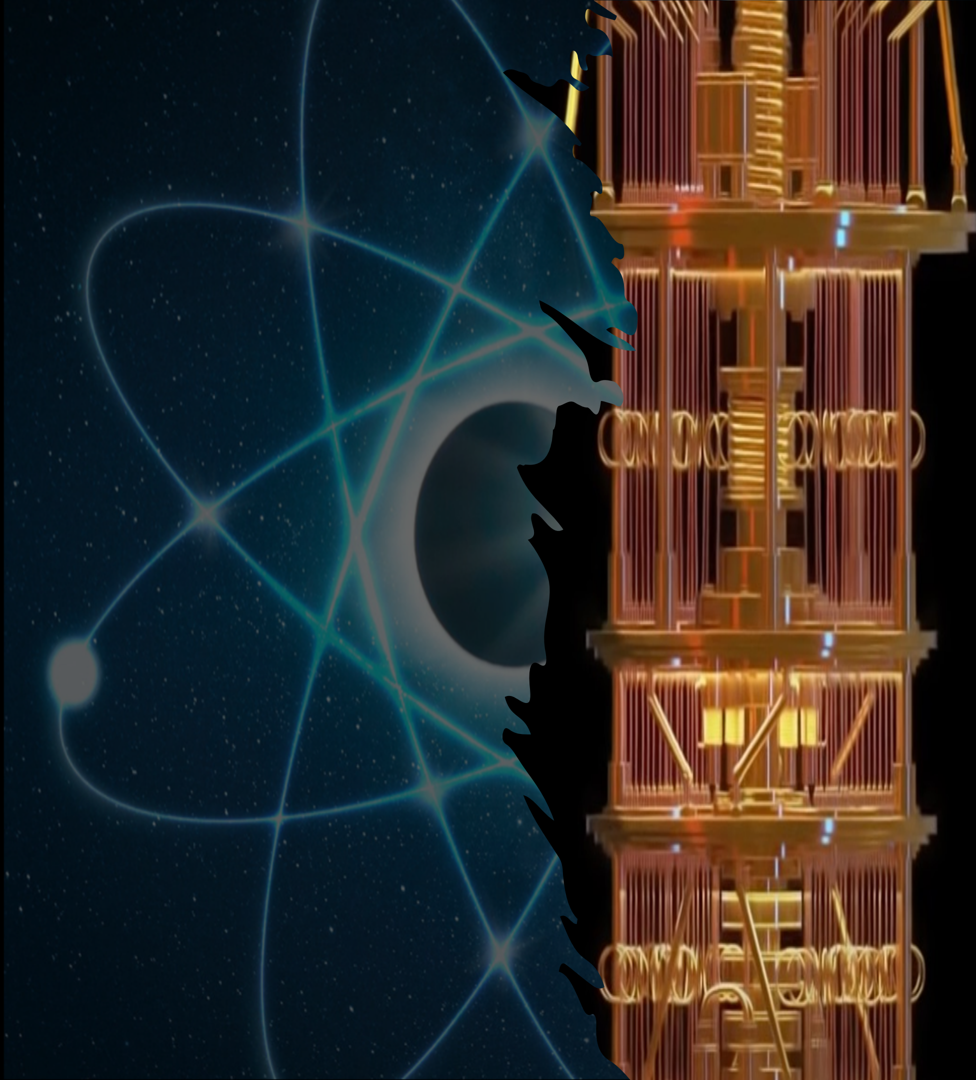
Quantum Computing
&
Strange (Java) API

Sasi Peri



We are *Essential to care*™

We power our
customers' missions

By bringing together
unmatched solutions from across our enterprise

To achieve both **clinical and operational success**

Our scale, breadth and expertise maximize your impact

A GLOBAL, INTEGRATED HEALTHCARE PRODUCTS & SERVICES COMPANY

~90%
of U.S. hospitals

>29K
pharmacies

>10K
specialty physician offices and clinics

3M+
patients

46K+
home healthcare products

>6.2K
labs

>51K
lab products

