# ADVANCED NUMERICAL TECHNIQUES FOR MULTI-SCALE PROBLEMS WITH APPLICATIONS

**STEFANO DI GIOVACCHINO[1], NICOLA FERRO[2], SUSANNA MIRABELLA[2], GIOVANNI PAGANO[3], AND FEDERICO PICHI[4]**

[1] Department of Engineering, Computer Science and Mathematics, University of L'Aquila
Palazzo Camponeschi, via Vetoio 67100, L'Aquila, Italy
stefano.digiovacchino@univaq.it

[2] MOX, Department of Mathematics, Politecnico di Milano
Piazza L. da Vinci, 32, Milano, Italy, I-20133
nicola.ferro@polimi.it, susanna.mirabella@polimi.it

[3] Department of Mathematics, University of Salerno
Via Giovanni Paolo II, 132, 84084 Fisciano (SA), Italy
gpagano@unisa.it, G. P. thanks the PRIN PNRR project BAT-MEN P20228C2PP

[4] SISSA, International School for Advanced Studies
Via Bonomea, 265, 34136, Trieste, Italy
fpichi@sissa.it

**Key words:** Multi-Scale problems and simulations, Advanced numerical techniques, Real-world applications, Deep Learning, Parameter estimation, Stiff problems, Stochastic problems.

## ABSTRACT

Mathematical models for real-world applications are often characterized by concurrent macroscopic and microscopic dynamics, both at the temporal and the spatial level, as they aim to describe phenomena evolving across different scales. The derivation of such multi-scale models and the development of advanced numerical techniques able to treat them efficiently represent a fascinating and open challenge. In this context, it is indeed necessary to use mathematical models and numerical methods capable of combining large-scale data with detailed small-scale simulations, managing the strong heterogeneity of the involved phenomena, describing and reproducing interactions between quantities on different levels of magnitude. Typical examples from which multi-scale problems arise are, for instance, models for the management of natural resources with the consequent assessment of environmental impact, chemical reactions that can occur in the charging/discharging processes in batteries, ecological and hydrological phenomena related to plant-soil interactions.

The aim of this session is to bring together researchers oriented towards both mathematical models and advanced efficient numerical methods for the simulation of complex applications, with a focus on the challenging solution of different spatial and temporal scales, as well as stiffness properties. Indicative topics for presentations and discussions include, but are not limited to: innovative multi-scale modeling approaches; development and use of deep learning and artificial intelligence techniques; advanced methods for parameter estimation; numerical modeling for stiff differential equations; numerical modeling for stochastic problems; applications to real-world problems (e.g., materials deterioration, supply chain dynamics, sustainability issues at large).