neural networks for optical communications**
Research group link	http://nanolab.physics.unitn.it/index.php
Contacts:	Lorenzo Pavesi (lorenzo.pavesi@unitn.it) Mattia Mancinelli (mattia.mancinelli@unitn.it)
Synthetic description of the activity and expected research outcome	Artificial Neural Networks (ANN) are computational network models that mimic how biological neurons elaborate data. These models have dramatically improved the performance of many learning tasks, including speech and object recognition. The scientific community developed specific electronic architectures that directly behave as an ANN trying to improve the computational speed and energy efficiency. Photonics already boosted the telecom field to a new performance level by exploiting the huge data handling capabilities, speed, and flexibility of optical fibers. The same paradigm is going to be applied to the ANN. The project is inserted in this context where optics will be exploited to find new ways to correct distortion in optical signals that propagate in optical fiber. The aim of the research is the development, simulation, and testing of a neural network chip to mitigate optical nonlinearities in optical fibers. The activity will comprehend the system transmission simulation (with and without the neural network), the neural network simulation, the test of the fabricated circuits, the setup of the testing system, and the validation of the neural network mitigation action in high-frequency transmission experiments which will comprehend multiple fiber spans and different data format. The objective is to demonstrate that photonic neural networks are able to mitigate fiber optic nonlinearities at a high transmission rate. Different protocols will be used to encode the data in order to increase the transmission rates and the benefit of the protocol. This PhD will be part of the ERC-funded BACKUP project (P.I. Prof. Lorenzo Pavesi, Dept. of Physics). More info at https://r1.unitn.it/back-up/
Ideal candidate (skills and competencies):	We are seeking a highly motivated and passionate student, with a strong attitude to work in a collaborative and interdisciplinary team, and with a background in photonics and, possibly, in machine learning.

Scholarship F

PhD Scholarship Title	**Theory of ultrafast phase transitions**
Research group link	https://webapps.unitn.it/du/it/Persona/PER0195318/Pubblicazioni https://mcalandra.github.io/
Contacts:	m.calandrabuonaura@unitn.it
Synthetic description of the activity and expected	Femtoseconds laser can be used to promote charge density waves, order/disorder phase transitions, the non-thermal melting of solids and many other broken symmetry states. However, a complete theoretical understanding for the occurrence of these broken symmetry states after ultrafast light irradiation

research outcome	is missing. We will develop a therotical framework to study and predict possible phase transitions in order to spot relevant photoinduced phases and new exotic phase of matters induced by light (thermoelectricity, ferroelectricity, magnetism, amorphous systems with special properties). Moreover, we will develop a consistent scheme to spot materials in which such kind of transition can take place. Ideal applications will be bulk systems close to structural transitions and 2D materials.
Ideal candidate (skills and competencies):	Passion for theory and computational approaches, good knowledge of quantum mechanics of solid state theory. Knowledge of ab-initio of many body perturbation theory codes will be a plus (albeit it is not necessary as the candidate can lear these techniques in the theory group at uniTN).

Scholarship G

PhD Scholarship Title	**Quantum many-body systems and ultracold gases**
Research group link	https://bec.science.unitn.it/BEC/0_Home.html
Contacts:	Gabriele Ferrari, gabriele.ferrari@unitn.it
Synthetic description of the activity and expected research outcome	Ultracold atomic gases offer a flexible platform to address open problems in fundamental physics such as many-body properties in quantum gases, transport phenomena, quantum simulation of fundamental interactions and gauge fields. The PhD student will work within the interdisciplinary environment of the BEC Center (https://bec.science.unitn.it/BEC/0_Home.html) where research both on theory and experiments is done covering a wide range of themes.
Ideal candidate (skills and competencies):	The ideal candidate should possess good knowledge of quantum mechanics, statistical physics, atomic physics with applications to data analysis and experimental research. The PhD student will work within the interdisciplinary environment of the BEC Center ((https://bec.science.unitn.it/BEC/0_Home.html) where research both on theory and experiments is done covering a wide range of themes.

Scholarship H

PhD Scholarship Title	**Quantum-classical hybrid algorithms for real-world inspired application problems using qudits**
Research group link	https://hauke-group.physics.unitn.it/
Contacts.:	Prof. Philipp Hauke (University of Trento) Dr. Sebastian Schmitt (Honda Research Institute Europe GmbH)
Synthetic description of the activity and expected research outcome	Despite fascinating recent advancements in quantum computers, there are central impediments for their widespread deployment. In particular, there is the need of finding practical and useful applications as well as to overcome restrictions of the scalability of existing hardware.

