



ALMA MATER STUDIORUM
UNIVERSITÀ DI BOLOGNA

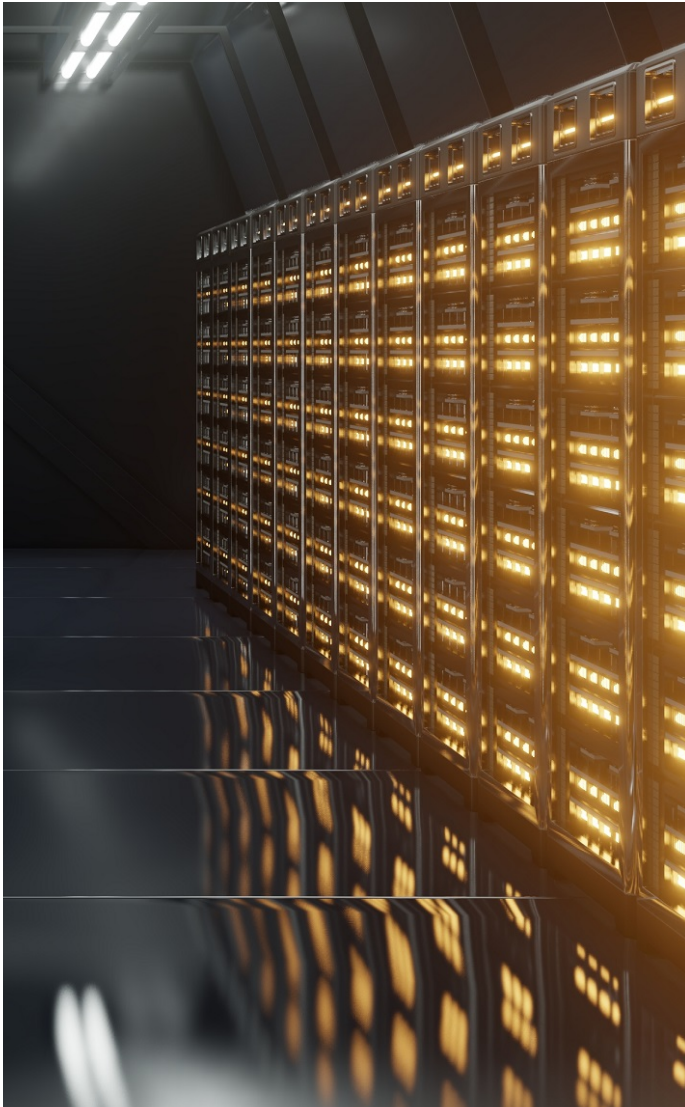
High-Performance and Quantum Computing

A.Y. 2024/2025

II LEVEL PROFESSIONAL MASTER

High-Performance and Quantum Computing

Context and Motivations



- The HPQC Master is **designed and promoted by the Physics and Astronomy Department** of the Bologna University (in collaboration with several other departments in the STEM area)
- In our research activities as physicists, we have witnessed **a steady increase in the relevance of computational methods and technologies** over the past decades
- Such a trend has seen **an impressive acceleration in the past few years** thanks to the development of **Machine Learning** algorithms, the huge increase in the **computational power** of the largest supercomputers in the world, and the advent of the first prototypes of **Quantum Computers**
- In parallel, computational methods and technologies — often directly inherited from scientific developments — **have become of fundamental importance in all strategic sectors of society**, in the R&D activities of private companies and industries, and in the management of Big Data.

