Key-Note

Les King
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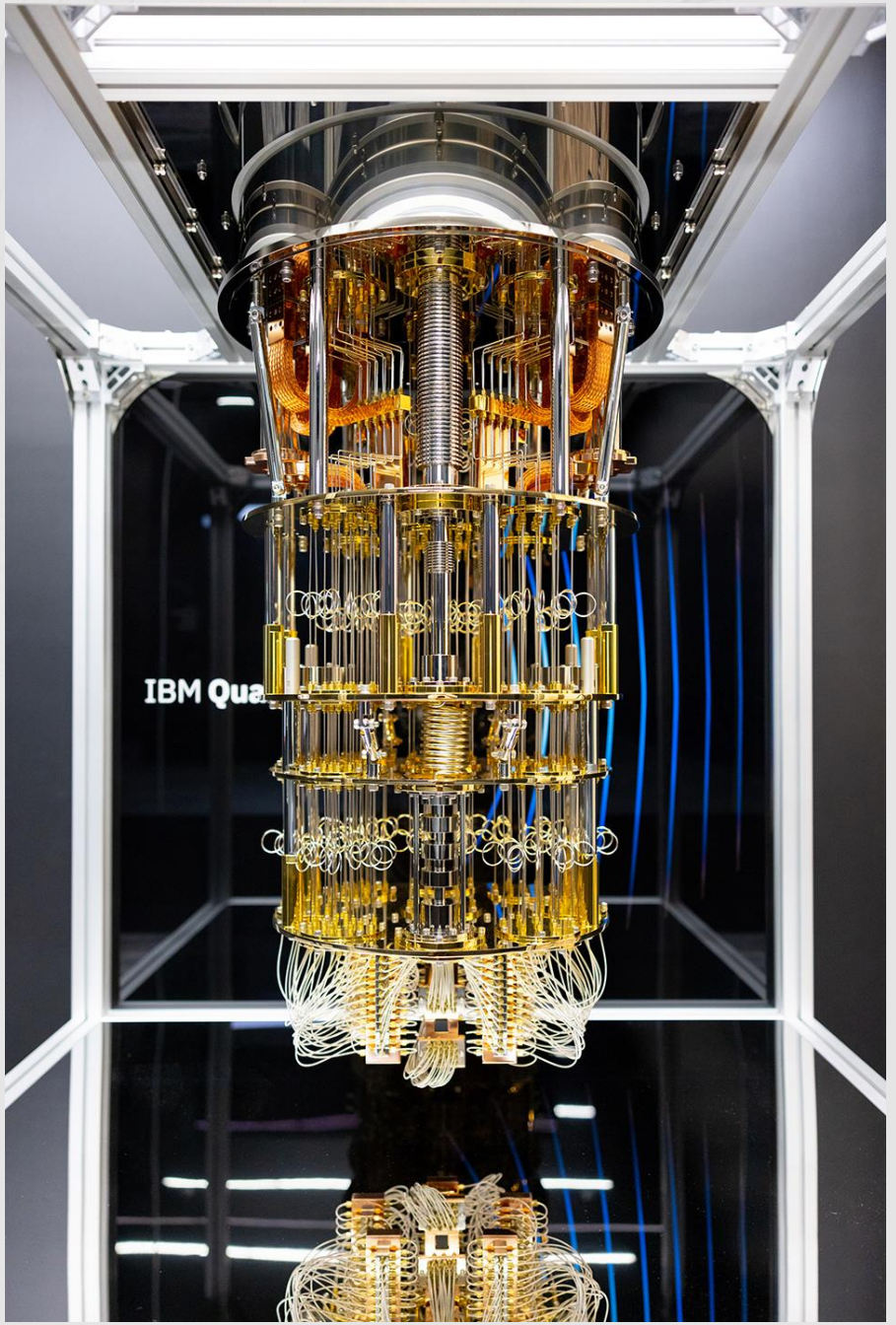
September 2024
Data Server Day – Stockholm, Sweden

Quantum Computing

Concepts

Use Cases

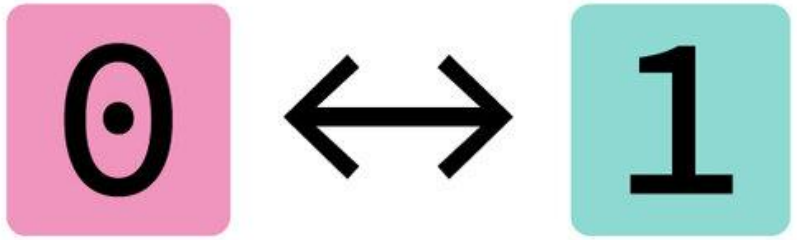
What’s Next



Qubit

TRADITIONAL COMPUTERS

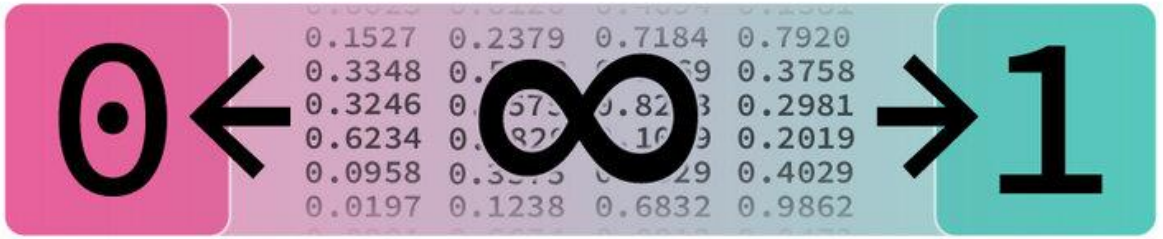
Technology based on ‘bits’



Bits have two states: 0 or 1

QUANTUM COMPUTERS

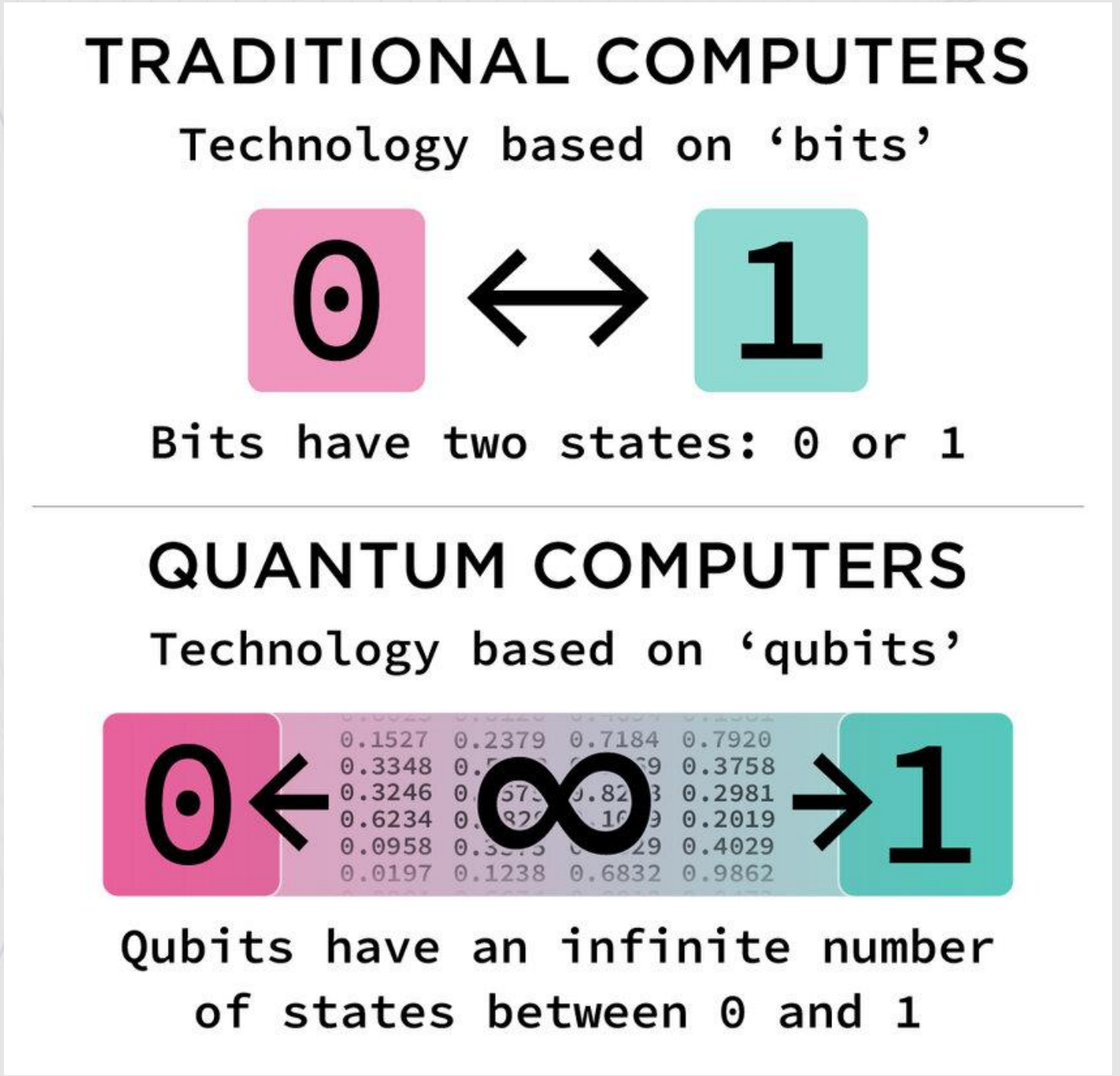
Technology based on ‘qubits’



Qubits have an infinite number of states between 0 and 1

Qubit

A Qubit is a physical subatomic particle such as electron or proton – usually a mix of aluminum and niobium

