Quantum Computing @ Leonardo Labs

Daniele Dragoni P.I.

Alberto Bianchi
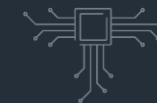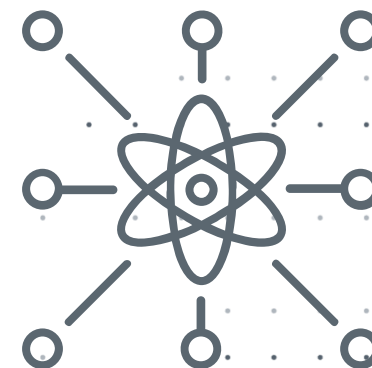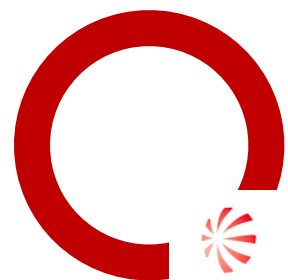
Quantum Computing Lab in a Nut-shell
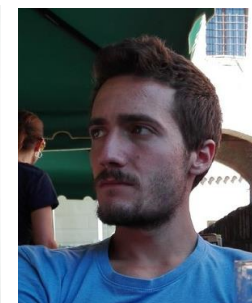
Quantum Computing Laboratory

The Team

Daniele Dragoni PhD
Principal Investigator

Alessandra Lignarolo
Researcher

Matteo Vandelli PhD
Researcher

Francesco Ferrari PhD
Researcher

Francesco Turro PhD
Researcher

Marco Maronese PhD
Researcher

Internal Projects	External Collaborations	Ph.D.s	Innovation Grants	Hardware Providers
CYBER PROTECTED FUTURE	ISTITUTO ITALIANO DI TECNOLOGIA, CINECA, UNIVERSITÀ DEGLI STUDI DI PADOVA, NASA Ames Research Center	GRAN SASSO SCIENCE INSTITUTE SCHOOL OF ADVANCED STUDIES Scuola Universitaria Superiore, POLITECNICO MILANO 1863, SISSA	ICSC Centro Nazionale di Ricerca in HPC, Big Data and Quantum Computing, eni, ThalesAlenia Space, iFAB, UNIVERSITÀ DEGLI STUDI DI PADOVA, iit ISTITUTO ITALIANO DI TECNOLOGIA	D:WAVE The Quantum Computing Company, IBM, PASQAL, NVIDIA, IONQ, DAVINCI-1 LEONARDO'S NEW SUPERCOMPUTER

Quantum Computing Lab

Quantum Computing
Laboratory

Mission

Explore **opportunities & challenges** of QC to evaluate practical utility – build **in-house expertise** to generate pre-competitive advantage

Vision

Deliver Quantum Computing solutions for **LDO Divisions** and *key* **External Clients**

Positioning

Many **HW platforms** with rapid advancements but **ALL small** with **Pros & Cons**

→ Focus on **algorithm development**
→ Develop in-house **HPC emulation capabilities**
→ Benchmark most promising platforms
→ Investigate **QC and HPC HW integration**
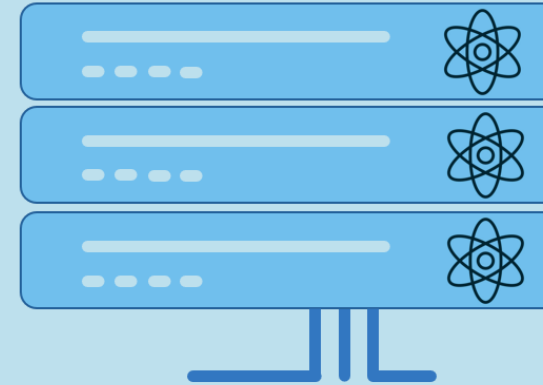
Quantum Computing Streams