High-Performance and Quantum Computing

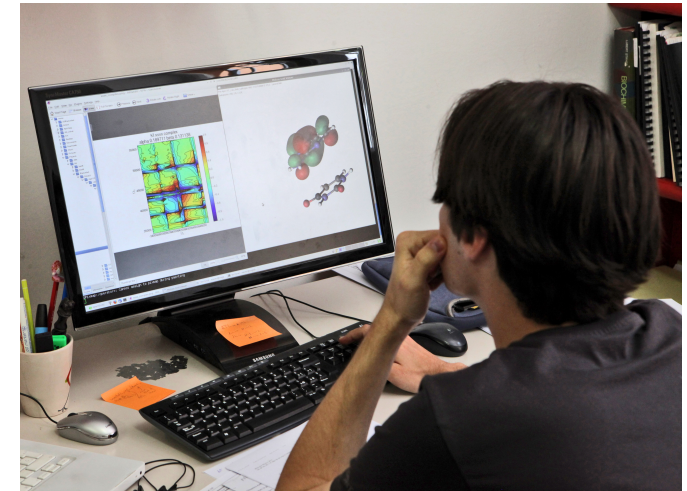
General Overview

- Such rapid development of computing and data-sharing technologies has led to **a revolution in the use of computational resources in all sectors of society**
- This led to **the emergence of new professional profiles** with the ability to **bridge the gap** between scientific research (where computational methods and technologies are developed) and the business world where these are applied to practical problems in all strategic sectors of society.
- The HPQC Master aims to offer **a professionalizing pathway** that allows young graduates in technical and scientific disciplines **to fit into such a dynamic and rapidly expanding national and international context**, by training experts in:
 - ◆ Algorithms and numerical methods for the **modelling** and the **simulation** of complex systems
 - ◆ **High-performance and large-scale computation** and **data management**
 - ◆ **Quantum methods and algorithms** on different platforms
 - ◆ Machine Learning and **Artificial Intelligence methods and applications**

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Goals and Opportunities

- The main goal of the HPQC Master is to integrate expertise and skills from different academic disciplines into **a new professional figure matching the needs of the rapidly expanding market of scientific computing**
- At the end of the Master, participants will have acquired a sound knowledge of **scientific modeling and computational techniques**, proficiency in **programming** for high-performance computing, and practical skills to **apply such techniques for analysing and solving complex problems**
- HPQC experts can **join private and public companies, agencies, archives and institutions** nationally and internationally, holding roles such as e.g.:
 - ◆ Responsible for a scientific or industrial research project requiring advanced computational techniques
 - ◆ Developer of parallel codes and quantum algorithms
 - ◆ Expert in management and analysis of large amounts of data (Big Data) in public or private research
 - ◆ Support and management of computing centers



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Structure of the Master

- The HPQC Master is structured to **combine academic lectures, thematic seminars, and practical internships** to work on specific projects directly at the premises of the HPQC Master's Partners

Frontal Lectures and Hands-on

- 280 hours of lectures divided into 15 distinct courses, **all in English**
- Each course may be further divided into modules
- Many courses include **specific hands-on modules** to directly apply the skills presented in the frontal lectures
- **Compulsory attendance** of minimum 80%
- **Most Lectures** will be delivered **online**
- Average of **~20 hours/week, Monday through Friday, from January to June**

Thematic Seminars

- A series of seminars held by **national and international experts**
- Show current **state-of-the-art applications** of the concepts presented in the lectures
- 24 hours in total

Internship or Project Work

- **575 hours of internship** to be held directly at the premises of some of the HPQC Master's Partners
- The list of Partners includes several **public agencies and private companies** with a strong involvement in cutting-edge computational enterprises (see below)
- For PhD Students or workers the **internship may be replaced by a Project Work** to be defined in agreement with their PhD or professional supervisor

High-Performance and Quantum Computing

The 3 main pillars of the HPQC Master

High-Performance Computing

Learn how to model complex physical systems and build efficient numerical codes to simulate their evolution, exploiting at best the most advanced supercomputing infrastructures, including large parallel systems and accelerators such as GPUs

Machine Learning & Artificial Intelligence

Grow cutting-edge skills in AI and ML/DL techniques, develop intelligent systems capable of learning from vast data, optimize complex processes, solve complex problems and drive innovation.

Quantum Computing

Explore Quantum Computing paradigms (digital, analogue, hybrid) and quantum machine learning, starting from fundamentals to examples of digital and variational algorithms as well as providing an introduction to error correction codes.

High-Performance and Quantum Computing

The 3 main pillars of the HPQC Master

High-Performance Computing

Applications may include e.g. weather and climate modeling, aerospace or automotive engineering simulations, computational fluid dynamics simulations, Big Data analysis models, materials modelling and design, and many others

Machine Learning & Artificial Intelligence

Application may include e.g. autonomous technologies for scientific discovery, anomaly detection in complex datasets, predictive modeling in finance, healthcare diagnostics through pattern recognition, optimisation of resource allocation in logistics, and more.

Quantum Computing

Applications may range from classical combinatorial problems that describe optimization problems in many fields (logistics, scheduling, finance) to inherently quantum cases such as molecule or materials modelling; advantages and disadvantages of different real hardware platforms will be examined.

