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Quantum Computing on HPC Systems

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What is Quantum Computing?

"Quantum computation ... will be the first technology that allows ... distributing components of a complex task among vast numbers of parallel universes, and then sharing the results."

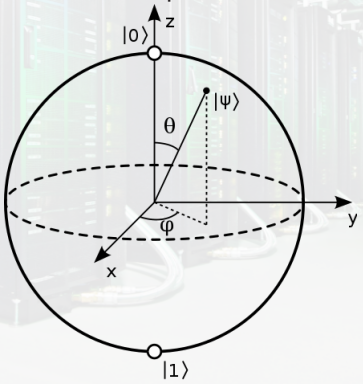
- David Deutsch, The fabric of reality: the science of parallel universes (1997) [1]

Again: What is Quantum Computing?

- A QC utilizes quantum mechanics to solve complex problems
- QC *may* be superior to classical computing in
  - Simulating Quantum systems (highly probable)
  - Combinatorial optimization problems (probable)
  - Cryptography / prime factorization (probable)
  - Machine learning and other fields (unknown)

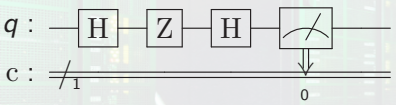
Quantum information

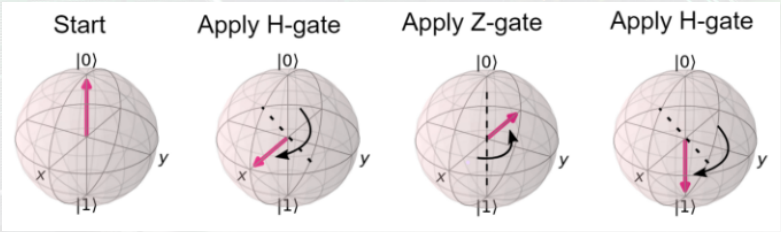
- The smallest unit of information in QC is the **qubit**
- They can be visualized with the Bloch sphere:



Quantum algorithms

- **Quantum gates** do operations on qubits
  (like logic gates in classical computing)
- **Quantum Circuits** can represent quantum computations:

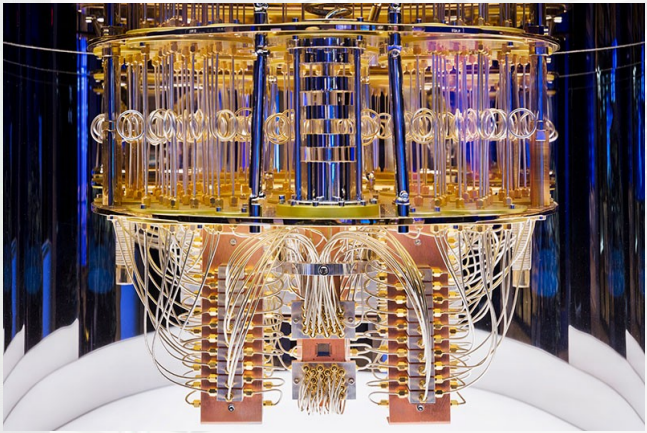




Developing with Qiskit

- `https://qiskit.org/` enables you to develop and run quantum algorithms
  - ... on real quantum computers
  - ... on the integrated simulator(s)
- Why run on a simulator?

Reason number one for simulating QC right now



Real QC are expensive, error prone and not easily available (yet). (Image source: IBM)

More reasons to simulate QC now and in future

- Debugging on real devices is hard to impossible (no intermediate states)
- Teaching and learning (more insights)
- Testing & verification (noise models for studying noise impact)
- So, start here: `https://gitlab-ce.gwdg.de/lourens.van-niekerk/isc-2023-qml-tutorial`