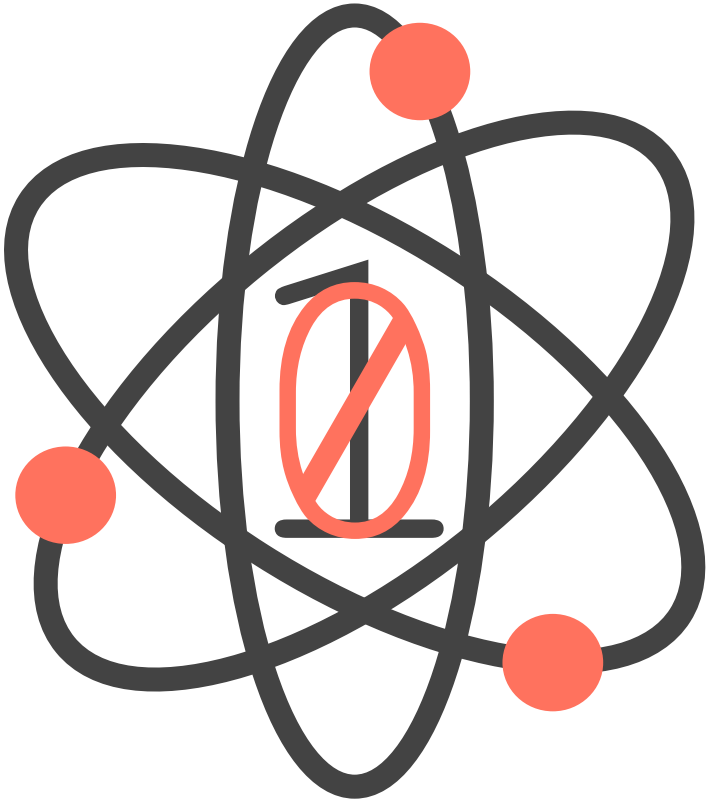
# Quantum Computing

Quantum Day

Phila Rembold
Atominstitut, TU Wien

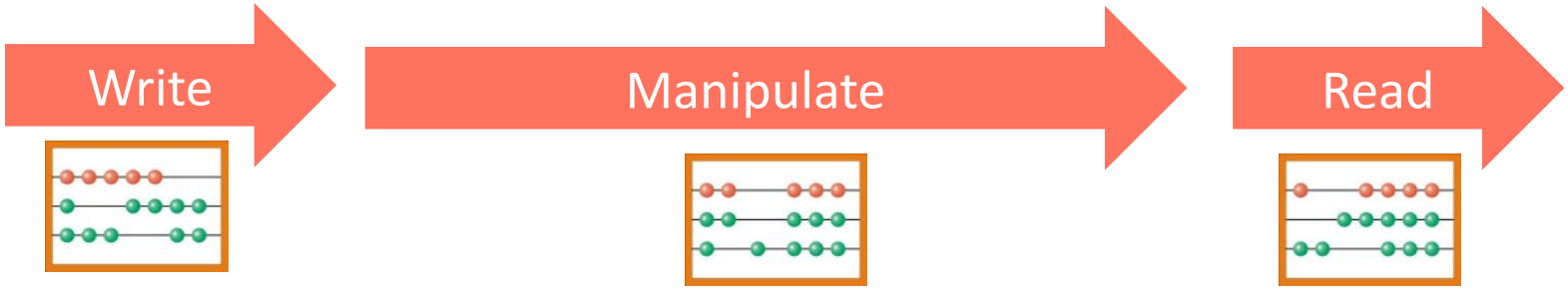


# Computation

Classical computers compute using the laws of **classical physics**

Quantum computers compute using the laws of **quantum physics**

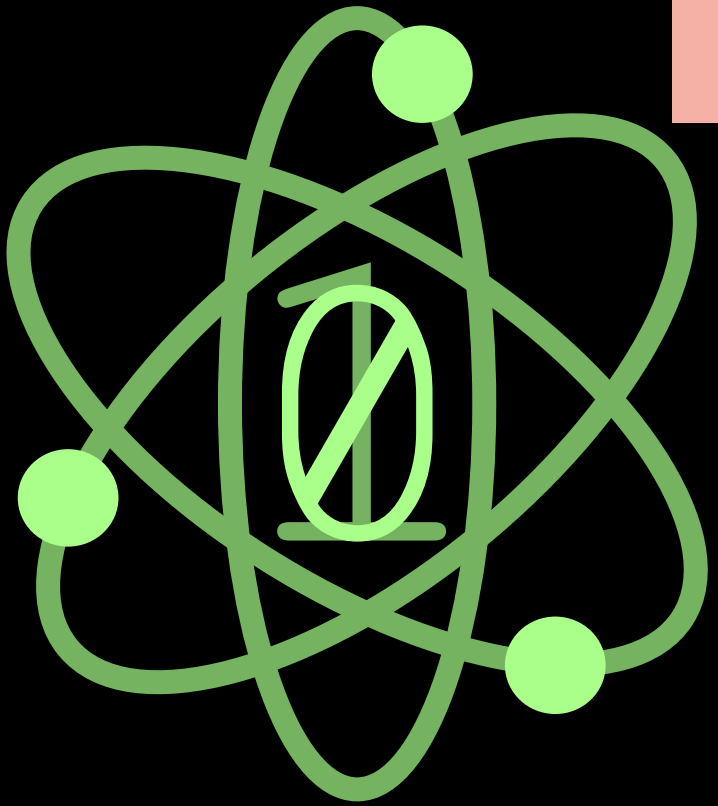
Physics



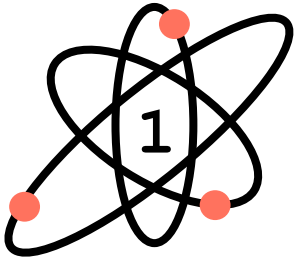
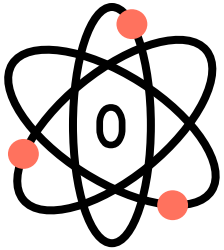
# Bits to Qubits