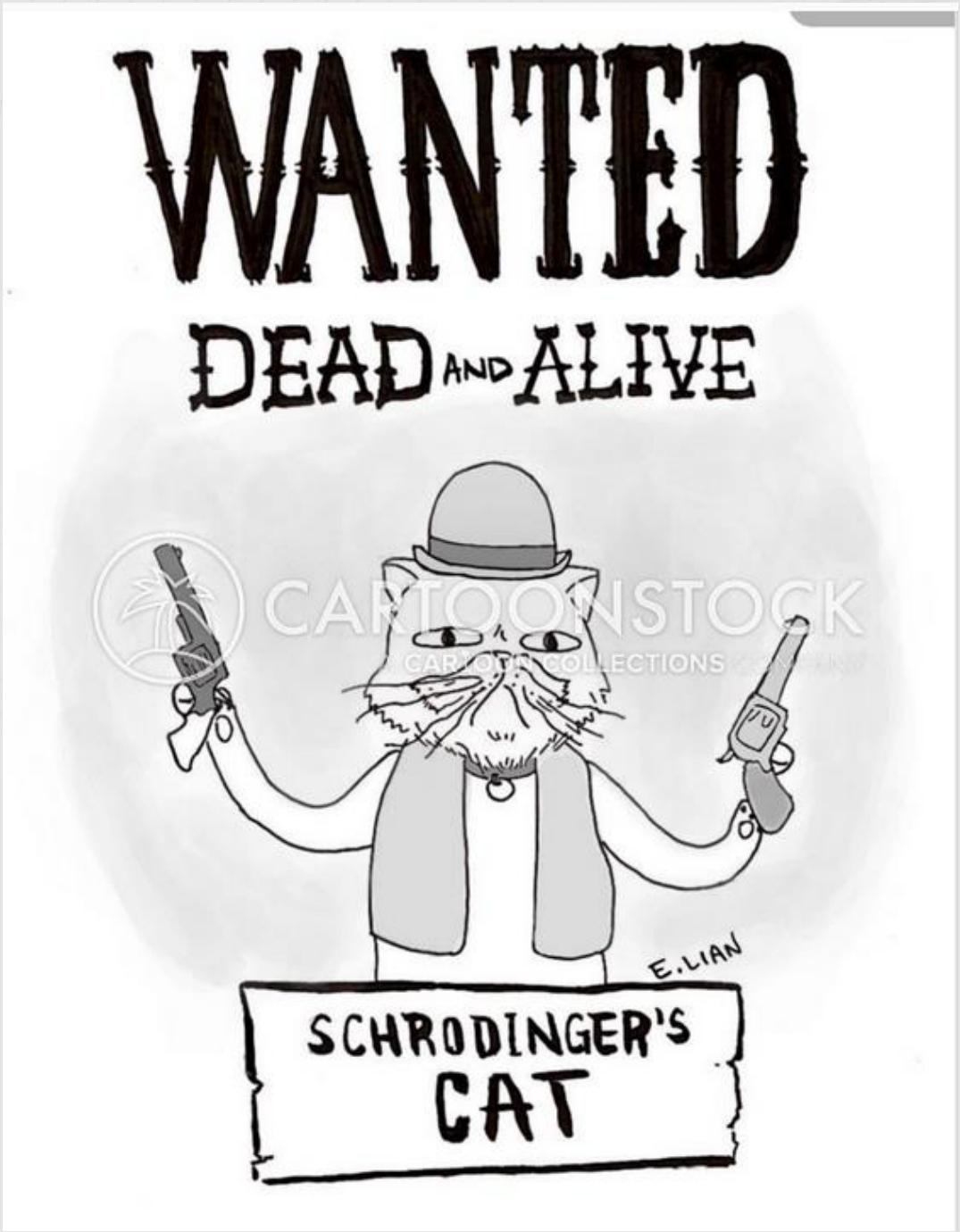


Schrodinger’s Cat

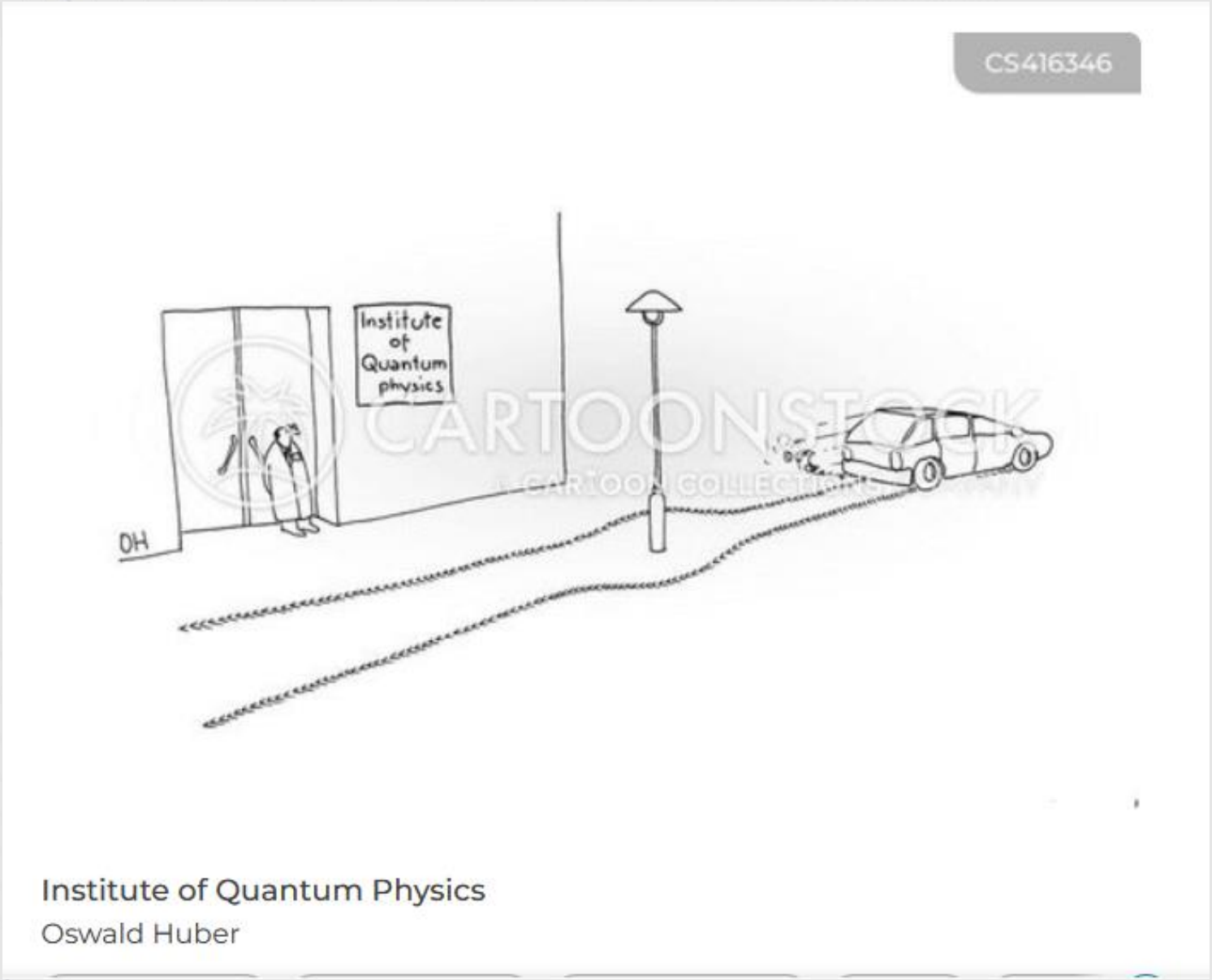
Schrödinger's Cat is **a famous thought experiment that demonstrates the idea in quantum physics that tiny particles can be in two states at once until they're observed**. It asks you to imagine a cat in a box with a mechanism that might kill it. Until you look inside, the cat is both alive and dead at the same time.

Schrodinger's Cat

"About your cat, Mr. Schrödinger—I have good news and bad news."

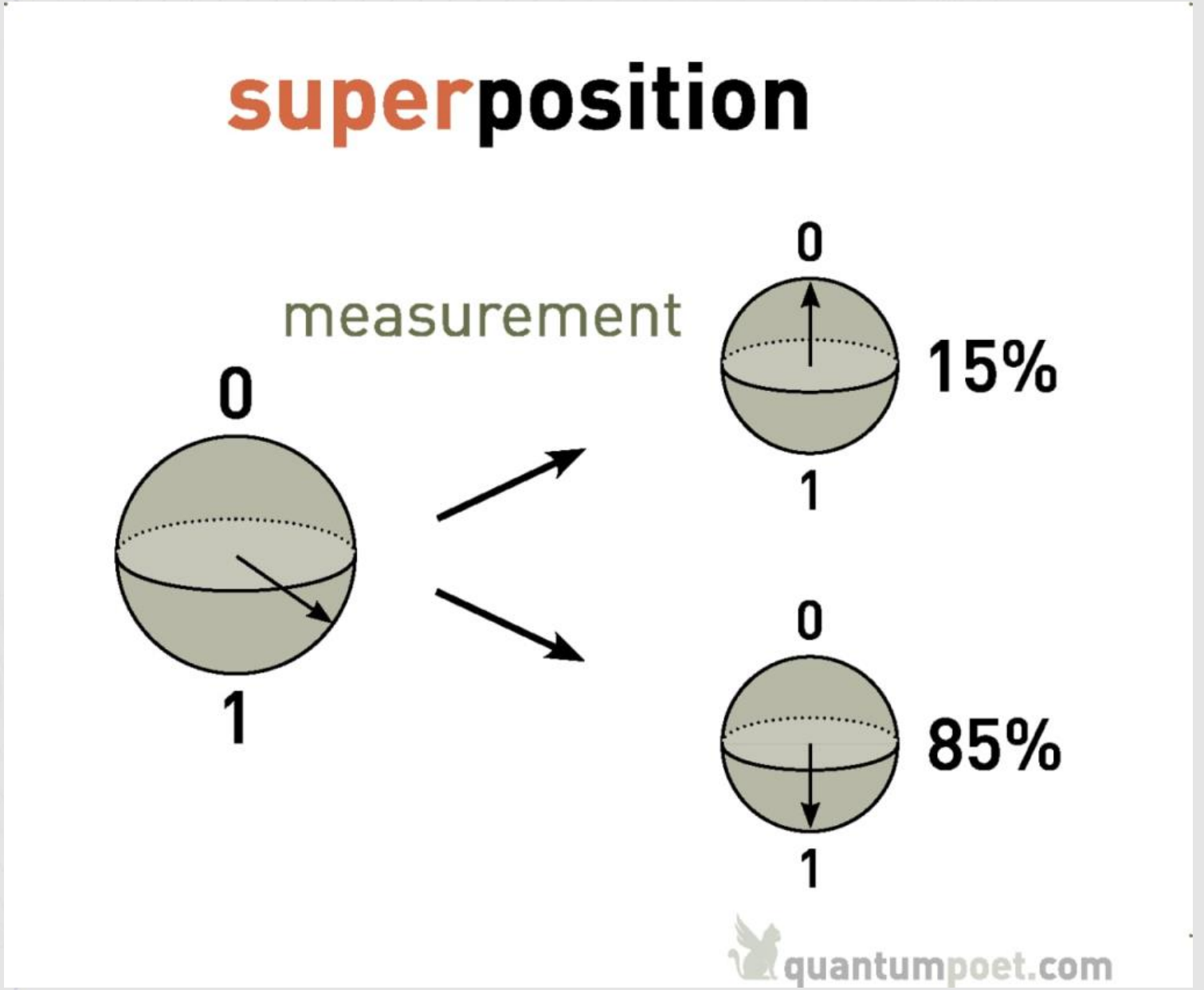


Concept 1: Superposition



Concept 1: Superposition

Based on Probability



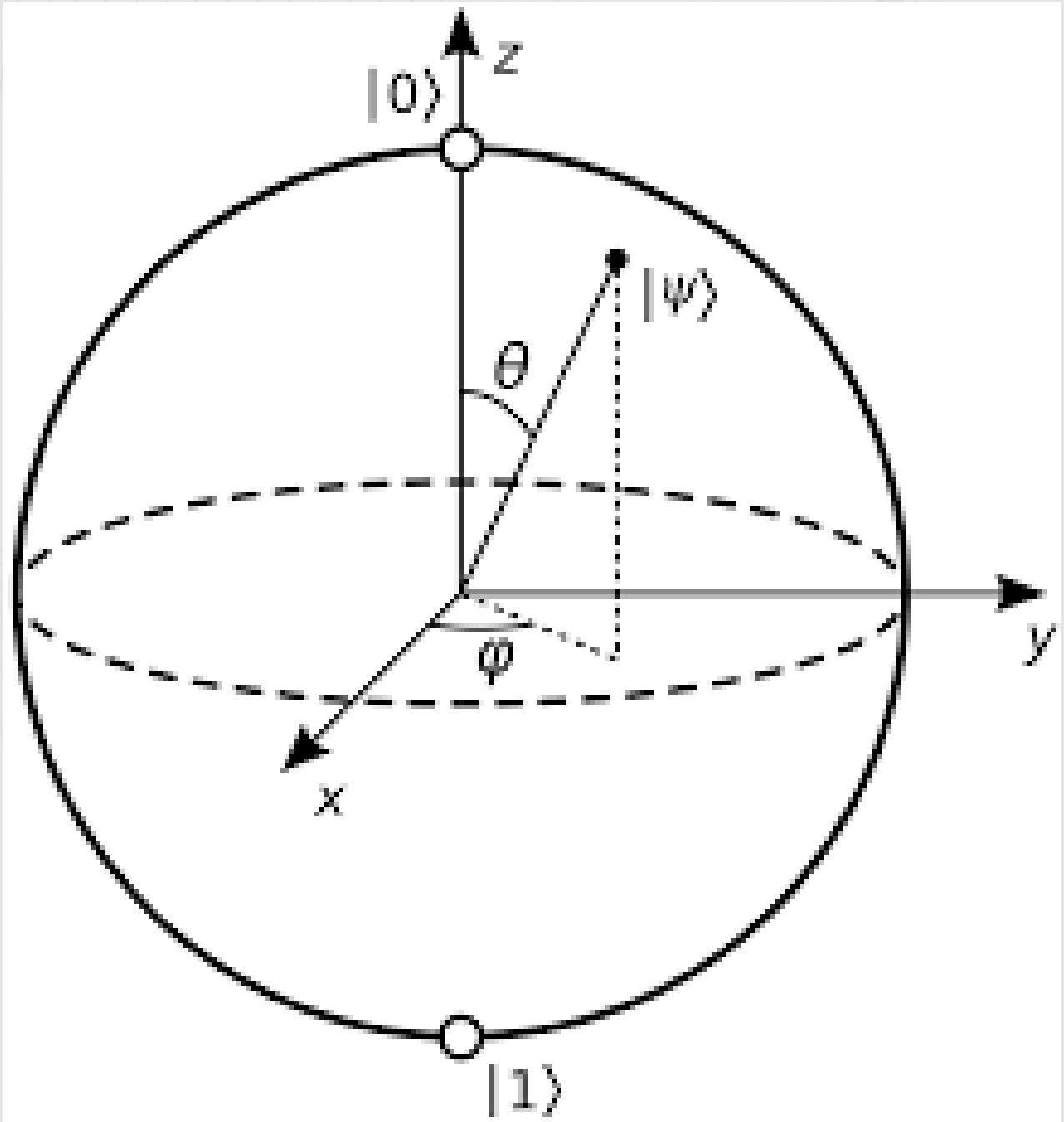
Concept 1: Superposition

A single Qubit is best visualized with a **Bloch Sphere**

The arrow pointing straight down represents 1

The arrow pointing straight up it corresponds to 0

in any other position it represents a **superposition** of 0 and 1

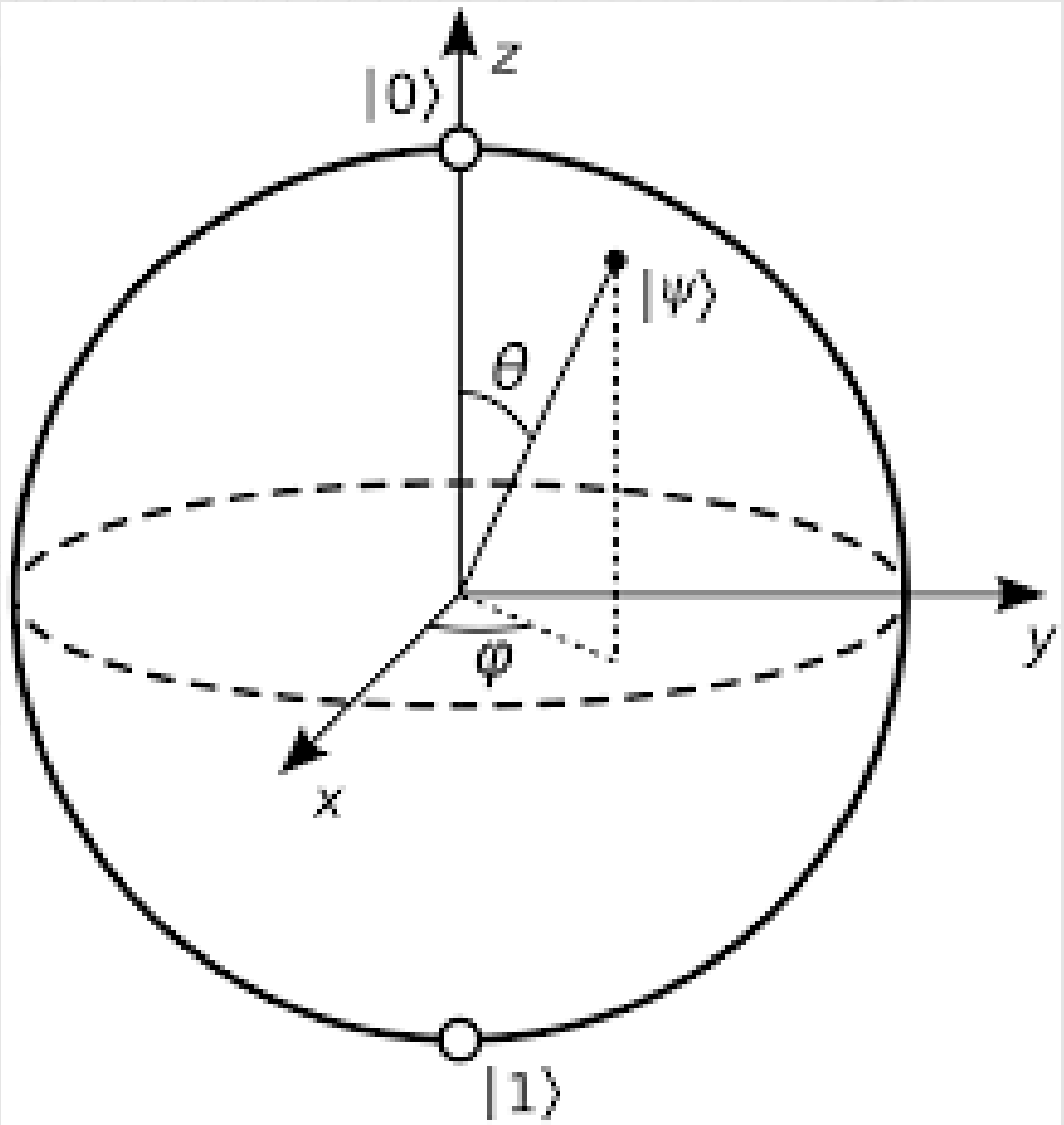


Concept 1: Superposition

A Qubit in its superposition state can have any of an infinite number of values between 0 and 1