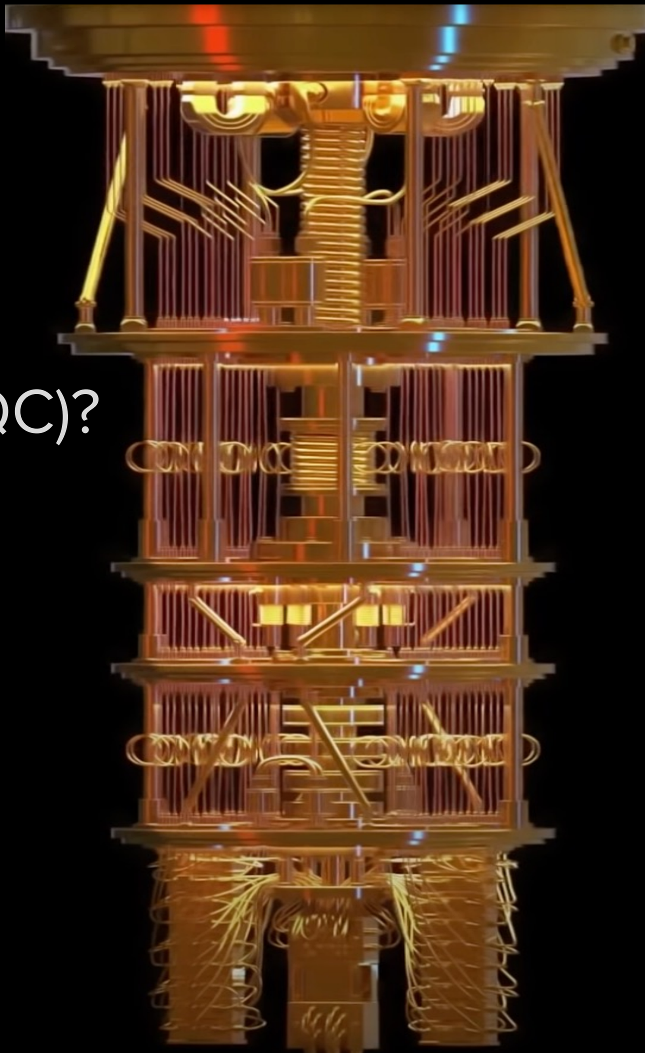
CardinalHealth

Disclaimer

The following is my general findings and is intended for information purposes only. You are encouraged to do your own thorough analysis and research before the use of the technology.

Agenda

1. Quantum physics (quantum particles)
2. What and why of Quantum Computing (QC)?
3. How can we get involved?
4. Java QC API (Strange) & Demo
5. Use cases and key takeaways
6. Q & A



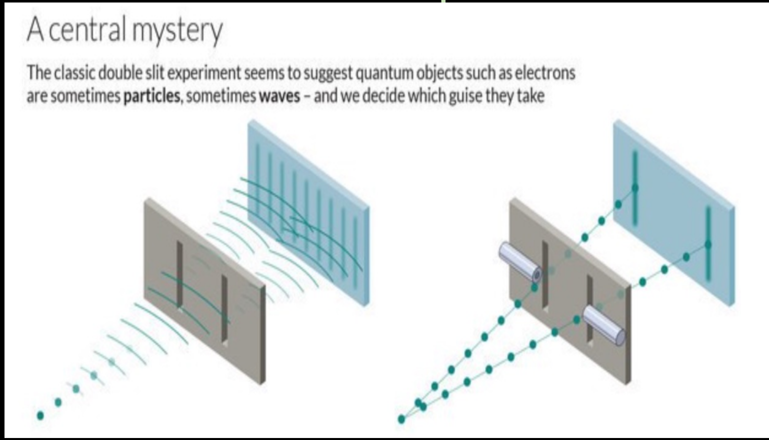
Quantum Physics

(Fundamental Properties Of Quantum Particles in Nature)