High-Performance Computing
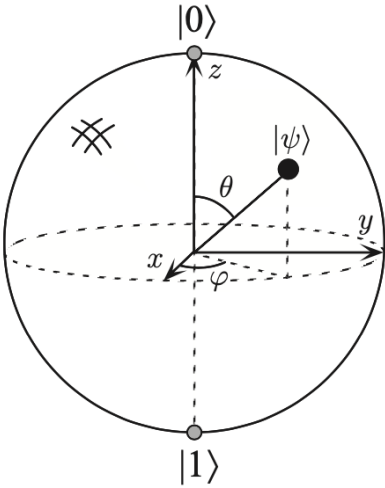
FULL QUANTUM algorithms/methods

- Real Q-Hardware (hybrid) or Q-Emulators (HPC)

- **Lighthouse projects** with internal use cases at small scale

LONG TERM

QUANTUM INSPIRED algorithms/methods

- Ideas from quantum world → transpose into **algorithms for digital HW**

- **Scale-up** lighthouse projects → impact LDO chain value

NEAR/MID TERM

Computing Infrastructures

Running Further Upgrades with latest GPUs !!!

DAVINCI-1 HPC

- **60 CPU nodes** – 2x24 cores Intel Xeon, 1TB RAM
- **80 GPU nodes** – 2x24 cores AMD 0.5/1TB DRAM memory, 4 NVIDIA GPUs
- 20 PB storage capacity
- 5 petaflops
- Libraries: Qiskit, cuQuantum, Qibo, Pennylane, ..
- Up to **36 qubit** exactly emulated (40-qubit target)
- Up to **1000 qubit** approximately emulated (10k target)

Quantum Resources

- Exploit cloud-based services for Quantum (free, pay-per-use)
- Contribute to developing European devices to maximize industrial exploitation
- Support installation of on-prem solutions for Italian ecosystem
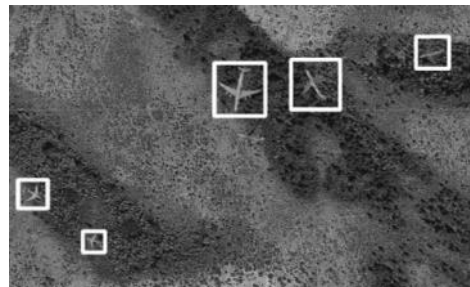- Scouting on-prem solutions for Leonardo

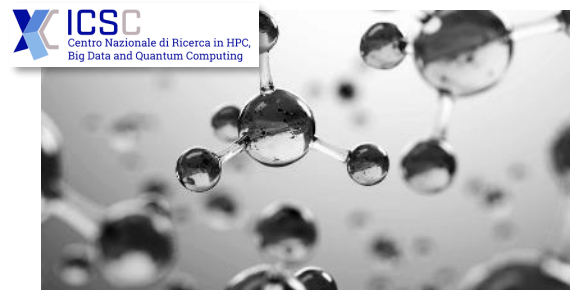# QC Application Clusters

Combinatorial Optimization

Logistics/Teleco (planning, routing, scheduling,…)

Machine Learning

Computer vision, NLP, … (Detection, Classification, Feature Extraction, GM, …)

Physical Simulations

Computational Fluid Dynamics (Navier-Stokes), Quantum chemistry/materials (correlated systems)

Cryptography

How far from breaking classical encryption protocols ??