It's **measured value** always resolves to 0 or 1

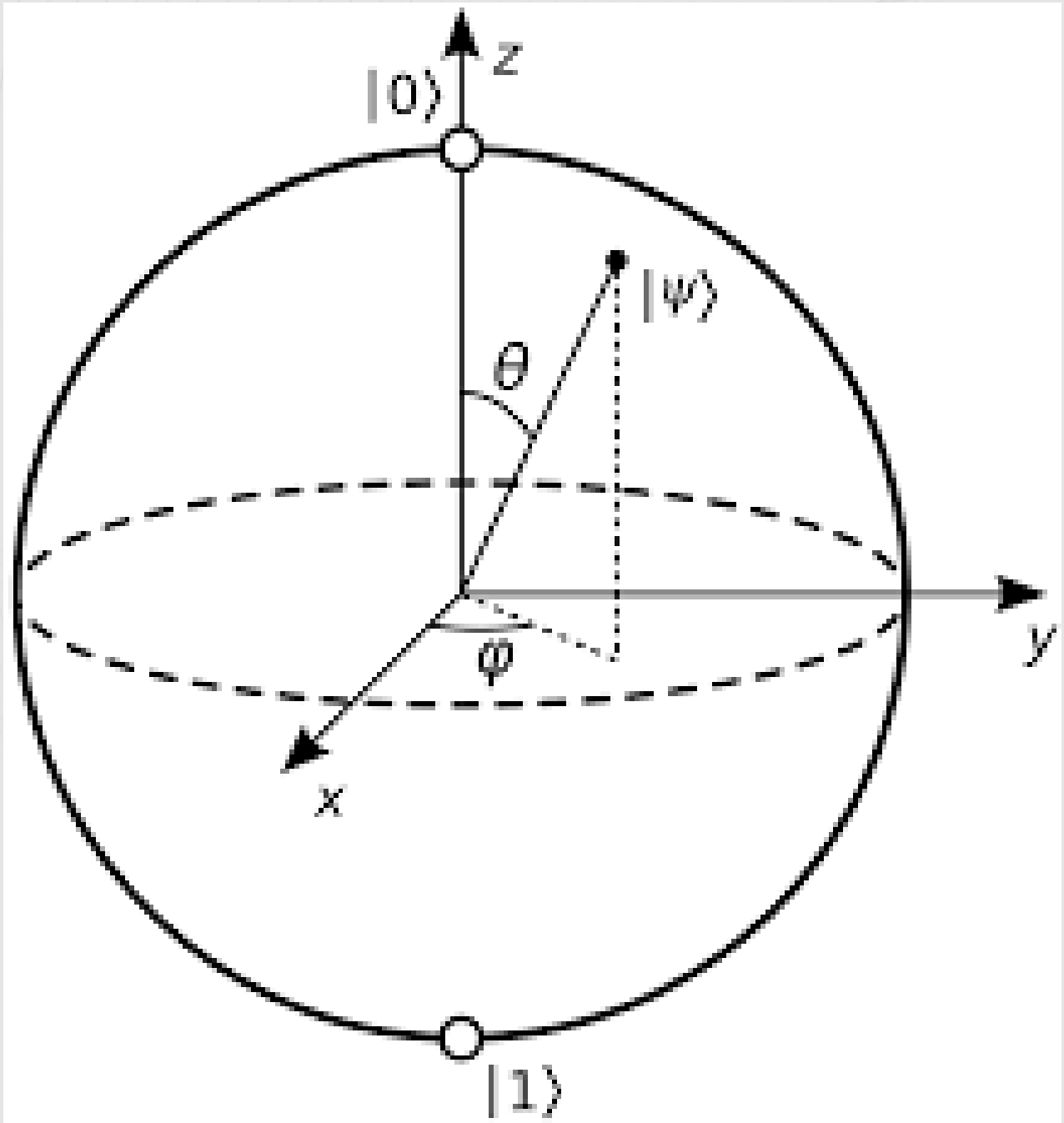
The measurement "collapses" the Qubit's quantum state



Concept 1: Superposition

Can never PREDICT a specific outcome

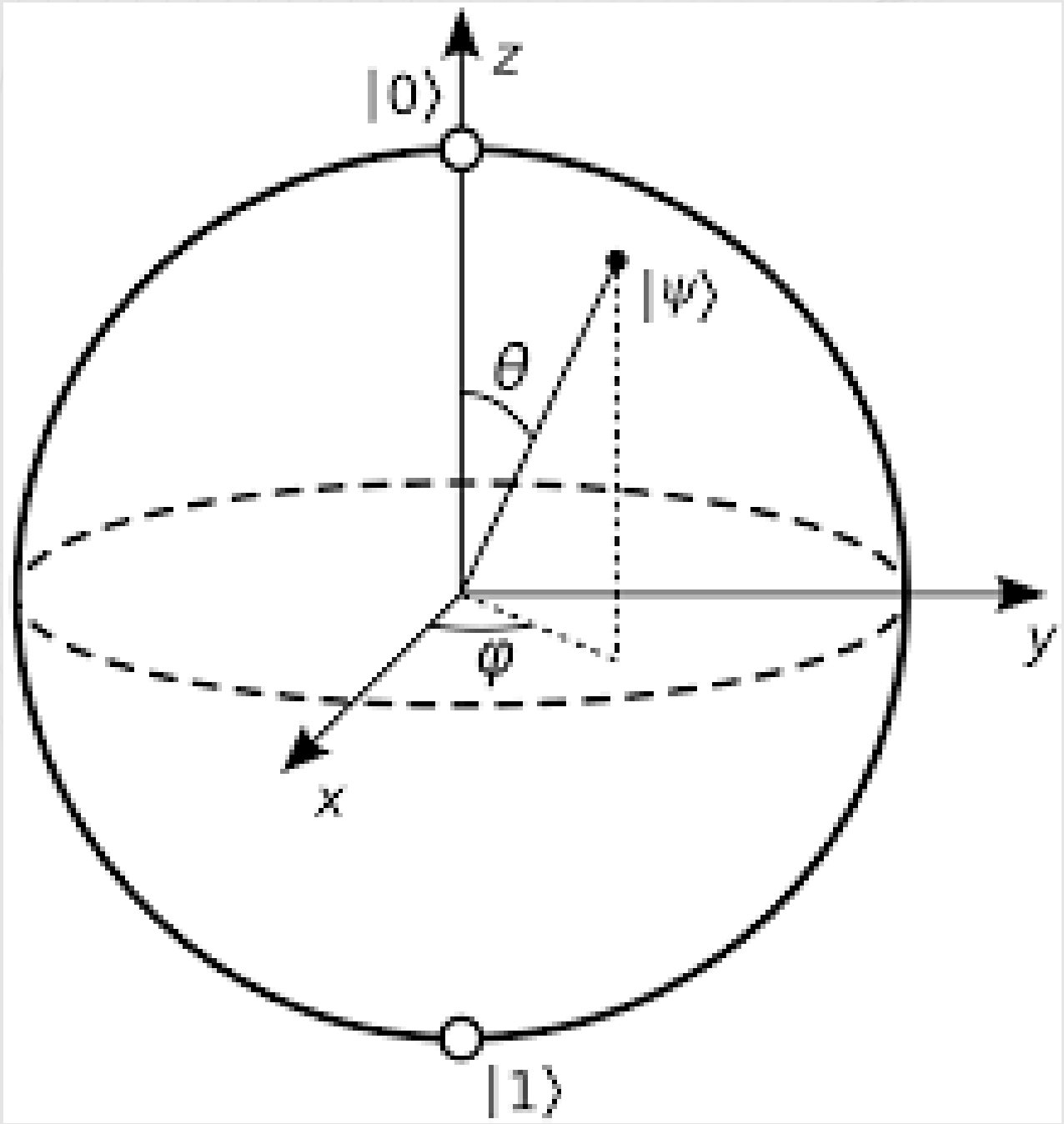
Can calculate the PROBABILITY of a specific outcome



Concept 1: Superposition

Spin Down = 0 – no energy applied to the electron or proton

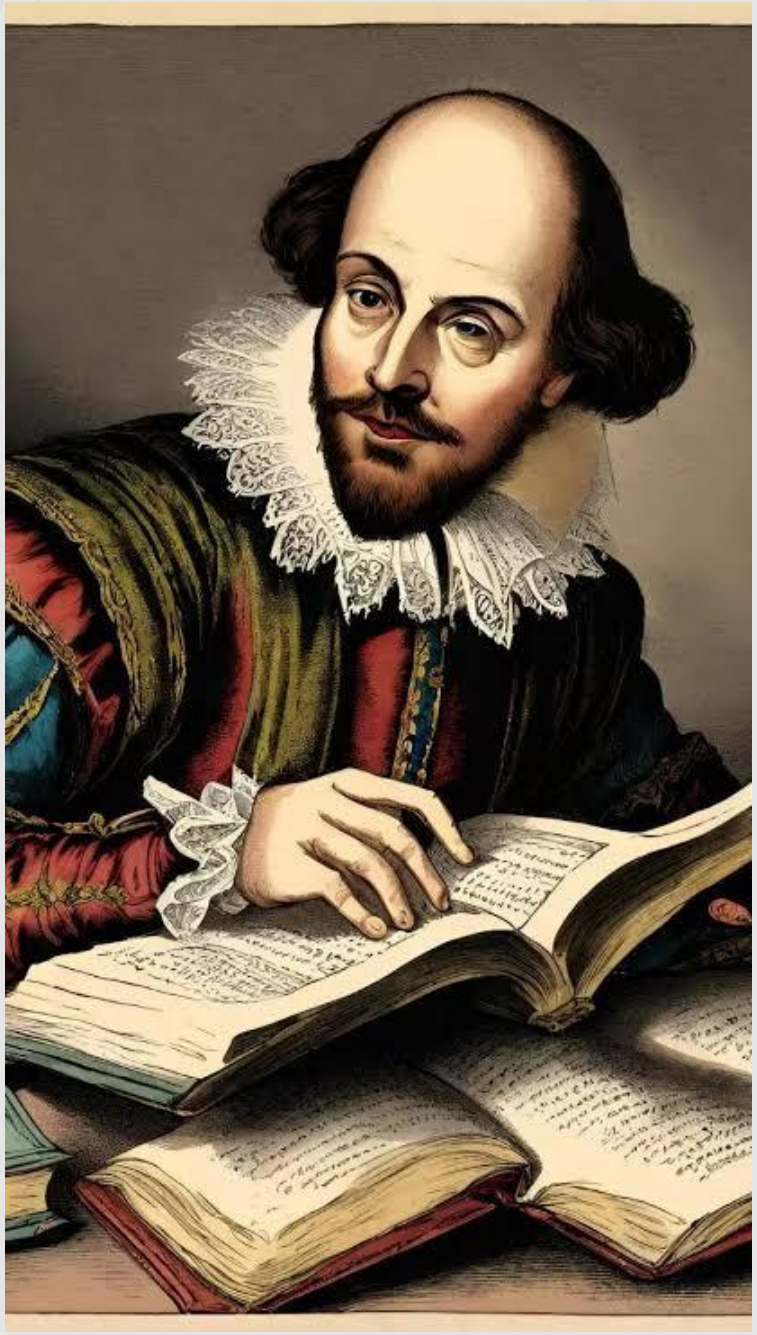
Spin Up = 1 – energy applied to the electron or proton



Concept 1: Superposition

Classic Shakespeare: “To be **or** not to be”

Quantum Shakespeare: “To be **and** not to be”

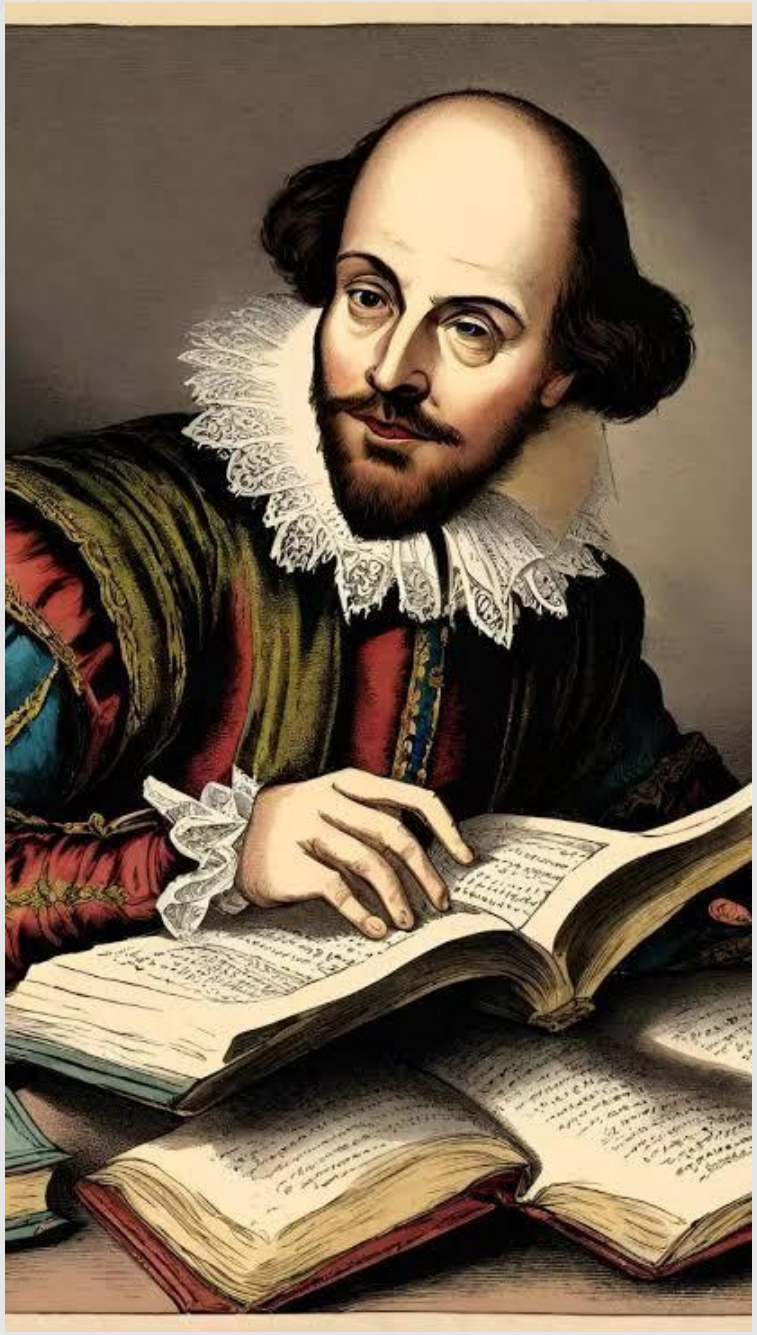


Concept 1: Superposition

Classic Shakespeare: “To be **or** not to be”

Quantum Shakespeare: “To be **and** not to be”

Actually – that’s not really true



Concept 1: Superposition

Superposition states are unobservable – there's no actual value

A measured stated – we can observe – a state of Spin Up or Spin Down is defined

Concept 1: Superposition

Think of a spinning coin …..