Superposition & Observer Effect

- Subatomic particles in nature can be in multiple states, all at the same time.
- Multiple possibilities collapses into a probability with interference.
- Nondeterministic nature turns deterministic only when observed

Double slit experiment



Lead -186 & Many Shapes

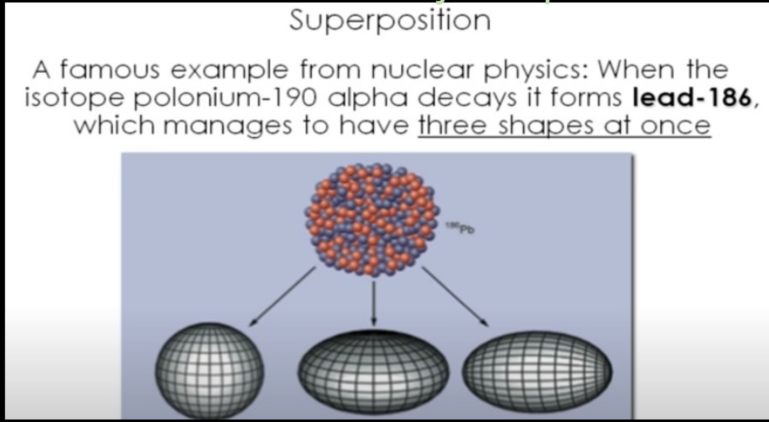
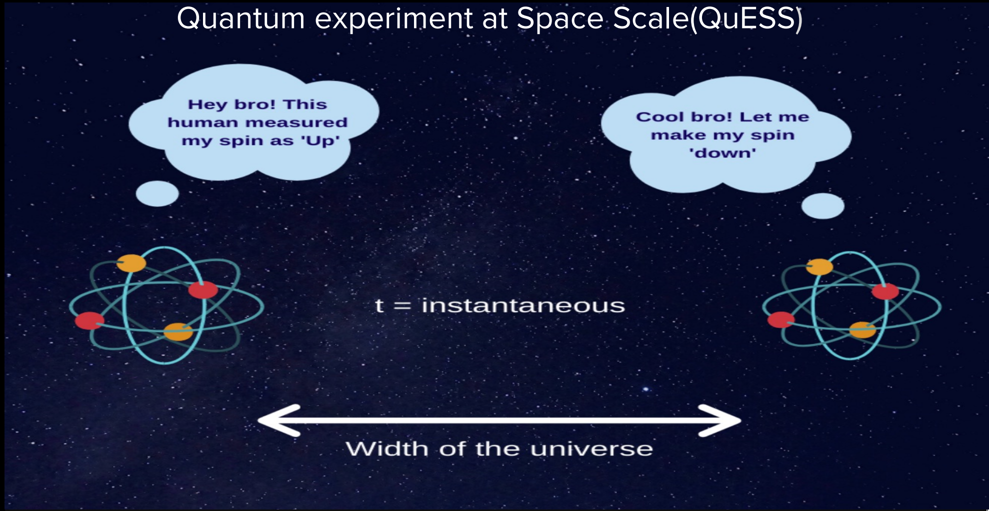


Image Source:

- [Double Split]
- [Lead 186]

