Quantum Phase Change

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Going over the basics of Phase Change and how it can become **Quantum**

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Just like water to ice or steam, quantum phase changes have more than one type

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Quantum Phase changes have a big impact in Quantum Computing

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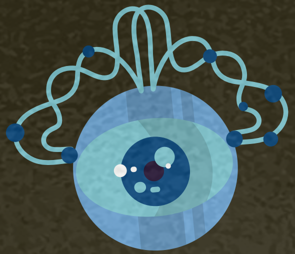
INTRODUCTION

What are Phase Changes? Why are they important?



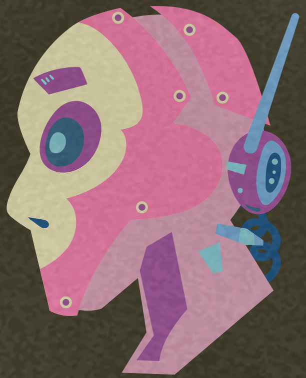
Phase Changes

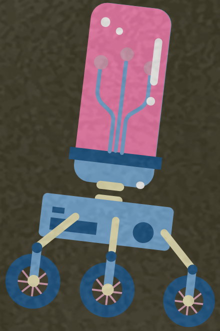
Before even going into the quantum part, normal phase changes happen all the time. These occur due to temperature such as when water turns to steam when boiling or when water freezes and turns to ice. At a microscopic level, it is the heat energy that drives these atoms to become more or less tightly packed which results in a phase change.

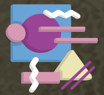
Quantum phase change

What makes it quantum?

The Quantum part comes in when temperature is at absolute zero where no heat energy is being transferred.







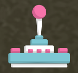
How it happens

Instead of relying on temperature, these phase changes happen because of quantum fluctuations.

Origin of Quantum Phase Change

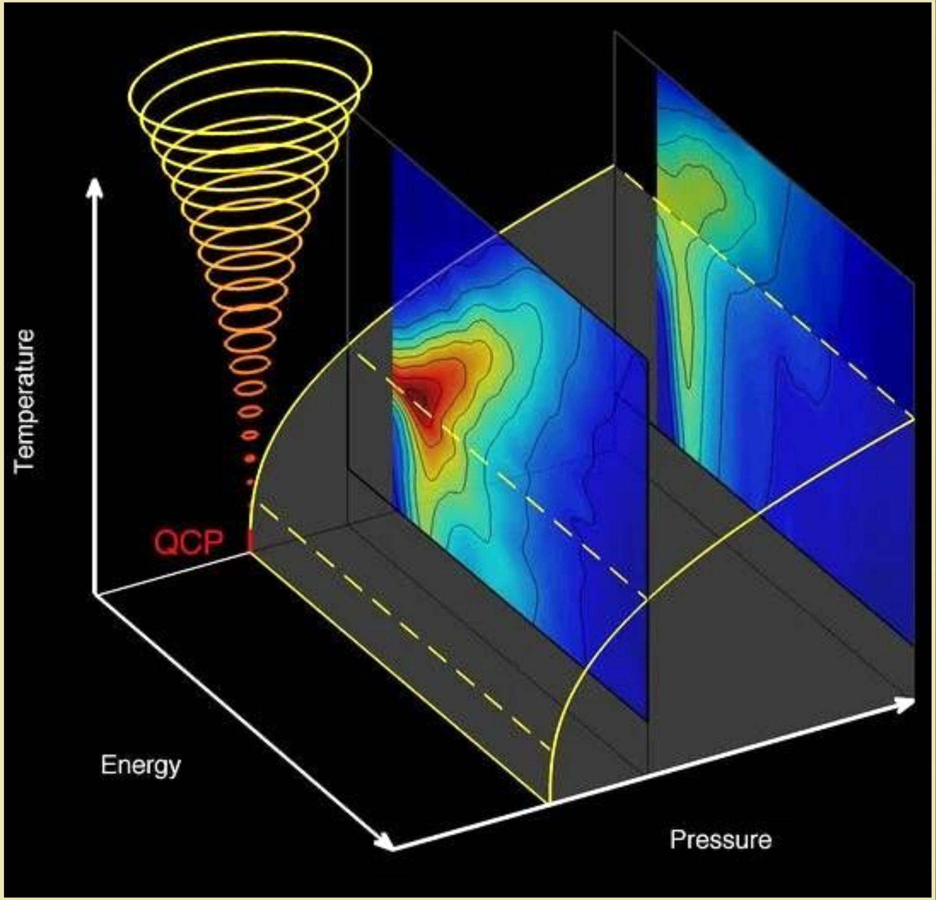
Well how did we discover Quantum Phase Changes?