Spin Up = Heads

Spin Down = Tails

While it is spinning it can be in an infinite number of positions

Measured – it “collapses” to either a heads or tails

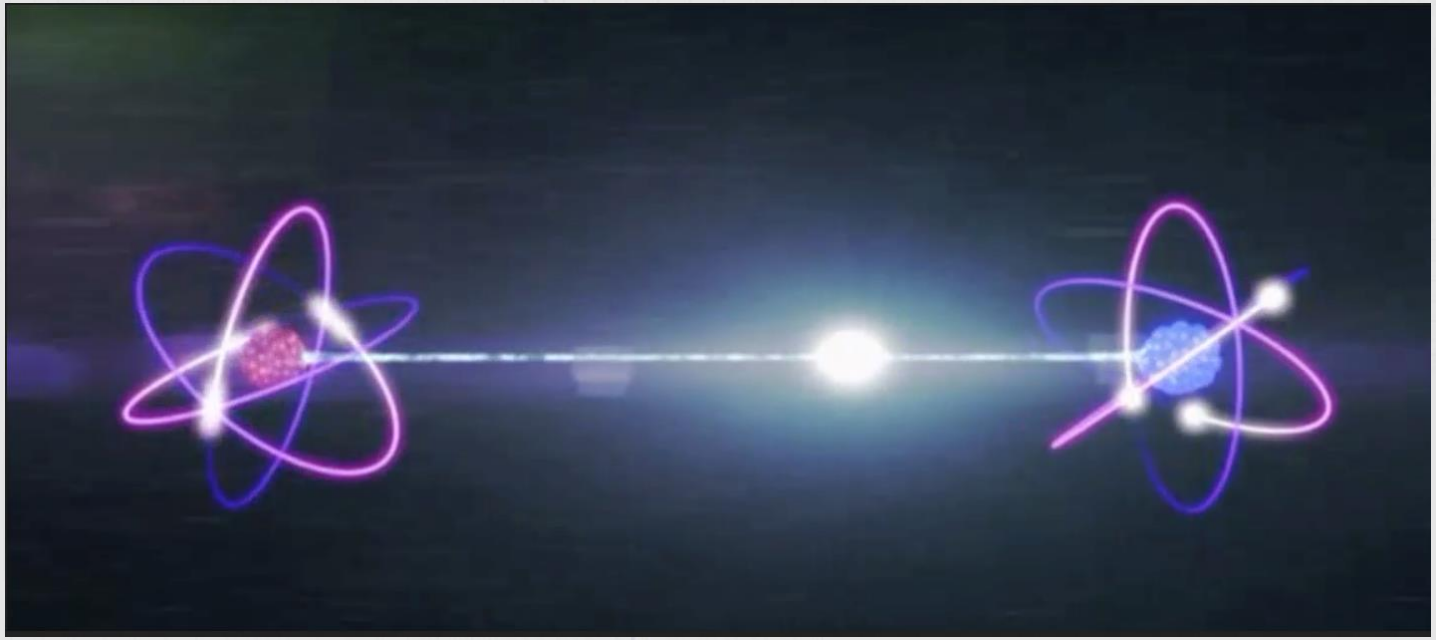
50% Probability of either result

Concept 2: Entanglement

The Physiciatrist...

Sidney Harris

Concept 2: Entanglement



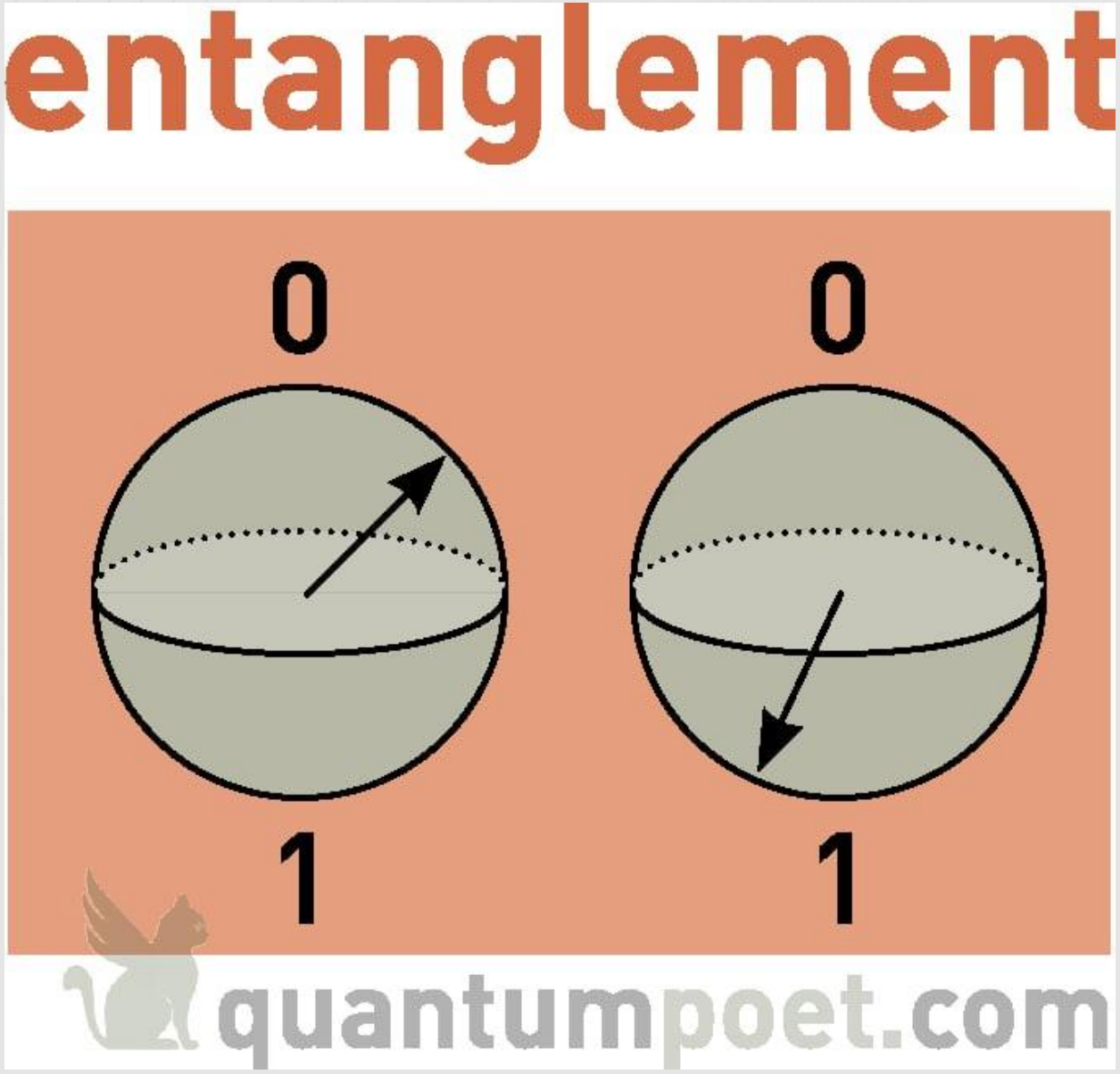
In quantum mechanics, entanglement occurs when, minimally, two particles pair up in such a way that the quantum state of one particle cannot be determined independently of the state of the other particle, irrespective of the distance between the two.

Concept 2: Entanglement

Can be harnessed by quantum computers

Two or more Qubits are entangled to create a SINGLE QUANTUM STATE

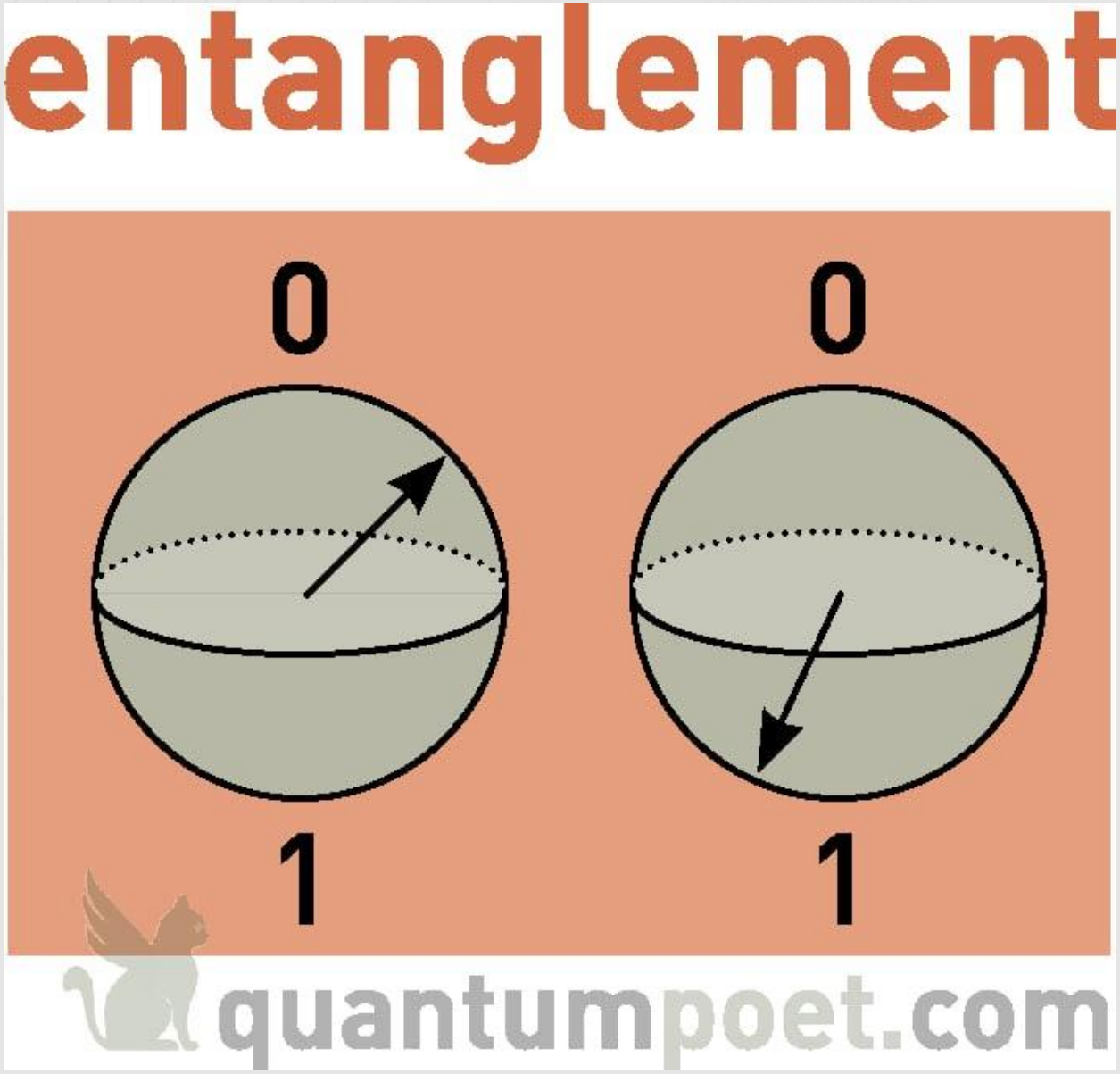
Changing the state of one Qubit instantaneously changes the state of the other entangled Qubits



Concept 2: Entanglement

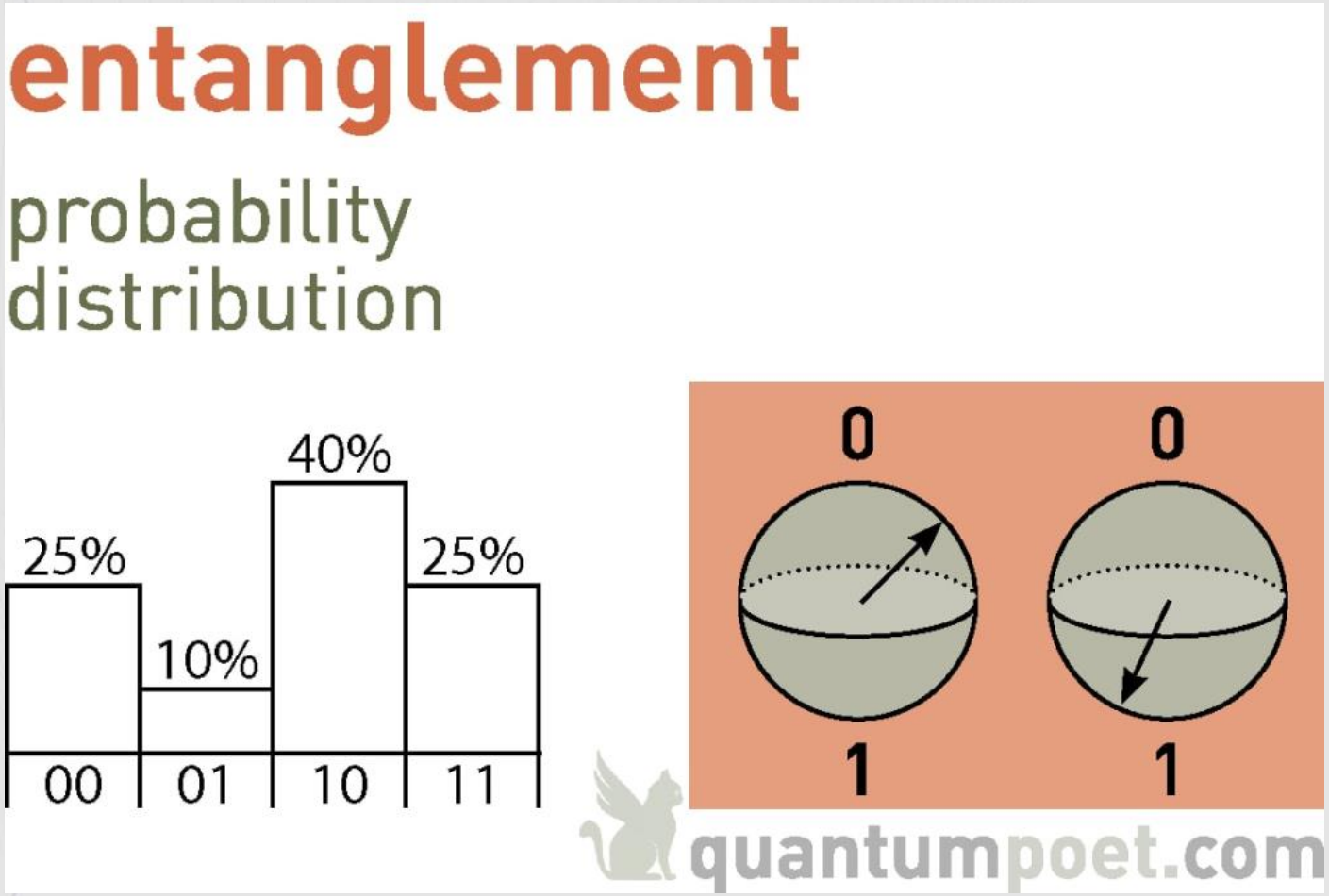
Entangling Qubits can be leveraged to provide “quantum speed-up” in quantum computing