Information encoding

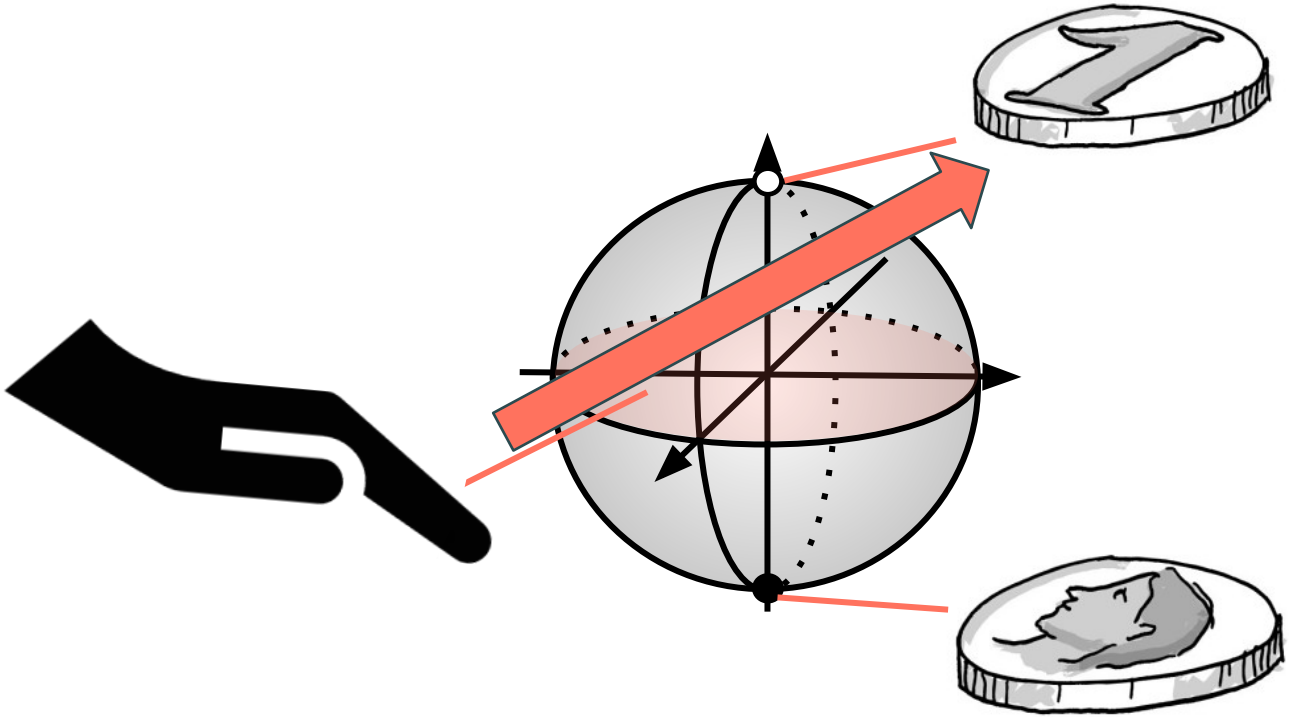
1 or 0



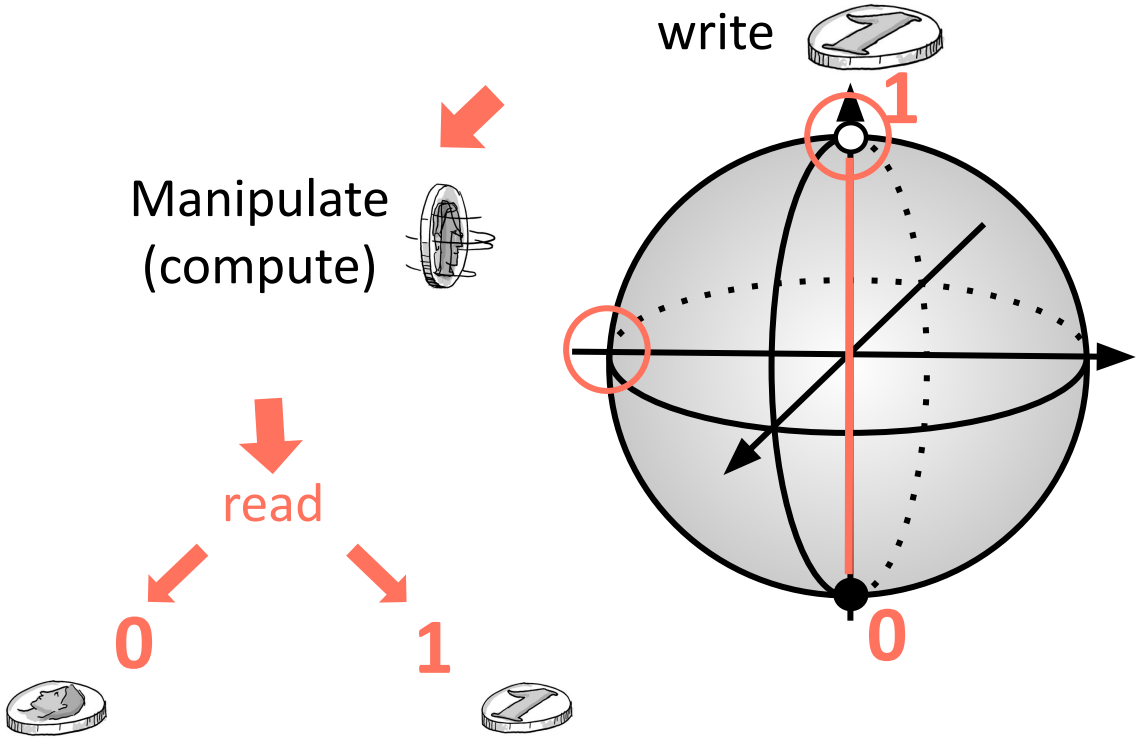
# Bits to Qubits

| Classical Bits | | Quantum Bits | Our Analogy |
|---|---|---|---|
| “on“ | 1 |  |  |
| “off“ | 0 |  |  |

