



ETTORE MAJORANA FOUNDATION AND CENTRE FOR SCIENTIFIC CULTURE
1963–2023
60th ANNIVERSARY OF ACTIVITIES



INTERNATIONAL SCHOOL OF COMPLEXITY

18th Course: MACHINE LEARNING APPROACHES FOR COMPLEXITY

ERICE-SICILY: 23 – 29 APRIL 2024

Sponsored by the: • Italian Ministry of Education, University and Scientific Research • Sicilian Regional Government

PROGRAMME AND LECTURERS

Machine learning and artificial intelligence
• F. FABROCINI, Tongji University, CN

Machine learning and graph methods
• C. CANNISTRACI, Tsinghua University, Beijing, CN

Modelling capabilities of energy-based generative models
• B. SEOANE, Paris-Saclay University, FR

Large language models and deep learning for computer vision and time series: From academia to industry
• F. FREITAS, EDF Energy, London, UK

Applications of Fourier analytic Barron space theory
• J.A. MILLER, Euler Scientific, Fremont, CA, US

Statistical physics for machine learning
• A. DECELLE, Universidad Complutense, Madrid, ES

Modelling complex systems as interacting agents
• C. FIELDS, Tufts University, Medford, MA, US

Neural networks, quantum physics, and gravity
• K. HASHIMOTO, Kyoto University, JP

Data-driven and equations informed tools for Eulerian and Lagrangian turbulence
• L. BIFERALE, Università di Roma Tor Vergata, IT

Sparse Communication in machine learning and Hopfield networks
• A. MARTINS, Instituto Superior Técnico, Lisbon, PT

Quantum machine learning
• F. CARUSO, University of Firenze, IT

Analytical approaches to the learning dynamics of neural networks
• S. GOLDT, International School of Advanced Studies, Trieste, IT

Data, relations and their shape
• R. SAZDANOVIC, North Carolina State University, Raleigh, NC, US

PURPOSE OF THE COURSE

With this School, we aim at highlighting to the students and young researchers a strong link between topological geometry, statistical mechanics, condense matter physics, quantum chemistry and high energy physics, shedding light on the emergence of a wealth of intriguing and unprecedented possibilities involving Artificial Intelligence, notably Quantum Machine Learning (QML). On the other hand, QML has been proved to be a very fertile and promising field of research, interweaving among quantum computing and machine learning. Within this framework, QNNs have been introduced that can be labelled by data that are classical or quantum, and can be trained by supervised learning. These structures allow to implement most part of the analyses developed on the side of TQFT, further providing the great chance to implement and engineer topological constructions within TMs of novel generations, including novel materials featuring fragile topologies based on either topological insulators or devices composed by graphene sheet layers. Thus, one of the key goals of the School is to demonstrate a strong link between topological quantum physics and QML, resorting to a cross-fertilisation among different research areas, including also topological geometry and quantum field theory and related areas. The main focus of the School is to connect the mathematical foundation of complex systems to quantum computing and Artificial Intelligence, and to elucidate the applications of these approaches to the fields of statistical physics, quantum theory, condensed matter theory and topological materials. The main topics will include fundamental physics applications of QML and quantum neural networks, categorification of topological properties, string-net models in solid state physics. These topics will be interwoven in order to shed light on their mutual interdependence. World leading experts will be invited to give lectures on selected topics to PhD students and young scientists with interests in theoretical physics, geometric topology, theoretical computer science, material science. Our School thus that would bring deep knowledge, insights and inspiration from dynamics of complex systems in fundamental physics, condensed matter, quantum chemistry, topological geometry as well as advancements in QML shedding light on their common features, novel synergies and advance applications.

APPLICATIONS

Persons wishing to attend the Course should send an application, by electronic mail, to:
Professor Andrea RAPISARDA
email: andrea.rapisarda@ct.infn.it

Specifying: i) Date and place of birth together with present nationality; ii) Present position and place of work; iii) An abstract, if they wish to give a contribution (oral or poster).

POETIC TOUCH

According to legend, Erice, son of Venus and Neptune, founded a small town on top of a mountain (750 metres above sea level) more than three thousand years ago. The founder of modern history — i.e. the recording of events in a methodic and chronological sequence as they really happened without reference to mythical causes — the great Thucydides (~500 B.C.), writing about events connected with the conquest of Troy (1183 B.C.) said: «*After the fall of Troy some Trojans on their escape from the Achaei arrived in Sicily by boat and as they settled near the border with the Sicanians all together they were named Elymi: their towns were Segesta and Erice.*»

This inspired Virgil to describe the arrival of the Trojan royal family in Erice and the burial of Anchises, by his son Aeneas, on the coast below Erice. Homer (~1000 B.C.), Theocritus (~300 B.C.), Polybius (~200 B.C.), Virgil (~50 B.C.), Horace (~20 B.C.), and others have celebrated this magnificent spot in Sicily in their poems. During seven centuries (XIII-XIX) the town of Erice was under the leadership of a local oligarchy, whose wisdom assured a long period of cultural development and economic prosperity which in turn gave rise to the many churches, monasteries and private palaces which you see today.

In Erice you can admire the Castle of Venus, the Cyclopean Walls (~800 B.C.) and the Gothic Cathedral (~1300 A.D.). Erice is at present a mixture of ancient and medieval architecture. Other masterpieces of ancient civilization are to be found in the neighbourhood: at Motya (Phoenician), Segesta (Elymian), and Selinunte (Greek). On the Aegadian Islands — theatre of the decisive naval battle of the first Punic War (264-241 B.C.) — suggestive neolithic and paleolithic vestiges are still visible: the grottoes of Favignana, the carvings and murals of Levanzo.

More information about the activities of the Ettore Majorana Foundation can be found on the WWW at the following address:
<https://ettoremajoranafoundation.it>

PLEASE NOTE

Participants must arrive in Erice no later than 12 a.m. on 23rd April 2024.

M. LULLI – A. MARCIANO – R. PASECHNIK – E. ZAPPALA
DIRECTORS OF THE COURSE

A. ZICHICHI
DIRECTOR OF THE SCHOOL
G. BENEDEK – A. RAPISARDA – C. TSALLIS
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