Entangling Qubits can provide an exponential speed-up in quantum computing



Concept 2: Entanglement

Entangling Qubits can only be measured (remember “collapsing”) based on a probability distribution across the Qubits



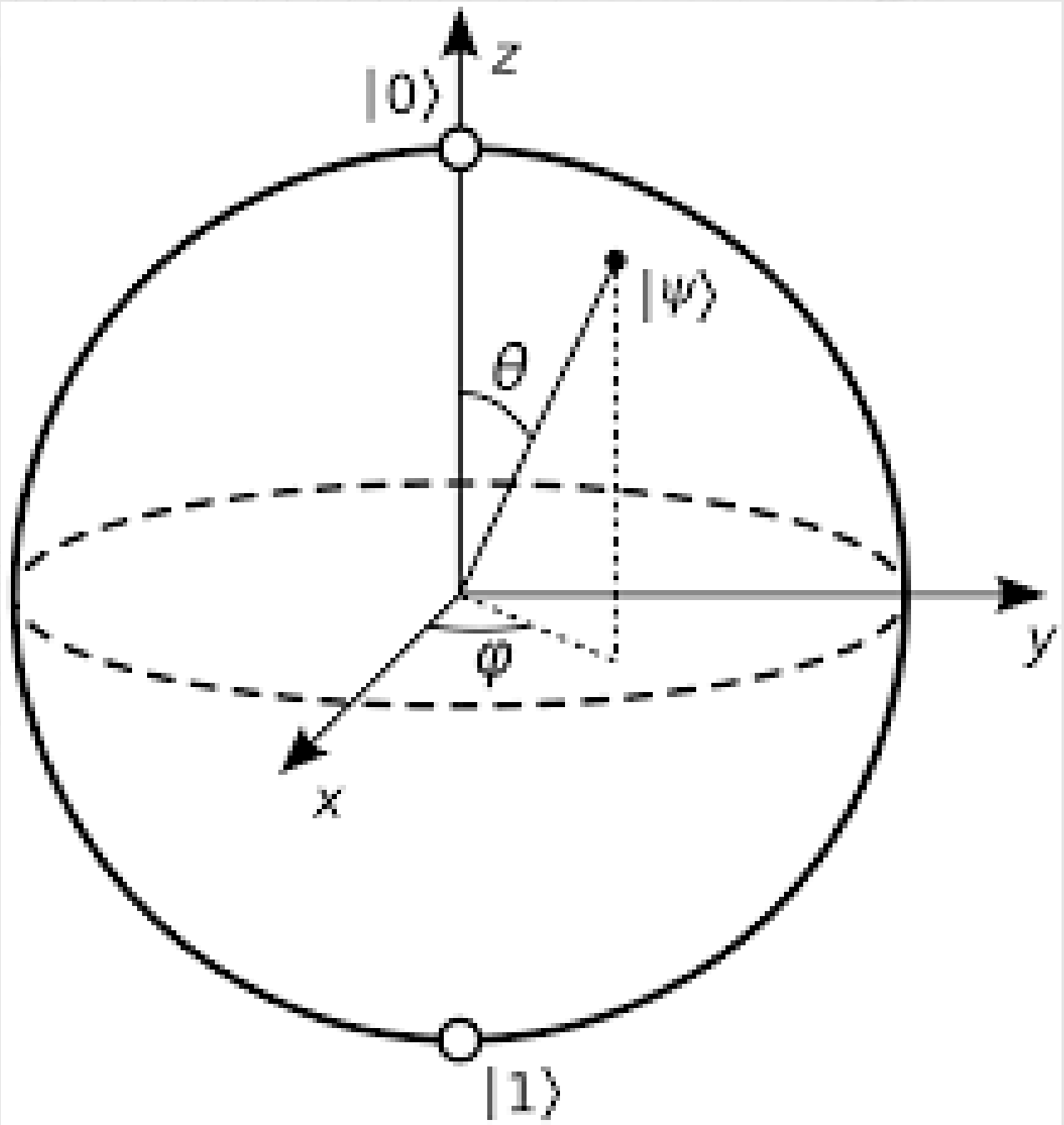
Concept 2: Entanglement

For one qubit we have a probability distribution over two states.

For two qubits, the probability distribution is over four states.

For three qubits, it is eight …..

In general, for N qubits, the probability distribution is over 2^N states.

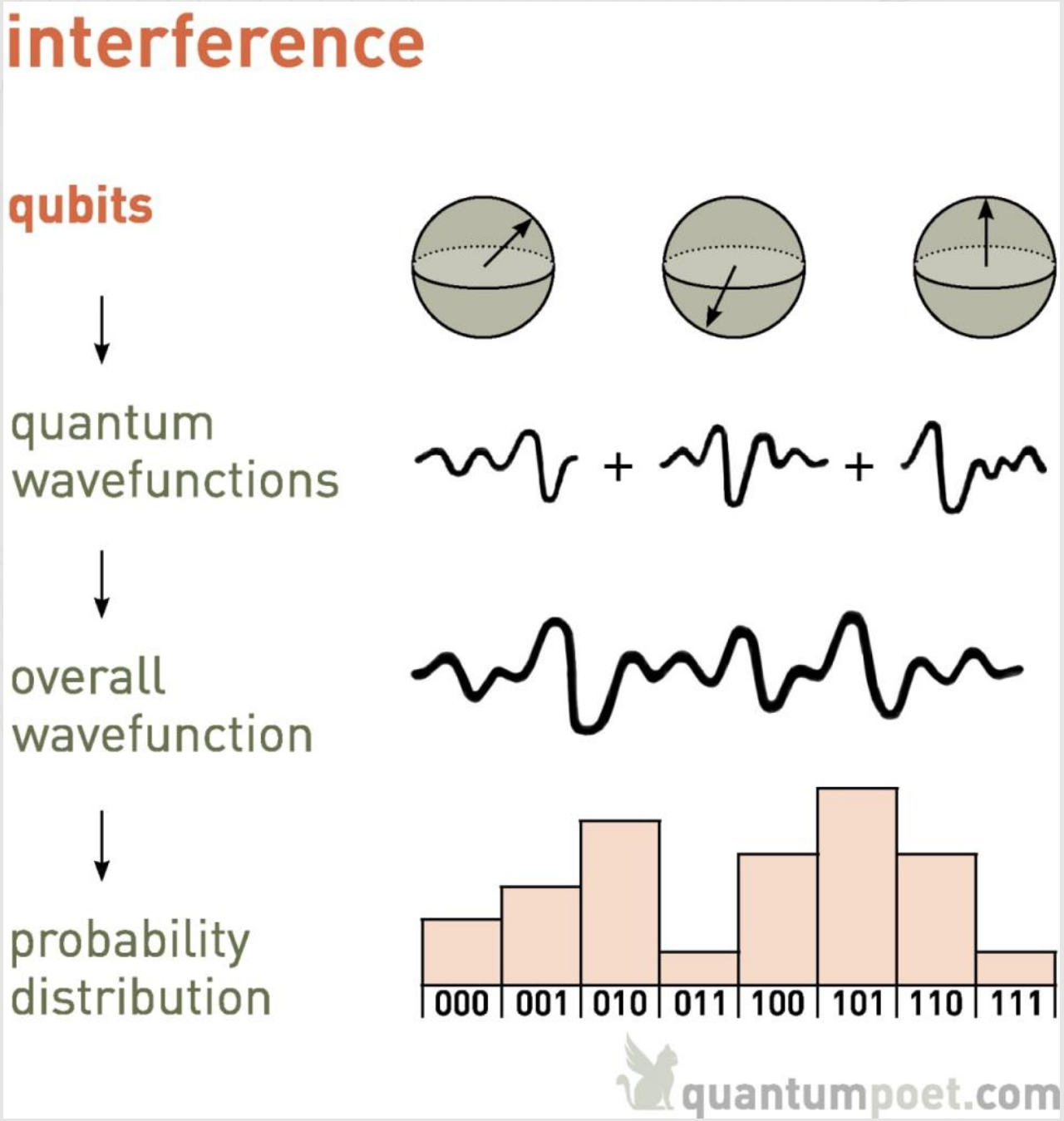


Concept 3: Interference

A wave function is the basic mathematical description of everything in quantum physics.

To measure the entangled qubits, we add the individual wave functions of each qubit, producing a single wave function of a single quantum state.

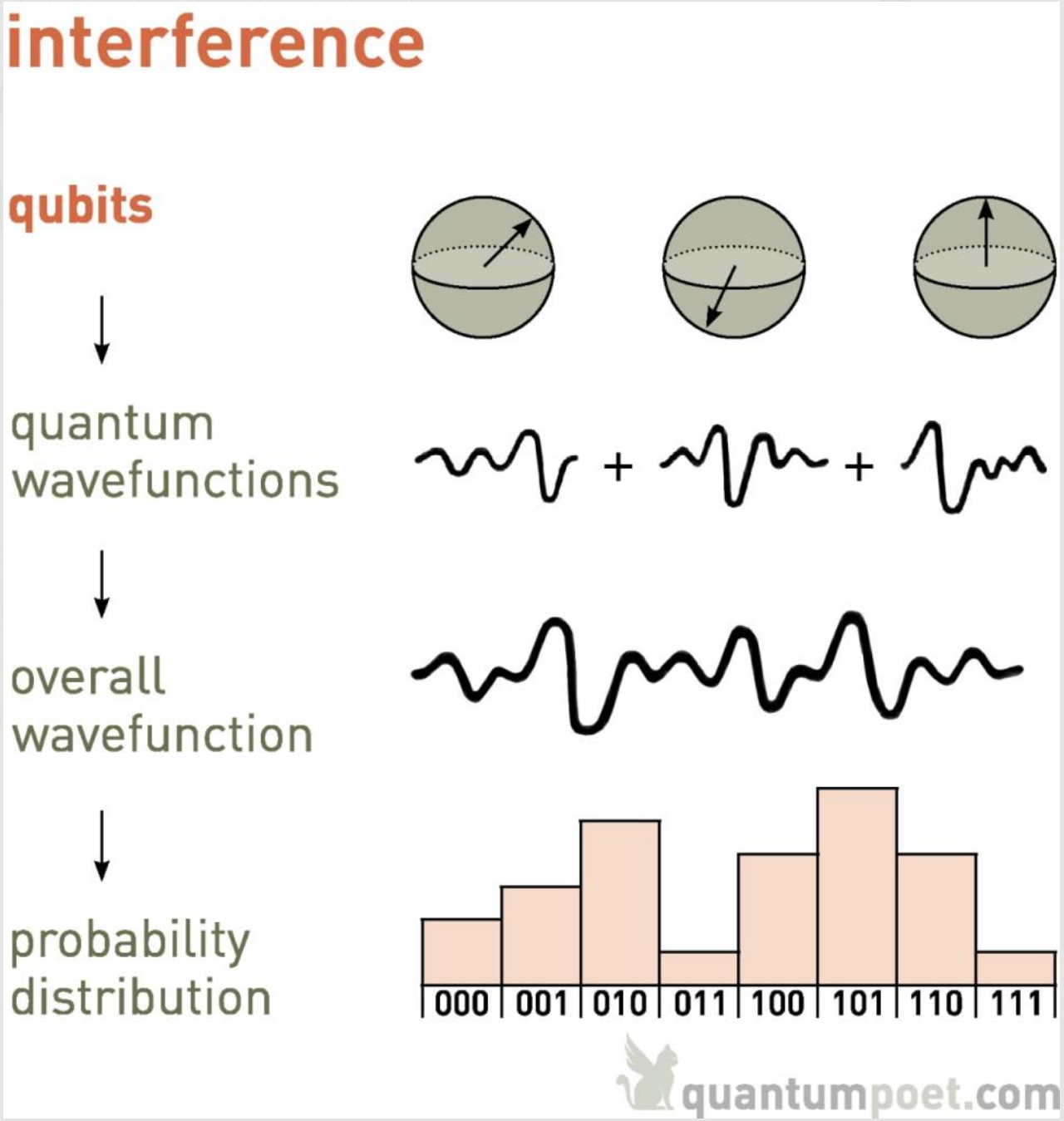
The adding together of the individual wave functions gives us the interference pattern.



Concept 3: Interference

To increase the probability of the correct answer, leverage a constructive interference (where two wave crests add up, producing a larger wave).

