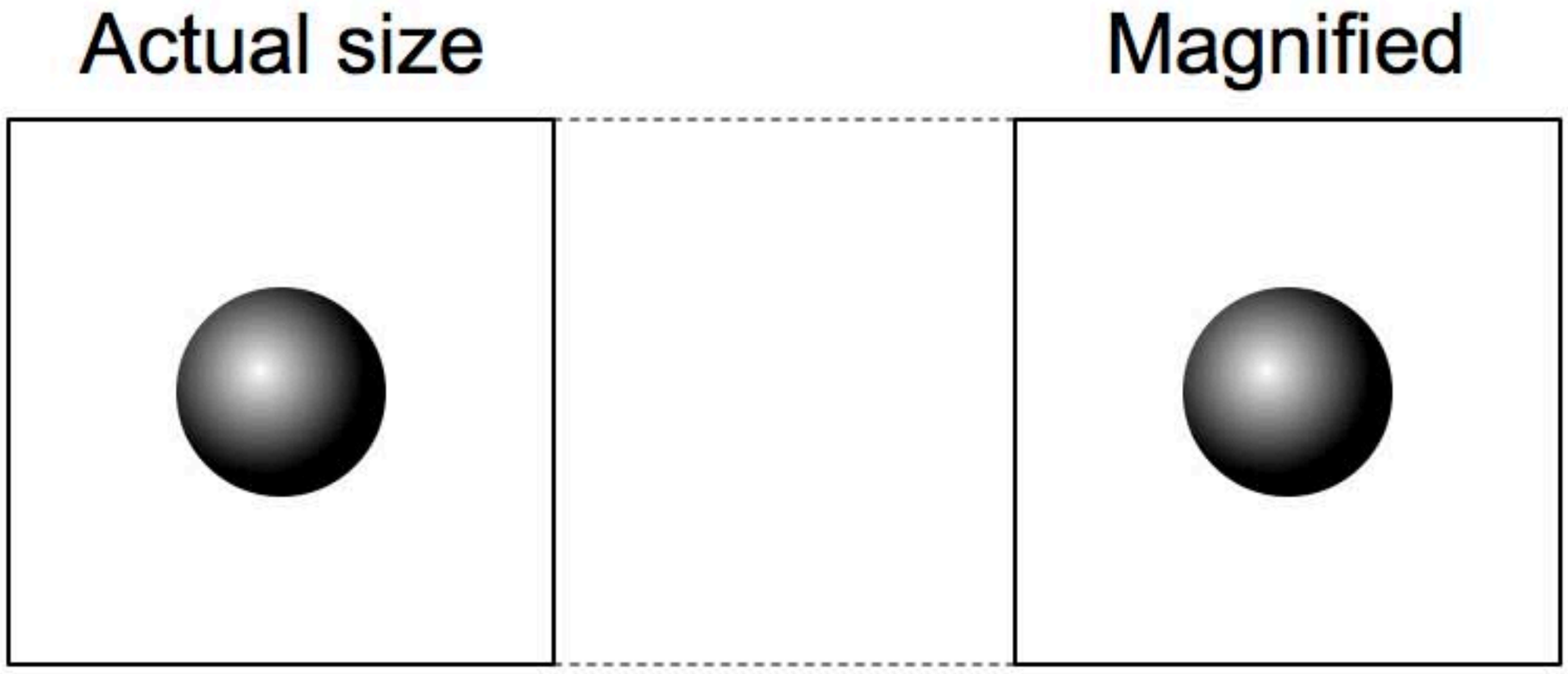
CodeQuest

a Weapon of Mass Simulation in the War on Noise

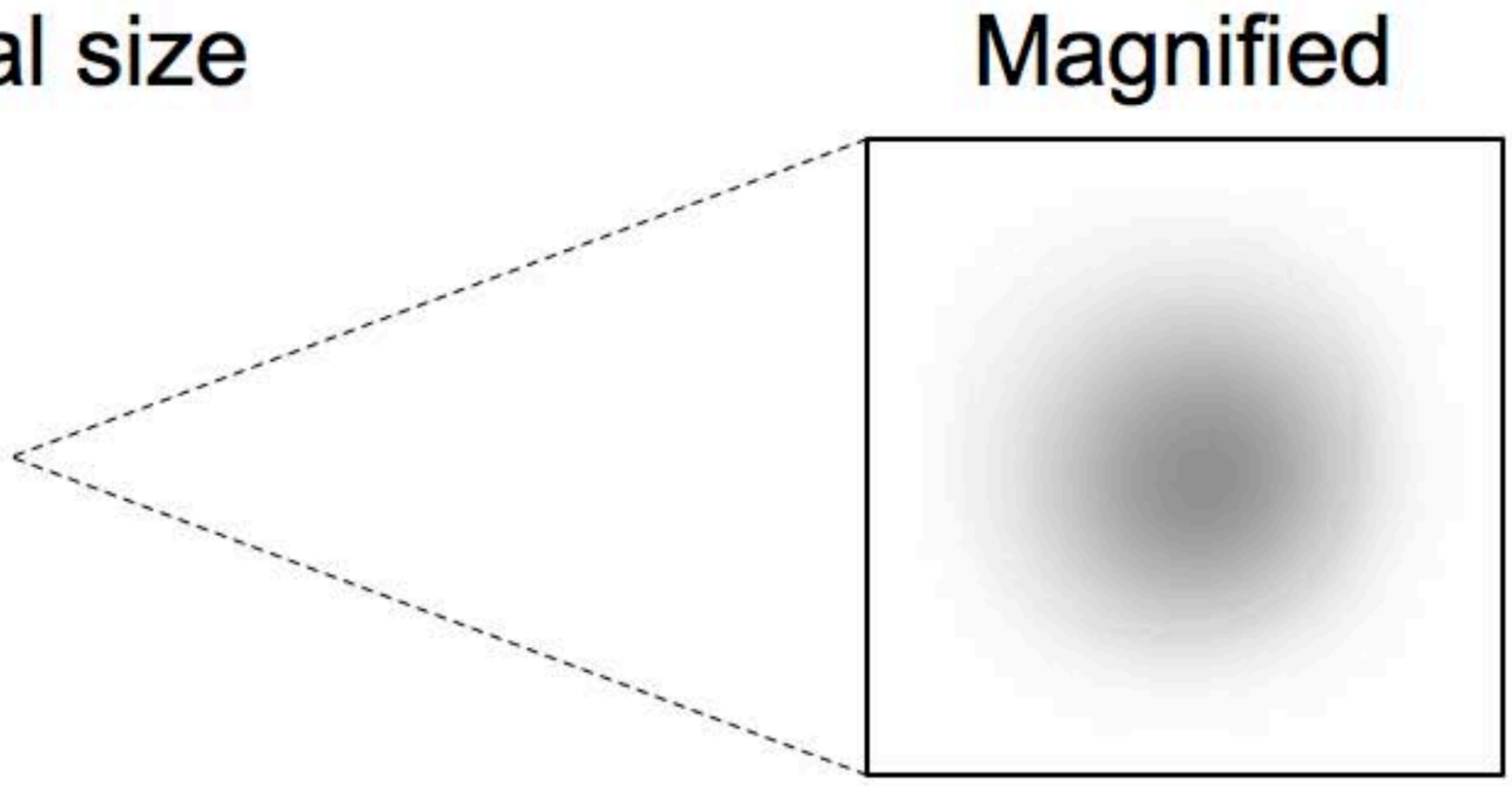
Outline

- Why we care about building a quantum computer.
- Why quantum information is constantly at risk.
- How codes can protect information.
- What CodeQuest is, and why it matters.
- Case Study: Lattice Codes
- Conclusions

Quantum mechanics is fuzzy



Quantum mechanics is fuzzy



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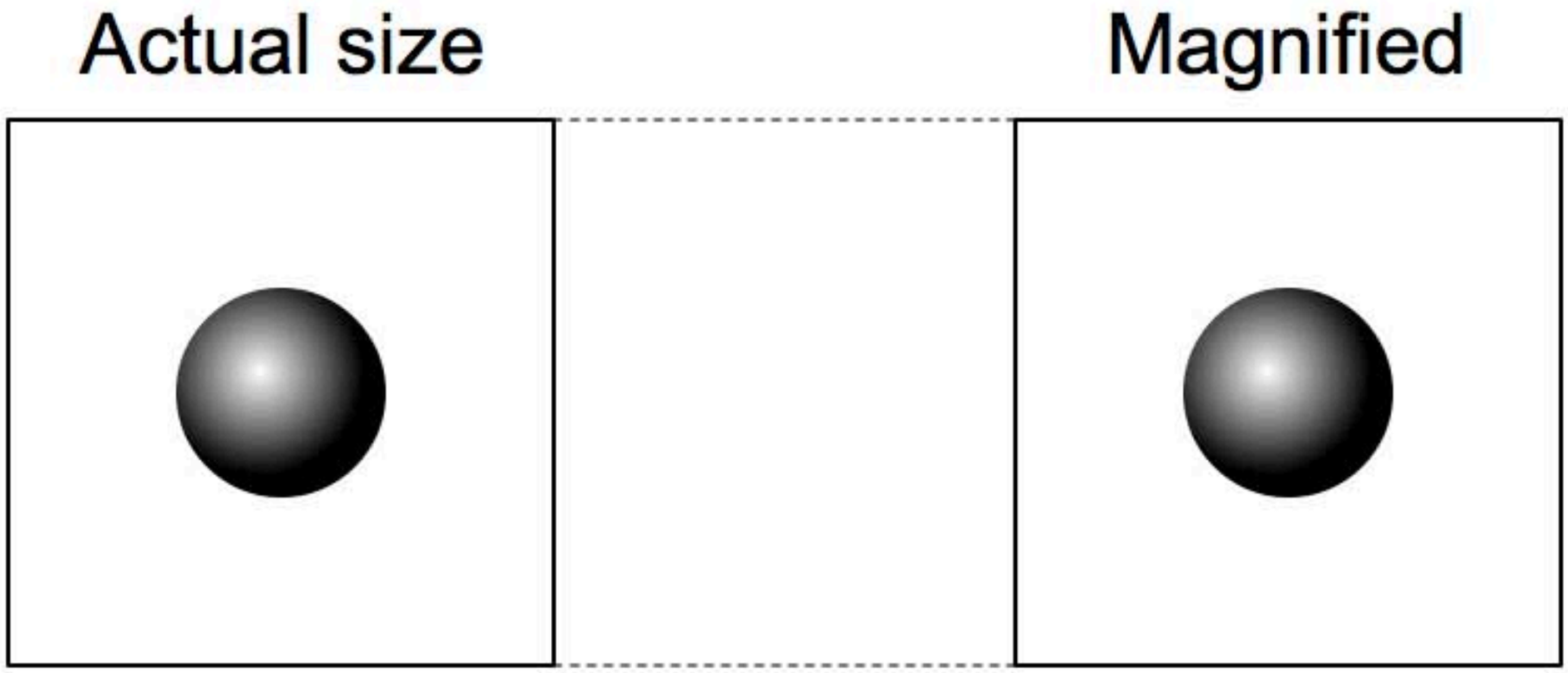

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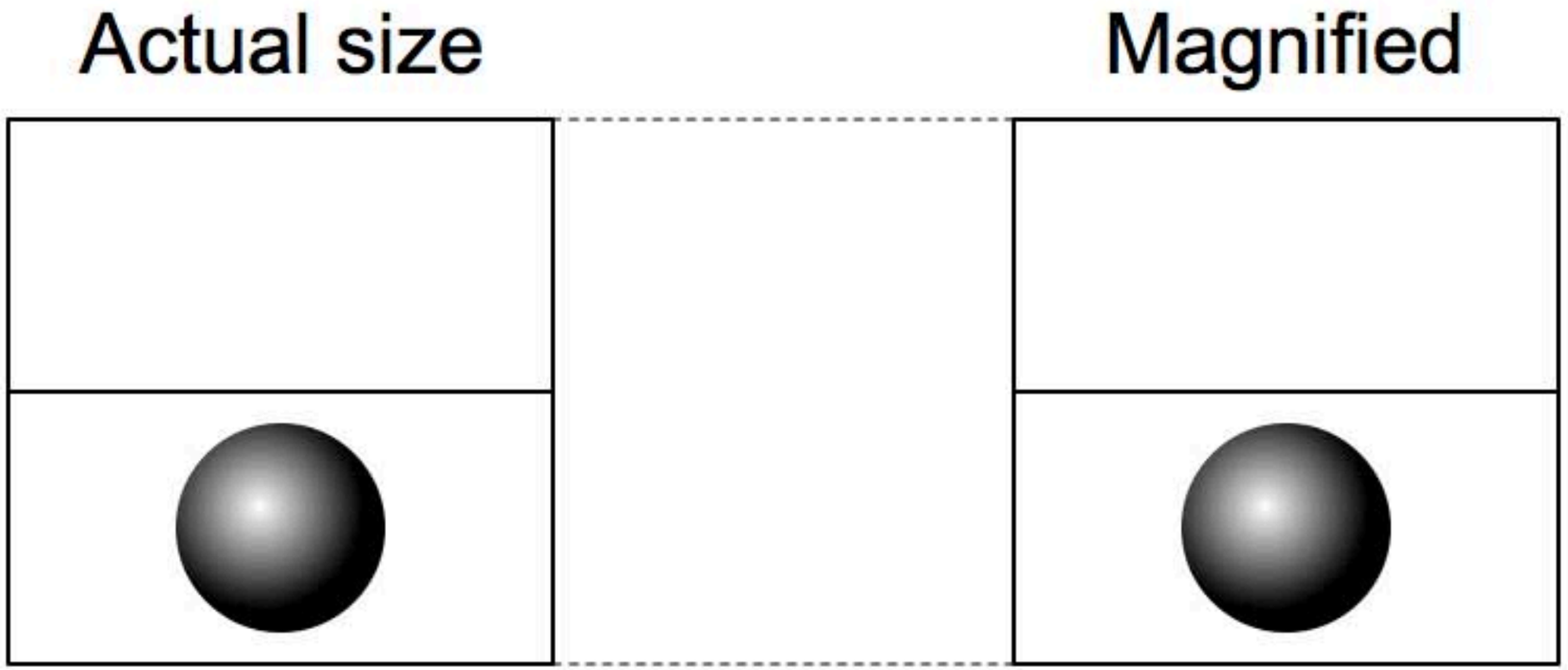

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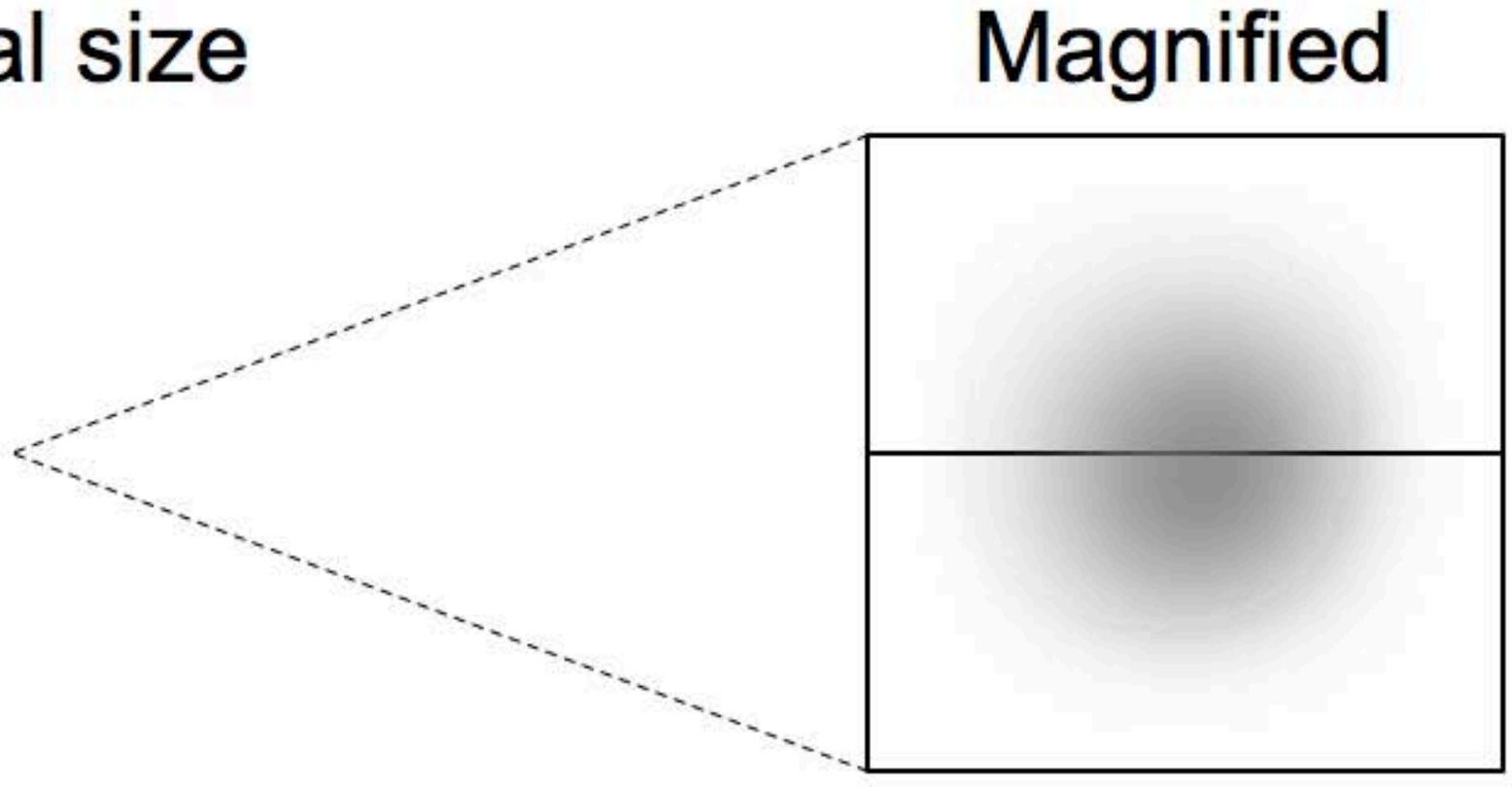
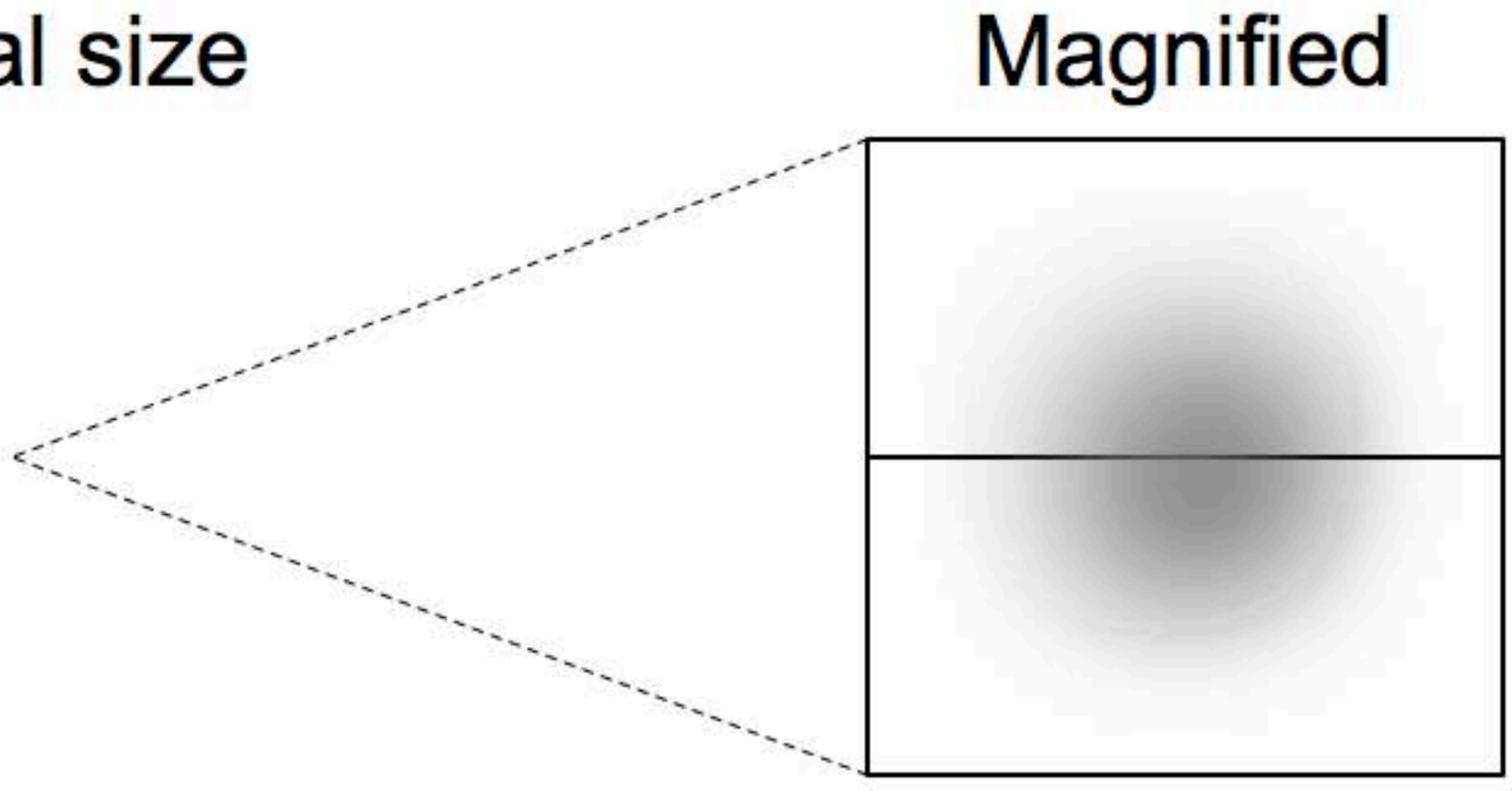


But who actually makes things that small?