# Superposition



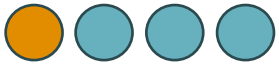
# Superposition




Problem but also opportunity: exponentially large space in # of qubits

# Exponential Space

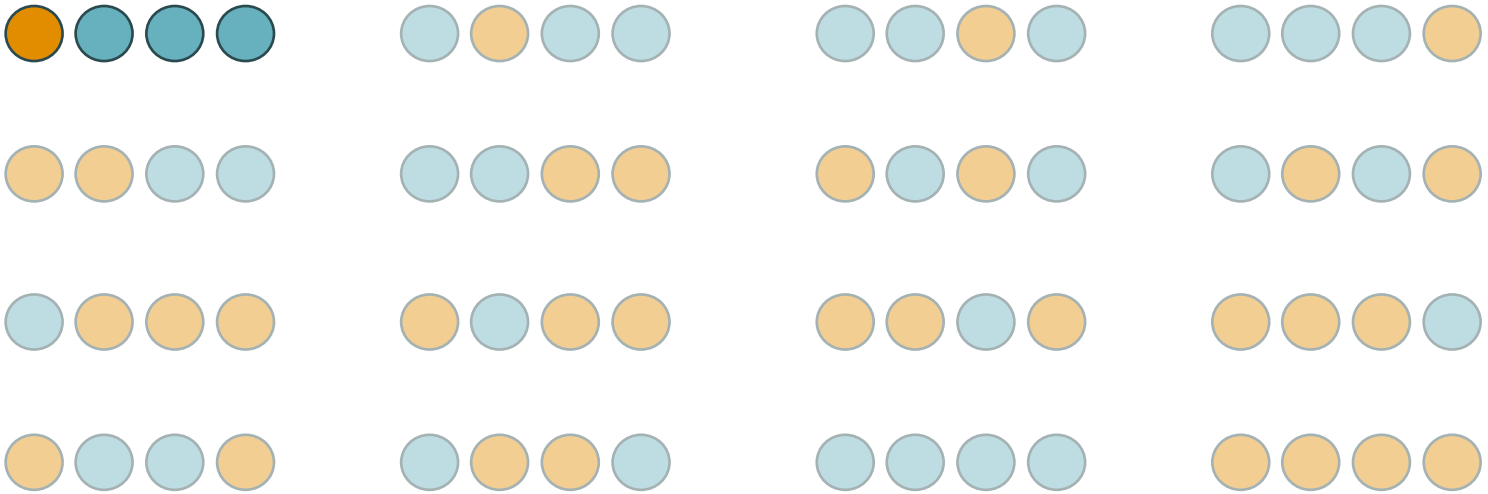
$2^n$ combinations: $n = 4$



Classical register: Occupies 1 out of 16 states

# Exponential Space

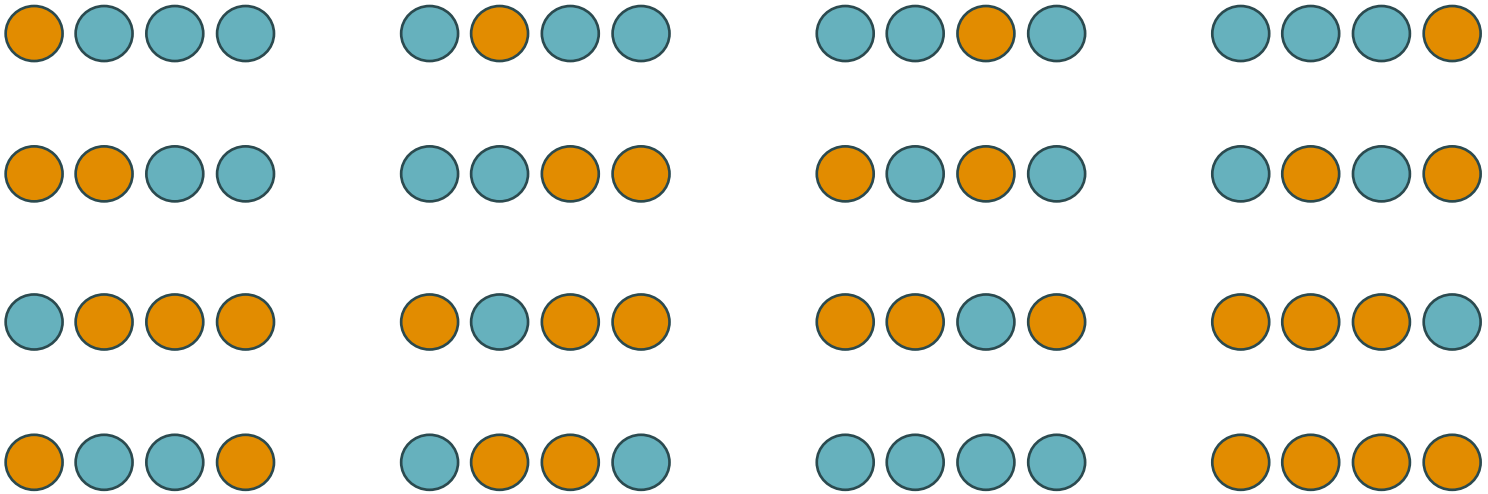
$2^n$ combinations: $n = 4$



Classical register : Occupies 1 out of 16 states

# Exponential Space

$2^n$ combinations: $n = 4$



Quantum register: May occupy **any superposition** of 16 states

# Exponential Space

$2^n$ combinations: $n = 4$

**BUT** measurements will collapse it – hence repetitions are needed for reconstruction

# What can Quantum Computers do (better)?

- (unstructured) **search** (Grover)

Find Ace of Hearts 

- Factoring (Shor): Find x and y such that N = x*y

=

55853666619936291260749204658315944968646527018488637480100523463198532883747 53

×

20758181946442382764570481370359469516293970800739520988120838703792729090324679382343143884144834882534053344769112223028158327696525376091410189105241993899334109711624358962065972167481161749004803659735573409253205425523689

# Quantum Simulation

**Very Quantum Systems**

Drug Design

Material Science (superconductors)