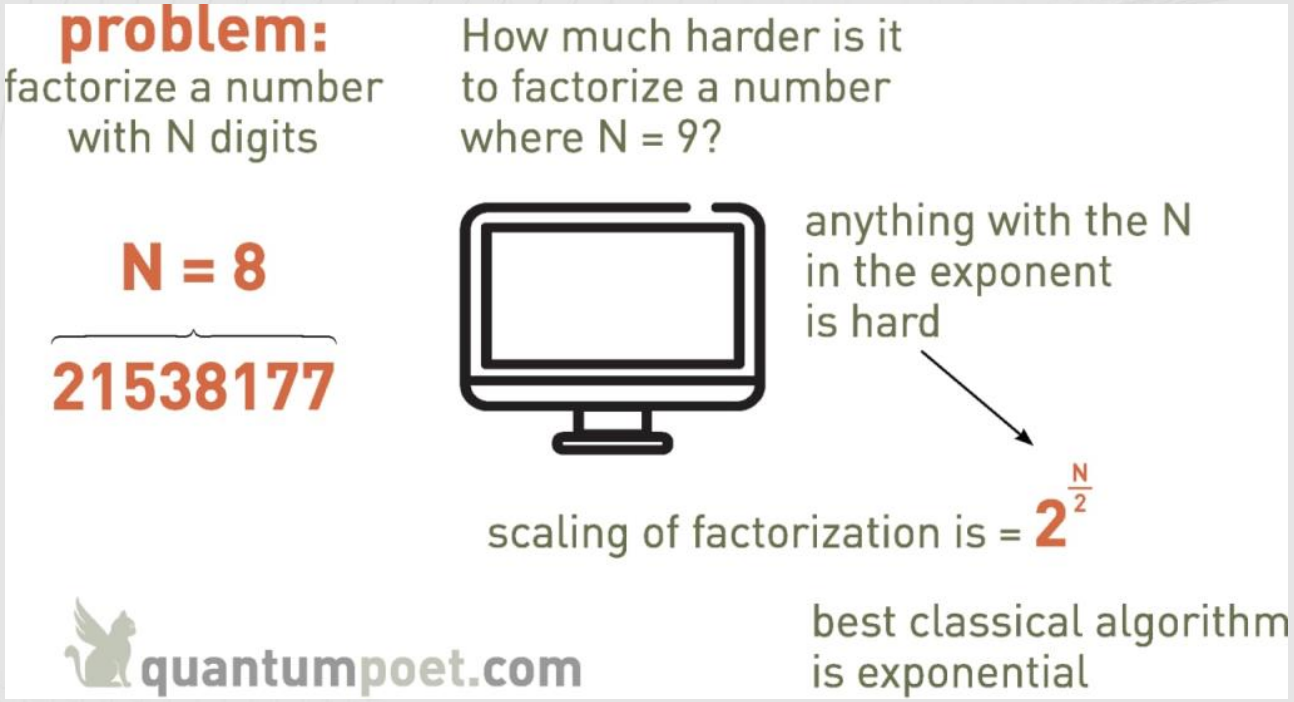
To decrease the probability of an incorrect answer, leverage destructive interference (where two waves cancel each other out).

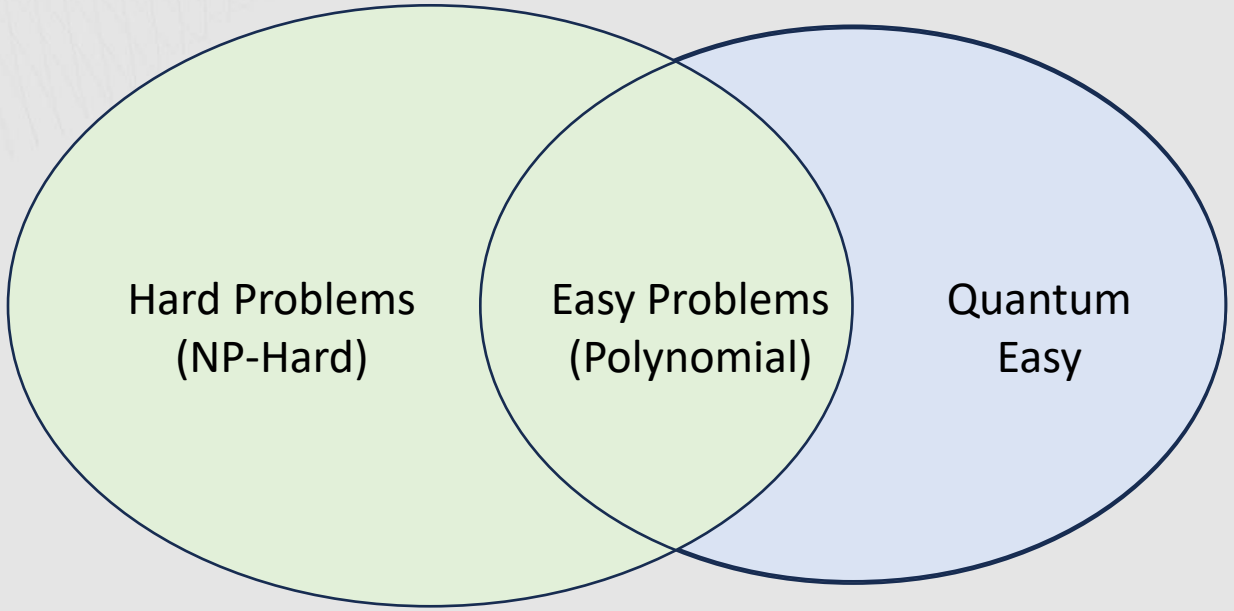


Concept 4: Algorithms

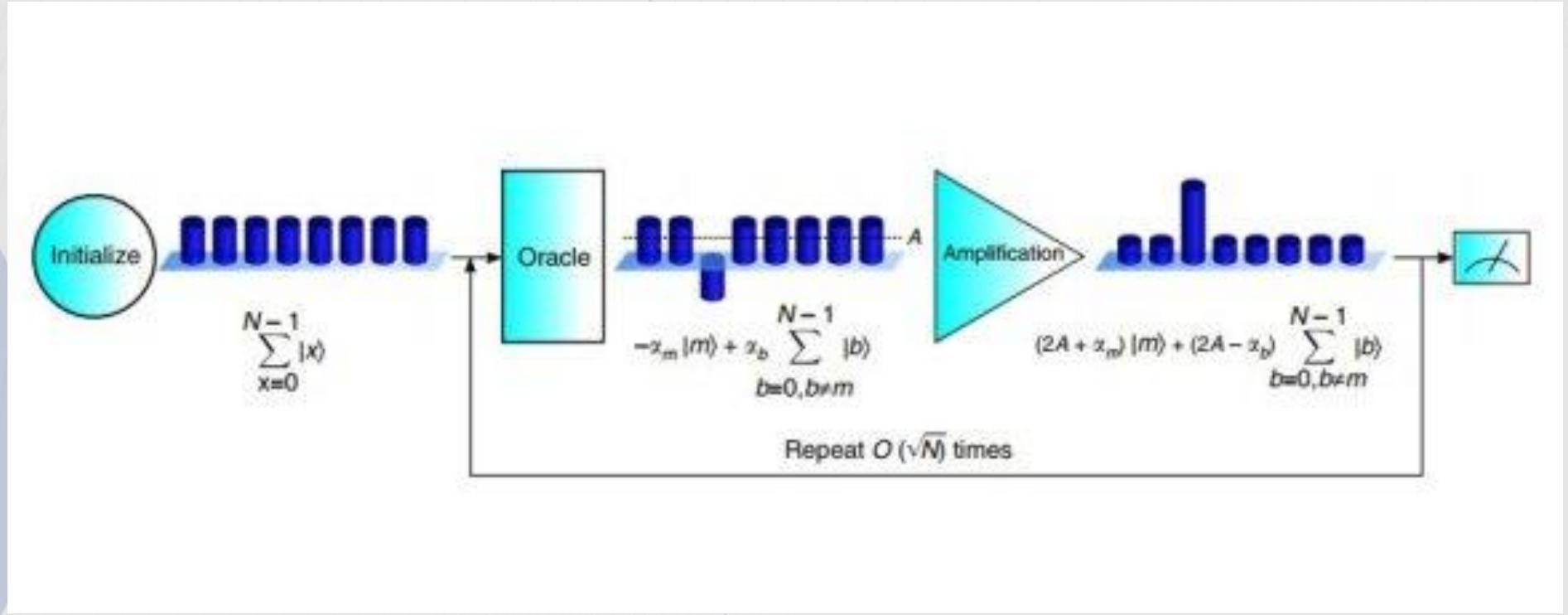
The objective is to develop quantum algorithms to solve intractable problems (problems which are unsolvable on classic computers) – NP and NP-Hard problems.

Prime factorization of very large numbers is an intractable problem because the search base of all possible integers is very large. Which is why prime factorization is used as the basis of present-day cybersecurity encryption.





Concept 5: Grover's Operator



Quantum Search Algorithm

Allows for searches on unstructured, unordered data in O(sqrt(N))

Very good at "sweeping away" all incorrect answers

Concept 6: Tunneling

Quantum Physics Lab: Please Use Wormhole

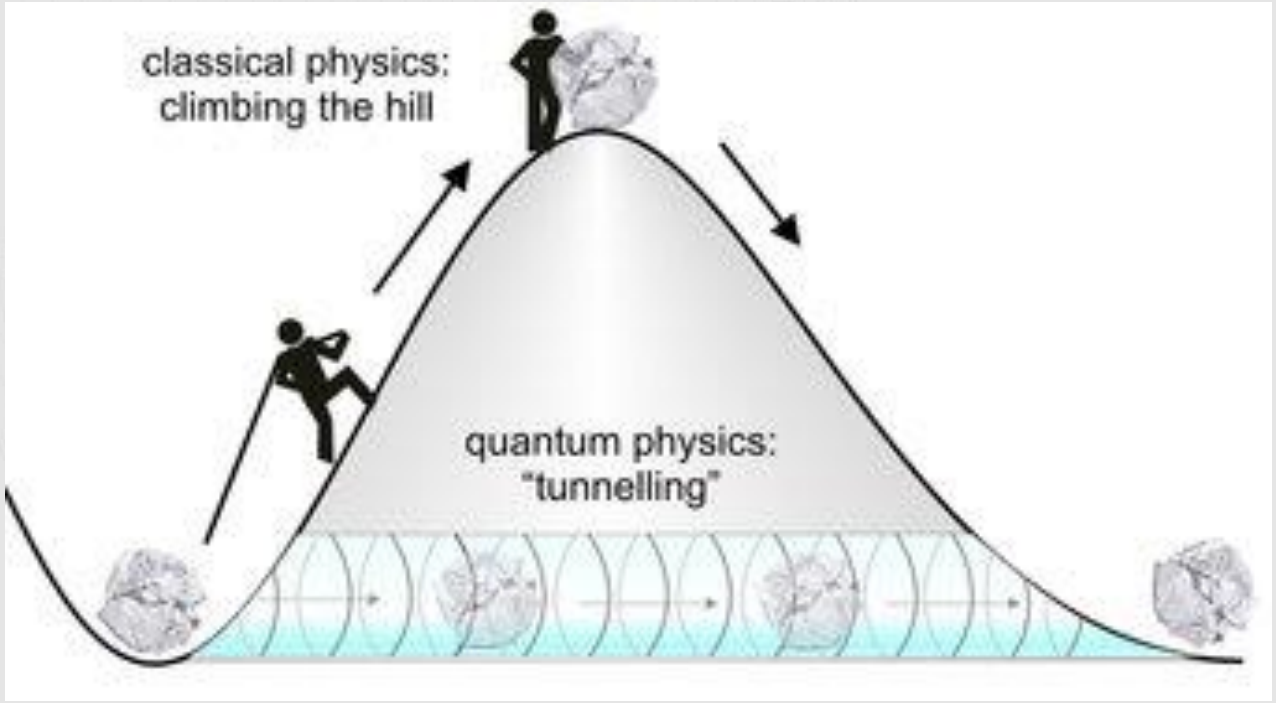
Trevor White

Concept 6: Tunneling

Phenomenon in which an object such as an electron passes through an energy barrier that, according classic mechanics, should not be passable due to the object not having sufficient energy to pass or surmount the barrier

A lot of the power comes from this phenomenon

Qubits need to be kept at near 0 Kv in order for this to be accomplished which drastically reduces friction and movement