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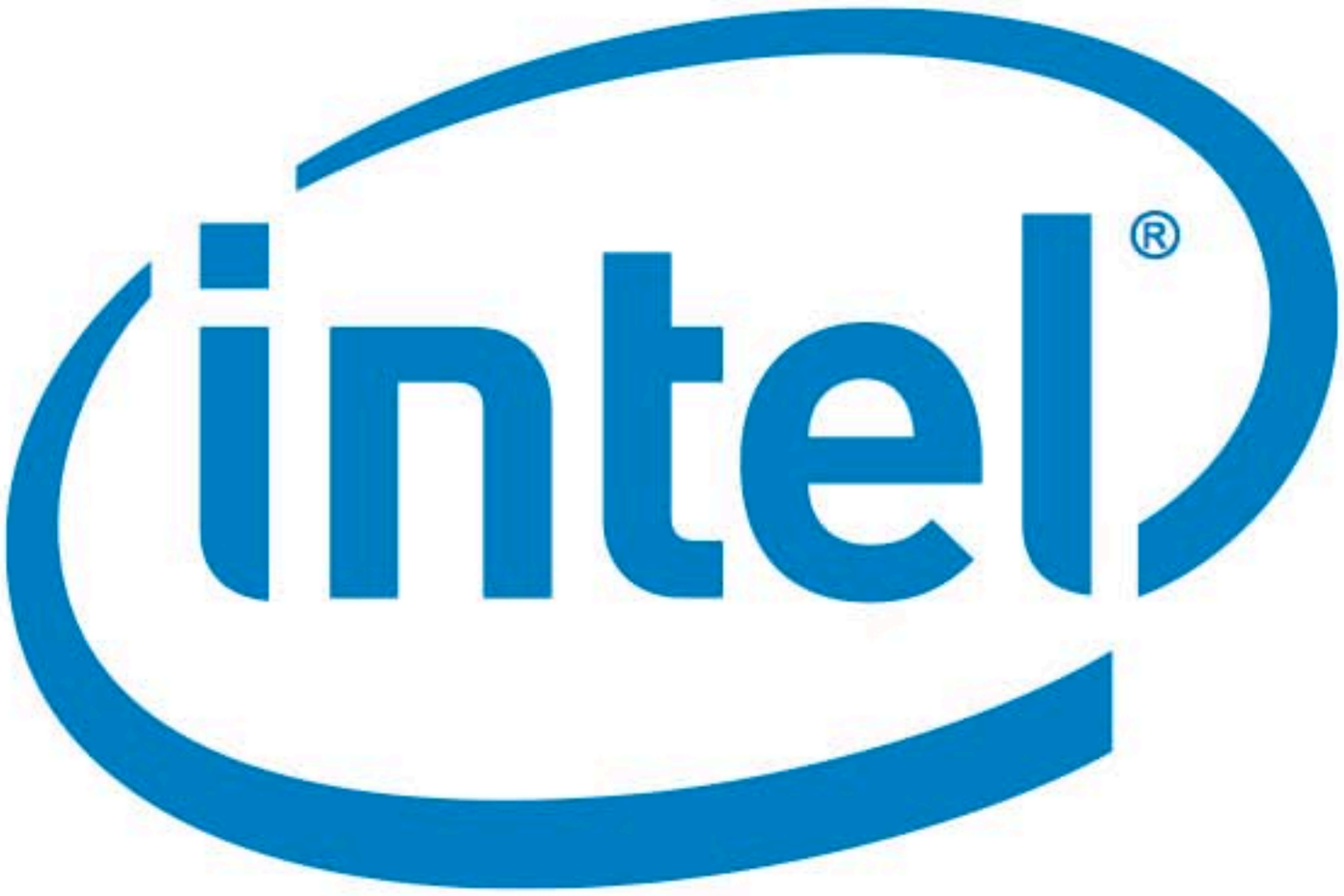

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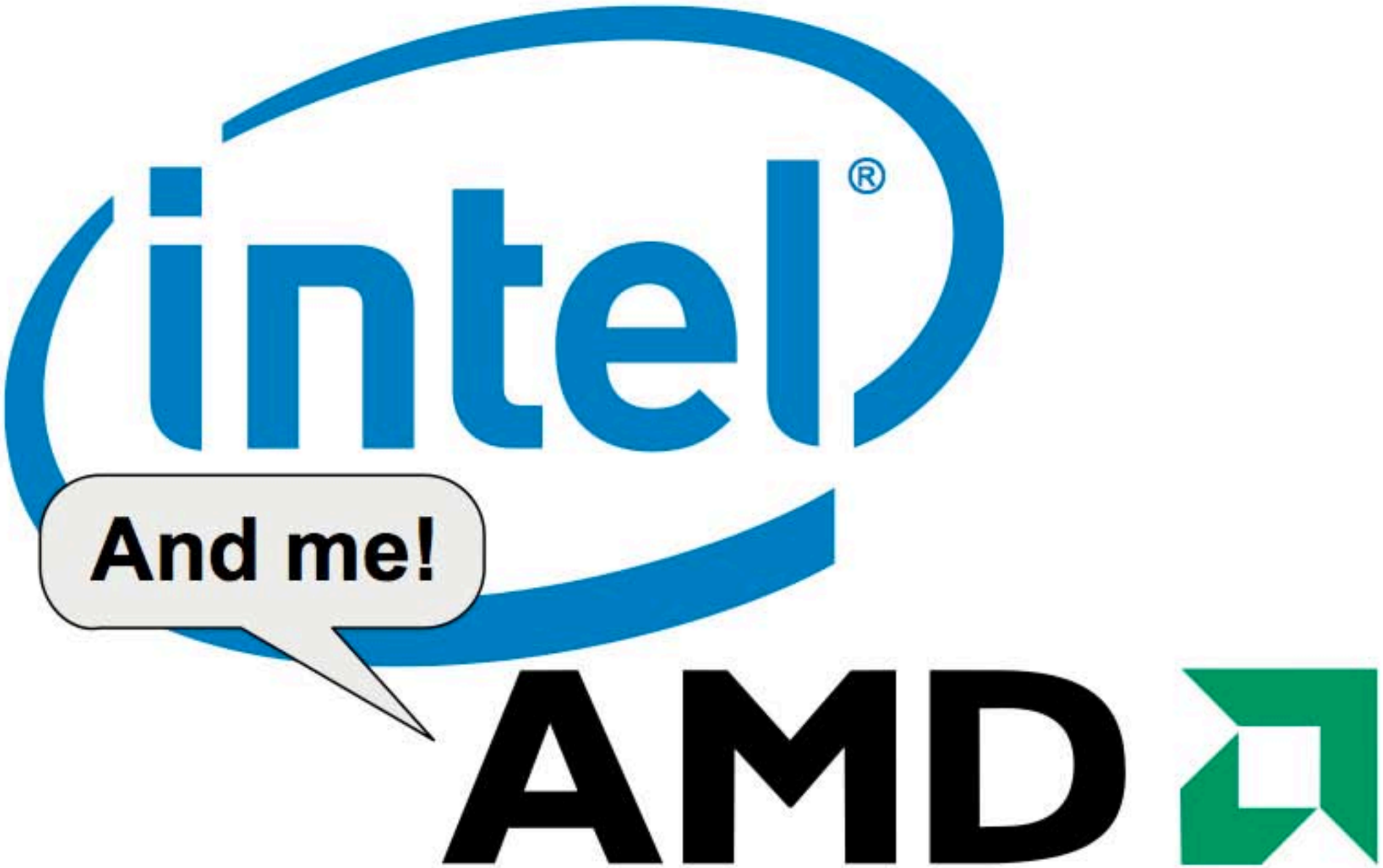

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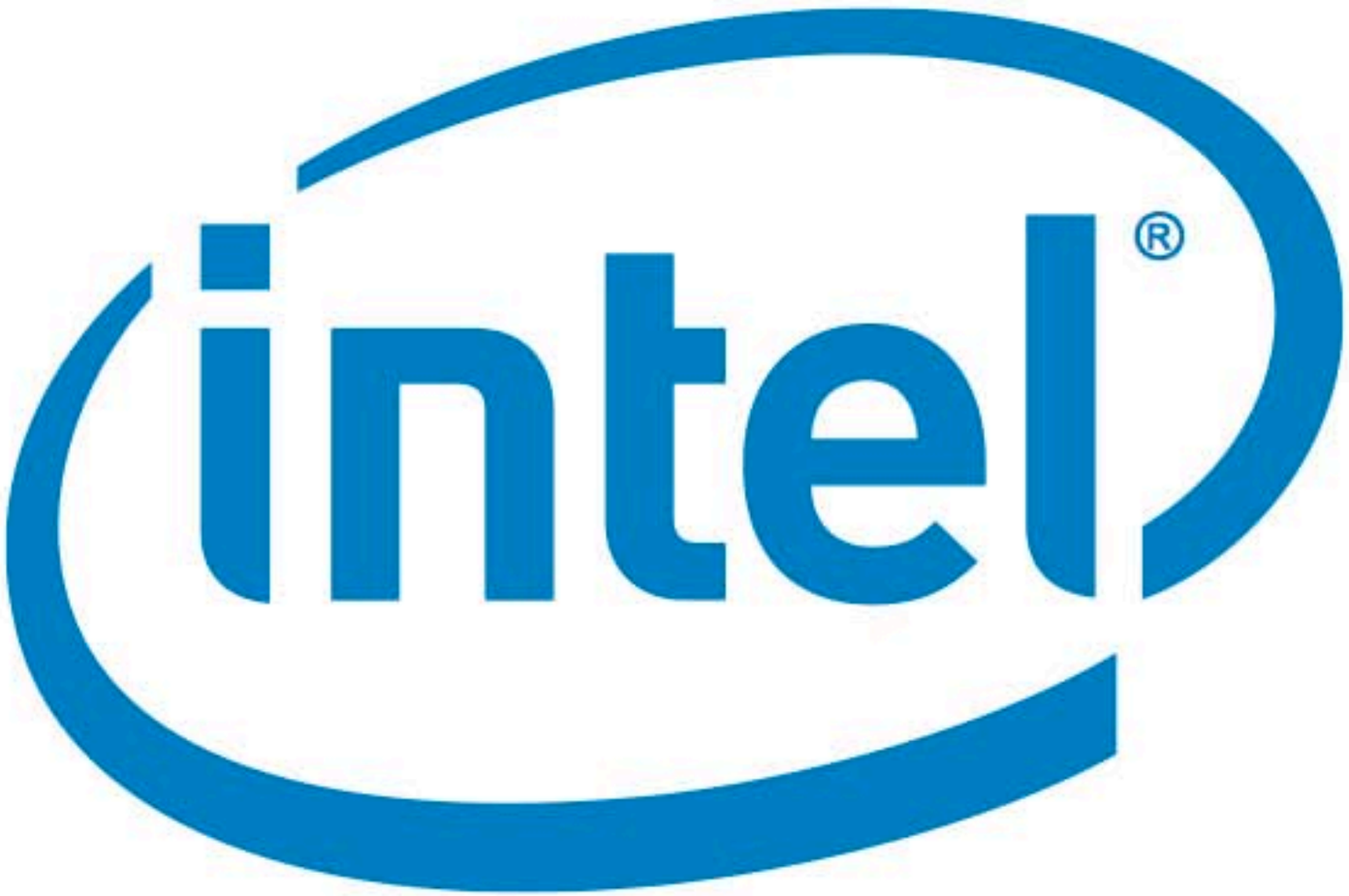

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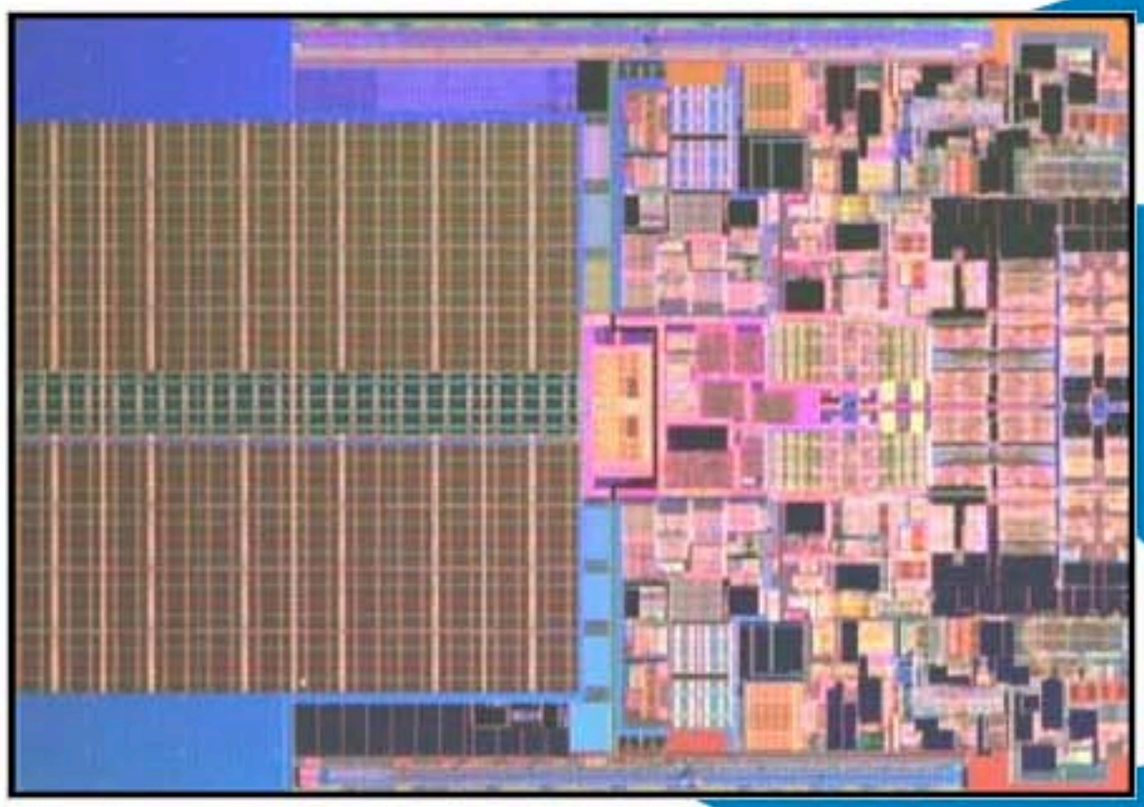

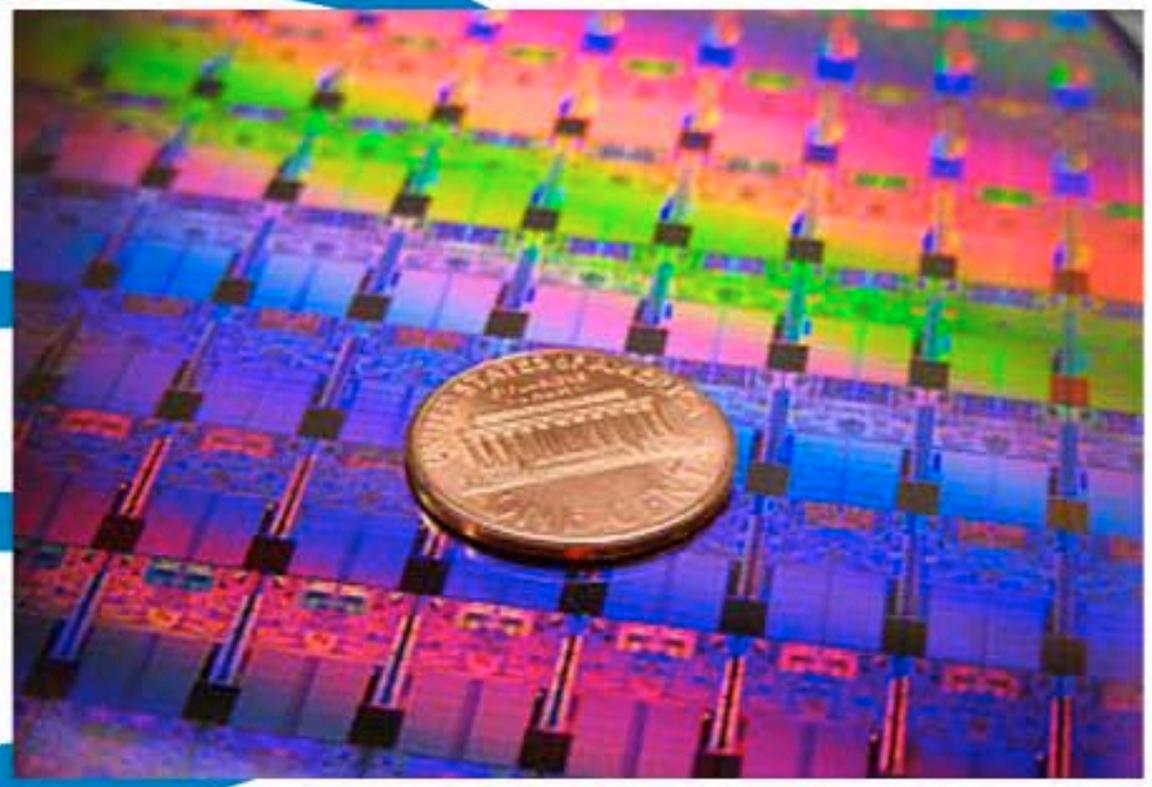

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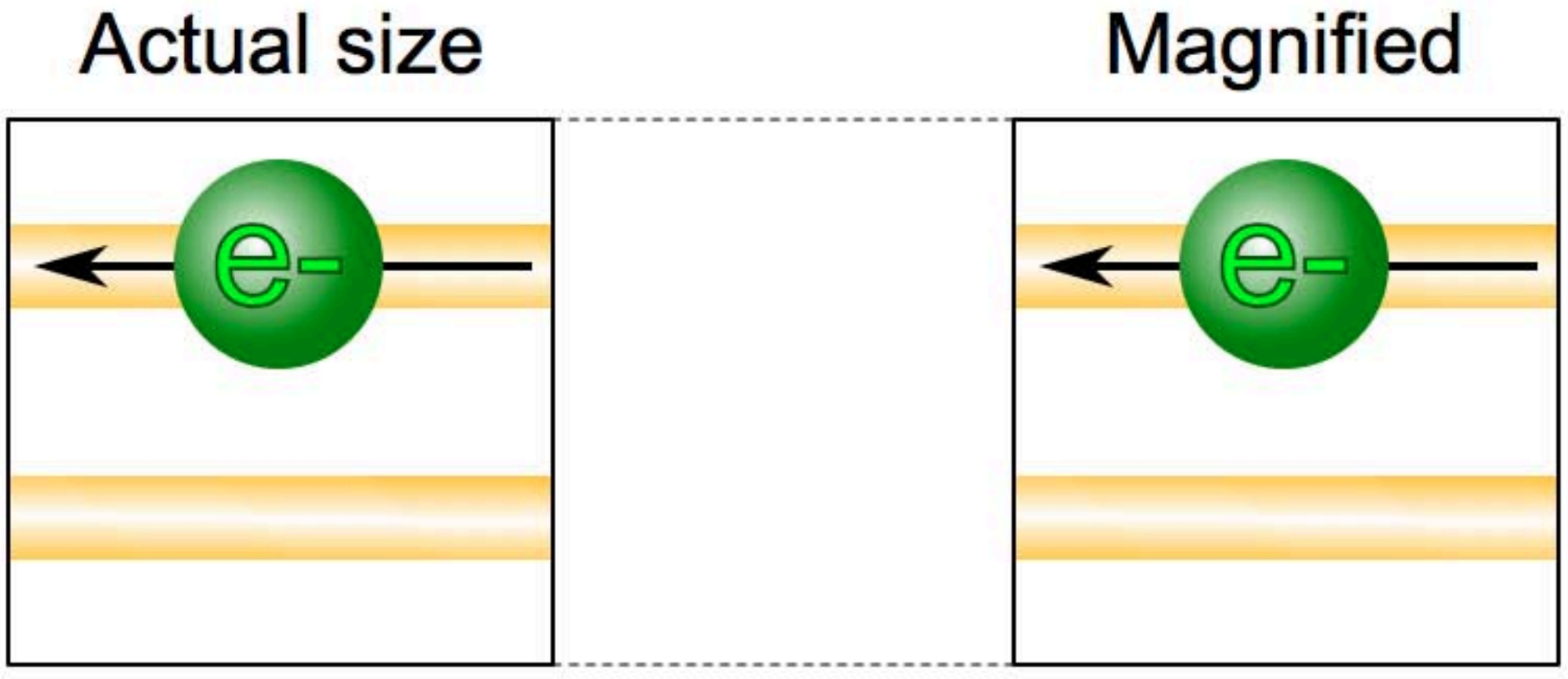

