POLITECNICO DI MILANO

PhD in FISICA / PHYSICS - 39th cycle

PNRR 118 PNRR Research Field: ADVANCED X-RAY SPECTROSCOPIES OF CORRELATED TRANSITION METAL OXIDES

Monthly net income of PhDscholarship (max 36 months)
€ 1195.5 In case of a change of the welfare rates during the three-year period, the amount could be modified.

Context of the research activity	
Motivation and objectives of the research in this field	With reference to the *Piano Nazionale della Ricerca* (PNR 2021-2027), and according to the research priority actions on "nuovi materiali e nuove tecnologie per batterie ad alta capacità" within the "CLIMA, ENERGIA, MOBILITÀ SOSTENIBILE", and on "Tecnologie quantistiche per la sensoristica e la metrologia" and "Tecnologie quantistiche per l'efficienza e la sostenibilità energetica", within the DIGITALE, INDUSTRIA, AEROSPAZIO research and innovation areas, we will conduct research on the design of new functional materials useful to reduce energy consumption and to enhance performances of electronic devices (*green ICT*).Transition-metal oxides display a variety of physical properties, thus making them a vast playground for fundamental investigations and appealing for technological applications. Ultimately, this richness derives from the spin, charge, orbital and lattice degrees of freedom simultaneously at play, giving rise to a delicate competition between various energy scales of comparable magnitude. This makes transition metal oxides sensitive to external stimuli, such as electric and magnetic fields, physical and chemical pressure, strain and doping, and produces peculiar cross-coupled effects, including magnetoresistance, magnetoelectricity and piezoelectricity. Understanding and exploiting these effects is still one of the challenges in fundamental and materials sciences.In recent years, particular attention has been paid to transition metal oxides of the 5d series having simultaneously strong spin-orbit interaction and sizable electronic correlation and featuring a plethora of unconventional properties. Research in this field focuses

	on the study of relativistic Mott insulators, a novel family of correlated electron systems in the strong spin-orbit coupling regime, which we aim to understand, engineer and, ultimately, control. We concentrate on superlattices of iridium oxides to explore the regime where the energy scales of electronic correlation, bandwidth, spin-orbit interaction and ligand field are comparable. The main impact of our project is scientific, as we aim to understand the quantum origin of their unexpected macroscopic behaviours, related to metal-to-insulator and magnetic transitions. But we speculate that the possibility to tune and control macroscopic transport and magnetic properties of iridate thin films by strain could be particularly appealing for technological exploitation in the field of spintronics.
Methods and techniques that will be developed and used to carry out the research	Knowledge of the microscopic mechanisms governing the physics of iridates is a prerequisite to build a solid understanding of the macroscopic transport and magnetic properties of superlattices of relativistic oxides. To this aim, the electronic structure will be studied by x-ray absorption (XAS), including x-ray linear dichroism (XLD), and resonant inelastic x-ray scattering (RIXS). We will collect information on both intra- (ligand-field, spin-orbit coupling, Hund's coupling, magneto-crystalline anisotropy, etc.) and inter- (hopping integrals, exchange interactions of various nature, mixing/hybridization, etc.) ion interactions, as well as other fundamental quantities.
Educational objectives	The student will learn to start, develop, and complete an original and innovative piece of research, which culminates in his or her PhD thesis. In particular, the student will learn the physics of correlated quantum materials through advanced spectroscopy studies and will become an expert of x-ray resonant spectroscopy.
Job opportunities	The PhD programme provides the following principal career options: - research work at university or in public or private research centres, both fundamental and applied; - work at R&D departments in companies in any area of physics, material science and engineering;

	- consultancy or data scientist in companies; - entrepreneurship in high-technology sectors;teaching physics or mathematics at primary and secondary level schools.
Composition of the research group	1 Full Professors 1 Associated Professors 1 Assistant Professors 1 PhD Students
Name of the research directors	Marco Moretti, Giacomo Ghiringhelli

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Additional support - Financial aid per PhD student per year (gross amount)	
Housing - Foreign Students	--
Housing - Out-of-town residents (more than 80Km out of Milano)	--

Scholarship Increase for a period abroad	
Amount monthly	597.75 €
By number of months	6

National Operational Program for Research and Innovation	
Company where the candidate will attend the stage (name and brief description)	Not applicable
By number of months at the company	0
Institution or company where the candidate will spend the period abroad (name and brief description)	The European Synchrotron Radiation Facility (ESRF) - www.esrf.fr - Grenoble (France)
By number of months abroad	6

Additional information: educational activity, teaching assistantship, computer availability, desk availability, any other information
***Educational activities*:** Educational activities (purchase of study books and material, funding for participation to courses, summer schools, workshops and conferences). Financial aid per PhD

student per 3 years: max **4.872,90** euros per student.

***Teaching assistantship*:**There are various forms of financial aid for activities of support to the teaching practice. The PhD student is encouraged to take part in these activities, within the limits allowed by the regulations.

Computer and Desk availability: *a personal laptop and a desk will be made available.*