Pulling This Together

N Qubits

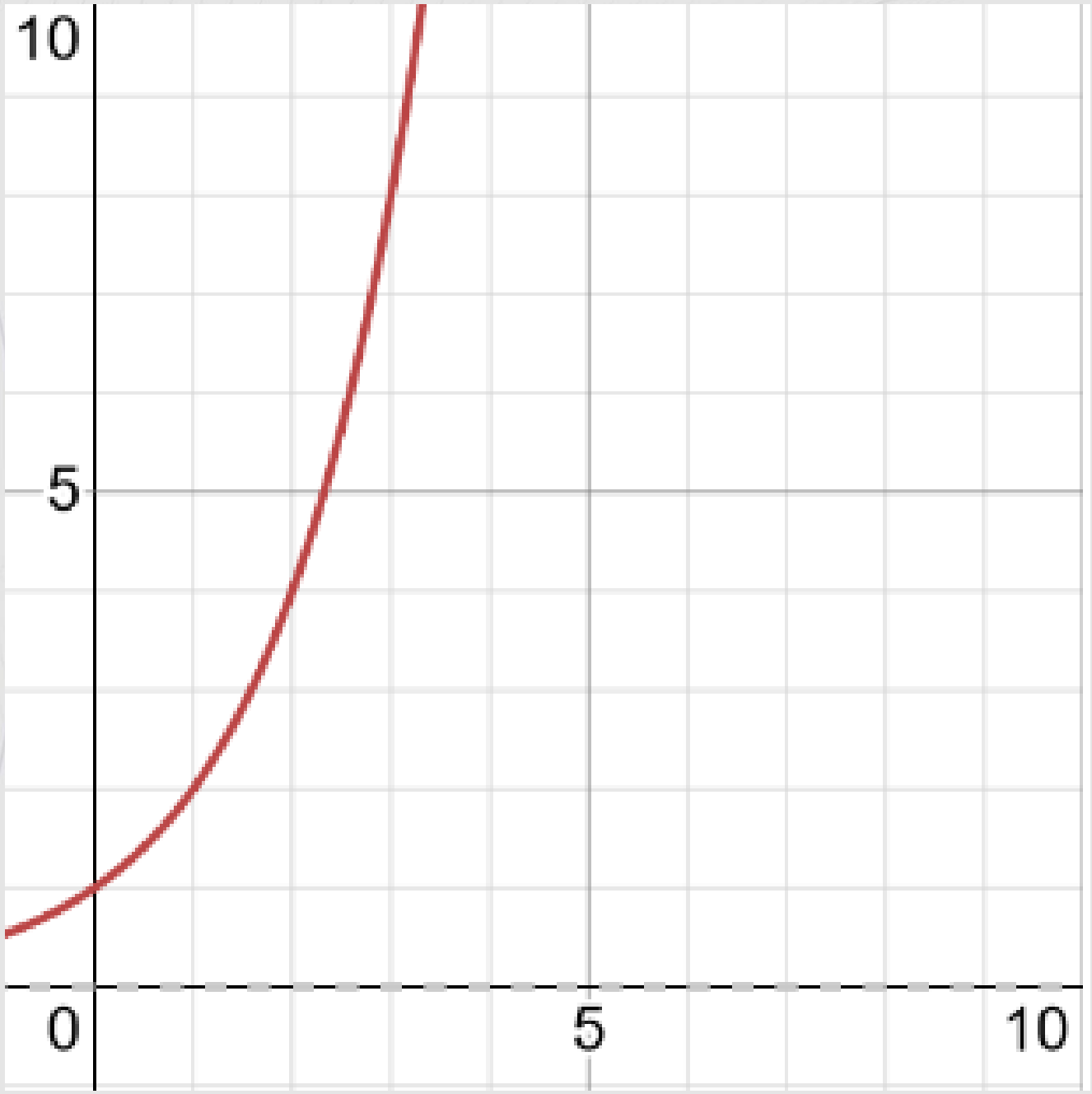
2^n Compressed Numbers

Think of a reasonable number of Qubits like N = 300

$2^{300} = \sim 10^{90}$

Leverage Linear Quantum Mechanics

Apply algorithms to Superposition

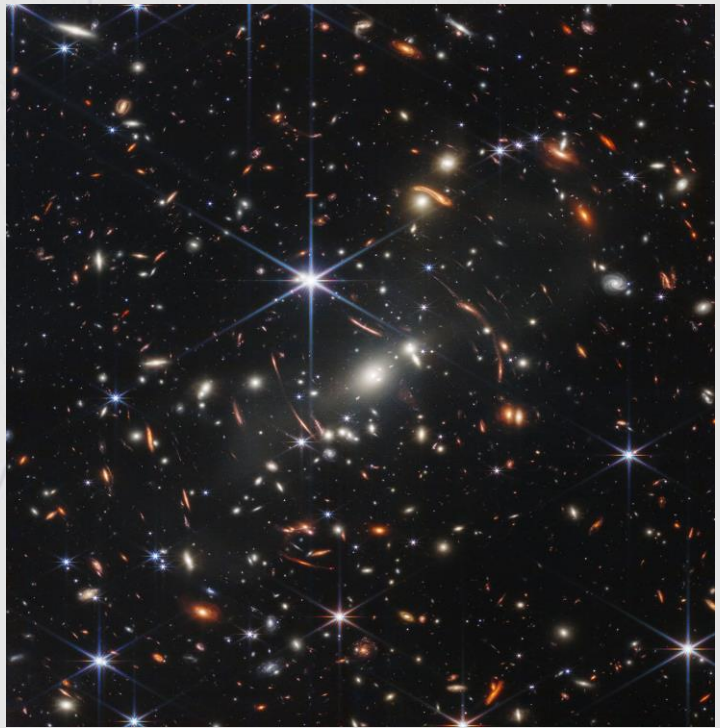


Perspective

$2^{300} = \sim 10^{90}$

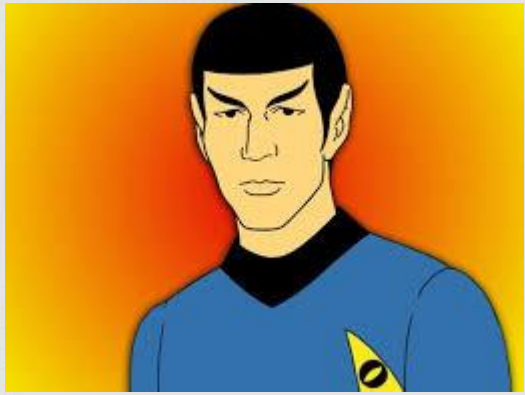
Total Number of storage bytes in the world < $\sim 10^{21}$

Total Number of atoms in the universe < = $\sim 10^{82}$



Parallelization



$2^{300} = \sim 10^{90}$

Think of 300 parallel universes

Each computing simultaneously






Use Cases – Traveling Salesman – Best Route

Ising Machine using Ising model

Partnership building the largest in the world

Caltech Department of Applied Physics and materials Science

NTT Research Physics & Informatics Lab

Use Cases – Traveling Salesman – Best Route

Nature likes to optimize energy naturally

Examples: Think of fish swimming or birds flying in a “V” formation

Lets check out a simple example of exactly this

Ising Machine uses a collection of spinning particles – one particle for each city – eventually they will all synchronize on the most efficient path
They are calibrated to the distance (or any cost formula) between the cities

https://www.youtube.com/watch?v=Aaxw4zbULMs

Security Risk

Traditional Computer – Check one password at a time – could take millions of years

Quantum Computing – Check all passwords simultaneously – Use Grover's Operator to "sweep away" all incorrect results – takes seconds

What's left ? The correct password

How to protect ? Check out:
https://www.ibm.com/quantum/quantum-safe

Drug Development

New classes of antibiotics to counter the emergence of multidrug resistant bacterial strains

Sustainability

Global Farming

Solar & Wind Power

Natural Resources

Weather

CERN

Use particle physics (quantum computing) to research particle physics

Entangled particles – don’t know why this happens

Start-up Issues

New discoveries nano-seconds after collision

AI

Combine the power of Quantum Computing with GenAI

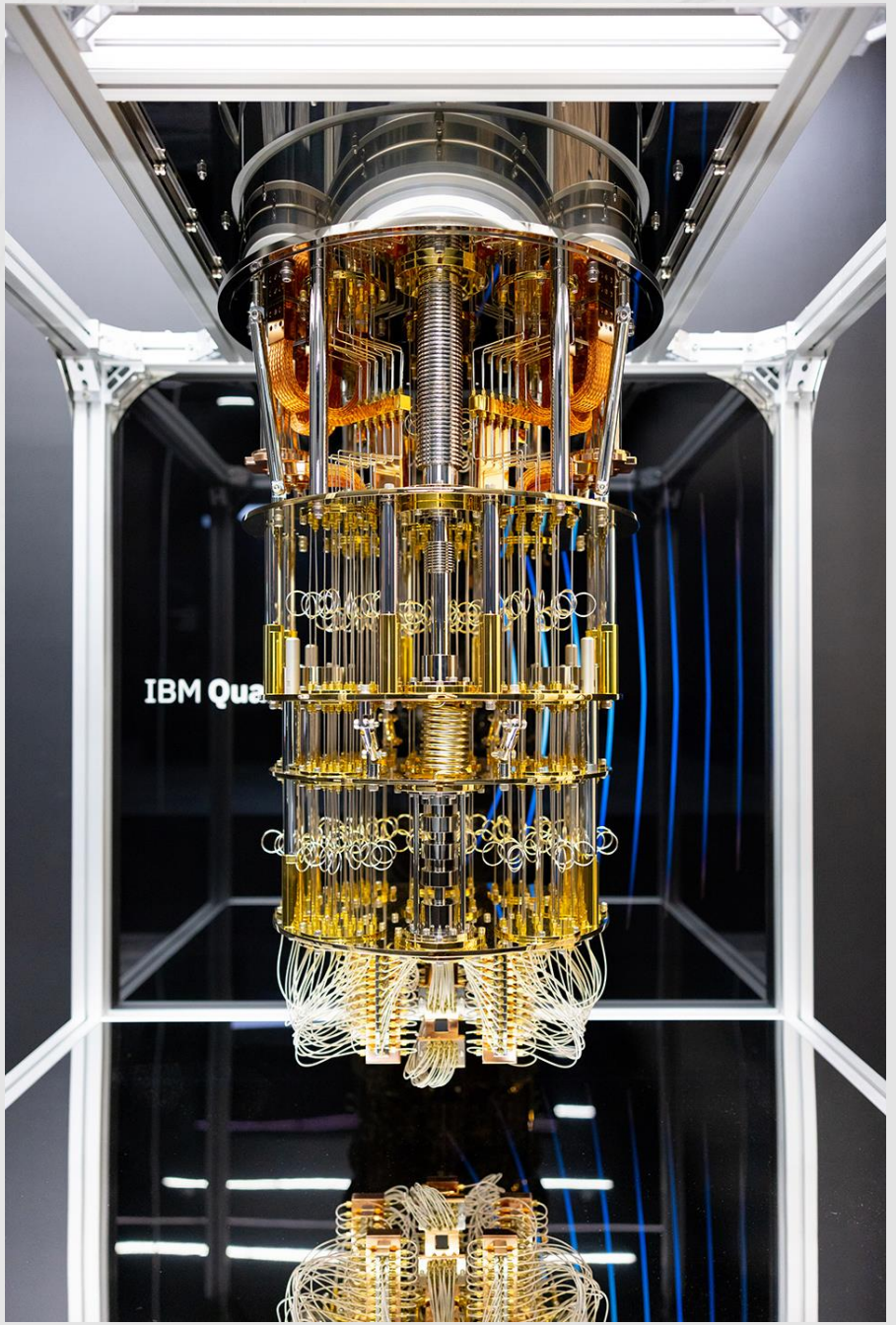
Hardest Machine Learning problems

Ability to consider millions of options in parallel – in seconds

Self-learning programs – look at all learning paths – simultaneously – in seconds

Challenges


PAUL NOTH
"Well, your quantum computer is broken in every way possible simultaneously."

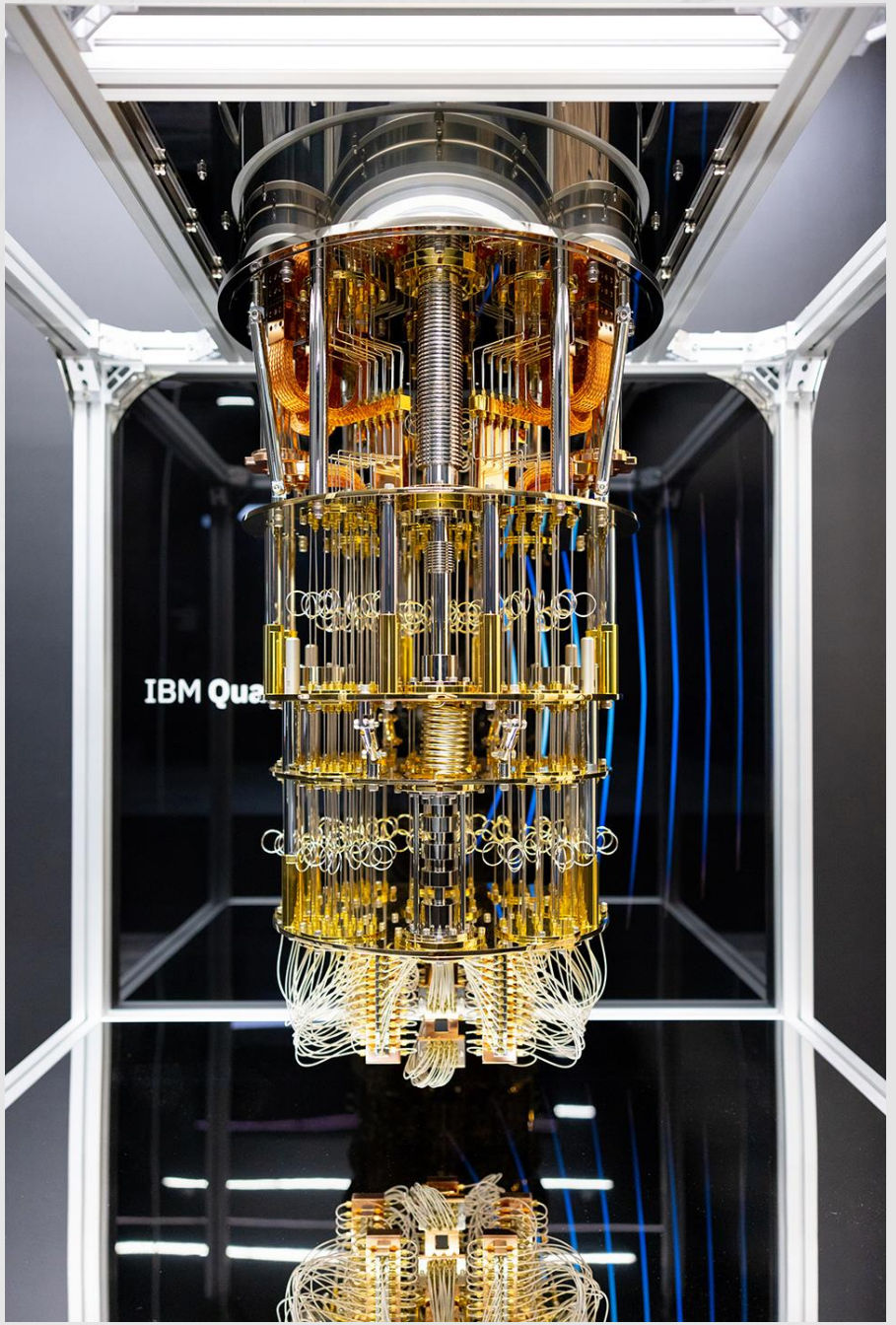

IBM Qua

Challenges

Current Size – approximately 1.5m wide and 6m long – not very practical in personal devices or even in Commander Data

Cost - $10K per Qubit – Realistically - $15M (D-Wave 2000Q) - $Bs depending on the size of system

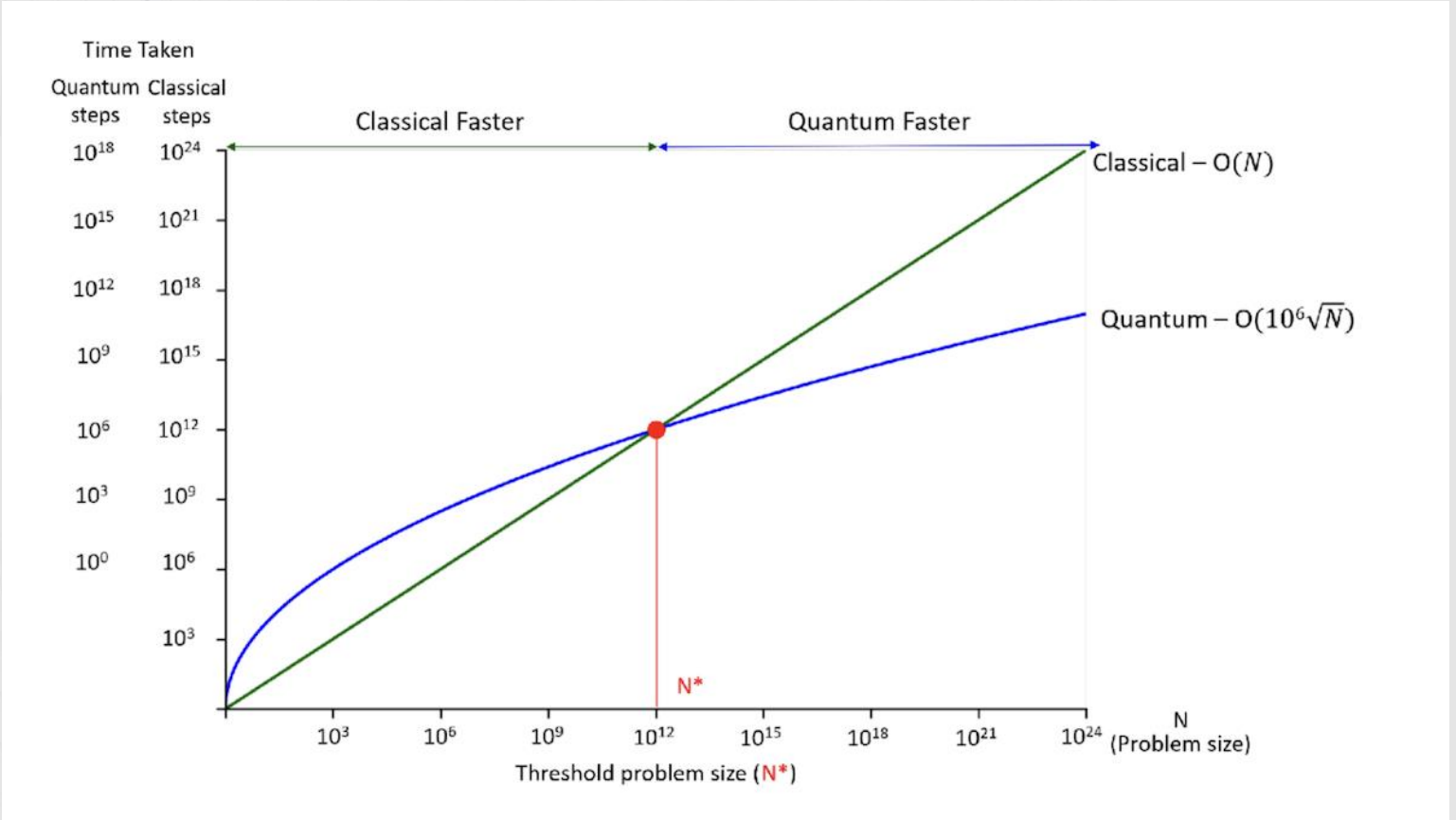
Technology – Circuit quality which allows Ks->Mx of gates (we are between 5-10K now); logical Qubits;