- The Ising Model(1920) which was designed to show symmetry breaking in low-temperature phase.
- Landau Phase Transition theory which explains how systems phase change and how these systems behave at transition points.
- The Monte Carlo Methods are ways to measure quantum phase change with order parameters and random sampling. It is incredibly consistent in simulating these phase changes.



There were many theoretical and experimental observations when it came to quantum phase change but they all prove to be useful in many fields today.

An example of when Quantum Phase Change occurs



How does it occur?

Near zero temperature

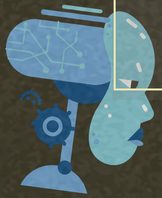
First temperature has to be at 0 to remove thermal fluctuations and allow quantum fluctuations.

Quantum fluctuations

Next fluctuations happen explained by Heisenberg's uncertainty principle and this can force a phase change.

Qubit Manipulation

Finally these phase changes are essential in Qubit Manipulation which is the premise of Quantum Computing.



Types of Quantum Phase Change

Ising Transition

The simplest transition where a ferromagnetic field(orderly) becomes a paramagnetic phase(disorderly)

Conductor-Insulator Transition

A transition that turns a material from superconducting to insulating due to quantum fluctuations.

Quantum Hall Transition

Transitions based on strong magnetic fields that lead to quantum Hall state transitions.

Dirac Semimetal Transitions

Fundamental transitions that deal with changing electronic properties. These can develop new types of qubits or gates.

Relevance for Computing

Qubit Manipulation

Qubits can be controlled with QPT such as conducting to insulating changes.

Quantum Simulations

Other Quantum processes can be simulated using QPTs as it helps us study more.

Quantum Algorithms

More Algorithms can be made with QPTs as more things can be optimized.

Quantum Hardware

Quantum Computers are the first thing that comes to mind but other quantum hardware can also use QPT.

Quantum Networks

Networks can be even more optimized with new properties of quantum networks.

Discrete Structures

Discrete Structures in relation to lattice models where we can observe changes due to QPT

Conclusion

Quantum Phase Change(QPC)

Quantum Phase Change provide a lot more information on the physics of computing or even the relevancy of certain algorithms. These fluctuations that cause QPC can control Qubits for computing or provide information even in the presence of problems which happens a lot in quantum computing.

Discrete Mathematics

These QPTs can be found a lot in Discrete Mathematics such as in Graph theory and in Discrete Structures. Along with this is in logic and computation structures as Quantum logic that introduces randomness is used quite a lot in solving discrete problems like Boolean satisfiability.

THANKS!

Do you have any questions?

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References

- https://pratt.duke.edu/news/glimpses-quantum-computing-phase-changes-show-researchers-tipping-point/
- https://www.princeton.edu/news/2024/01/19/researchers-discover-abrupt-change-quantum-behavior-defies-current-theories
- https://cryo.caltech.edu/research/quantum-phase-transitions
- https://en.wikipedia.org/wiki/Quantum_Hall_effect
- https://stanford.edu/~jeffjar/statmech/intro4.html
- https://en.wikipedia.org/wiki/Landau_theory
- https://www.sciencedirect.com/science/article/abs/pii/B9780128020494000026
- https://youtu.be/_LILRUprucU