	Existing quantum computation hardware employs qubits, i.e., two-state quantum systems. A very promising and much less researched alternative is given by multi-level quantum systems, so-called qudits. In principle, qudits allow for more efficient and error-tolerant quantum computation [1]. Yet, qudit quantum computing is a hitherto little researched topic on the level of hardware (e.g., [2-4]) as well as quantum algorithms (e.g., [5,6]). The aim of this PhD work is to make significant advances towards qudit quantum computing. We will investigate the application of hybrid quantum-classical optimization algorithms to industry-inspired optimization problems, e.g., from the scheduling or energy management domain. Here, an important aspect will be the inclusion of constraints as are typically found for industry-relevant problems [6]. A further focus is the theoretical investigation of quantum platforms (ultracold atoms, trapped ions, superconducting qubits) that can naturally realize qudit systems, potentially in collaboration with leading experimental groups. The project will be co-supervised by Honda Research Institute Europe GmbH, which will also ensure the relevance of the considered problems for actual problems from an industry environment. The PhD work will open the door to exploiting an alternative paradigm for quantum computing, leading to increased efficiency and relevant application algorithms. **Literature** [1] See, e.g., https://spectrum.ieee.org/tech-talk/computing/hardware/qudits-the-real-future-of-quantum-computing [2] Kues, et al., On-chip generation of high-dimensional entangled quantum states and their coherent control, Nature 546, 622–626 (2017). [3] Ringbauer, et al., A universal qudit quantum processor with trapped ions, arXiv:2109.06903 [4] Weggemans, et al., Solving correlation clustering with QAOA and a Rydberg qudit system: a full-stack approach, arXiv:2106.11672 (2021) [5] Kasper, et al. Universal quantum computation and quantum error correction with ultracold atomic mixtures, Quantum Sci. Technol. 7 015008 [6] Deller, et al., Quantum approximate optimization algorithm with qudits, in preparation (2021)
Ideal candidate (skills and competencies):	The ideal candidate has a strong background in quantum mechanics, in particular with courses on quantum information and quantum computing, as well as related subjects such as quantum optics, atomic physics, classical information theory, and numerical optimization. Furthermore, strong analytical and computational skills are required. He/she should have a high interest in interdisciplinary research questions.

Scholarship I-J

PhD Scholarship Title	**Particle, astroparticle, nuclear, theoretical physics, related technologies and applications, including medical Physics** (2 positions)
Research group link	INFN
Contacts.:	For further information on the possible research topics see www.infn.it or contact Rita Dolesi for experimental Physics (Rita.Dolesi@unitn.it); Francesco Pederiva for theoretical Physics (Francesco.Pederiva@unitn.it) Chiara La Tessa for applied and medical physics (chiara.latessa@unitn.it)
Synthetic description of the activity and expected research outcome	The thesis topics will be selected within the many areas of forefront research pursued at Trento Institute for Fundamental Physics and Applications (TIFPA) of INFN. Current main activities include: 1) experimental particle and astroparticle Physics, 2) experimental gravitation both earth and space based, 3) gravitational wave astronomy,

	4) antimatter related experiments, 5) R&D on particle and radiation detectors and other solid state quantum micro devices, 6) computational Physics and AstroPhysics, 7) theory of fundamental interactions, 8) theoretical cosmology , 9) medical physics applied to therapy with high energy charged particles
Ideal candidate (skills and competencies):	

Scholarship K

PhD Scholarship Title	**Development of a payload for differential flux measurement of low energy particles in space**
Research group link	https://sd.fbk.eu/en/research/custom-radiation-sensors-crs/
Contacts.:	Dr. Giancarlo Pepponi, (FBK) pepponi@fbk.eu prof. Francesco Nozzoli (TIFPA)
Synthetic description of the activity and expected research outcome	Precise monitoring of the highly dynamic space radiation environment around Earth is crucial for spacecraft safety. It supports development of solar particle flux models and allows studies of space weather and of the interaction of radiation belts with Earth's lithosphere. The project activities include the study of a flat detection geometry to reduce the size of the low energy particle detector. The project also includes the parametric characterization of the sensors, the development as well as testing with particle beams of a detector prototype and more in general the integration of the payload.
Ideal candidate (skills and competencies):	

Scholarship L

PhD Scholarship Title	**Deep Learning for event selection at the LHC**
Research group link	https://www.physics.unitn.it/en/237/astro-particle-physics
Contacts:	roberto.iuppa@unitn.it marco.cristoforetti@fbk.eu
Synthetic description of the activity and expected research outcome	The LHC experiments produce about 90 petabytes of data per year. Inferring the nature of particles produced in high-energy collisions is crucial for both probing the Standard Model with greater precision and searching for phenomena beyond the Standard Model. In this context, event selection is becoming more difficult than ever before and requires expertise at the border between physics and computer science. During the PhD the student will be guided in exploring and designing Deep Learning algorithms to tackle this problem learning how to apply rigorous Data Science methodologies. The activity will be carried out in collaboration with INFN-TIFPA, Fondazione Bruno Kessler and within the ATLAS experiment at the LHC. Candidates familiar with High Energy Physics are welcome, and basic knowledge of Machine Learning/Deep Learning is recommended.

Ideal candidate (skills and competencies):	Basic knowledge of particle physics. Basic skills of scientific programming.