

Building Blocks of the Universe and the Weirdness of Quantum World

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Presented at 2nd Transdisciplinary Tea Talk, Bogor, February 2019

Outline...

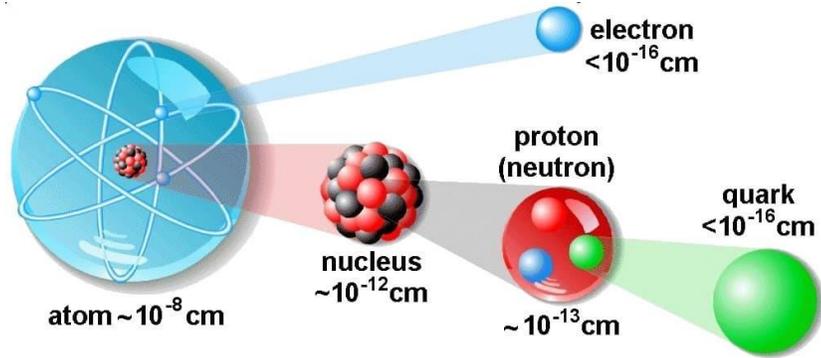
- ④ Our Universe

 - ④ Building Blocks of Our Universe

 - ④ Quantum World and its Weirdness

Physics Play Ground: The Whole Universe...

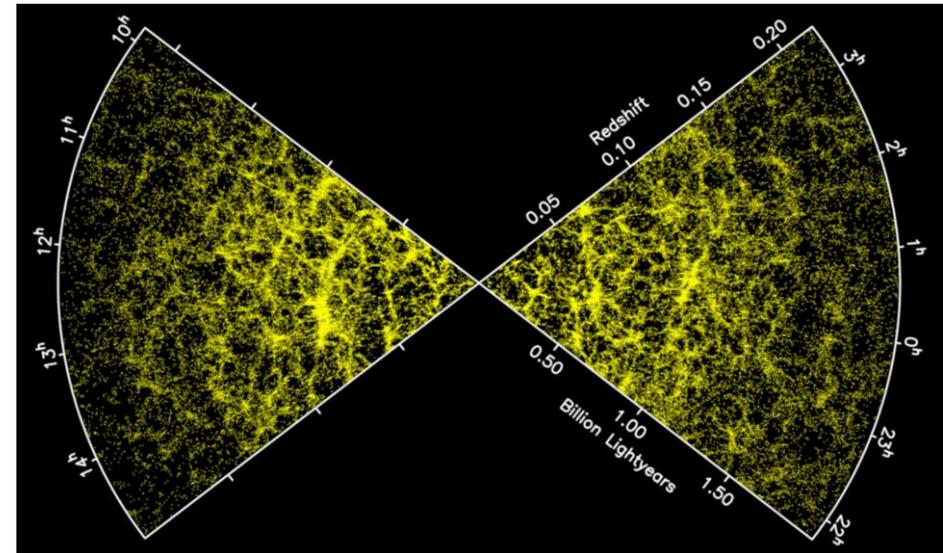
From



Quarks & Leptons: tiny particles with size $< 10^{-18}$ m.

<https://www.nuclear-power.net/nuclear-power/reactor-physics/atomic-nuclear-physics/atomic-nuclear-structure/volume-atom-nucleus/>

to



Observable Universe with size 10^{26} m.