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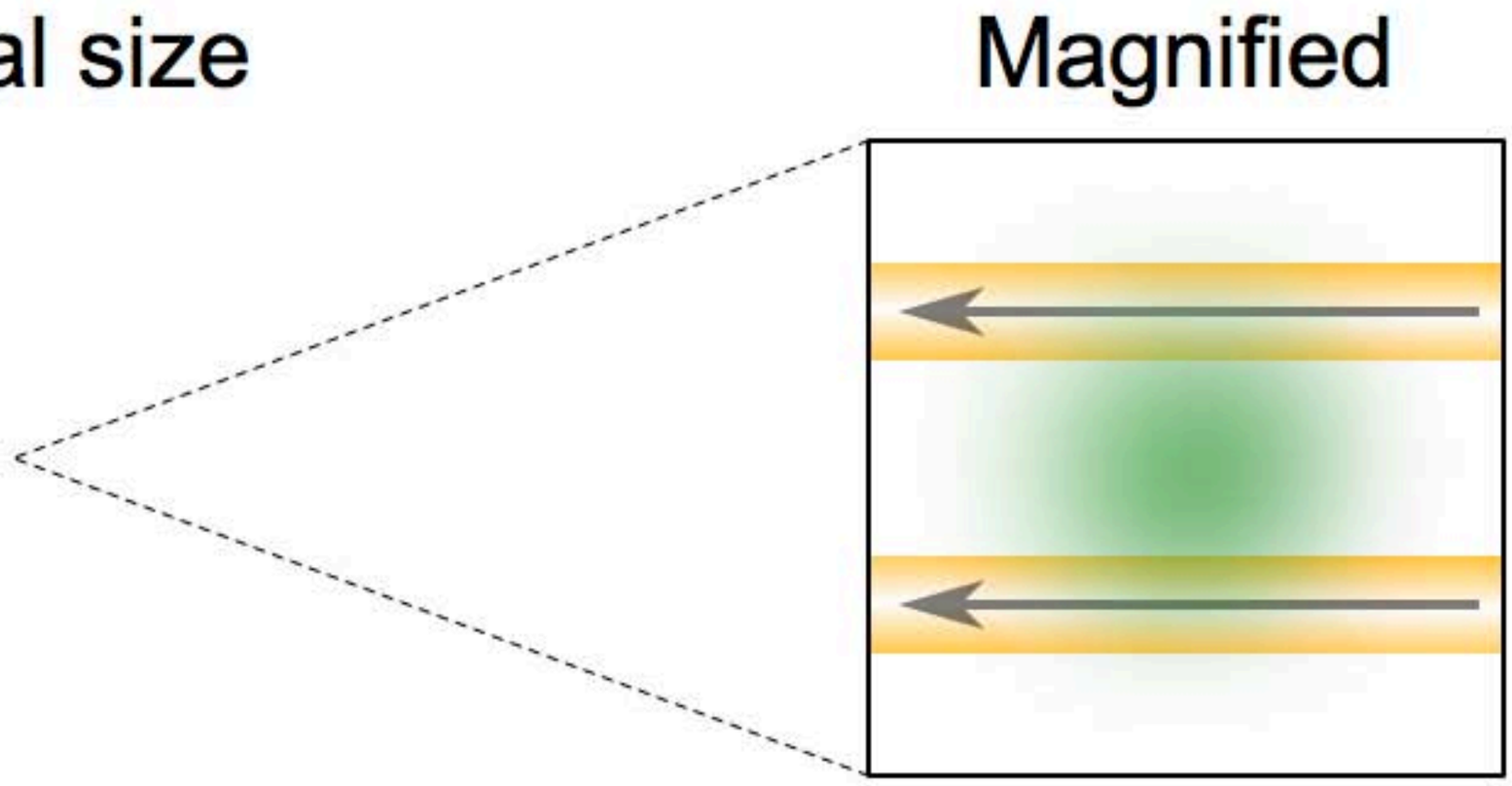
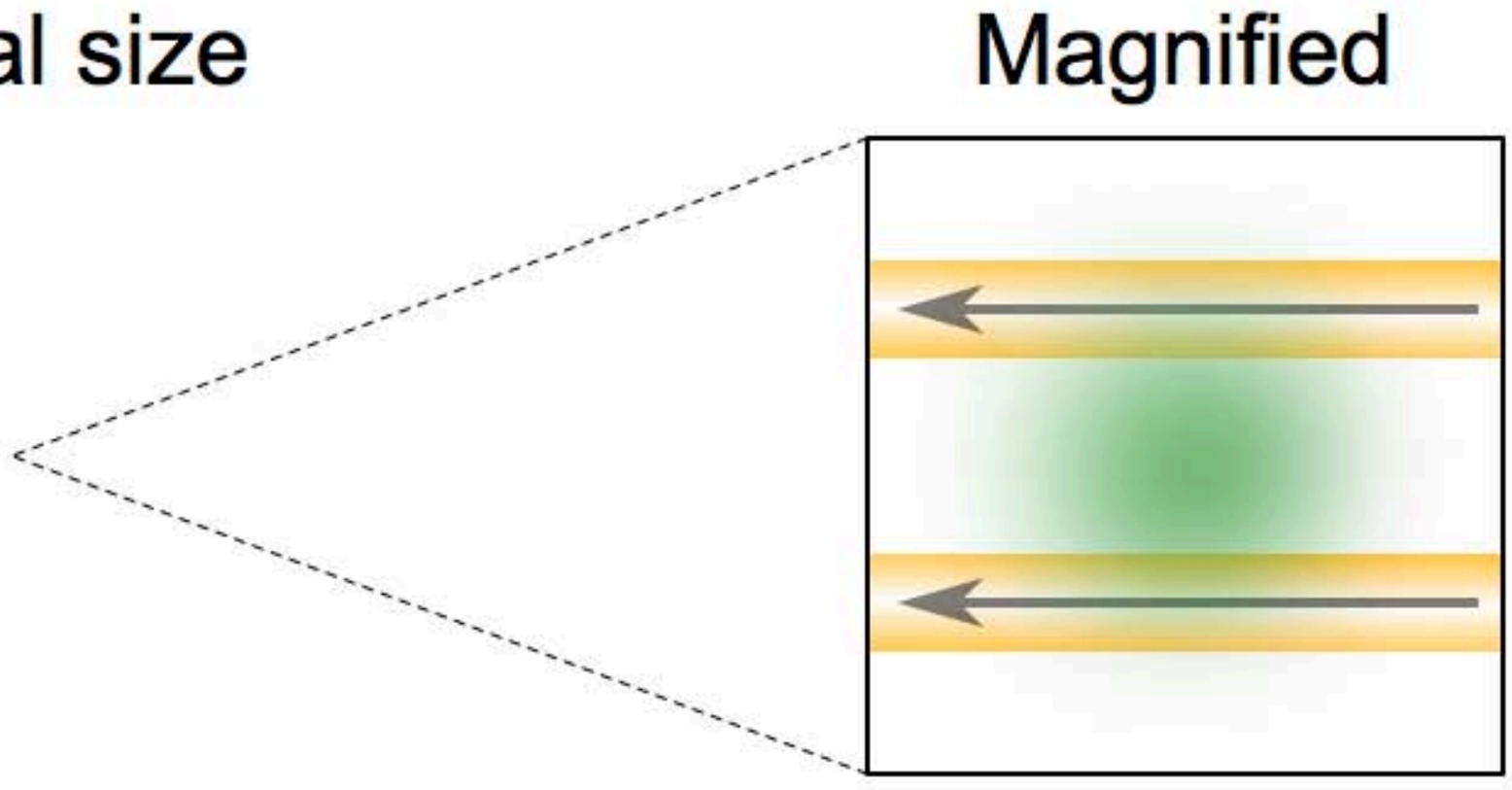


Quantum computing: embrace the fuzz!



Quantum computing: embrace the fuzz!

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00 10

01 11

Quantum computing: embrace the fuzz!

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001

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111

Quantum computing: embrace the fuzz!

0000	0001	1000	1001
0010	0011	1010	1011
0100	0101	1100	1101
0110	0111	1110	1111

Quantum computing: embrace the fuzz!

f(0000) f(0001) f(1000) f(1001)

f(0010) f(0011) f(1010) f(1011)

f(0100) f(0101) f(1100) f(1101)

f(0110) f(0111) f(1110) f(1111)

Quantum computing: embrace the fuzz!

f(0000) f(0001) f(1000) f(1001)

f(0010) f(0011) f(1010) f(1011)

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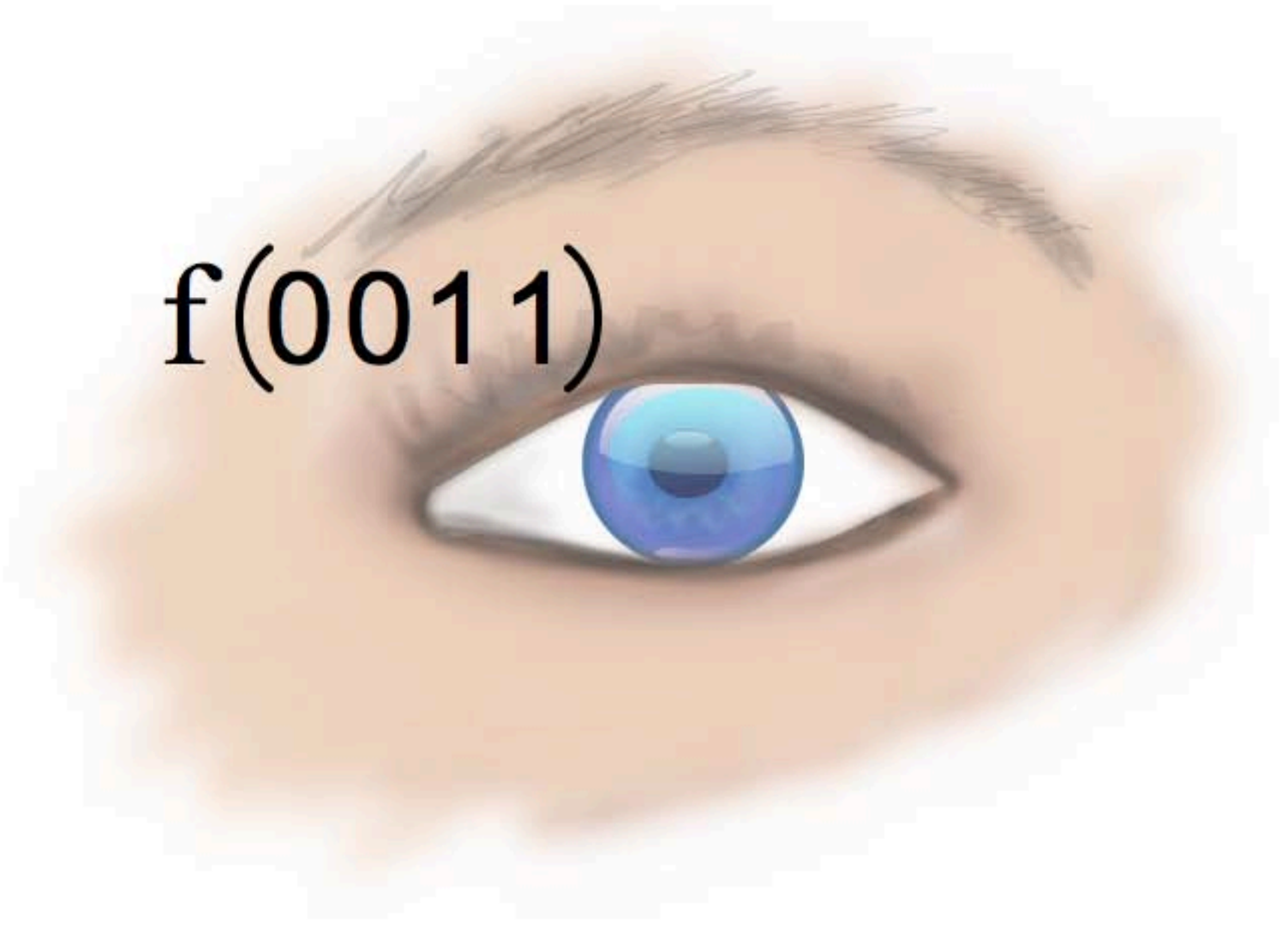
Quantum computing: embrace the fuzz!



Quantum computing: embrace the fuzz!

Factoring, discrete log [Shor 94]

Unstructured search [Grover 96]

Pell's equation [Hallgren 02]

Hidden shift problems [van Dam, Hallgren, Ip 03]

Graph traversal [CCDFGS 03]

Spatial search [AA 03, CG 03/04, AKR 04]

Element distinctness [Ambainis 03]

Various graph problems [DHHM 04, MSS 03,…]

Testing matrix multiplication [Buhrman, Špalek 04]

Quantum computing: embrace the fuzz!

Factoring, discrete log [S[illegible]94]

Unstructured sea[illegible]

Pell's equatio[illegible]

Hidden shift[illegible]ren, Ip 03]

Graph trave[illegible]

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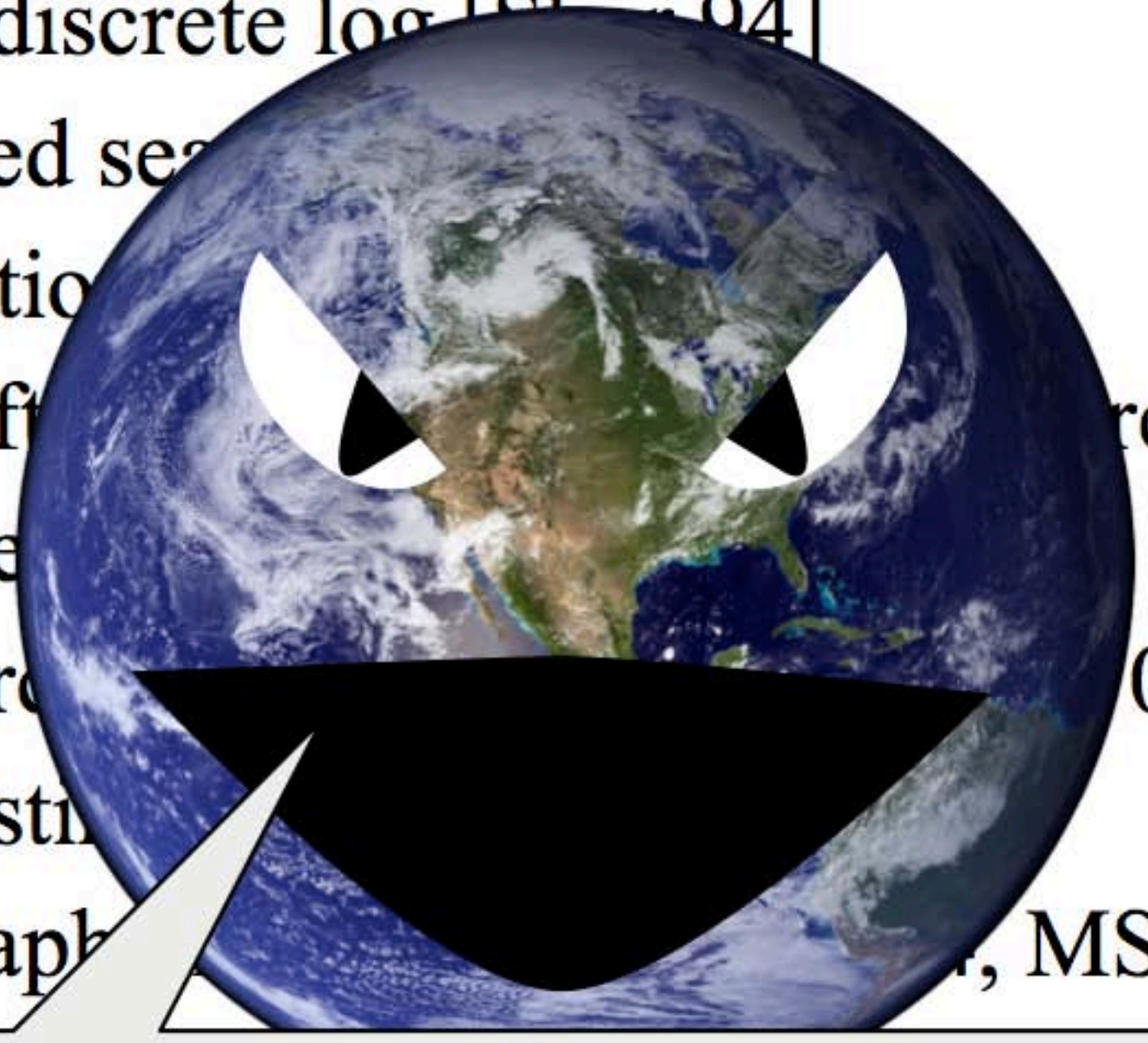
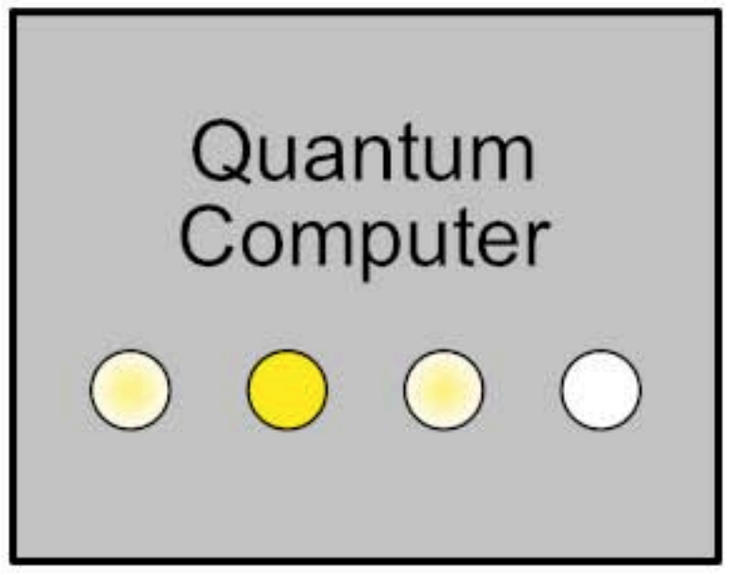


I HATE QUANTUM COMPUTERS!!!