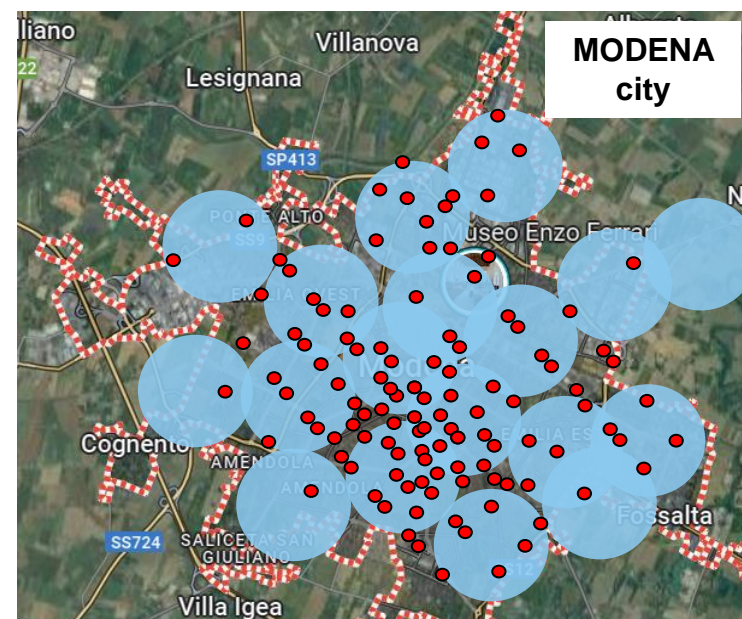# Combinatorial Optimization: The Antenna Problem

ACAT: Approaches to Scale up Quantum Optimization Algorithms for Industrial Aerospace & Telecommunication applications

Goal: optimal deployment of reconfigurable antenna networks on territory with rescuers for disaster response applicataions

Methodology: Emulation on davinci-1 and execution on Quantum devices

Problem Size: GPU emulation and solution quality verification up to 30+ qubits – evaluate results on Q-devices

https://link.springer.com/article/10.1007/s11128-024-04560-1

MODENA city

Evaluating the practicality of quantum optimization algorithms for prototypical industrial applications

Published: 09 October 2024
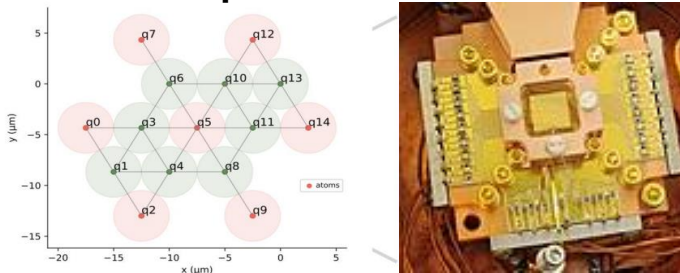Volume 23, article number 344, (2024)   Cite this article

Area covered by antennas

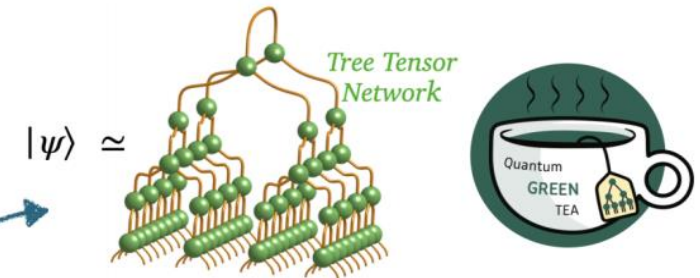Devices

Approaches to Tackle the Problem

Multiple QUBO formulations with **increasing** levels of **realism** and mathematical **complexity**

