All.1)

ANNEX ___)

PROFILE

PHD PROGRAM IN PHYSICS
in agreement with NATIONAL INSTITUTE OF NUCLEAR PHYSICS, FRASCATI – ROME

CUN Scientific Areas: 02 – Scienze Fisiche

Academic disciplines: FIS/01, FIS/02, FIS/03, FIS/04, FIS/07 (nuovi PHYS-01/A, PHYS-02/A, PHYS-03/A, PHYS-04/A, PHYS-06/A)

Coordinator: Prof. Domenico Di Bari

Administrative Office: Dipartimento Interateneo di Fisica "M. Merlin"
PEC: direzione.fisica@pec.uniba.it

Duration: 3 anni

Curricula: YES
1) Nuclear, subnuclear and astroparticle physics (Academic disciplines: FIS/01, FIS/04) (new PHYS-01/A)
2) Condensed Matter Physics, Photonics and Quantum Technologies (Academic disciplines: FIS/01, FIS/03) (new PHYS-01/A, PHYS-03/A)
3) Fisica applicata (Academic disciplines: FIS/01 e FIS/07) (new PHYS-01/A, PHYS-06/A)
4) Fisica Teorica (Academic discipline: FIS/02) (new PHYS-02/A, PHYS-04/A)

Total positions advertised: **n.14**
- with University scholarship: **n.4**
- with scholarship pursuant to Ministerial Decree no. 630/24: **n.3**
- with scholarship **n.3** funded by the National Institute of Nuclear Physics (INFN) of Frascati, Rome;
- with scholarship **n.2** in the context of the '*Patti territoriali dell'alta formazione per le imprese'*
- with scholarship **n.2** funded by the Italian Space Agency (ASI), Rome;

- **D.M.630/24**

1. **Notice: D.M.630/24:** PNRR - Missione 4, componente 2 "Dalla Ricerca all'Impresa" - Investimento 3.3

- **Project title and scholarship topic**:_ "*Development of an RF electric field atomic quantum sensor"*
- **Description of research activities:** The project falls within the themes of Spoke 7 of the PNRR NQSTI - National Quantum Science and Technology Institute (PE4 - Quantum Science and Technology) extended partnership, with a strong scientific-technological vocation. In particular, the scientific activity will concern the realization of a radiofrequency electric field sensor with vapors of alkaline atoms, confined in microfabricated cells. The project is aimed at the integration of electric field sensors for space and space surveillance awareness (SSA) applications. The project involves interdisciplinarity between atomic physics, quantum optics and microfabrication of alkaline vapor cells. The project is part of the research activities of Prof. Lucivero's group, thanks to which UNIBA is the only Italian member of the international network INMAQS – International Network for micro-fabricated atomic quantum sensors. The project involves co-financing by the company Thales Alenia Space (TASI), in the framework of the PNRR-NQSTI partnership and a period of research abroad at the University of Stuttgart.
- **Co-financing Company/Entity:** Thales Alenia Space (TASI)
- **Period abroad**: minimum 6 months
- **Period at the company/institution provided for by Ministerial Decree no. 630/24**: minimum 6 months

2. **Notice: D.M.630/24:** PNRR - Missione 4, componente 2 "Dalla Ricerca all'Impresa" - Investimento 3.3

- **Project title and scholarship topic**:_ "*Development of radiation-hardened, Silicon Photomultipliers optimized for earth observation and for astroparticle physics experiments"*
- **Description of research activities:** The aim of the project is to contribute to the development of the next generation of single photon detectors, SiPM, currently under development at FBK, through their theoretical study and advanced experimental characterization. In particular, the activity will focus on the development of Backside Illuminated SiPMs, on SiPMs equipped with advanced interconnection techniques towards the reading electronics (e.g., TSV), on 2.5D (and 3D) integration activities between SiPM sensor and reading electronics. The technology of single

photon detectors is strategic in many application sectors, with great potential for impact on society, ranging from medical, to industrial, from space to large physics experiments. The developments covered by this project will allow to achieve improvements in many of these applications and maintain a competitive advantage for FBK and for the Italian research ecosystem. In particular, resistance to radiation damage is one of the major unsolved problems that limit the use of SiPMs in strategic space and "high energy physics" sectors. As a result, a significant part of the efforts will focus on characterizing and improving the characteristics of SiPMs in this area, exploiting the potential introduced by Backside Illuminated technologies.

- **Co-financing company/body:** Fondazione Bruno Kessler (FBK)
- **Period abroad**: minimum 6 months
- **Period at the company/institution provided for by Ministerial Decree no. 630/24**: minimum 6 months

3. **Notice: D.M.630/24:** PNRR - Missione 4, componente 2 "Dalla Ricerca all'Impresa" - Investimento 3.3

- **Project title and scholarship topic**:_ "*Development of piezoelectric patterns by direct 3D writing applied to atomic layer deposition"*
- **Research description:** The deposition of piezoelectric materials in patterns on viscoelastic substrates is not trivial and will be the object of study of this project together with the study of the multimorphic materials obtained. To this end, the interface between substrates and piezoelectrics will be studied and, above all, the mechanical properties of piezoelectric substrates and patterns will be characterized. The central idea will be tested that any point where the stiffness of the material changes can behave as an inflection point and give complex deformations such as out-of-plane bending, bending, twisting, or bending. The method that will be used is direct atomic layer processing (DALP). This is an extremely innovative technique that adapts the ALD process to direct writing: it uses micro-nozzles that deliver the precursors in the immediate vicinity of the substrate, thus exposing only a limited area of the substrate to the action of the ALD process precursors. The process was invented by the Danish start-up, called Atlant 3D and which will be a partner in this PhD scholarship. So far, lateral resolutions of 200-300 μm have been achieved. This technique will be used in this project to create piezoelectric patterns on viscoelastic substrates. The project involves the development of a new multimorphic material with a state-of-the-art deposition technique. Their combination will lead to unprecedented adaptability and logical operation .
- **Co-financing Company/Entity:** Atlant 3D A.P.S.
- **Period abroad**: minimum 6 months
- **Period at the company/institution provided for by Ministerial Decree no. 630/24:** minimum 6 months