Entanglement & Observer Effect



Einstein's *“Spooky action at a distance”*

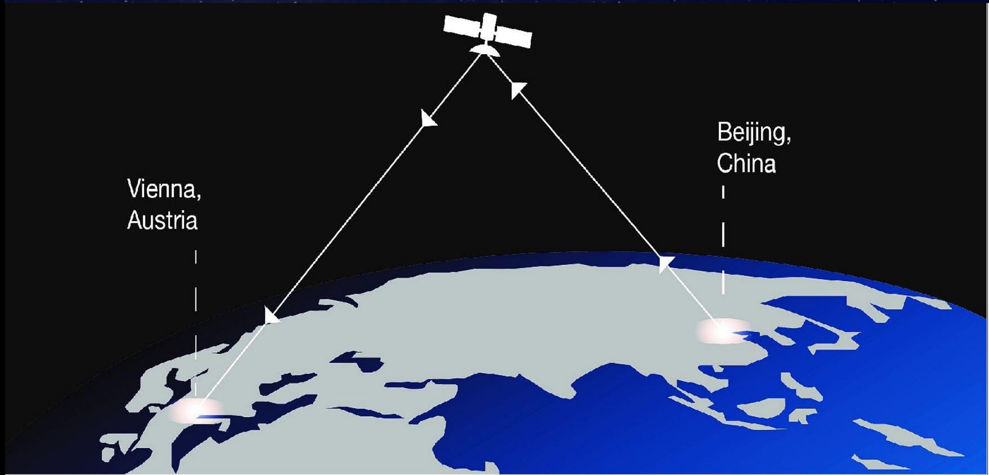


Image Ref: (courtesy)

- [Understanding The Theory And Math Behind Qubits]
- [Science direct - Entanglement]

Quantum Computers

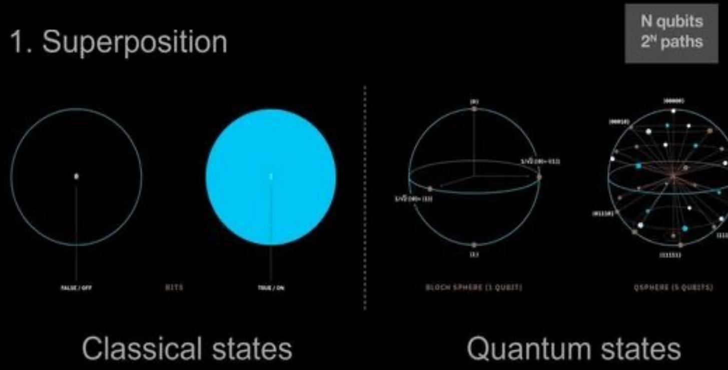
What’s Quantum Computer

Quantum computers mimic the laws of Quantum Physics. Electrons in quantum states are the building blocks, thus often said to be very close to how nature works.

QC creates new possibilities that classical computers cannot solve, due to exponentially growing space and time complexities.

Qubit

- Qubit is the basic unit of Quantum Computer
- Qubit in super position can be both “0 and 1” at the same time. *(leaner combination)*
  - Formula: $|\psi\rangle = \alpha|0\rangle + \beta|1\rangle$ such that $|\alpha|^2 + |\beta|^2 = 1$ *(Dirac notation)*
  - Best analogy is Switch vs Dimmer *(Chuck Bates)*



‘qsphere’ Source: IBM Research via YouTube

Time and space complexity

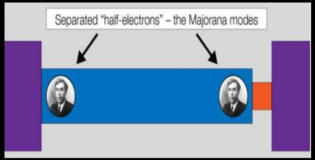
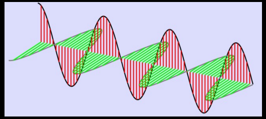
Quantum Qubits	Possibility #	Permutations (possible) states				Total QC Possibilities (states) (*Exponential function*))		Bits for Parallel Processing (Exponential Space)
1	1	0				2	2^1	2
	2	1						
2	1	0	0			4	2^2	8
	2	1	0					
	3	0	1					
	4	1	1					
3	1	0	0	0		8	2^3	24
	2	1	1	0				
	3	0	1	0				
	4	1	0	0				
	5	0	0	1				
	6	1	1	1				
	7	0	1	1				
	8	1	0	1				
4	1	0	0	0	0	16	2^4	64
	2	1	1	0	0			
	3	0	1	0	0			
	4	1	0	0	0			
	5	0	0	1	0			
	6	1	1	1	0			
	7	0	1	1	0			
	8	1	0	1	0			
	9	0	0	0	1			
	10	1	1	0	1			
	11	0	1	0	1			
	12	1	0	0	1			
	13	0	0	1	1			
	14	1	1	1	1			
	15	0	1	1	1			
	16	1	0	1	1			

64 qubits = 2^64 simultaneous paths = ***~ 1 million terabytes.*** If processed by classical computer, takes ***~ 400 years*** to traverse through all possibilities.