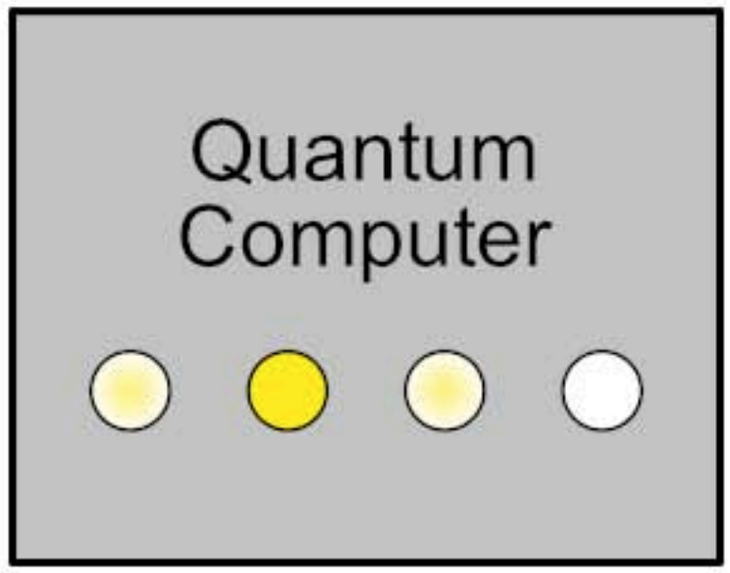
How quantum computers die



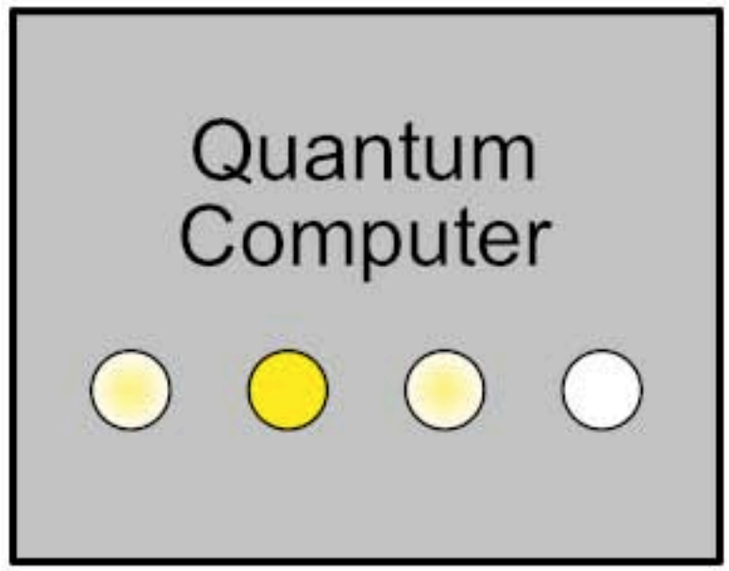
How quantum computers die

Quantum Computer

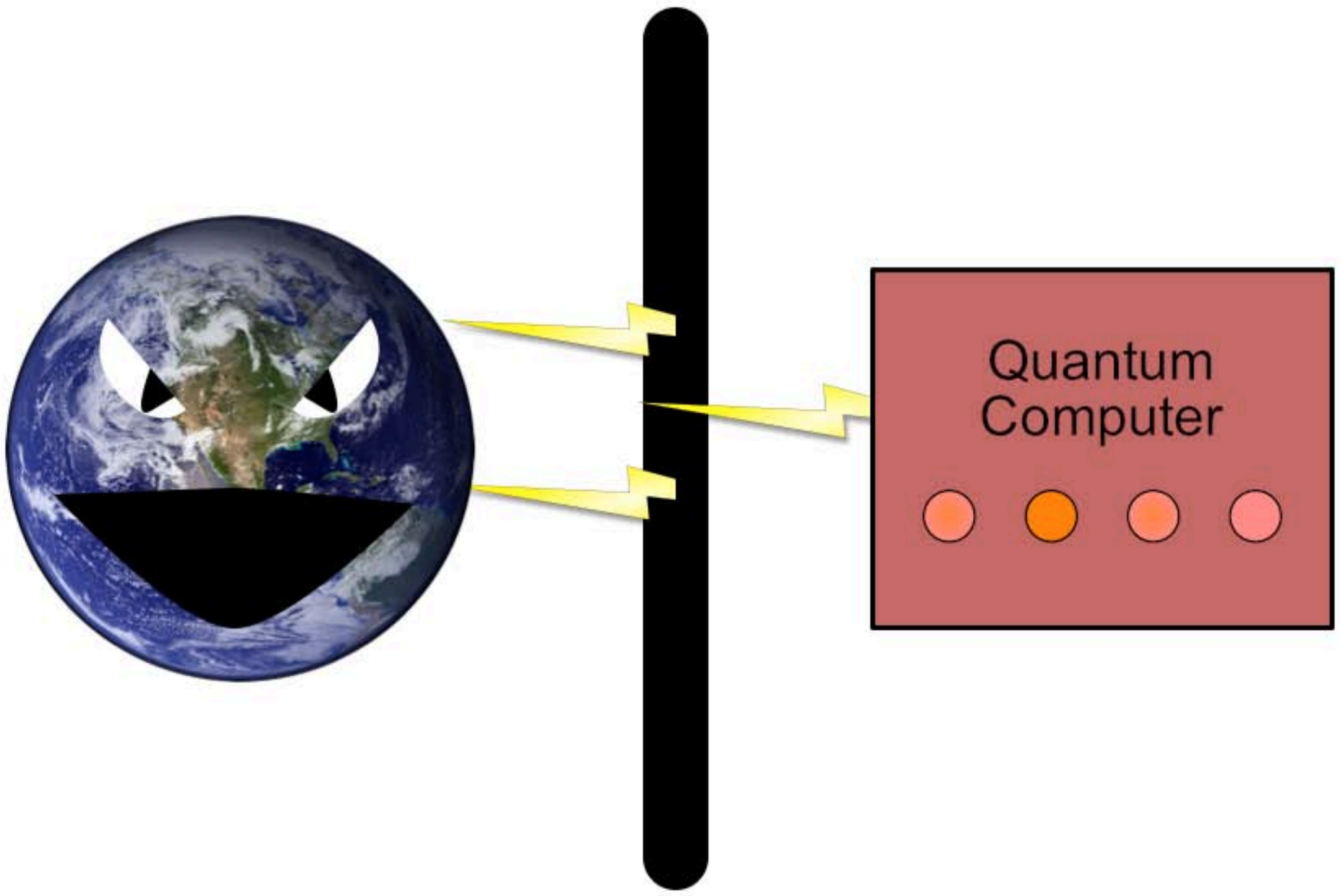
How quantum computers die



How quantum computers die

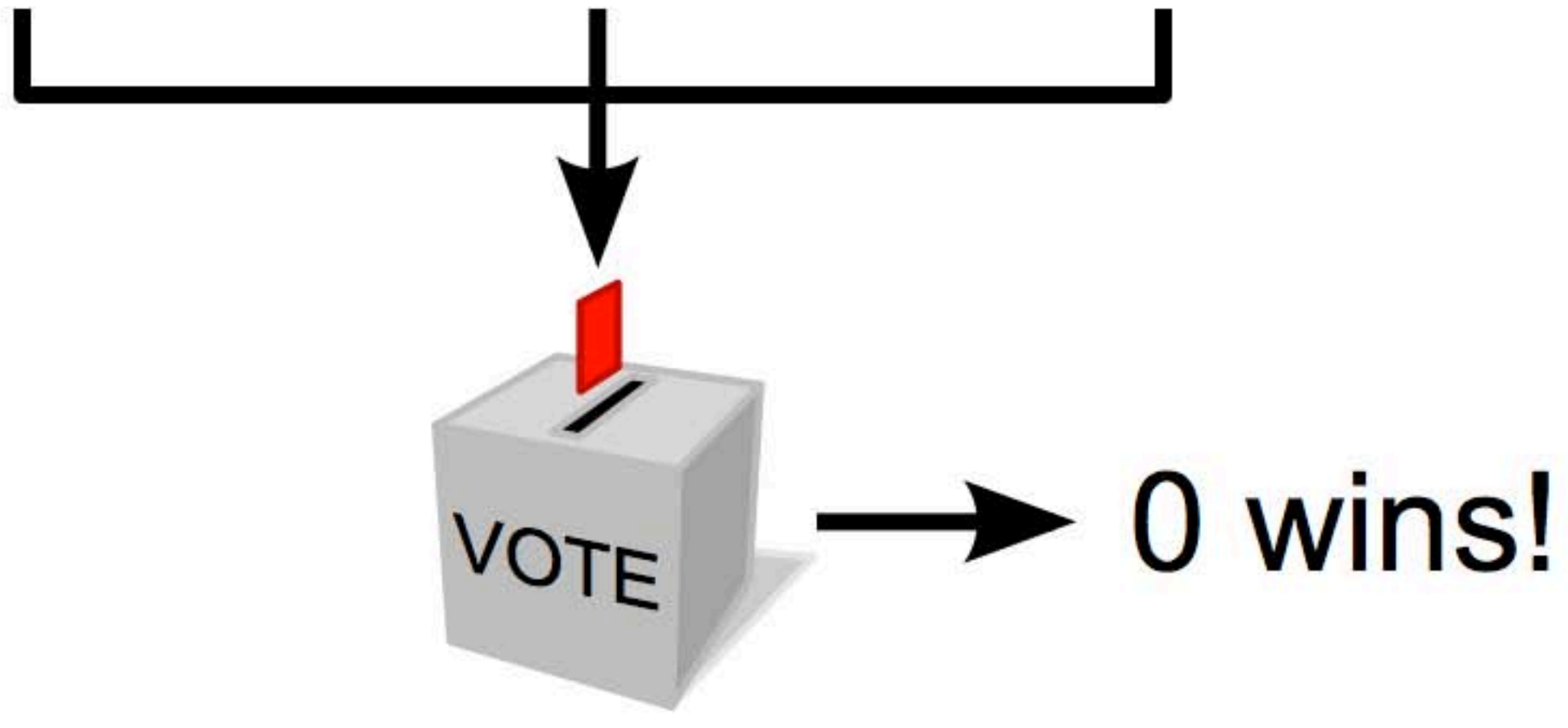


How quantum computers die



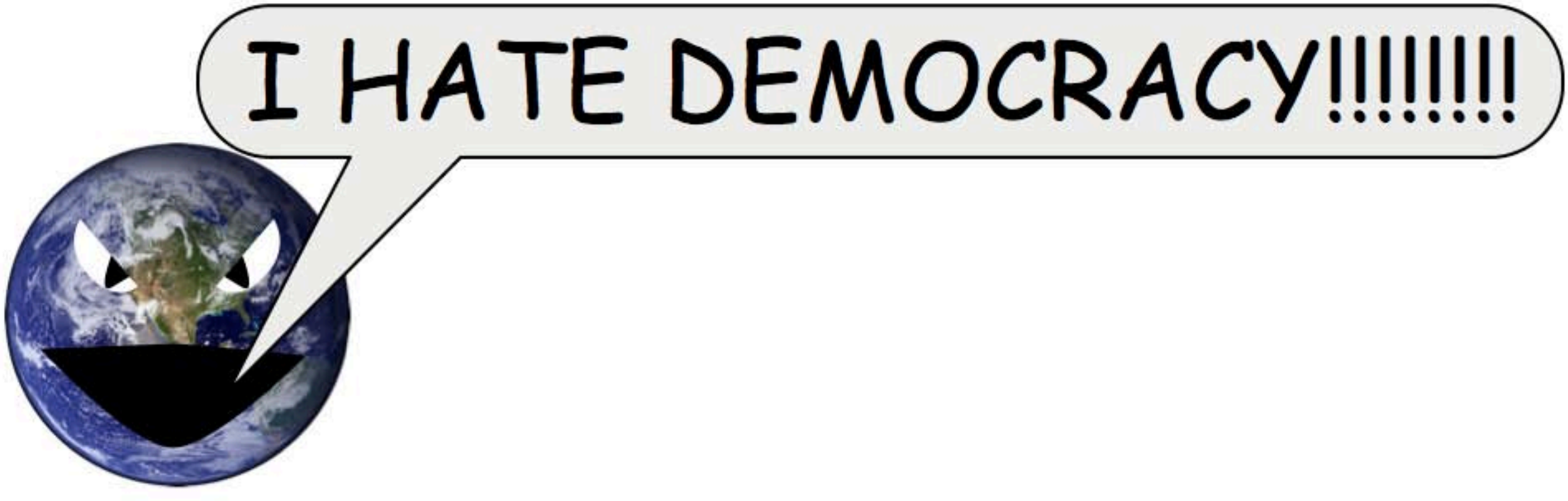
Classical error correction

0 1 0

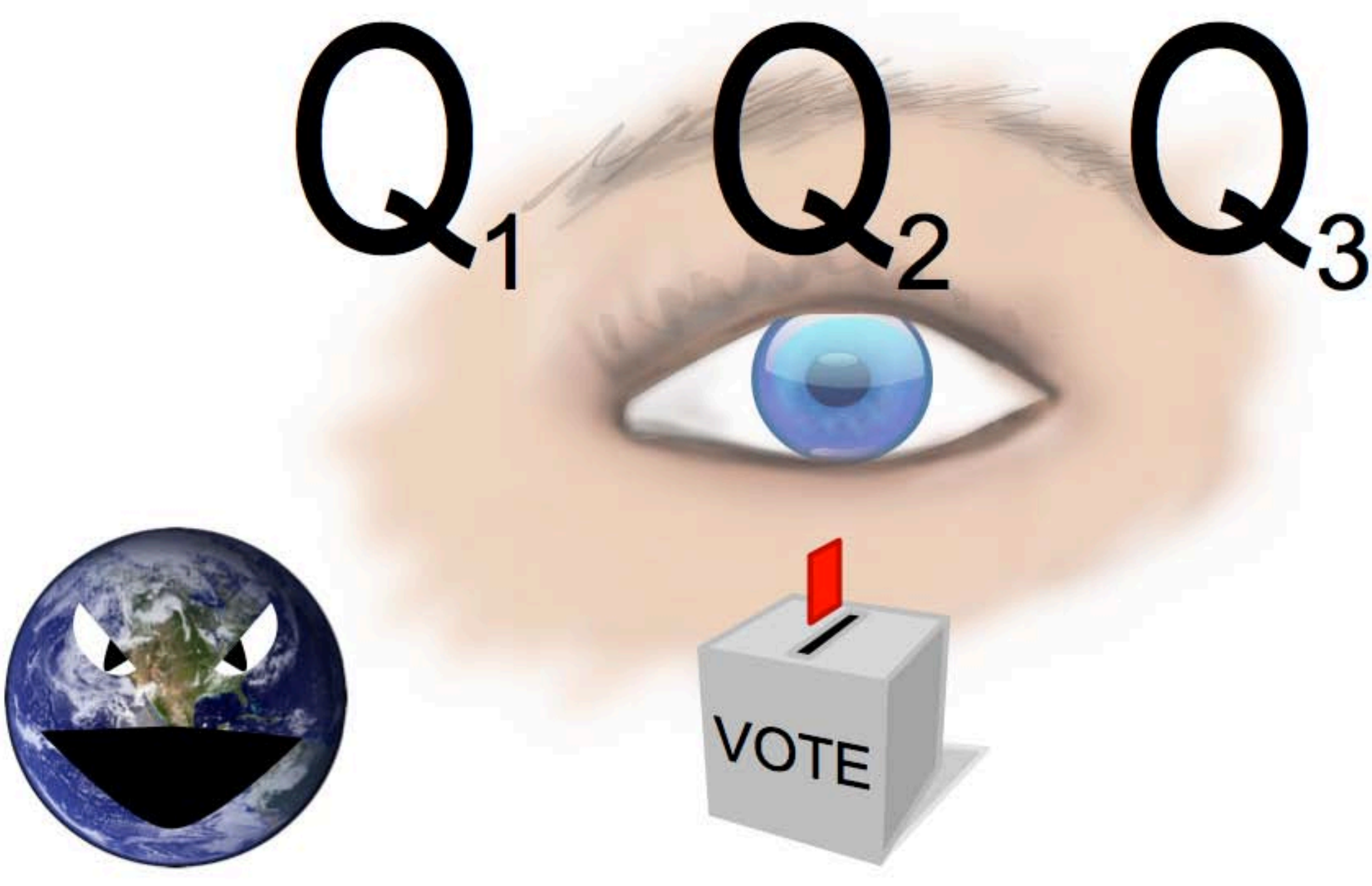


Classical error correction

0 0 0



Quantum error correction



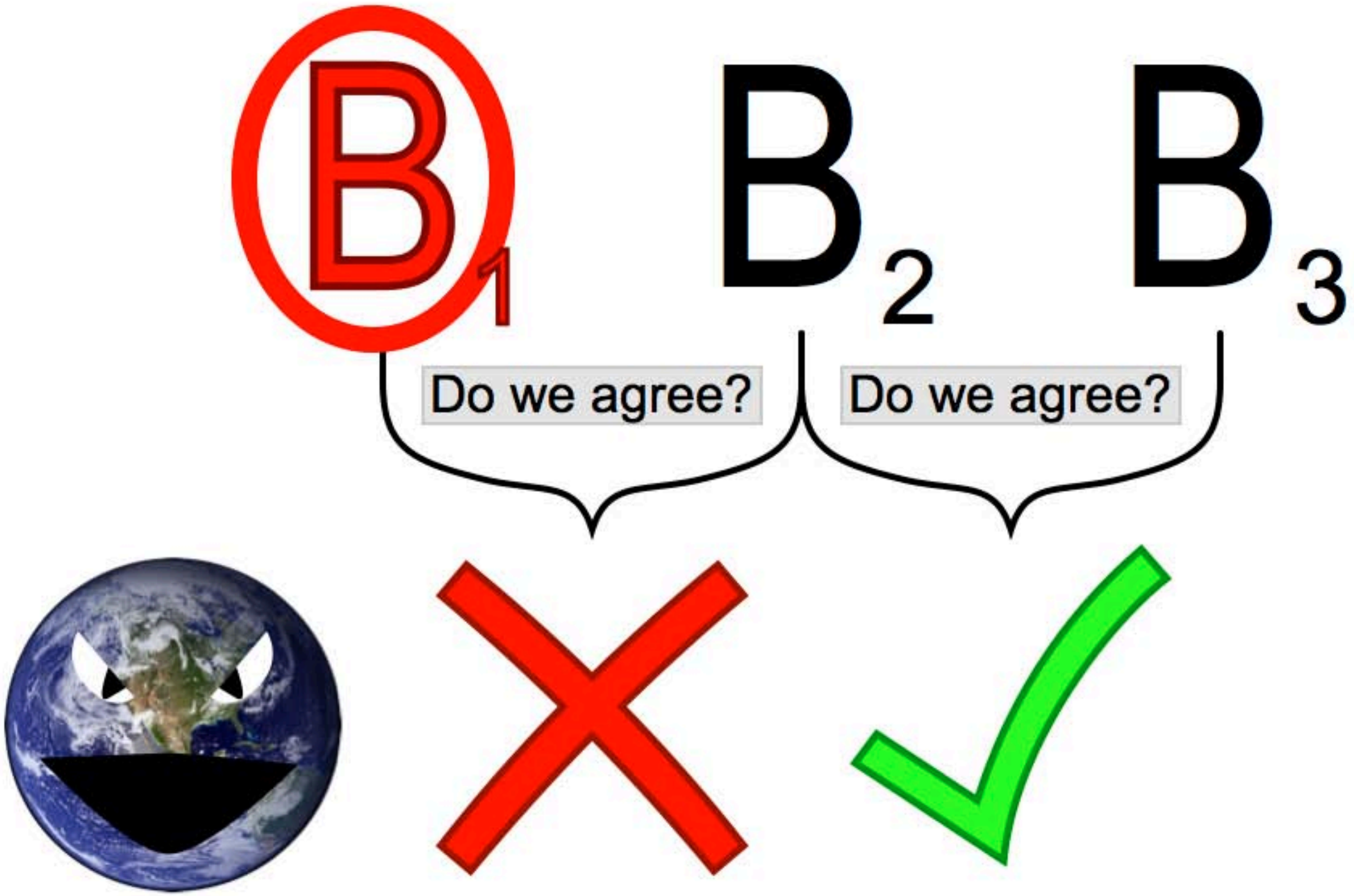
Quantum error correction

Classical error correction: an alternative

B_1 B_2 B_3

Do we agree? Do we agree?