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HPQC Teaching Plan

- 1. Big Data Paradigms and Technologies**
Paolo Bellavista, Daniele Cesini, Luca Foschini
- 2. Numerical Techniques for System Modelling**
Enrico Baglione, Paolo Oddo
- 3. Computational Fluid Dynamics**
Federico Marinacci, Francesco Calura, Carlo Cintolesi
- 4. Methods and Algorithms for Many-Body Global Problems**
Marco Baldi, Alessandro Casalino
- 5. Introduction to Discriminative AI Methods**
Daniele Bonacorsi, Tommaso Diotalevi, Luca Clissa, Andrea Galassi
- 6. Introduction to Generative AI Methods and Synthetic Data**
Mirko Degli Esposti, Daniel Remondini, Andrea Asperti
- 7. Introduction to Quantum Computing**
Elisa Ercolessi, Ugo Dal Lago, Marco Chiani, Lorenzo Valentini
- 8. Introduction to High-Performance Computing**
Gianluigi Zavattaro, Alessandro Casalino, Alessandro Romeo
- 9. Variational Quantum Algorithms and Quantum Machine Learning**
Ivan Rivalta, Giacomo De Palma, Filippo Orazi, Francesco Calcagno
- 10. Fundamentals of Computing**
Gianluigi Zavattaro, Andrea Bartolini
- 11. Accelerated Computing**
Moreno Marzolla, Claudio Gheller
- 12. Materials Modelling and Design**
Maria Clelia Righi, Paolo Restuccia
- 13. Quantum SDKs**
Davide Pastorello, Daniele Ottaviani, Simone Gasperini
- 14. Climate Change Modelling**
Paolo Ruggieri
- 15. Practical Applications for Fluid Dynamics**
Carlo Cintolesi, Federico Marinacci, Francesco Calura

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Admission Requirements

- Requirements for Admission:

- ◆ **A postgraduate degree in STEM disciplines**, including: Biology LM-6, Physics LM-17, Computer Science LM-18, Aerospace Engineering LM-20, Biomedical Engineering LM-21, Chemical Engineering LM-22, Automation Engineerings LM-25, Security Engineering LM-26, Telecommunications Engineering LM-27, Electrical Engineering LM-28, Electronic Engineering LM-29, Energy and Nuclear Engineering LM-30, Computer Engineering LM-32, Mechanical Engineering LM-33, Mathematics LM-40, Mathematical-physical Modeling for Engineering LM-44, Materials Science and Engineering LM-53, Chemical Sciences LM-54, Astrophysics and Cosmology LM-58, Computer Security LM-66, Industrial Chemistry LM-71, Geophysical Sciences LM-79
- ◆ Other Master degrees may be considered based on the CV of the candidate
- ◆ Familiarity with at least **some programming languages and environments**
- ◆ **Proficiency in English** (B2 CEFR level)

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Application Procedures and Enrolment

The application for the HPQC Master selection must include the following documents:

- front and back copy of a valid identity document;
- certification of degree (see the Call for Applications for details on the specific documents that are required)
- curriculum vitae
- Data sheet (available as annex to the call) including any other qualifications of the candidate

The payment of a **participation fee of Euro 60,00** is requested to submit your application.

The **fee for enrolling in the HPQC Master is 4,700 Euros**, to be paid in two installments (2,500 + 2,200)

Thanks to the financial contributions from INAF and CINECA some reduced fees are available:

- **1 reduced fee of 2,500 Euro for the first candidate in the selection ranking**
- **2 reduced fees of 3,700 Euro for the second and third candidates in the selection ranking**

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Possible adaptations for workers or PhD students

The HPQC Master can be attended **while being employed in a company** or **while pursuing a PhD project**, provided that these activities allow you to participate in at least 80% of the Master's lectures.

For PhD students

- The internship period can be replaced by a **Project Work** to be agreed between you/your PhD supervisor and the HPQC Master faculty staff and partners
- The Project Work must be approved by the HPQC Master's Director (as for standard internships)
- **Part of the HPQC Master's lectures may count as Doctoral University Credits** (depending on the regulations of your specific PhD program)

For workers

- The internship period can be replaced by a **Project Work** to be agreed between you/your employer and the HPQC Master faculty staff and partners
- The project work must be approved by the HPQC Master's Director (as for standard internships)

High-Performance and Quantum Computing

Patronage, Sponsorships and Partnerships

- The HPQC Master features **a solid network of public and private partners** that will provide **teaching contributions**, internships, access to computing infrastructures/resources, financial support and patronage

HPQC Lectures
will be delivered
by experts from:



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INGV

CINECA

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Internships will be available at several public agencies and private companies:



INGV

CINECA

ECMWF



cmcc

ItaliaMeteo

arpae
emilia-romagna

Leitha



E4
COMPUTER
ENGINEERING

IBM

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The access to computing infrastructures and the use of computational resources will be provided to all HPQC Master students by:



CINECA

High-Performance and Quantum Computing

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**Financial support is
provided to the HPQC
Master by:**



