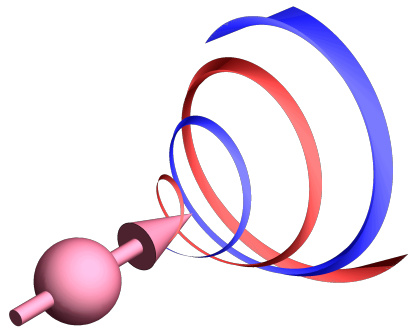


# The power of quantum computing

...on one page



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## Classical bits

one: 0 or 1

two: 00 or 01 or 10 or 11

N bits describe one number  $0 \dots 2^N$

## Quantum bits

$$|\Psi\rangle = c_0|0\rangle + c_1|1\rangle$$

$$|\Psi\rangle = c_{00}|00\rangle + c_{01}|01\rangle + c_{10}|10\rangle + c_{11}|11\rangle$$

N qubits: need  $2^N$  numbers to describe the N-qubit state!

it's both 0 and 1 until measured (quantum superposition)

$c_i$  are coefficients (numbers)

To describe only 265 qubits we need as many numbers than #atoms in universe ( $2^{265}$ ) - by definition, this is impossible with classical information/physics.

-> The information is in quantum correlations (often entanglement)

But, after measuring, only  $\sim N$  bits/numbers of information can be obtained

Don't forget: a single protein contains 10,000 atoms, assuming atoms are qubits, this space is far bigger ( $2^{10000}$ )! Apparently, the (possible?) amount of quantum information in our universe is much bigger than the maximum classical information content.

And, obviously, we cannot initialize even only  $2^{265}$  numbers. How can a quantum algorithm be useful?

Prepare all N qubits in some separable basis state (roughly N numbers needed)  
**N numbers**

Let the state evolve in a (very) clever way, where qubits interact, generate quantum correlations + entanglement  
 **$2^N$  numbers**

Measure each qubit  
**N numbers**

Can this really be advantageous compared to classical information processing? We don't know yet for sure, but most likely it is!

## Example: Deutsch algorithm with proven quantum advantage

- A function  $f(b_1, b_2, b_3, \dots, b_N)$  results either in the same answer (e.g. 0) independent of the input bits  $b_i$ ,
- or it is balanced: 50% of combinations of  $b_i$  result in 0, 1 otherwise.
- **Classical:** need to test  $> 50\%$  of possible inputs ( $= 2^N - 1$ )
- **Quantum:** one evaluation of  $f$  (but  $f$  must work on quantum inputs, this is a potential issue)