“Sloan Digital Sky Survey” www.sdss.org

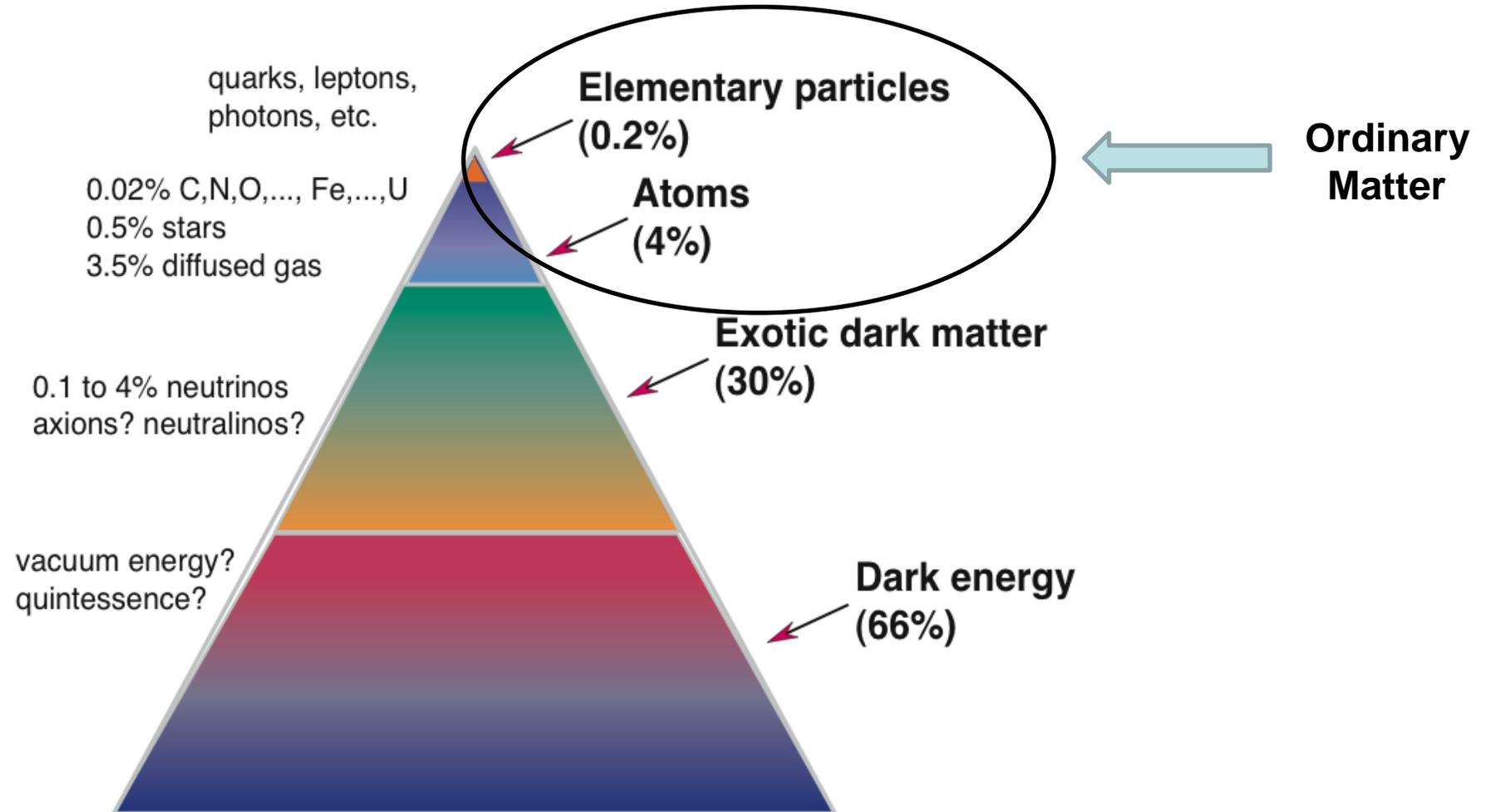
Characteristics of Natural Laws (So Far)...

1. The stability of nature obeys minimum energy principle (God's given rule).
2. Controlled by simple laws.
3. Symmetries underlying the laws.

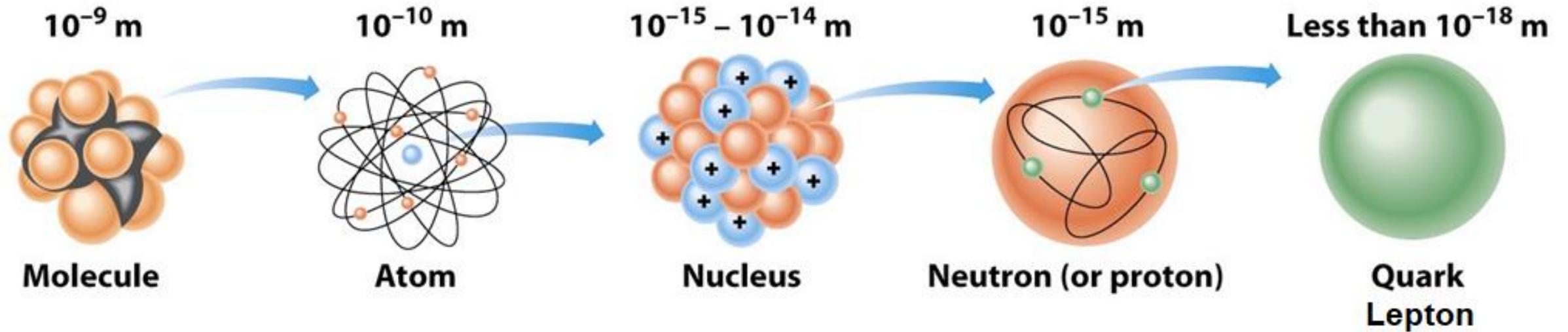
Ingredients of Our Universe...