Classic Computing vs Quantum Computing

There are situations where quantum computers will be slower than traditional computers

Lots of variables and lots of steps are the sweet spot for a quantum computer



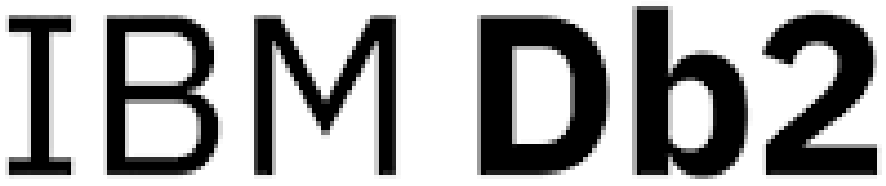
Databases

AI Optimizer combined with Quantum computing ?

Complex Queries ?

Resource Management optimizations ?

Likely not for “traditional” workloads



Check out what IBM is doing …..

IBM Quantum: https://www.ibm.com/quantum

IBM Quantum-Safe: https://www.ibm.com/quantum/quantum-safe

30+

Years running the world’s mission critical workloads with Db2

Governed, secure

Continuously available

Endlessly scalable

Highly performant

Real-time analytics

Automated operations

IBM **Db2 powers** the **modern economy**

10/10
largest banks

10/10
largest automotive manufacturers

10/10
largest insurance companies

#1
largest global retailer

40/50
state governments

23+
airlines globally

And our **customers** continue to realize the benefits of Db2

Price-performance at scale

>$1M

reduction in total cost of ownership for customers switching from Oracle, like Owens Illinois

Highly resilient, scalable applications

400%

more users supported with IBM Db2 pureScale® to run Puma's 24/7 mission-critical operations

Real-time decisions

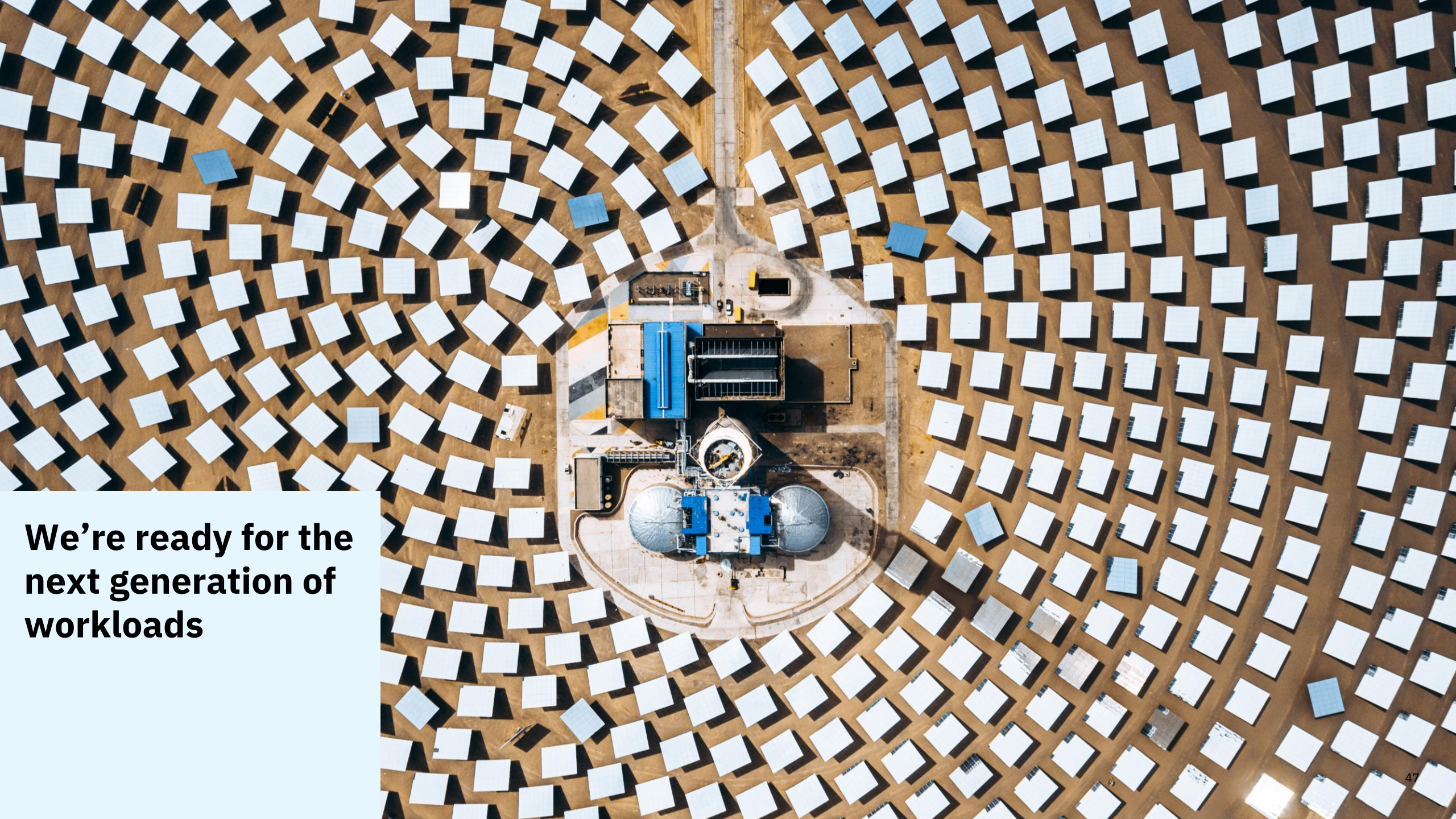
90%

faster data processing to support loyalty insights across Marriott Bonvoy's 140M+ members.

Improve customer experiences

100s

of hours saved annually for marketing teams with AI-powered prospecting at Active International



We’re ready for the next generation of workloads

Leaders are faced with
unprecedented data challenges,
making it difficult to
scale the adoption of AI

There's more data...

The aggregate volume of data stored is set to grow over 250% in the next 5 years

...in more locations

82% of enterprises are inhibited by data silos across multiple locations & cloud providers

...in more formats

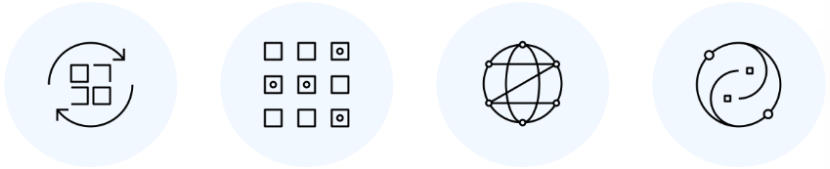
80% of time is spent on data cleaning, integration and preparation across numerous data formats

...with less quality.

82% of enterprises say data quality is a barrier on their data integration projects

IBM Db2 is the **one database** built to run the **next generation** of **mission-critical workloads**

Db2 ***for low latency applications***



Modernize mission-critical apps

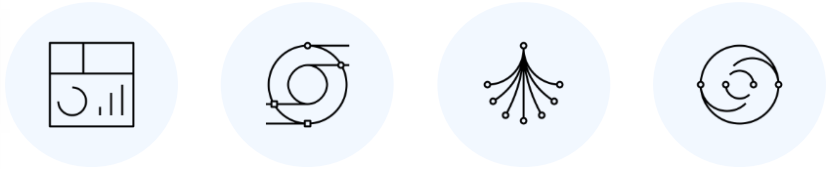
Run enterprise software

Build new cloud-native apps

Power next-gen AI assistants

IBM **Db2**

Db2 Warehouse ***for always-on analytics***



Build real-time dashboards

Run operational analytics

Share data across teams

Build ML & AI models

All major cloud providers

All deployment options

Everywhere

Revolutionizing the **Wimbledon** and **US Open** fan experience with **IBM AI**

Wimbledon and USTA leveraged **watsonx** and **Db2** to access disparate data and train their AI to create commentary and predict player favorability.

10M+ data points collected and analyzed:

– Minutes played
– Matches
– Strokes
– Distance run
– And more

IBM Db2
IBM watsonx.data
IBM watsonx.ai
IBM Power Index
IBM Watson Discovery

AI is only as good as your data.
Scale AI with Db2.

AI query optimizer

→ Up to **3x faster** query performance with new AI-based query optimizer

Db2 infused with Generative AI

→ We're adding **Gen AI** capabilities to Db2. Stay tuned.

In-database machine learning

→ **Build, train, evaluate and deploy ML** models directly in the database engine using SQL, Python and R, all without ever moving your data

watsonx integration

→ **Share and access all data** from a single point of entry, with governance and lineage for AI – no ETL required

IBM’s generative AI technology and expertise

AI assistants

Empower individuals to do work without expert knowledge across a variety of business processes and applications.

watsonx Code Assistant
watsonx Assistant
watsonx Orchestrate
watsonx Orders

SDKs and APIs

Embed watsonx platform in third party assistants and applications using programmatic interfaces.

Ecosystem integrations

AI and data platform

Leverage generative AI and machine learning — tuned with your data — with responsibility, transparency and explainability.

watsonx
watsonx.ai
watsonx.governance
watsonx.data

Foundation models
Granite | *IBM*
Open Source | *Hugging Face*
Llama 2 | *Meta*
Geospatial | *IBM + NASA*
...

Data services

Define, organize, manage, and deliver trusted data to train and tune AI models with data fabric services.

Cloud Pak for Data
watsonx Discovery

Hybrid cloud AI tools

Build on a consistent, scalable, foundation based on open-source technology.

Red Hat OpenShift AI
(*e.g.,* Ray, Pytorch)

Consulting
Generative AI strategy, experience, technology, operations

Ecosystem
System Integrators, Software and SaaS partners, Public Cloud providers

Investments in an open and trusted data foundation will accelerate and scale your AI initiatives

Databases

Store, unify, and share data with open formats and native integrations

Database
IBM Db2
IBM Informix

Data Warehouse
IBM Db2 Warehouse
IBM Netezza

Data Lakehouse
IBM watsonx.data

3rd party databases

SingleStore, mongoDB., PostgreSQL, DATASTAX, snowflake, aws, Any many more

Data Fabric

Simplify data access across the enterprise and hybrid cloud environments with a data fabric architecture

Data Governance
IBM Knowledge Catalog
Manta

Data Integration
IBM DataStage
IBM Data Replication
IBM Data Virtualization

Data as a Product
Delivering data products

Data Observability
IBM Databand

Master Data Management
IBM Master Data Management

IBM Cloud Pak for Data

Data

Delivering quality data to consumers and users

AI

Enabling data teams to be more productive with automated insights

watsonx™

Scale and accelerate the impact of AI with trusted data

AI and Data Platform

watsonx.ai
watsonx.data
watsonx.governance

AI Assistants

watsonx Orchestrate
watsonx Assistant
watsonx Code Assistant

Automated data lineage

Gain deeper visibility into your data and its journey from source to end-use for regulatory compliance and AI use cases with Manta, an IBM company

Db2 is for people who need to get things done

Developers

Build your next rockstar app with a vast array of **programming languages**, **development tools**, **documentation** and **ecosystem**

Data Scientists

Build, **train**, **evaluate** and **predict** with Db2's extensive library of in-database ML algorithms that mesh ML directly with your SQL

Data Analysts

Integrate data from multiple data sources, providing your business with **real-time access** to intelligence critical for a modern **data driven** company

Database Administrators

All the **tools** and **services** to **manage** the most **complex database deployments** on the planet, all from one command center

Db2 is your **one database engine** for all mission critical workloads

Db2 Database for transactional workloads

Choose the Db2 topology that best satisfies your needs for highly available, low-latency transactional workloads

Topology	Availability
Single node	★★☆☆☆
Multi-node with HA/DR	★★★★☆
Extreme scale with pureScale	★★★★★

- Single-node transactions with flexible uptime requirements
- Ideal for new app development, non-SLA smaller workloads or dev/test

- Multi-zone transactions with high availability & disaster recovery
- Ideal for production workloads with strict SLAs

- Distributed architecture for continuous availability with maximum scalability
- Ideal for mission critical workloads with extreme uptime demands

Db2 Warehouse for analytical workloads

Choose from single-node or MPP-clustered configuration for your high performance warehouse workloads

Topology	Scalability
Single node warehouse	★★☆☆☆
MPP warehouse	★★★★★

- Single-node SMP warehouse with option to scale up
- Ideal for new development or dev/test for existing warehousing projects

- MPP architecture with near infinite scale and continuous availability
- Ideal for high-performance, petabyte-scale data warehouses

Deploy Db2 anywhere your apps and dashboards run

Data proximity is critical for optimal performance. **Data locality** is critical for governance and access control. This is why we're **continuously expanding** where and how you can take advantage of **Db2**.

	Self-managed software	Cloud-managed IaaS	Cloud-managed container PaaS	Fully-managed SaaS
Db2	●	IBM Cloud, AWS, Azure, GCP	IBM Cloud, AWS, Azure	IBM Cloud, AWS
Db2 Warehouse	●	IBM Cloud, AWS, Azure, GCP	IBM Cloud, AWS, Azure	IBM Cloud, AWS
Db2 pureScale	●	AWS		

Key-Note

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