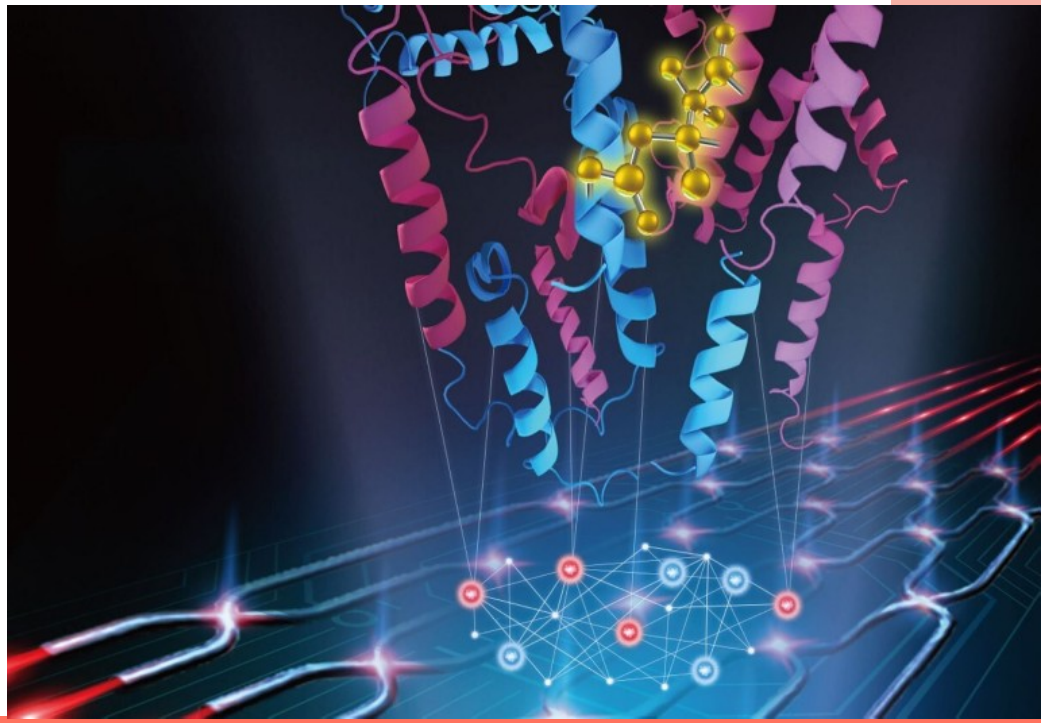
Fertiliser Design

**Analog Systems**

Chip Layout

Logistics

Maybe: New routes for machine learning



# What can't Quantum Computers do?

**Transfer information faster than the speed of light**

measurement cannot transfer information

and manipulation breaks the entanglement

**Replace Gaming PCs**

Quantum Processing Units (QPUs) might add new computing capabilities but won't replace everything

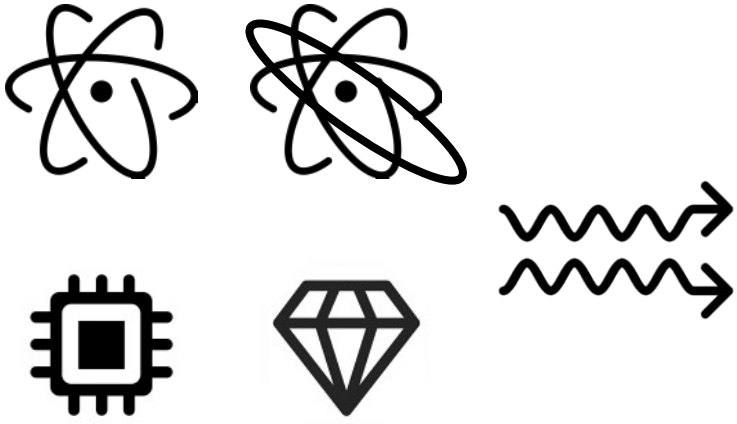
**Improve Logistics Today**

Be wary of big claims

# What differentiates QCs?

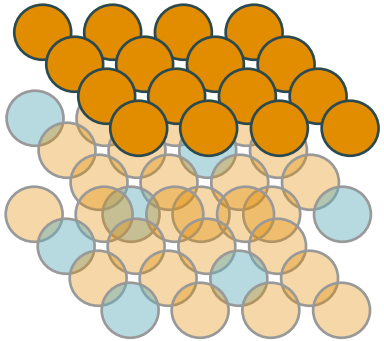
The Race for Fault Tolerance

**Different Physical Qubits**



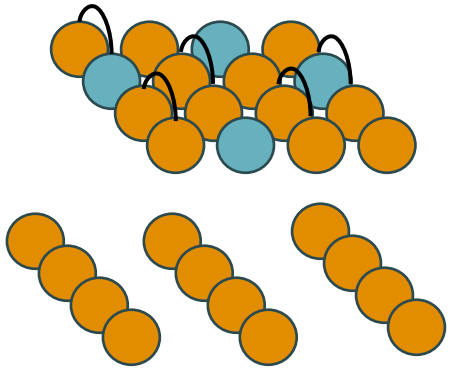
**The Stats**

Number of qubits



Number of qubits in a usefully entangled state

Number of operations



Number of error corrected qubits

# Summary

There is a number of interesting **applications** for quantum computers

e.g. in Cryptography, drug development

Quantum computers will **not replace** classical computers

A lot of **research still needs to be done** to reveal the true potential of quantum computers!