We don't know everything! (by far!)

What is the universe made of? 96% of contents not known!

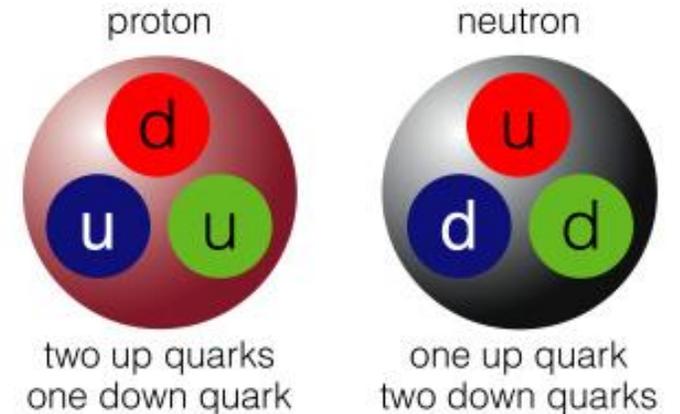


The Building Blocks of Ordinary Matter...



Quarks...

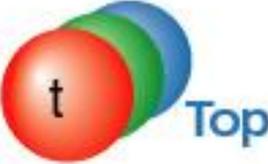
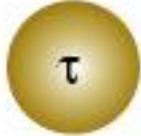
- There are six quarks with six flavors classified into three generations:
 1. up/down, 2. charm/strange, 3. top/bottom
- Most of the matter we see around us is made from protons and neutrons, which are composed of up and down quarks. No free quarks are found in nature due to asymptotic freedom. All are bounded in Hadrons (e.g. proton & neutron) or Mesons.
- Quarks have the unusual characteristic of having a fractional electric charge. Quarks also carry another type of charge called color charge (**RGB**).



Leptons...

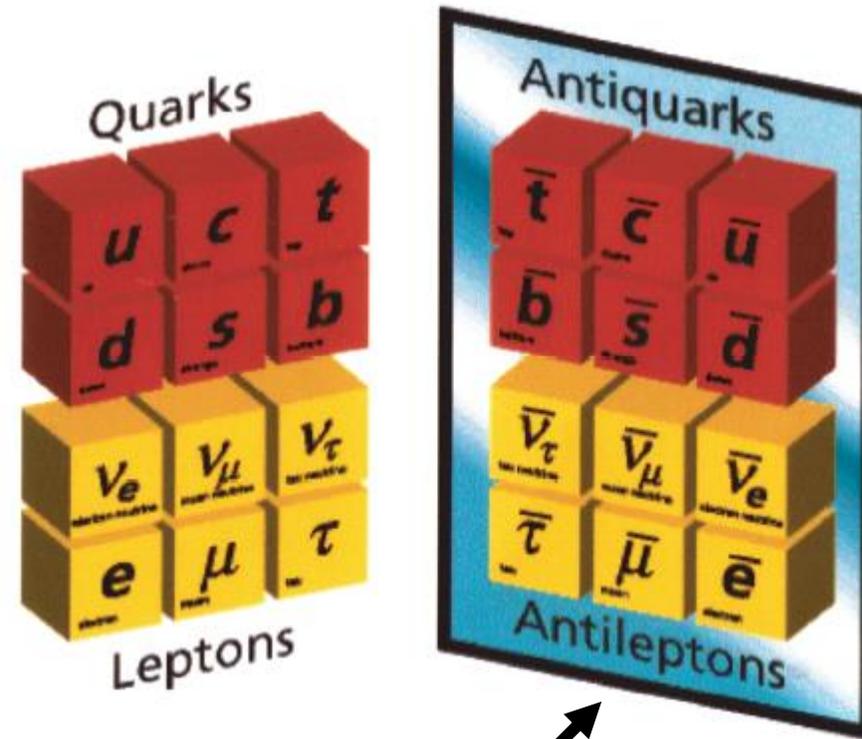
- There are three generations of Leptons: 1. Electron 2. Muon 3. Tau
- Each of those generations is accompanied by specific Neutrino.
- Only electron that is contained in ordinary matter and determines the chemical characteristics of atoms and molecules.
- Leptons have fundamental unit of electric charge.