300 qubits = 2^300 simultaneous paths = ~ 2 E +90 bits. *(greater than all the molecules that we can count in universe– Chuck Bates)*

How do you make a Qubit?

Few ways pursued outside academics

• Super conductors *(absolute ~0.0 K, colder than space)* • Google, IBM	
• Topological • Microsoft	
• Others e.g., Light Polarization	

How can we get involved?

Hardware and Software

Hardware

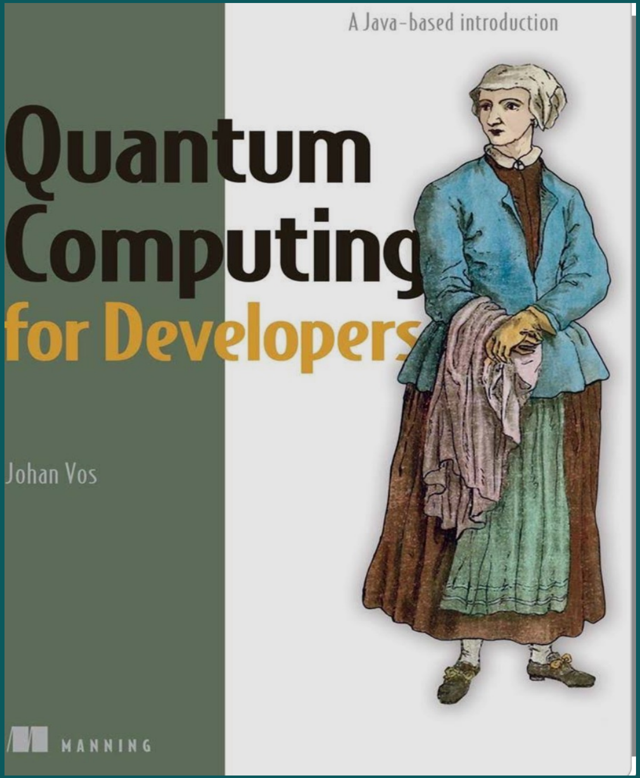
- QC in cloud, running in labs.
  - E.g., IBM’s 5 qubit QC in the lab, *free* to play with
- Hardware simulators

Software

- SDKs & APIs exist in many languages namely Q# (Microsoft), Python (QCWare), OpenQASM (IBM)