Classical error correction: an alternative



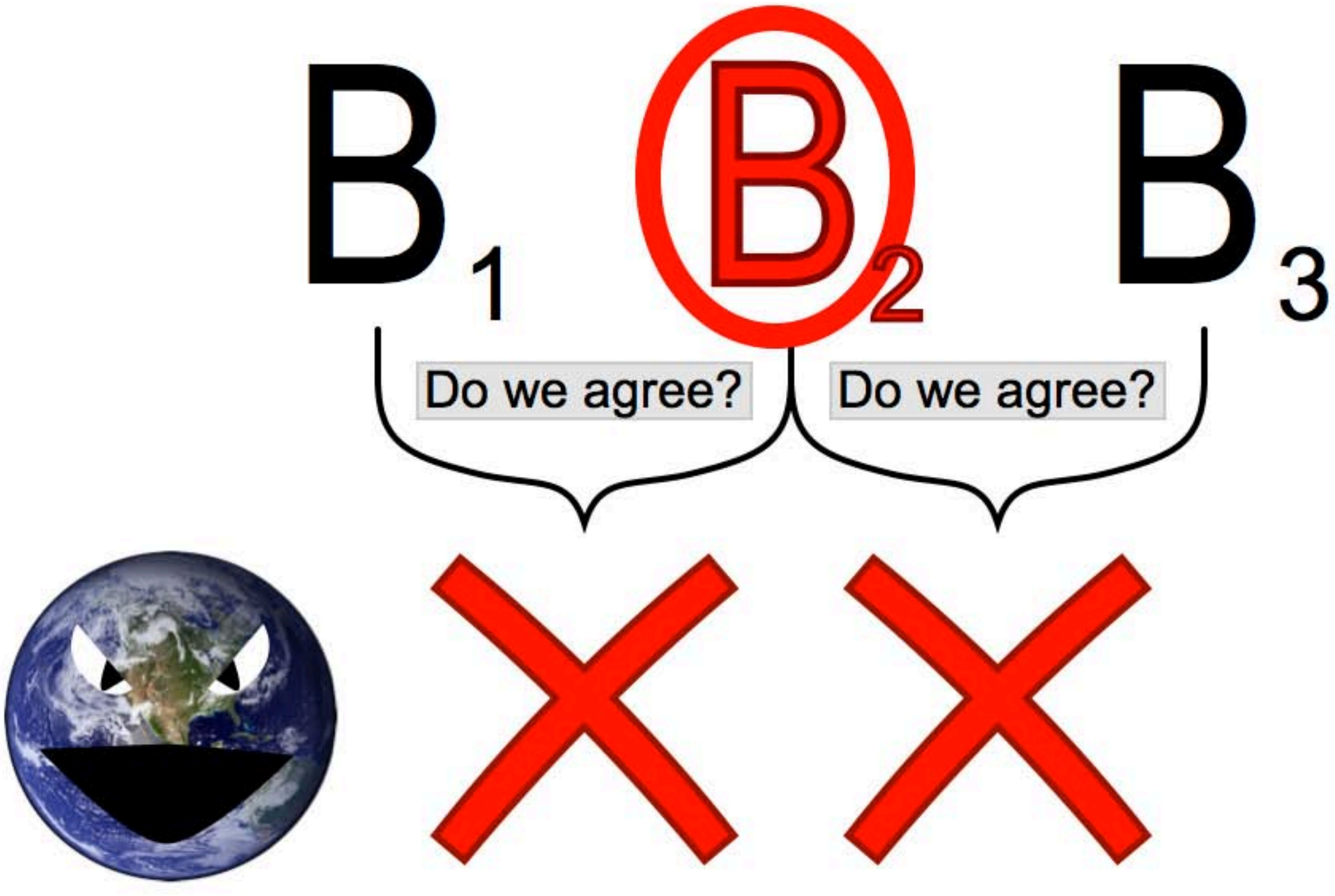
Classical error correction: an alternative

B_1 B_2 B_3

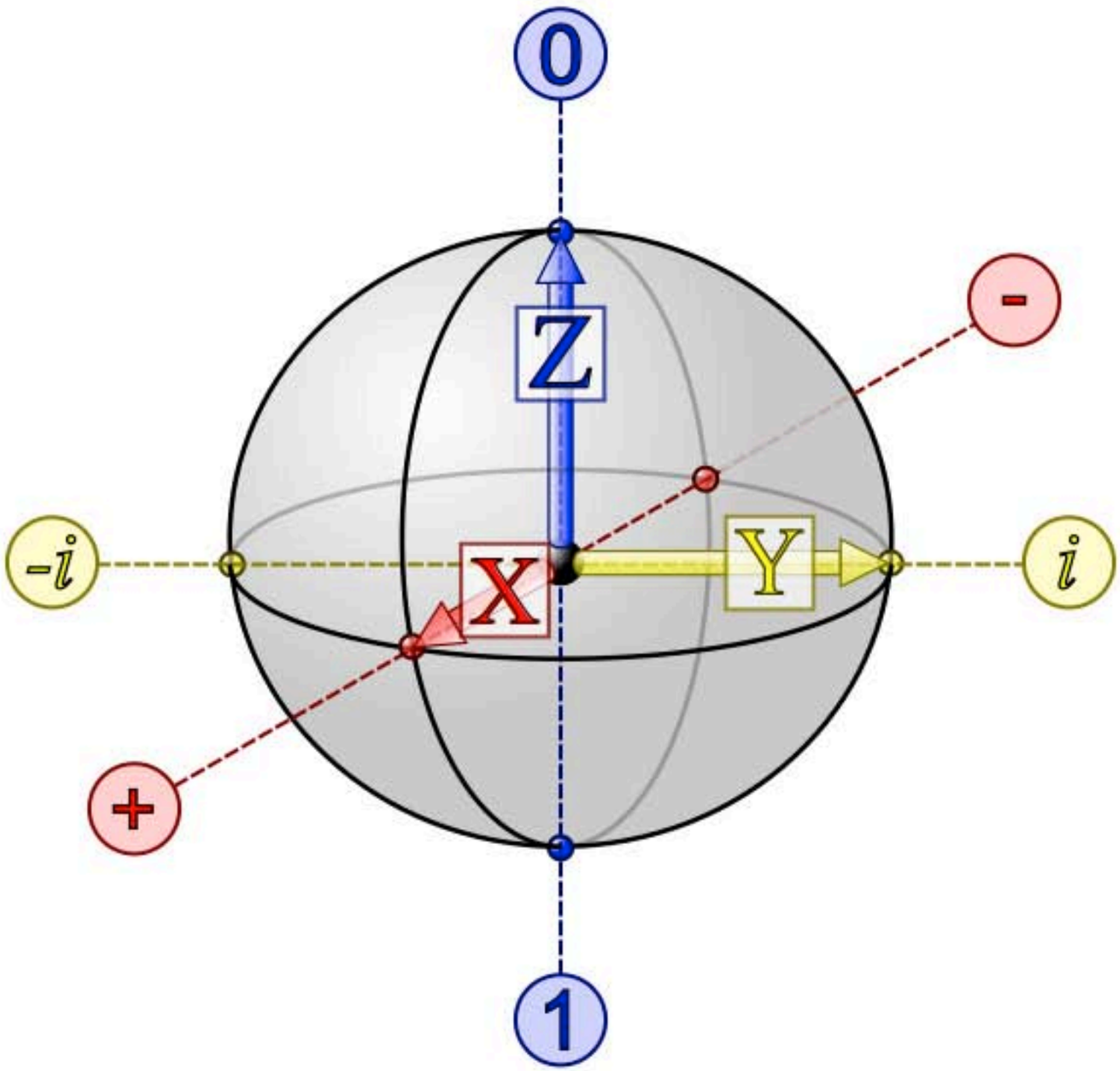
Do we agree?

Do we agree?

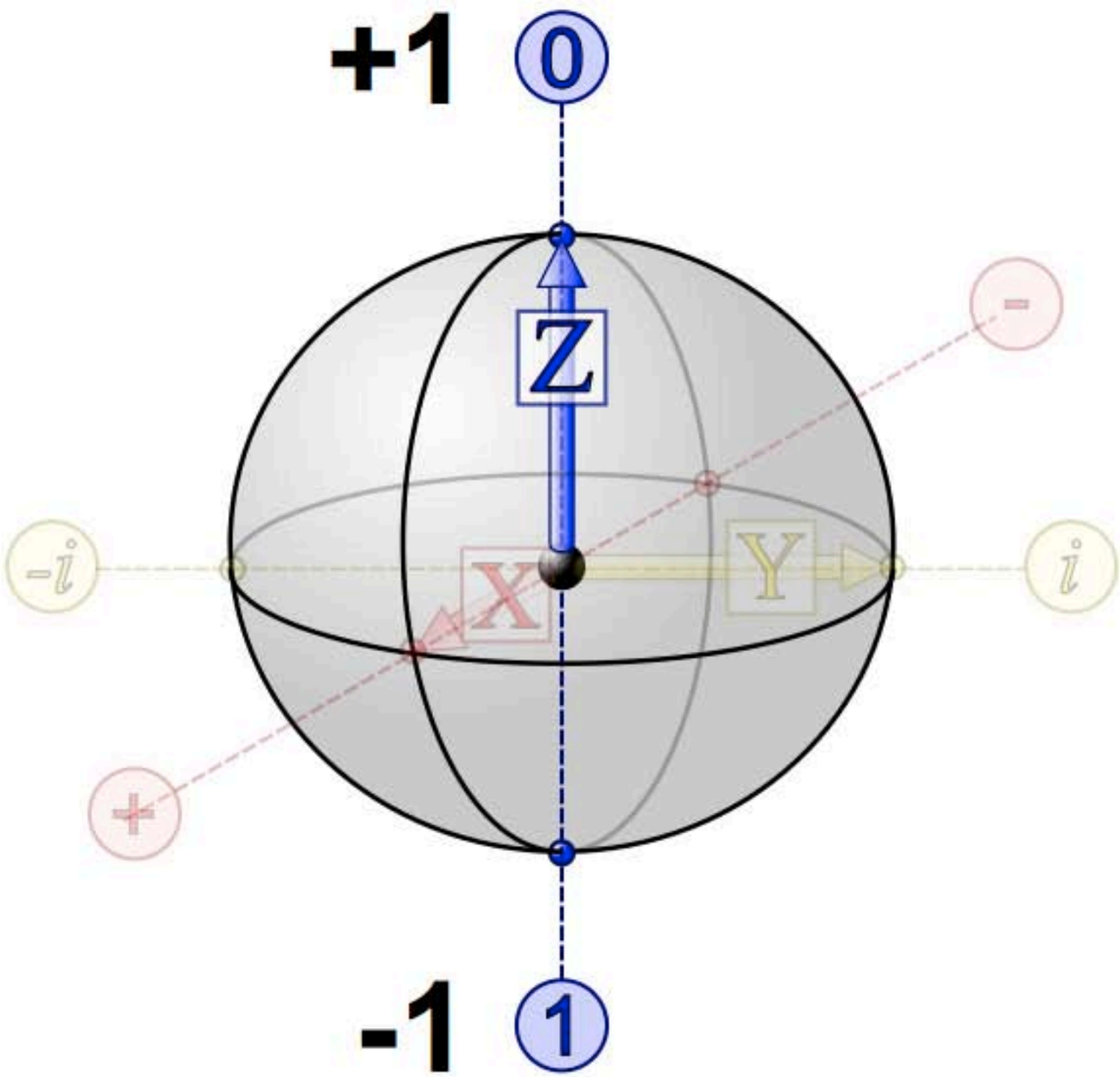
Classical error correction: an alternative