$$\sum_{i \neq j} \tilde{J}_{ij} z_i z_j + \sum_i \tilde{A}_i z_i$$

Ion Traps & Neutral atoms quantum devices

- «True» quantum approach
- Encoding QAOA into physical devices
- Additional encoding to unit disk graph needed for neutral atoms
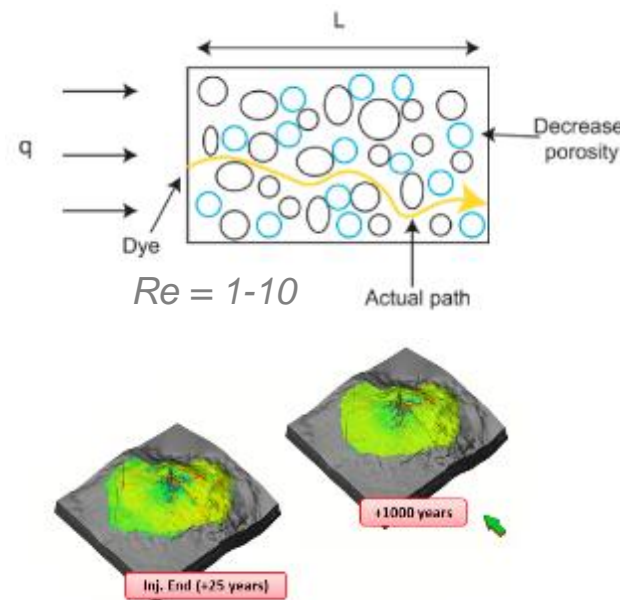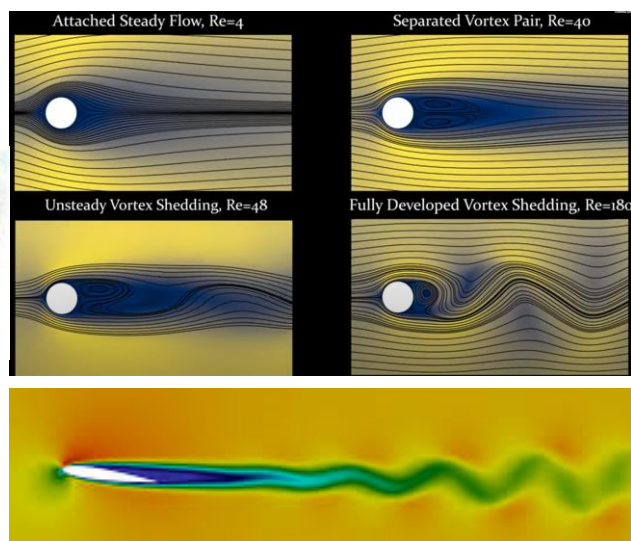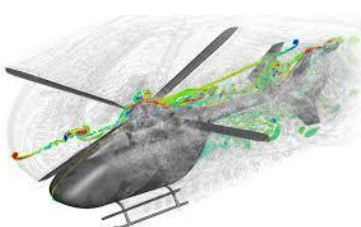
Tensor network approach

- Quantum-inspired approach
- Variational ground state search
- Ready to use

Physical Simulations: Computational Fluid Dynamics

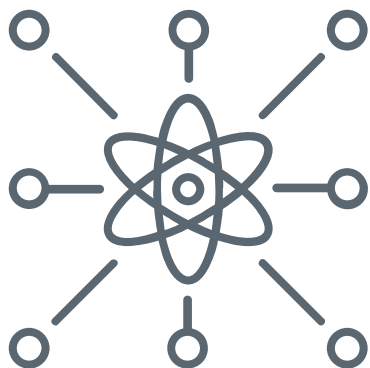**QA4SDE:** Quantum Algorithms for the solution of differential equations

- **GOAL: Achieve a better understanding of the potential (dis)advantage of using Quantum Algorithms for solving partial differential equations (PDEs)**

- Focus on Industrial relevant Applications (Linear and non-Linear eqs)
  - Navier-Stokes eqs for Fluid Dynamics and Design Optimization
  - Darcy eqs for Geophysics/Fluid Dynamics in porous media and Geo-sequestration of CO_2

Attached Steady Flow, Re=4 — Separated Vortex Pair, Re=40 — Unsteady Vortex Shedding, Re=48 — Fully Developed Vortex Shedding, Re=180

Re = 1-10

Inj. End (+25 years) — +1000 years

LEONARDO

INSIDE Connect 2025
Connect Our Community, Shape Our Future

3-4 September
Malaga

INSIDE
Industry Association

THANK **YOU**
FOR YOUR ATTENTION

leonardo.com

QUANTUM COMPUTING | Leonardo