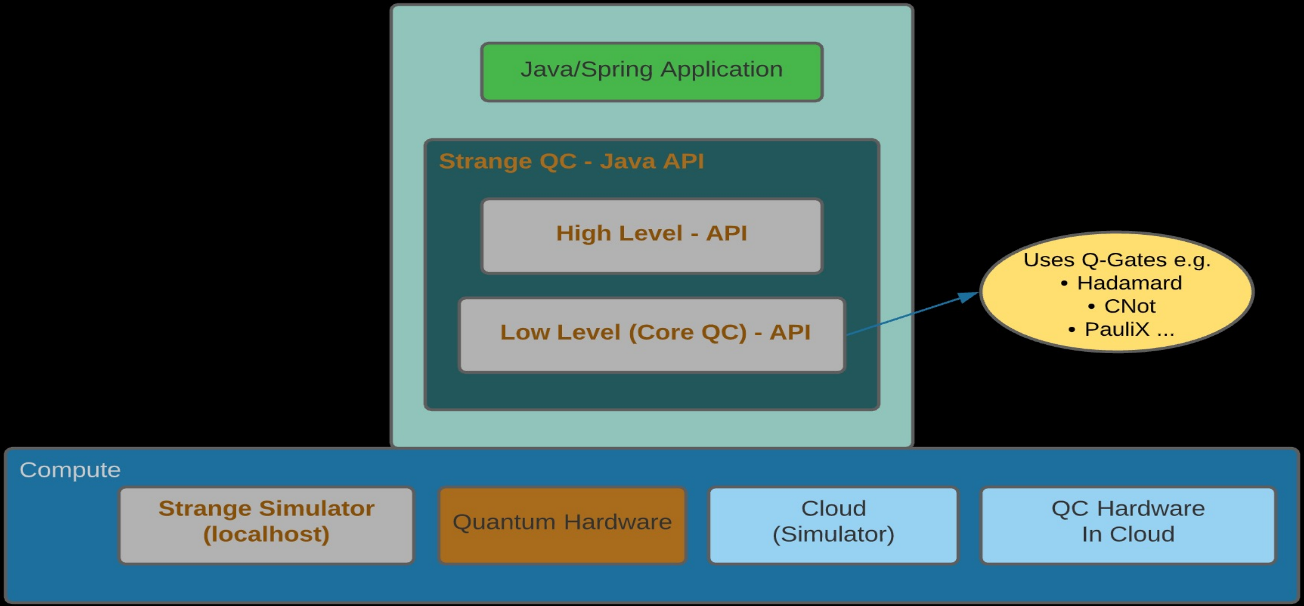
(links to sdk/apis and software providers are in the reference section)

Strange - Java QC API
&
Demo



Strange – QC API

- Opensource Java API , licensed under BSD (3-clause)
- Typical Quantum Java App Stack



Debug:
- Strange-GUI (JavaFX)
- Fictive Probability Gates

QC Software (Algorithms)

1. QC Problem
   - Classical problem should be transformed into a QC problem
   - Example: How to solve “Oracle Gate and (Blackbox)Function with QC?
     - f(bit)=0;   f(bit)=1;   f(bit)=bit;   f(bit)= !bit

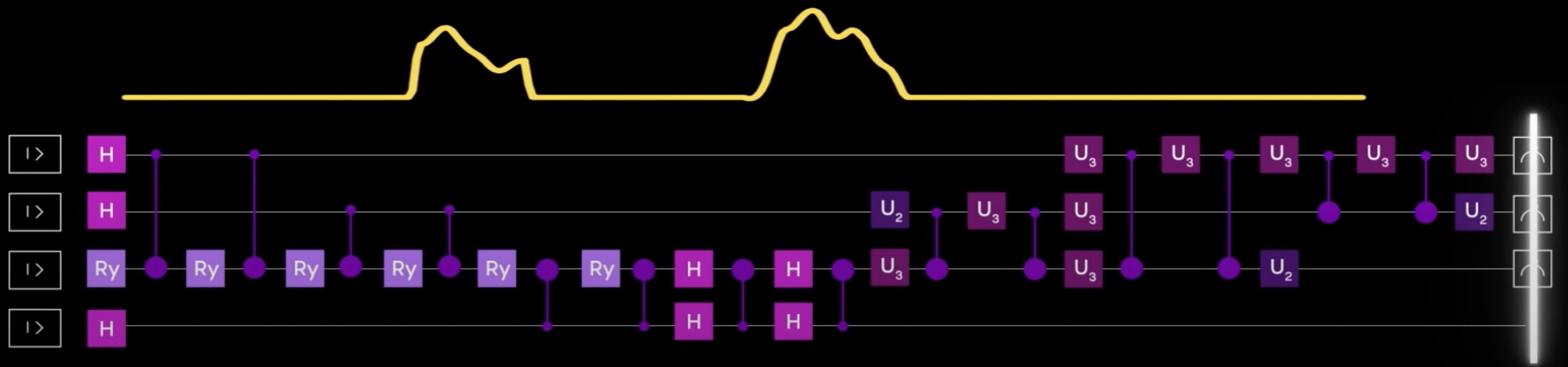
2. Write Algorithm
   - Write algorithm to the transformed problem, using QC gates and states