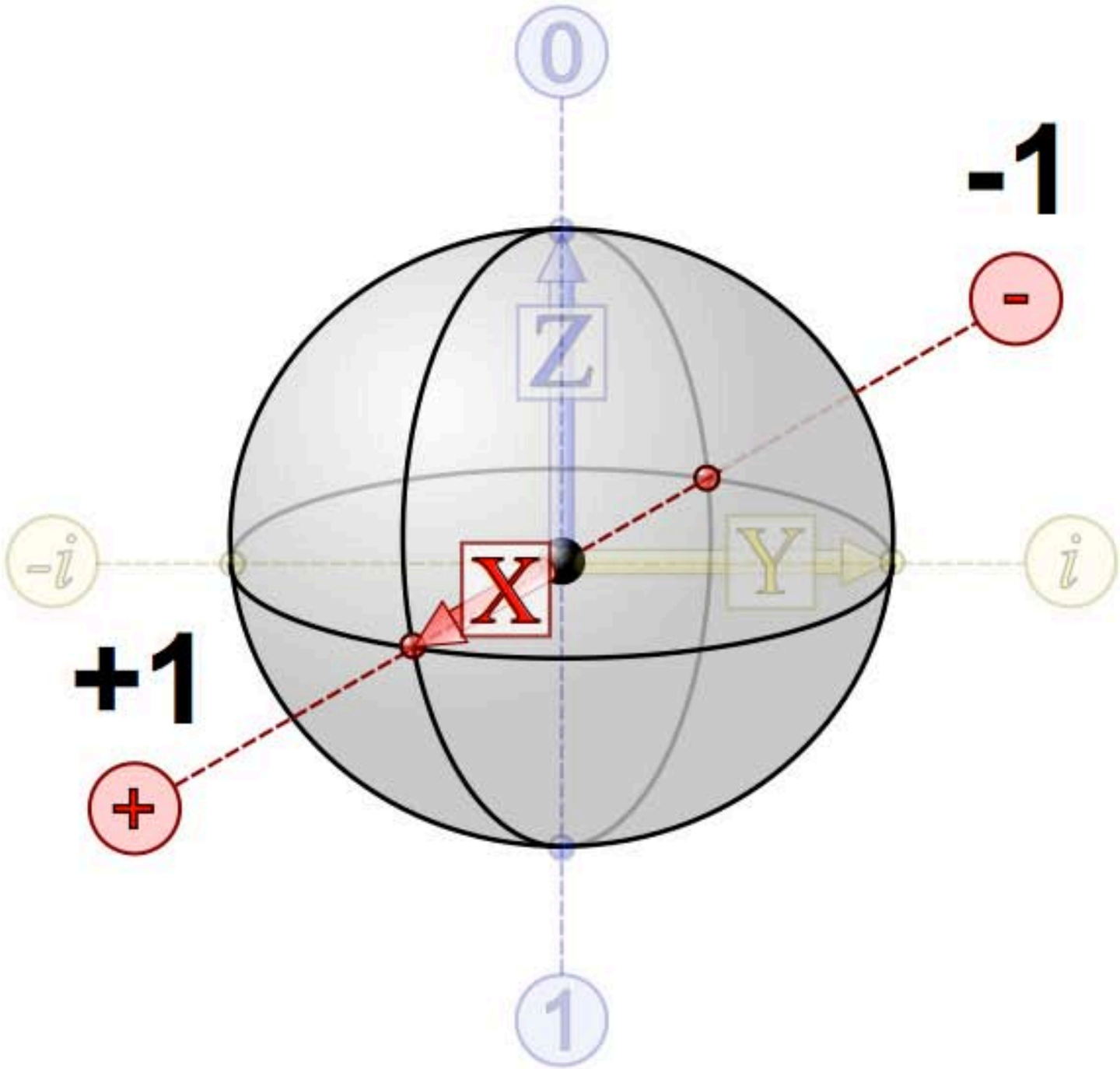
Quantum measurement



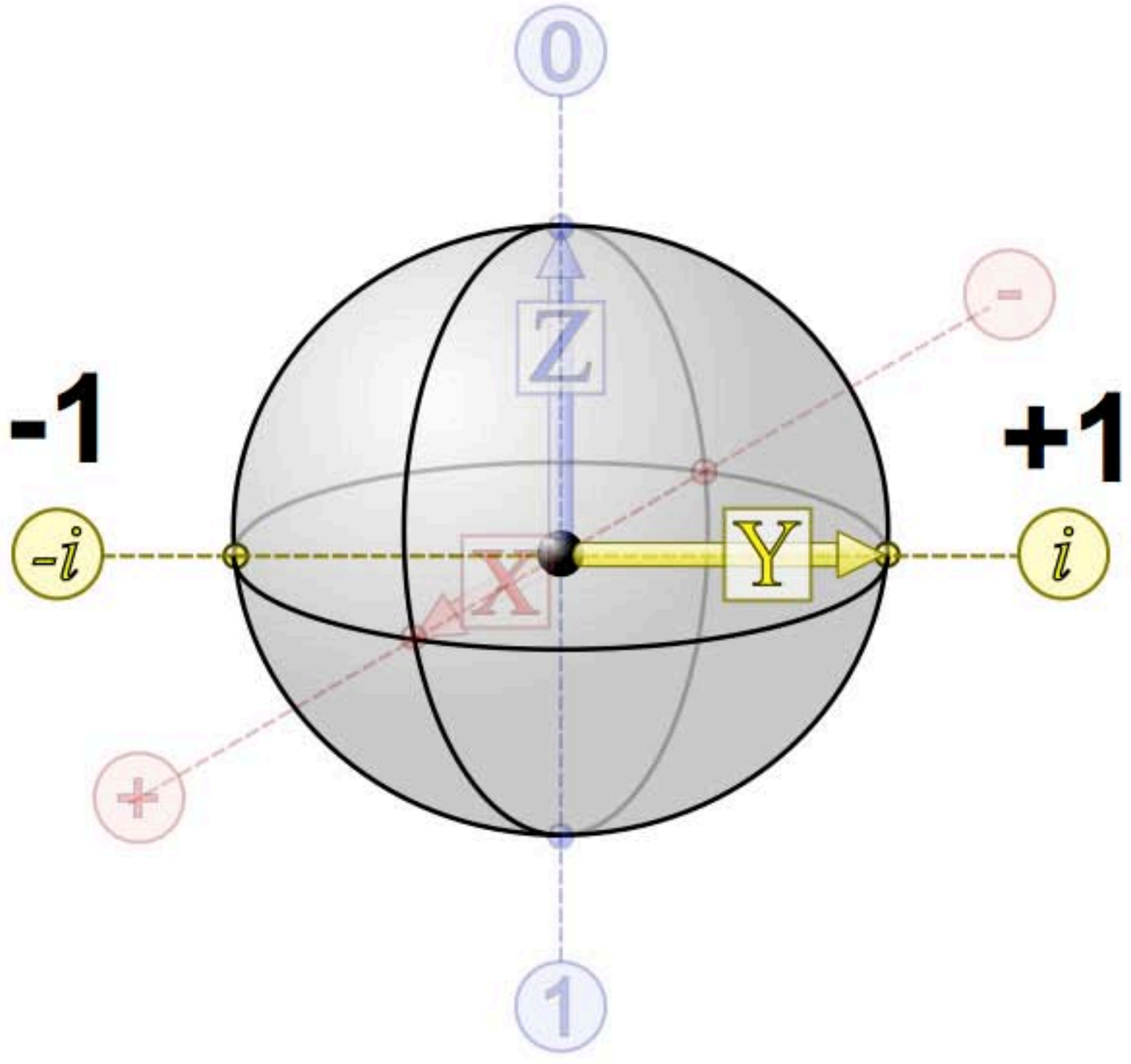
Quantum measurement



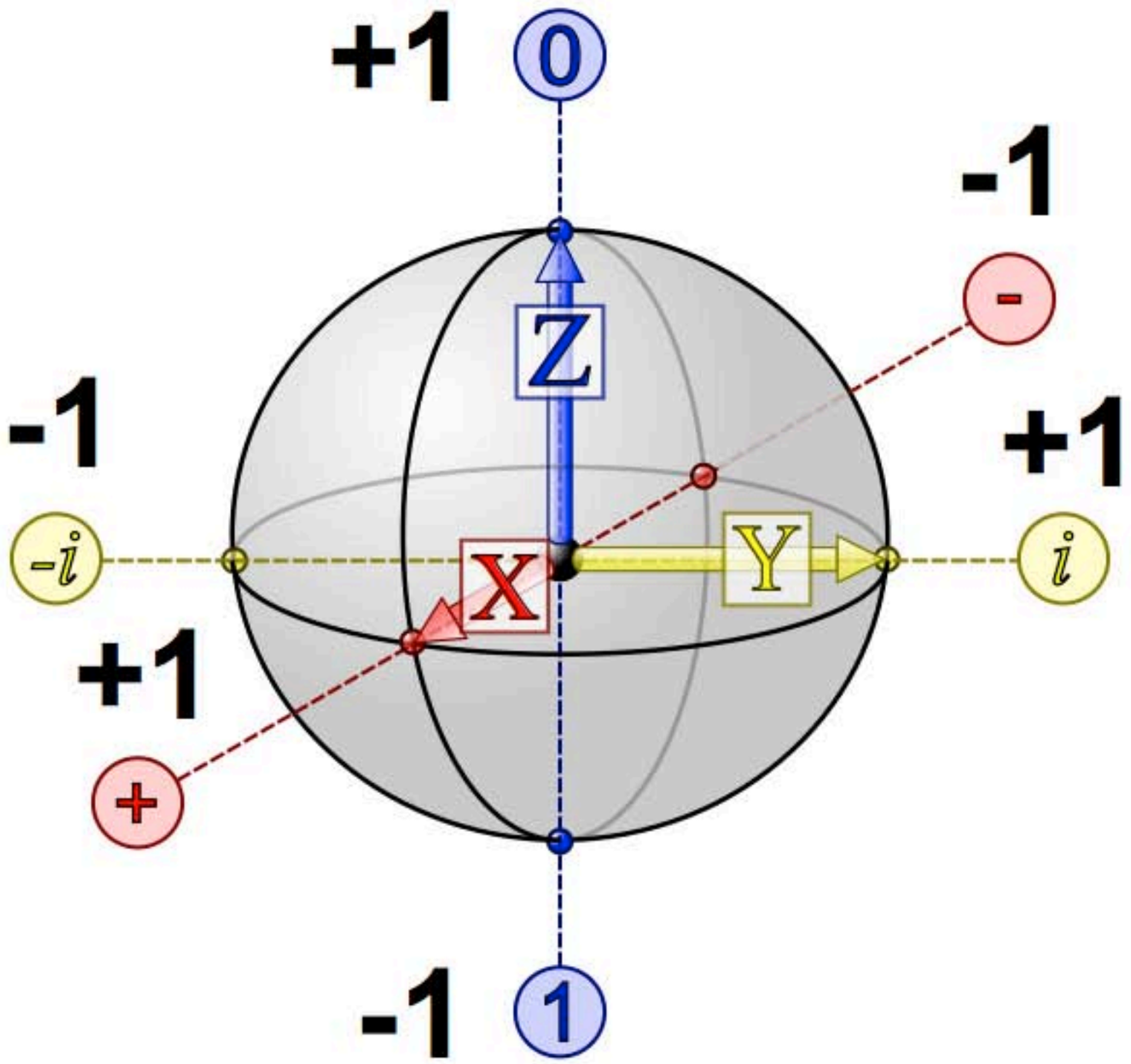
Quantum measurement



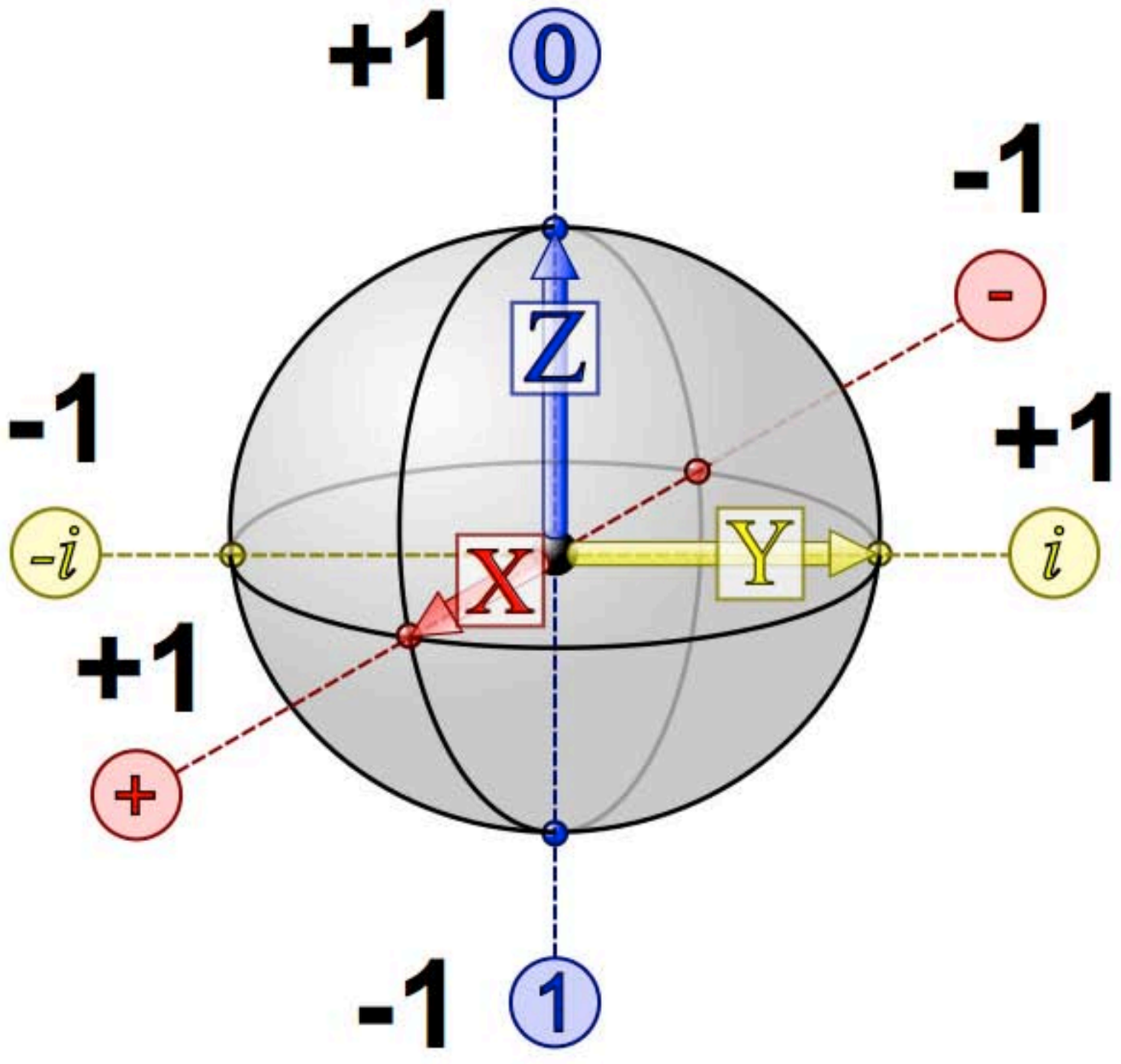
Quantum measurement



Quantum measurement



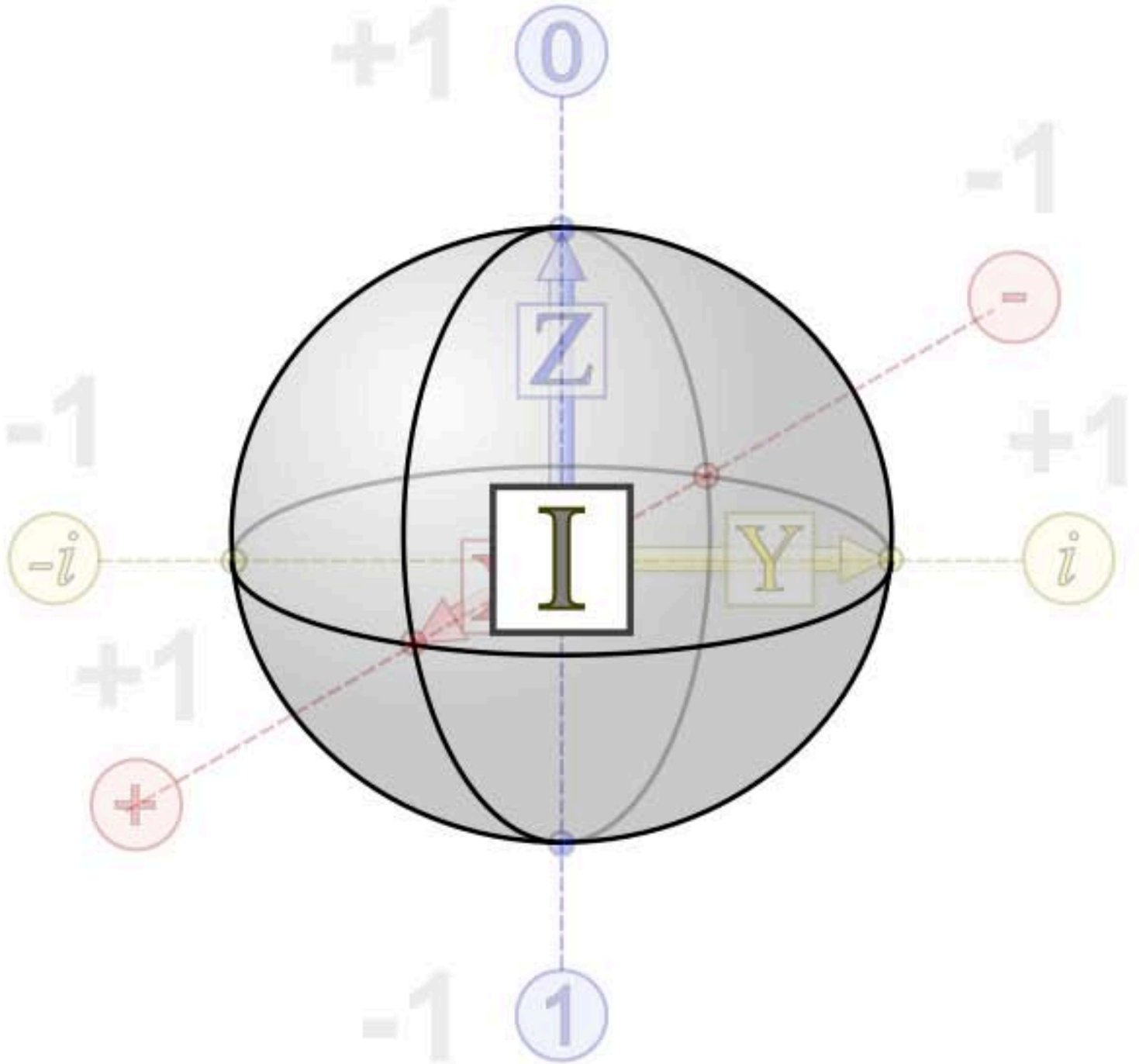
Quantum measurement



First code

Z	I	I
I	Z	I
I	I	Z

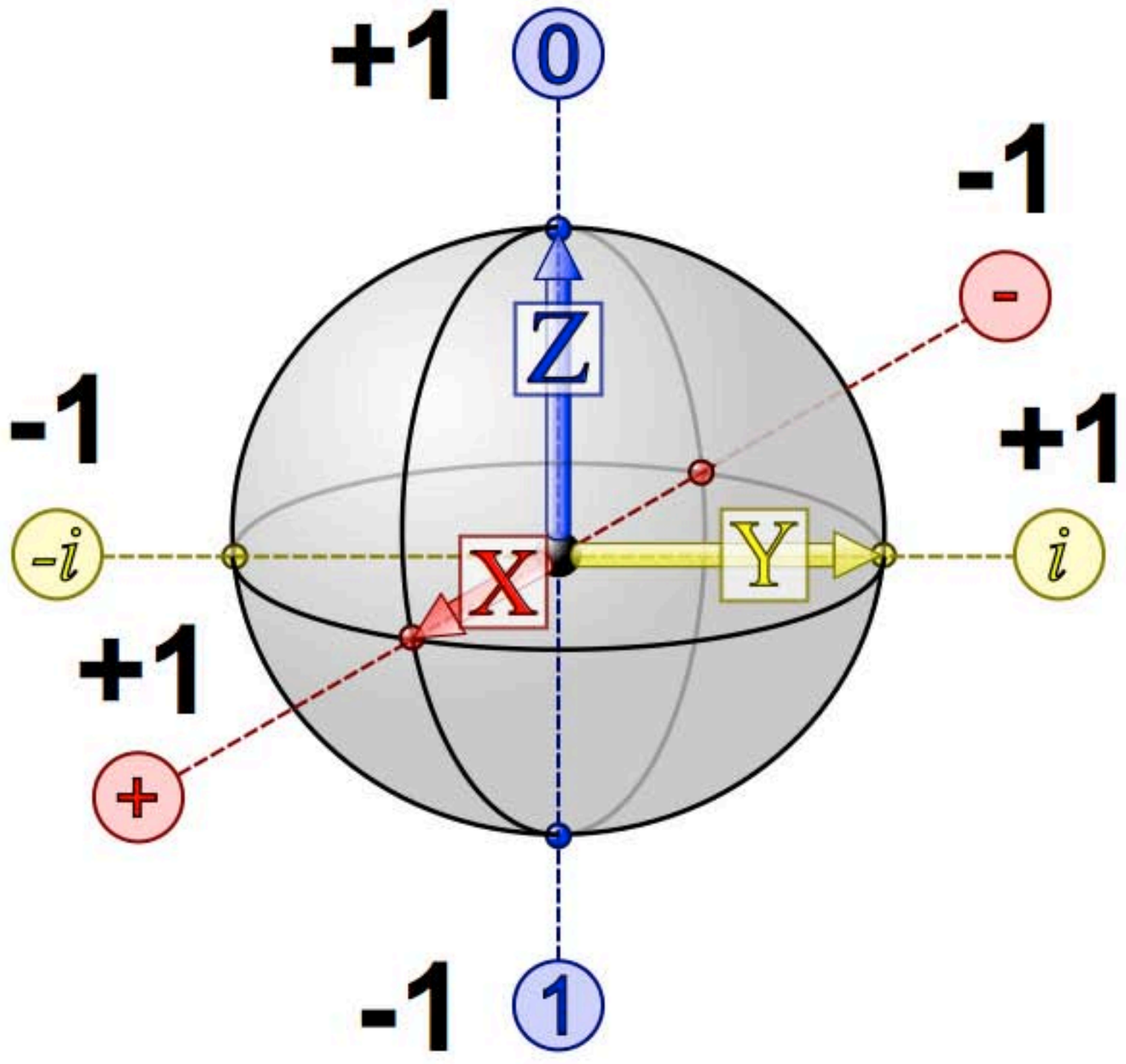
Quantum measurement



First code

Z	I	I
I	Z	I
I	I	Z

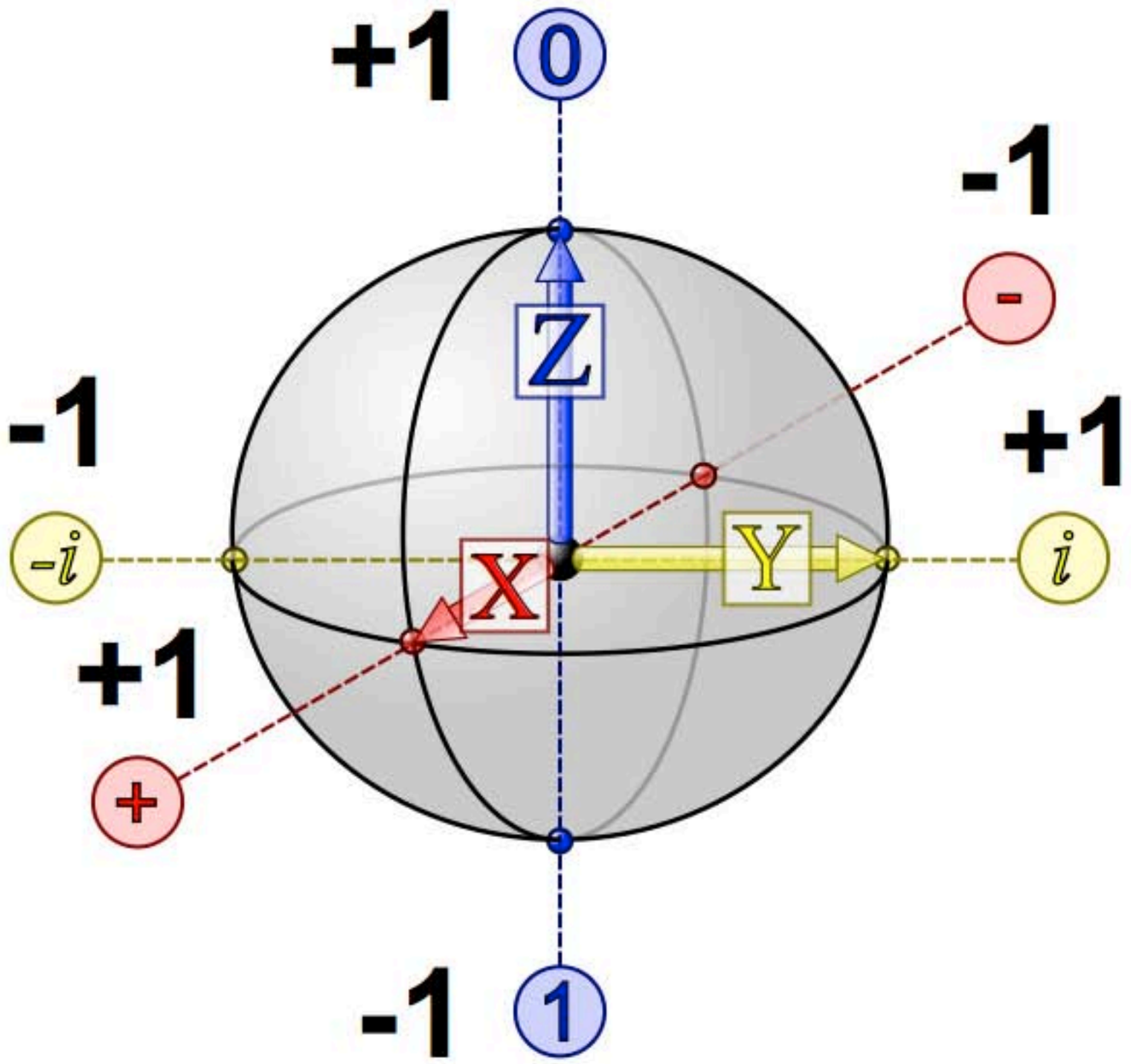
Quantum measurement



First code

Z	I	I
I	Z	I
I	I	Z

Quantum measurement



First code

Z	I	I
I	Z	I
I	I	Z

Second code

Z	Z	I
I	Z	Z

The Feynman Algorithm (applied to codes)

1. Write down the problem.

2. Think real hard.

3. Write down the answer.

The Feynman Algorithm (applied to codes)

1. Writ roblem.

2. I

3. Wr nswer.

A mind is a terrible thing to waste!

CodeQuest

a Weapon of Mass Simulation in the War on Noise

The CodeQuest Algorithm

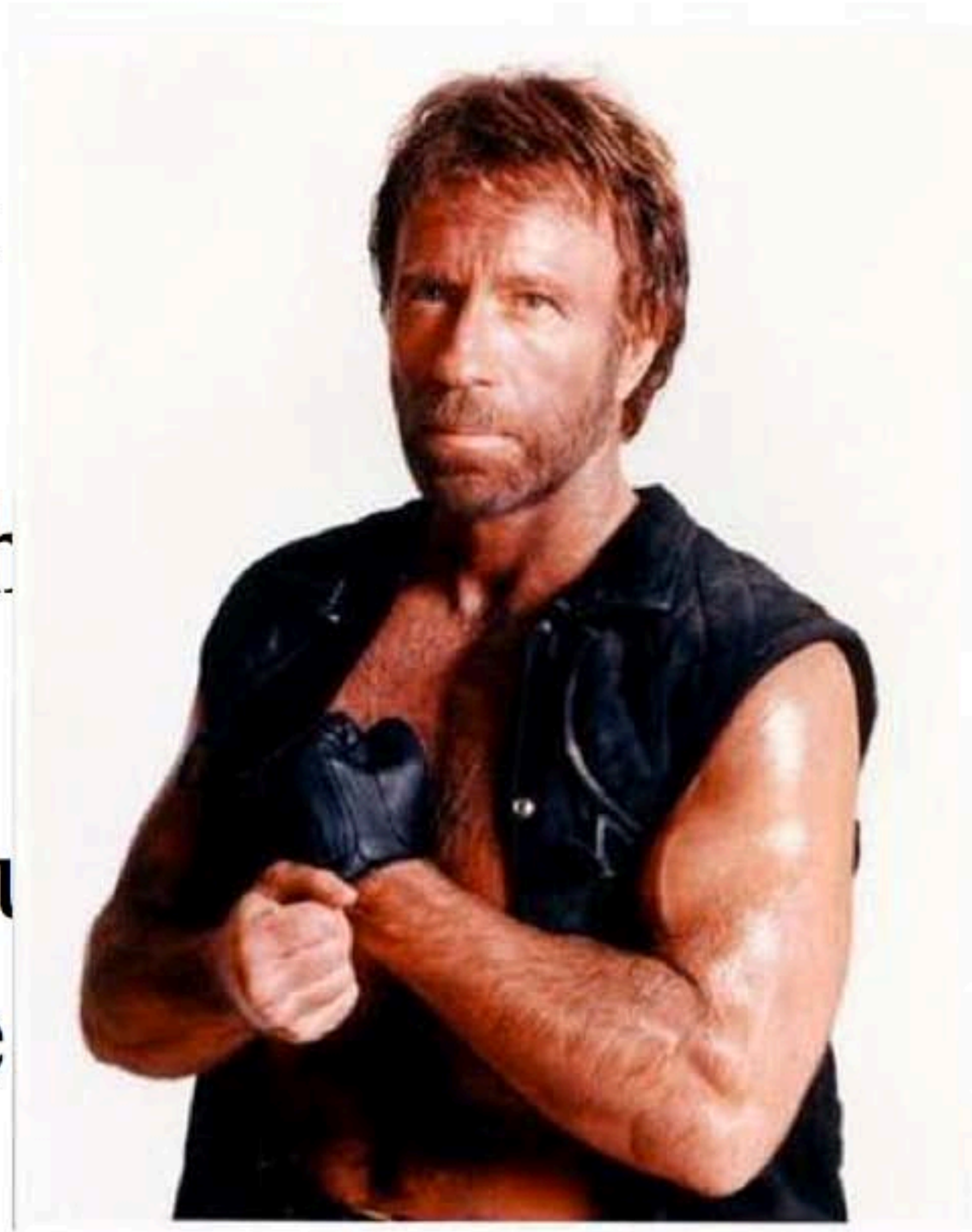
1. Input quantum measurements.