CINECA

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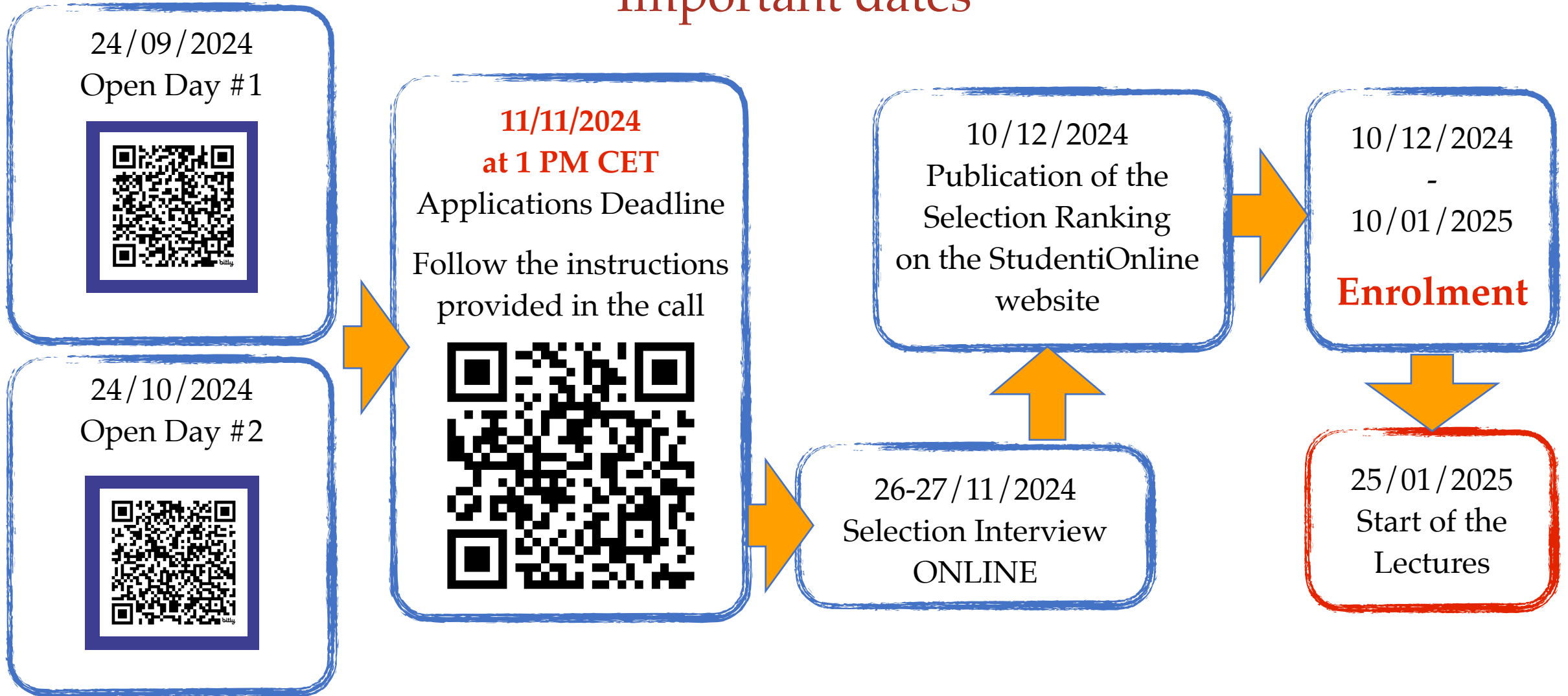


The HPQC Master has
received the patronage of:



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Important dates



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Contacts and other references

For any reference on the Master visit the HPQC official website

<https://master.unibo.it/hpqc/en>

For information and enquiries on the Masters activities, please contact:

master.hpqc@unibo.it

For information and enquiries on the Application procedures, please contact:

master@unibo.it





ALMA MATER STUDIORUM
UNIVERSITÀ DI BOLOGNA

II level professional Master High-Performance and Quantum Computing

DIRECTOR

Prof. Marco Baldi
Department of Physics and Astronomy
"Augusto Righi"

OPEN DAY ONLINE

September 24th, 2024 / 5 pm
October 24th, 2024 / 5 pm

APPLICATION DEADLINE

November 11th, 2024

LECTURE'S VENUE

Department of Physics and Astronomy
"Augusto Righi"
Viale Carlo Bertini Pichat 6/2, Bologna

TEACHING

January - December 2025
280 hours of lectures/seminars
80% mandatory attendance
60 CFU

GRANTSHIPS

Thanks to the contribution of INAF
and CINECA, reduced fees and
grants are available

CALL FOR APPLICATION

bit.ly/master-hpqc-24-25