- **Territorial pacts for higher education for companies**

1. **Project title and scholarship topic**: "*Study and development of quantum imaging for space observation"*

- **Description of research activities:** The topics of the project are perfectly consistent with those envisaged within the PNRR PE National Quantum Science and Technology Institute (NQSTI) project. The close collaboration of the proposing group with Italian and international institutions, companies and universities, strongly favors the adhesion of the project to international networks. The development of interdisciplinarity and intersectorality is guaranteed by the necessary interactions with colleagues from various disciplinary fields (from biology and medicine, to aerospace and security) interested in super-resolved imaging technologies; Collaborations with biologists, physicians, and corporate personnel in the aerospace and safety sector are already underway.
- **Co-financing company:** Thales Alenia Space (TASI)
- **Period abroad**: minimum 6 months
- **Period at the company/institution:** minimum 6 months

2. **Project title and scholarship topic**: **"***Development of satellite data fusion algorithms for inno-vative remote sensing services"*

- **Description of research activities:** L'obiettivo del progetto è l'analisi, la progettazione e lo sviluppo di tecniche, anche AI-based, finalizzate alla fusione di dati satellitari sia dati ottici che SAR al fine di mettere a punto servizio di osservazione della Terra innovativi basati sull'uso delle più recenti missioni satellitari. A tale scopo, saranno affrontati studi e sviluppi finalizzati a valorizzare i dati derivanti dalla costellazione satellitare IRIDE prevista dal PNRR.
- **Company/Co-financing body:** Geophysical Applications Processing (GAP) srl
- **Period abroad**: minimum 6 months
- **Period at the company/institution:** minimum 6 months

- ***Additional places with scholarships (2 ASI)***

1. **Project title and scholarship topic**: **"***Advanced cubesat technologies for space weather studies"*

- **Research Description:** CubeSats are miniaturized satellites that offer a versatile and cost-effective platform for conducting a wide range of experiments in space. The study of space weather is of great importance for understanding and mitigating the effects of solar radiation and magnetic storms on terrestrial technology, orbiting satellites and power grids. CubeSats can be used to monitor space climate in innovative and efficient ways. Advanced technologies employed in CubeSats to study the space climate may include solar sensors to measure the intensity and spectrum of solar radiation, magnetometers to monitor magnetic fields, spectrometers to analyze the composition of charged particles in the surrounding space, and devices to measure the density and temperature of plasmas. The use of CubeSats to study the space climate offers several advantages, including the ability to quickly and cheaply launch a constellation of satellites to cover a large area of space, the ability to conduct experiments in low Earth orbit for long periods of time, and the ability to rapidly deploy new technologies and sensors. The use of advanced technologies in CubeSats to study the space climate offers an exciting opportunity to broaden our understanding of this phenomenon and improve our ability to predict and mitigate its effects.
- **Co-financing company/body:** Italian Space Agency (ASI)
- **Period abroad**: 6 months
- **Period at company/institution:** 12 months

2. **Project title and scholarship topic**: **"***Security of Quantum Cryptography"*
- **Research description:** Among the main elements contributing to the development of quantum communications are security demonstrations. In fact, the security of a quantum cryptography protocol cannot be measured directly in the laboratory, but must be mathematically demonstrated from experimental data. Currently, one of the major open problems, to which numerous research groups around the world are dedicated, concerns the security of quantum cryptography based on continuous variables, i.e. on phase coding and quadrature of the electromagnetic field. Solving this problem will foster the development of quantum cryptography protocols that will be characterized by high compatibility with existing infrastructures, both for terrestrial and satellite communication channels. The research activity proposed for this PhD scholarship will therefore have as its object: - the mathematical modeling of the physical systems used for quantum cryptography with continuous variables; - the development of new continuous variable protocols; - the development of new techniques and methodologies to demonstrate the security of quantum cryptography; - the simulation and feasibility study of these protocols, with particular attention to satellite communications.
- **Co-financing company/body:** Italian Space Agency (ASI)
- **Period abroad**: 12 months
- **Period at the company/institution:** 3 months

- ***Additional positions with scholarships (3 INFN)***

- **n.3** scholarships with the **funding body**: National Institute of Nuclear Physics (INFN);

Admission procedures for ordinary places:

The selection will take place in accordance with art. 6 **letter C)** of the call for applications and oral exam, with verification of knowledge of the English language.
The test will consist of an interview on fundamental topics of physics of the Bachelor's Degree in Physics, on the candidate's research interests related to the PhD in physics, as well as on the research project presented.
The places put up for competition will be assigned according to the order in the merit list, until all places are filled.

Procedures for carrying out the tests for foreign candidates:
Foreign candidates can choose to take the entrance exam in Italian or English.

Calendar and location of the entrance exam:
Evaluation of qualifications: 31 July 2024, 10.00 am at the Department of Physics, Meeting Room, University Campus, via Orabona 4, Bari, Italy.
Oral exam: 1 August 2024, 10.00 am at the Department of Physics, Room A, University Campus, via Orabona 4, Bari, Italy.

For more information, please visit the website: https://dottorato.fisica.uniba.it/