2. Let the computer think real hard.

3. Output the optimal code using those measurements.

The CodeQuest Algorithm

1. Input



nents.

2. Let th

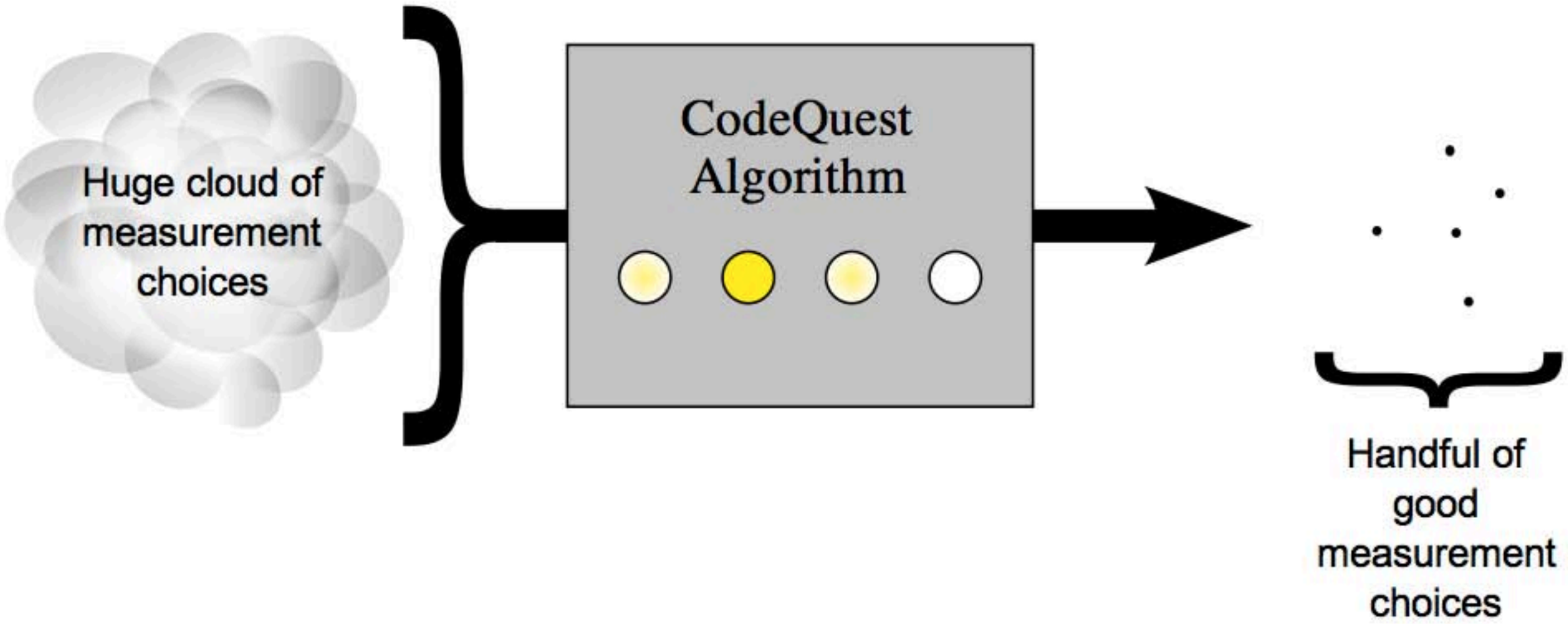
eal hard.

3. Outpu

using

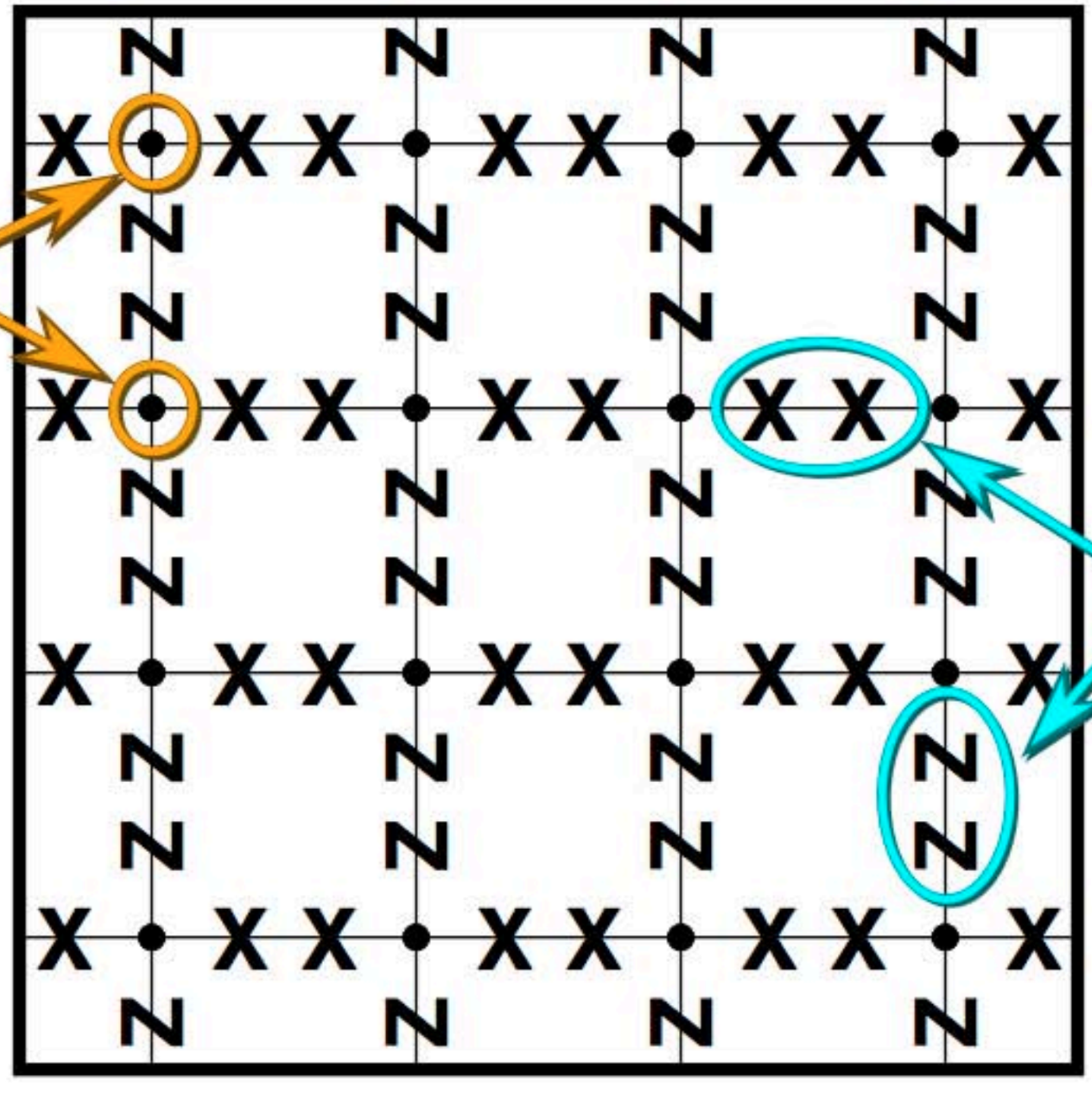
those

The CodeQuest Algorithm



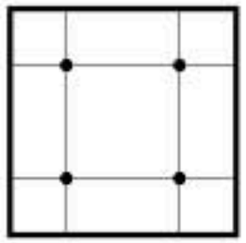
Case Study: Lattice codes

physical qubits



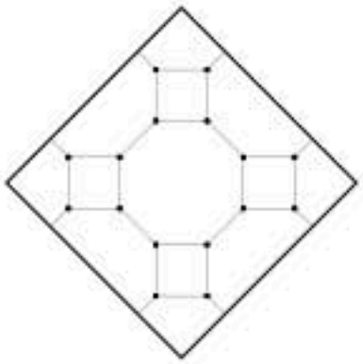
Case Study: Lattice codes

(# of measure-ment choices)



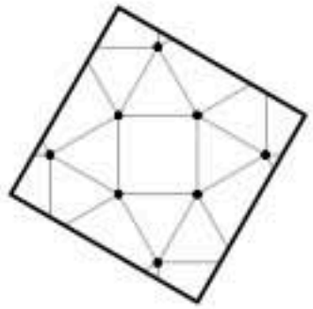
quadrille

(10)



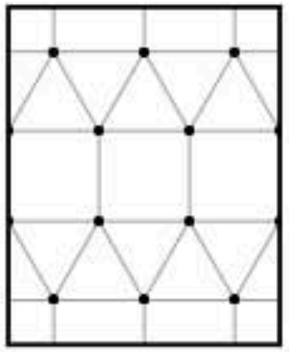
truncated quadrille

(155)



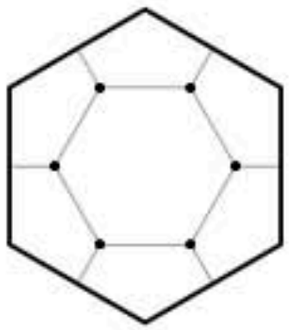
snub quadrille

(706,881)



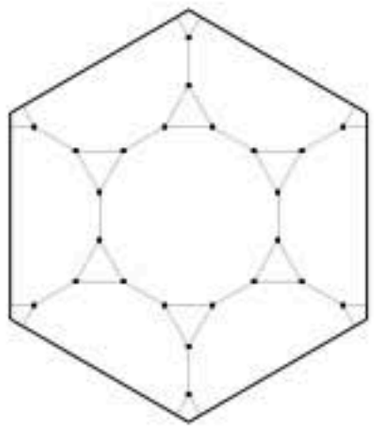
isosnub quadrille

(743)



hextille

(11)

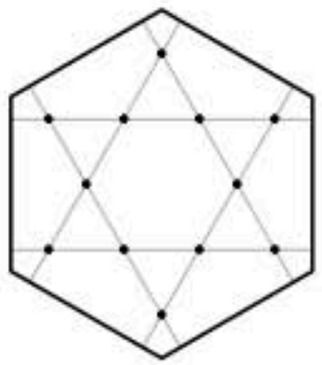


truncated hextille

(2392)

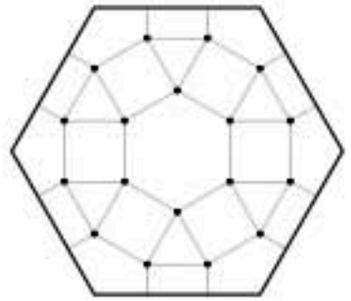
deltille

(58)



hexadeltille

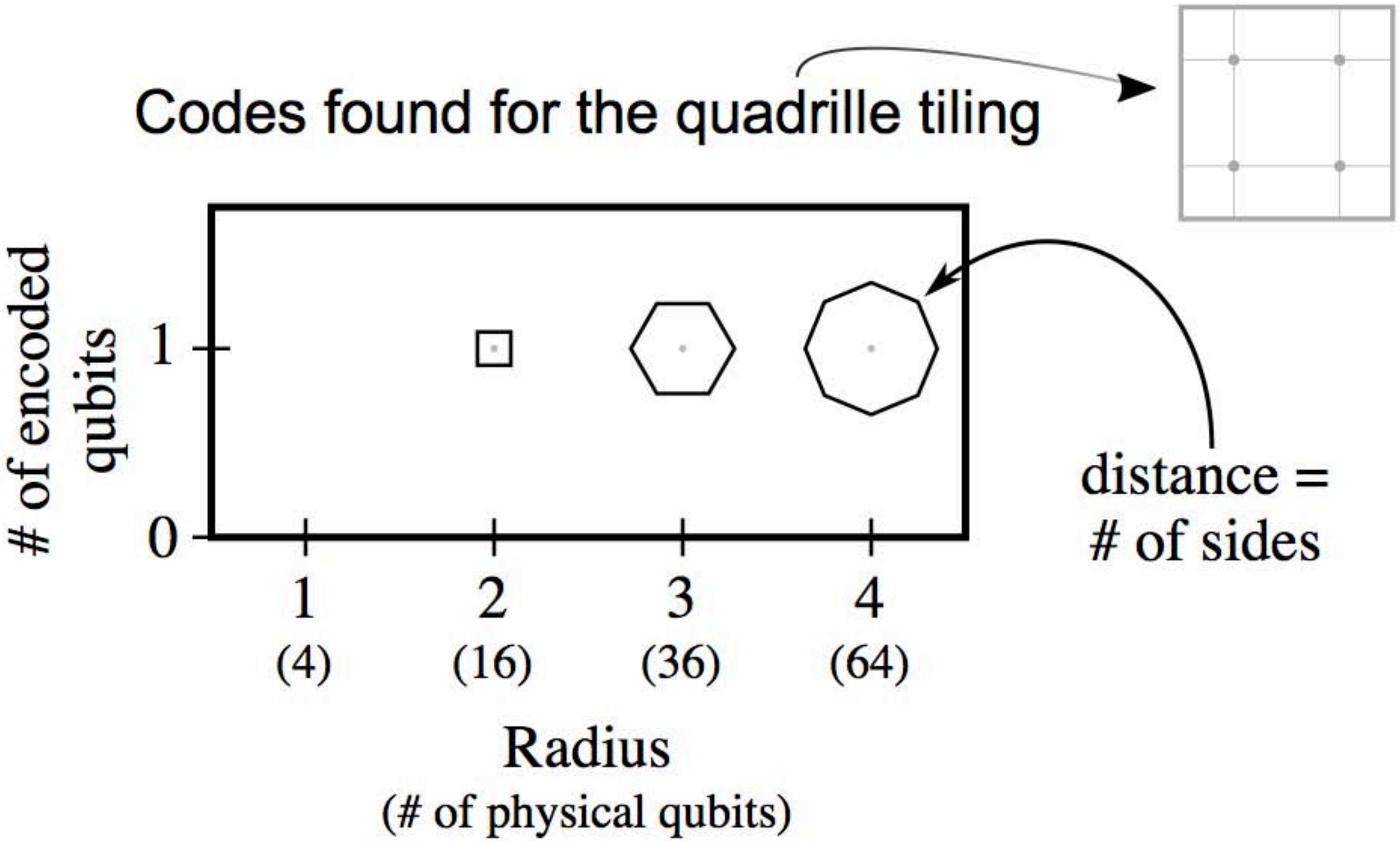
(594)



rhombi-hexadeltille

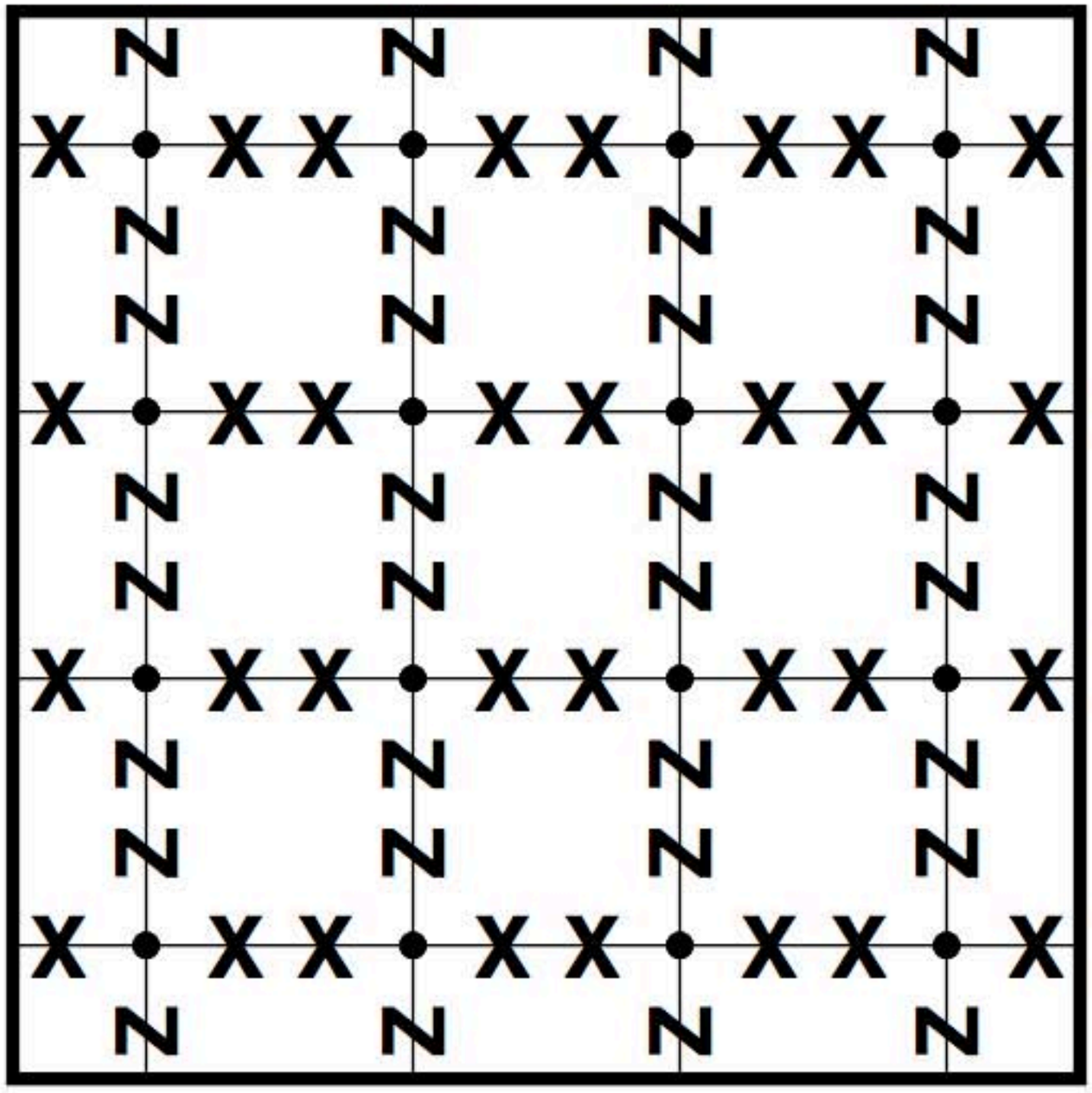
(904,741)

