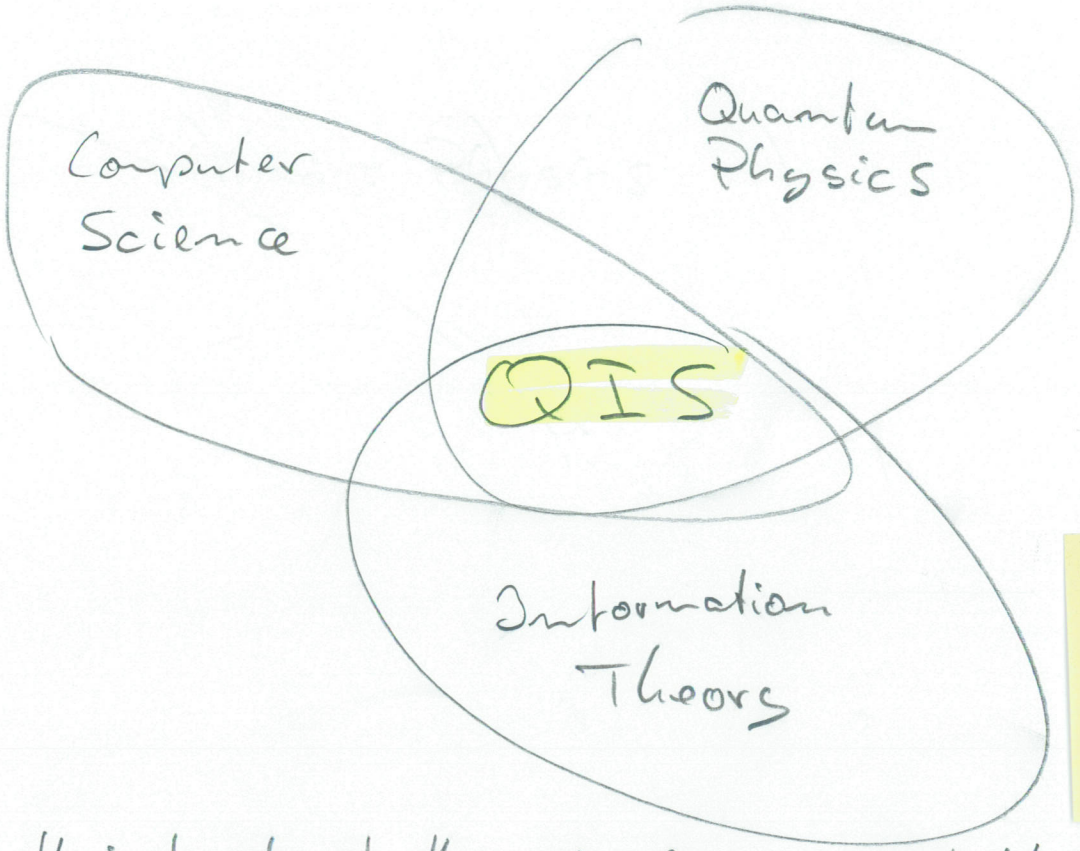
Brief historical background:

How did Quantum Information Science (QIS) develop?

QIS is an offspring of three different fields with their own development:



will be discussed in physics Colloquium on Thursday!

Let's briefly think about the development of these fields.

Quantum Physics

Why was quantum mechanics developed at turn of 20th century?

observation of phenomena in nature beyond classical physics

matter waves:
- particle diffraction (e^-, α, n, atoms, ...)

quantization of electromagnetic radiation:
- photo effect (energy of photon $h\nu$)
- Compton effect (momentum of photon $\frac{h\nu}{c}$)
- black body radiation (Planck spectrum)

tunnel effect:
- α-decay
- electronic tunnel junctions

energy level quantization:
- discrete spectra of atoms (and other systems)
- stability of atoms

quantum statistics:
- bosons, fermions

other phenomena:
- entanglement
- elementary particles
- structure of atoms and solids
- fission, fusion, superconductivity

In your opinion, which important experimental observations contributed most strongly to the development of quantum mechanics?

- Theory of quantum mechanics explains all of the mentioned phenomena and many more.

In your opinion which concepts are the most important ones to understand these phenomena?

- It does so based only on a few postulates

① complete description of the state of a physical system by a complex wave function (or equivalently by a vector in Hilbert space).

② the time evolution of any system is described by the Schrödinger equation

③ the measurement postulate governs the outcomes of measurements performed on quantum systems

④ composite quantum systems are completely described by tensor products of the component system states

these postulates are
- independent of the physical system under consideration
- hugely successful in description of physical world
- but consequences are not always easy to understand

Interpretation of quantum mechanics:

- predictions of quantum mechanics often contradict classical intuition
- paradoxical situations may arise
  - e.g. Schrödinger's cat in superposition of dead and alive states
- consequences of measurement postulate are not trivial to understand
  - e.g. collapse of wave function

Quantum Information Science helps:

- formulates procedures and suggests experiments to better understand basic properties of quantum mechanical systems
- allows one to develop intuition for the predictions of quantum mechanics through experiments

Developments in the field of quatum physics in the second half of 20th century and their importance for quatum information Science

Collective quatum phenomena

- consider ensembles of quatum systems
- no control over or access to quatum state of individual particles

e.g.: atoms: - spectroscopy in gas phase

solid state: - electronic band structure
- superconductivity

light: - LASERS

VS.

Single particle quatum phenomena

- isolate individual quatum systems
- control over quatum state and read-out of quatum state of individual particles

eg.: atoms: - ion traps
- atom dipole traps

photons: - single photon sources & detectors
- PDC, Cavity QED

charges & spins: - single electron transistor
- quatum dots
- superconducting qubits

spins:

What would you think were important developments in Q.M. that have allowed the field of quatum information science to develop?