QC Algorithms

Few QC Algorithms already implemented in Strange

1. *Deutsch, Deutsch-Jozsa algorithm (simplest deterministic)*
2. Grover's search algorithm *(probabilistic, nondeterministic)*
3. Shor's Algorithm (*Prime Factors, Cryptography, nondeterministic)*

Sample algorithm (Amplitudes) look like



Use cases and Takeway

Use Cases

Being Researched *(To dig deeper, see the references section for links)*

- Health care – Examples
  - Personalized drug manufacturing & testing.
- Security - Examples
  - Quantum Key Distribution (*Ref :QKD using entanglement*)
  - Quantum Cryptography
- Other areas like Banking, AI & ML

Fun stuff in the interim

- Games
- Quantum music (*James Weaver*, *SpringOne lighting talk*)

Takeaways

1. Use QC only for the right problems.
   - Quantum systems are the best to model quantum systems(inherently quantum), involving time & space complexities *(else overkill).*

2. Fault tolerant hardware, abstracted at all levels is still a challenge.
   - Your bank accounts are not going to be broken anytime soon (*Shor's algorithm requires big, fault tolerant quantum computer, still far from existence)*

3. You can get your hands on with real QC in cloud, today, for near term software possibilities.

4. Quantum simulators are memory hungry, meant to test logic on small scale.

5. Further reads: Quantum Networks; Teleportation …

Thank you

1. Jim Shingler *(Digital Transformation, Cloud Adoption and DevSecOps Leader)*
2. Ralph Meira *(Advisory Platform Architecture, Developer Advocate)*
3. Tom Halter, Doug Hoke *(Friends at Cardinal Health)*

Links and References

Strange GitHub

- ✓ API : https://github.com/redfx-quantum/strange
- ✓ JavaFx Simulator: https://github.com/redfx-quantum/strangefx
- ✓ Examples and Sample Apps : https://github.com/johanvos/quantumjava

Real QC in cloud (from Labs) and/or Simulator and SDK

- ✓ QC Ware: https://app.forge.qcware.com/
- ✓ IBM: https://docs.spring.io/spring-boot/docs/current/reference/htmlsingle/#boot-features-custom-starter-naming
- ✓ Rigetti: https://www.rigetti.com/what

Other References

- ✓ Nature (double slit): https://www.nature.com/articles/d41586-018-05892-6
- ✓ Entanglement explained: (Einstein vs Niels Bohr): https://www.youtube.com/watch?v=5_0o2fJhtSc
- ✓ Entanglement and quantum internet: https://spectrum.ieee.org/entangled-satellite
- ✓ David Duetsh's Lectures (videos) : http://www.quiprocone.org/Protected/Lecture_6.htm
- ✓ Qskit: https://qiskit.org/textbook/preface.html (SDK for OpenQASM)
- ✓ Qubit errors and ion loss: https://www.power-and-beyond.com/researchers-correct-qubit-loss-in-quantum-computers-a-979005/
- ✓ Topological Qubit: https://phys.org/news/2021-07-scientists-advance-potential-topological-quantum.html
- ✓ Quntum gates and circuits : https://youtu.be/Omv-bPvQ3E8
- ✓ QC by Nihal Mehta: https://www.pragprog.com/titles/nmquantum/quantum-computing/
- ✓ Erwin Schrodinger's *What's Life (1944):* https://www.raptisrarebooks.com/product/what-is-life-the-physical-aspect-of-the-living-cell-erwin-schrodinger-first-edition/
- ✓ QC Gates explained: https://www.quantum-inspire.com/kbase/ry-gate/

Thank You!