Case Study: Lattice codes

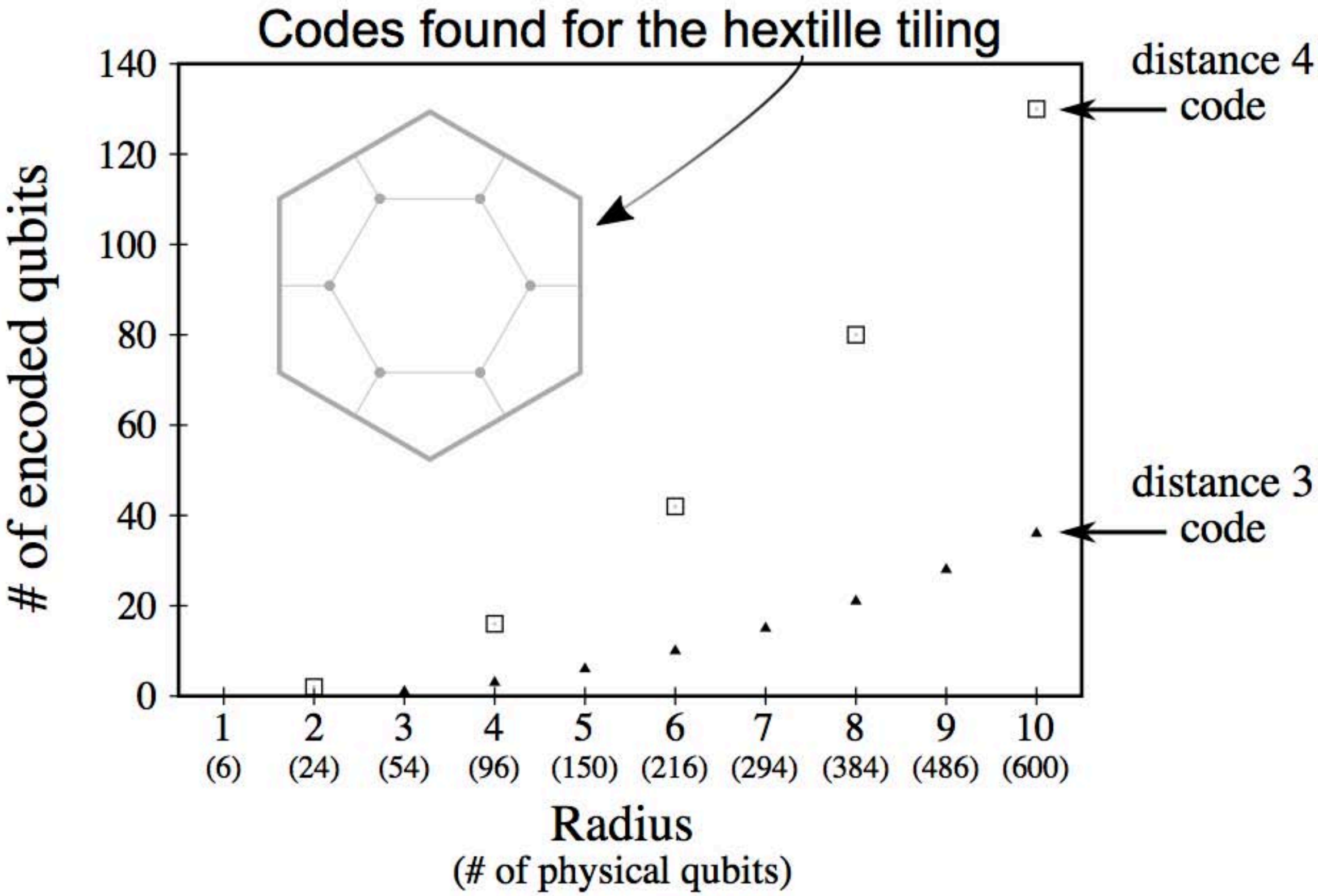


Case Study: Lattice codes

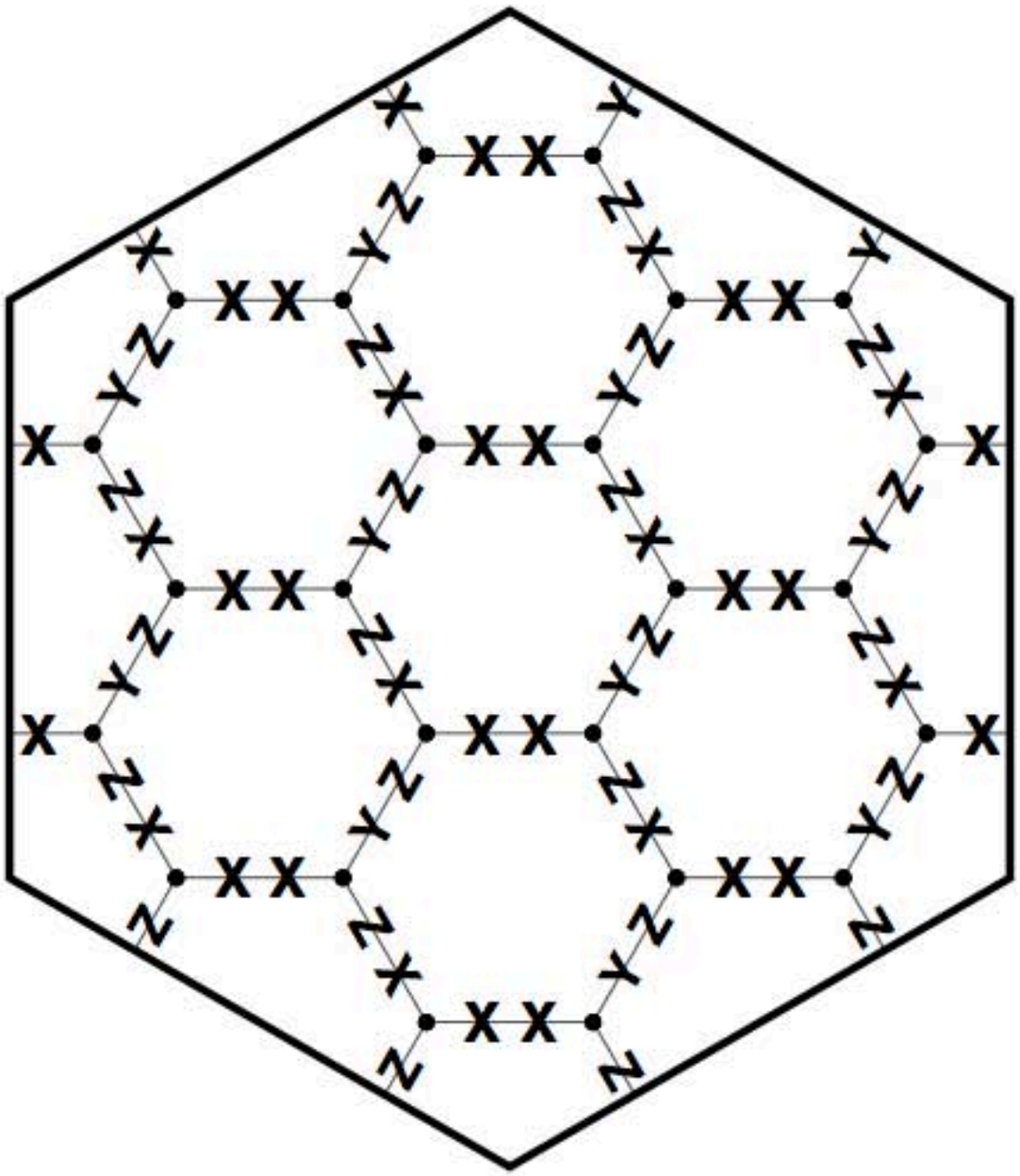
Bacon-Shor Code



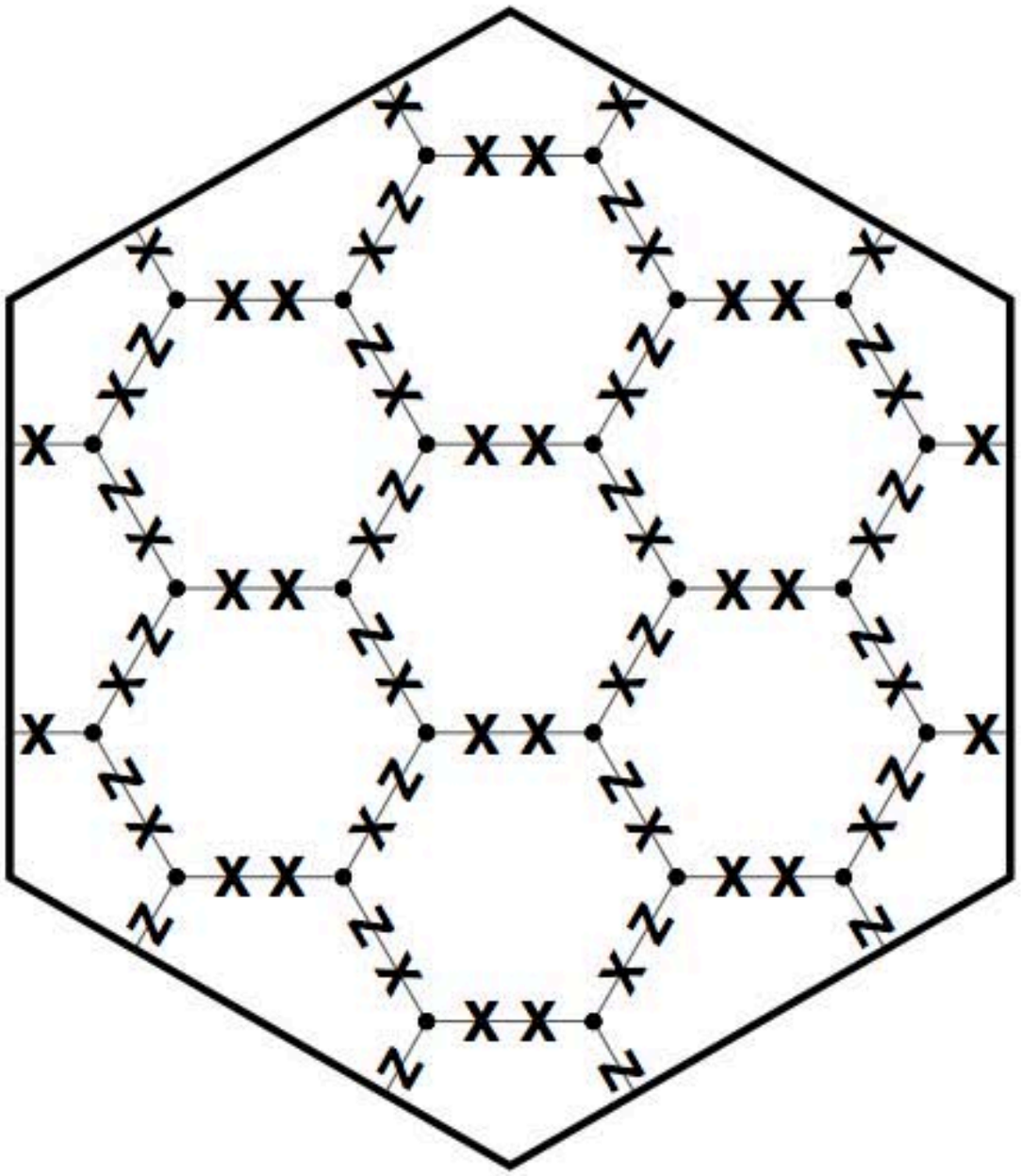
Case Study: Lattice codes



Case Study: Lattice codes



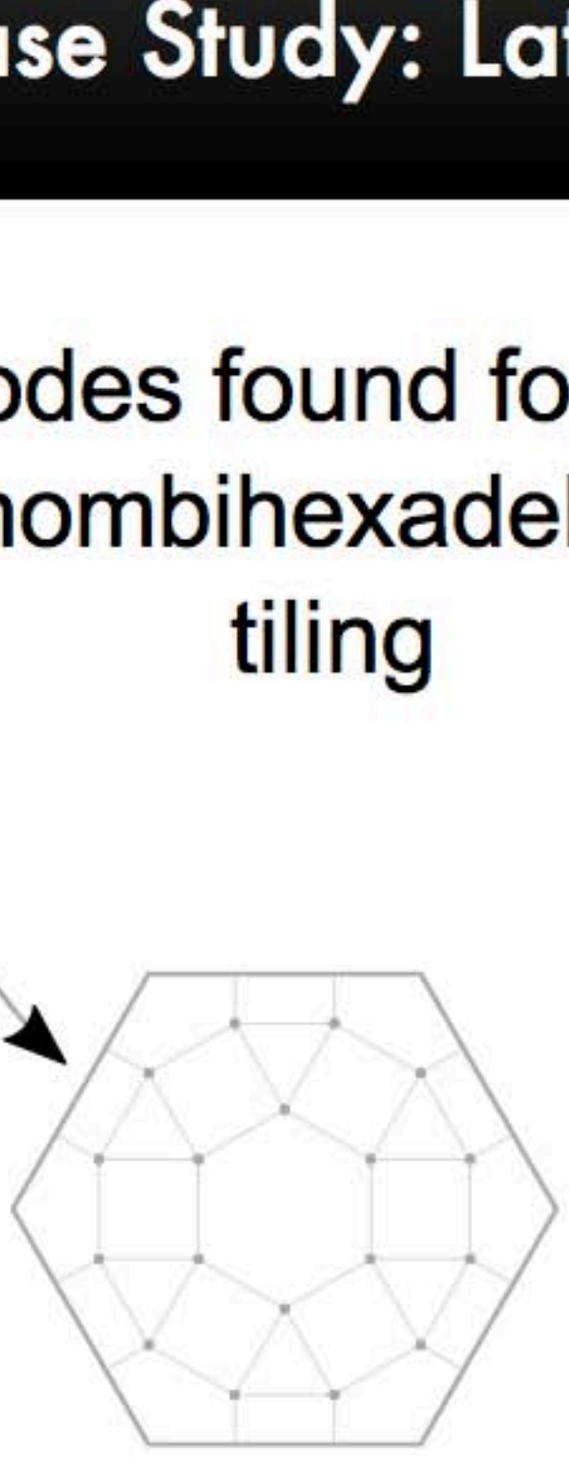
distance 3
code

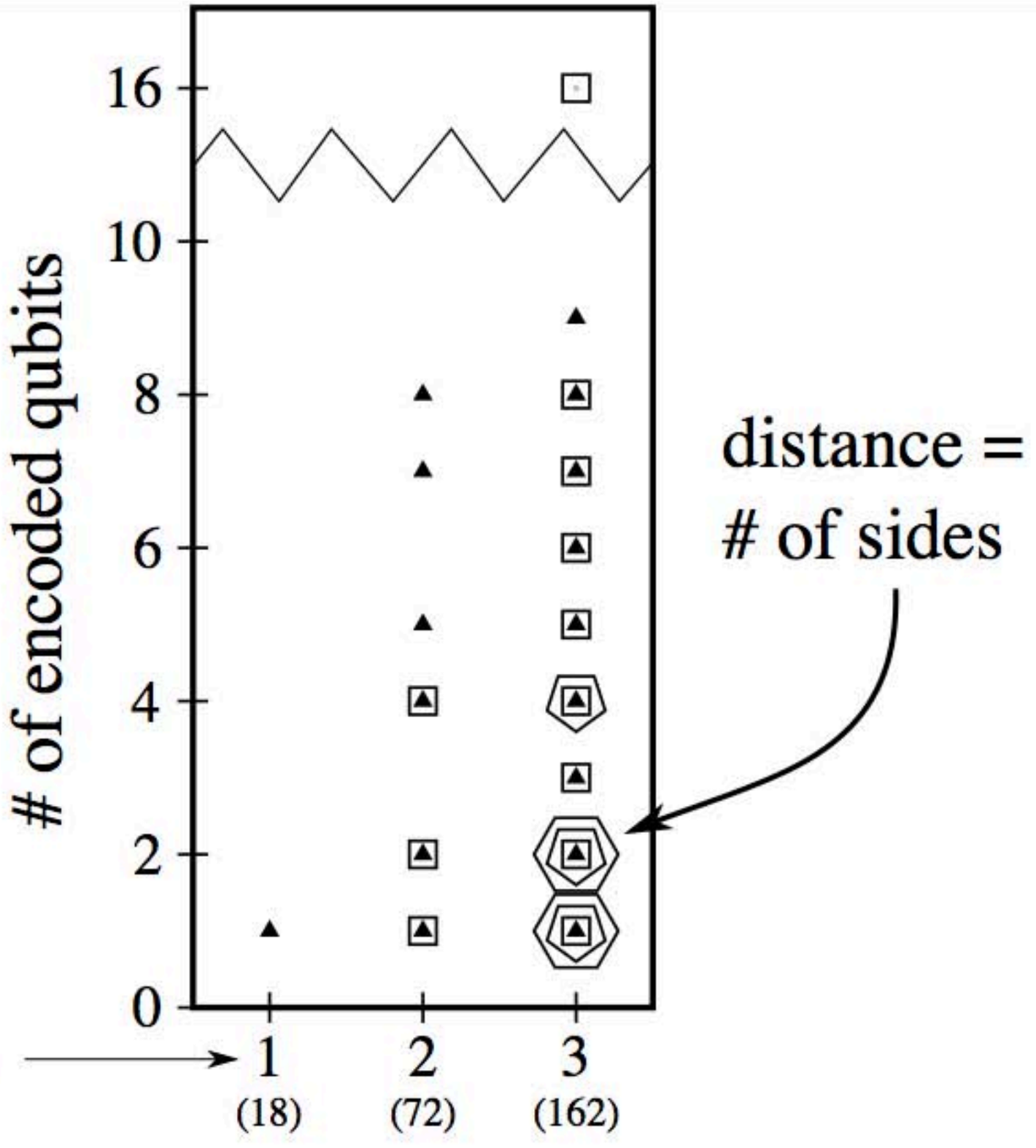


distance 4
code

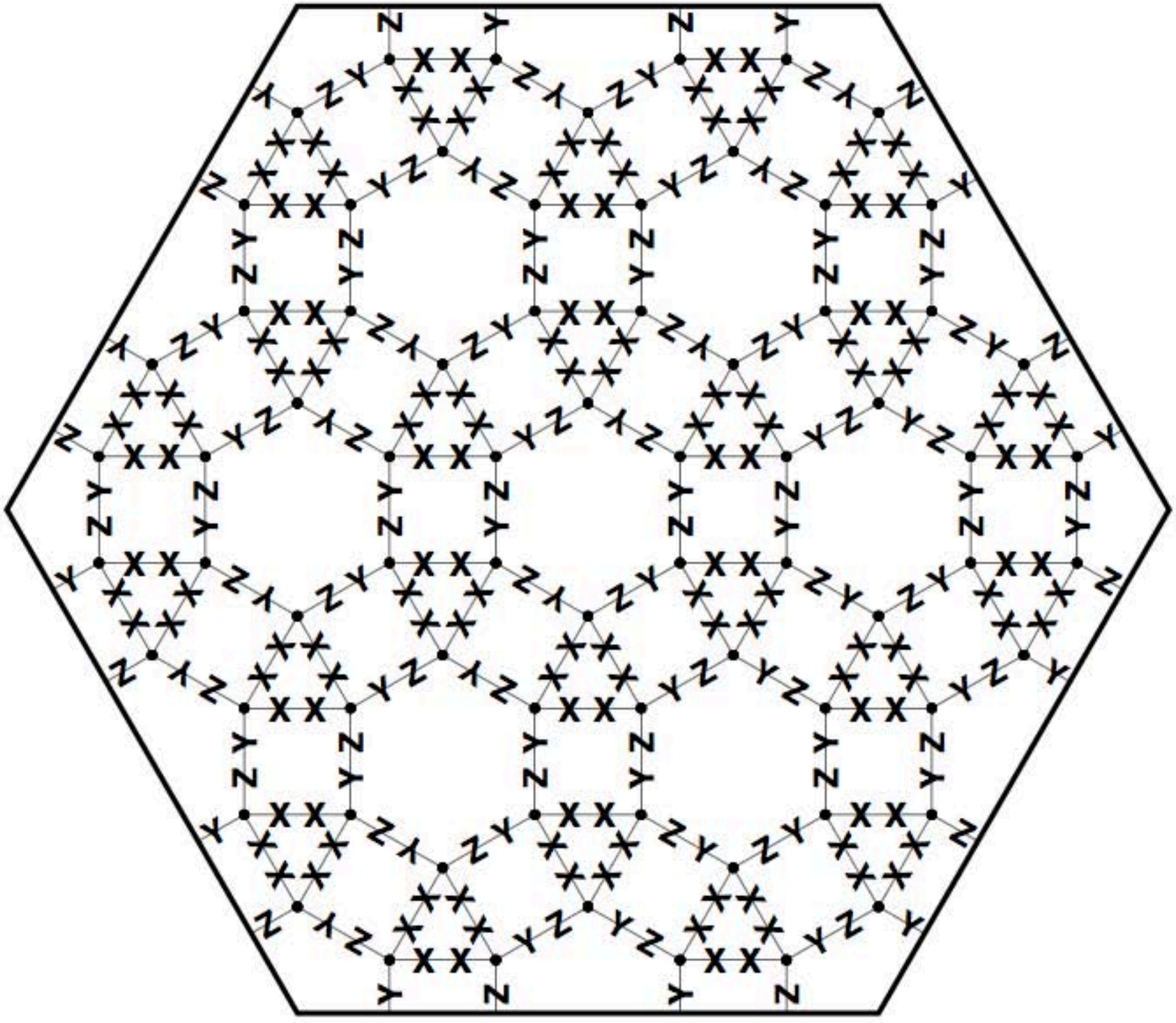
Case Study: Lattice codes

Codes found for the rhombihexadeltille tiling





Case Study: Lattice codes



Conclusions

- Building a quantum computer is an important project to attempt.
- Finding good codes to protect quantum information is a necessary part of building a robust quantum computer.
- CodeQuest changes the paradigm for finding codes by enabling the use of systematic computational search instead of scattershot mental guesswork.