Today's periodic system of the fundamental building blocks

	<i>Quarks</i>		<i>Leptons</i>	
<i>Generation 3</i>	 t Top	 b Bottom	 τ Tau	 ν_τ Tau-neutrino
<i>Generation 2</i>	 c Charm	 s Strange	 μ Muon	 ν_μ Muon-neutrino
<i>Generation 1</i>	 u Up	 d Down	 e Electron	 ν_e Electron-neutrino

The Standard Model of Elementary Particles (only 0.2%)...

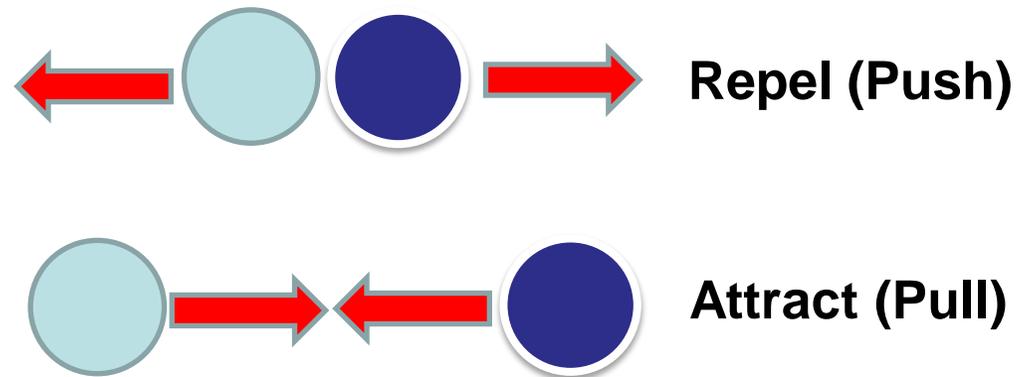
The matter around us is made up
of quarks and leptons

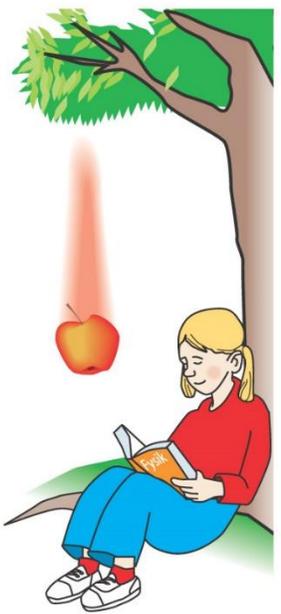
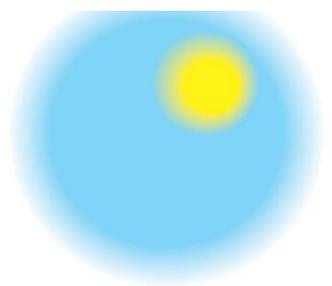


The marriage of quantum mechanics and special relativity required that antiparticles exist.

Fundamental Forces in Nature...

- Strong Nuclear Force (carried by gluon)
- Weak Nuclear Force (carried by Z and W particles)
- Electromagnetic Force (carried by photon)
- Gravitational Force (carried by graviton???)





Graviton?

Solar systems
Galaxies

Gravity Force

Gluons (8)

Quarks

Mesons
Baryons

Nuclei

up quark
down quark

up quark
up quark
down quark
proton

down quark
up quark
down quark
neutron

Strong force

Electromagnetic force

Hydrogen atom

Water molecule

Oxygen atom

Protons and Neutrons

Electron

Photon

Atoms
Light
Chemistry
Electronics

Weak force

Bosons (W,Z)

Neutron decay
Beta decay
Neutrino interactions
Burning of the sun

anti-neutrino

e electron

W force carrier particle

up quark
up quark
down quark
proton

down quark
up quark
down quark
neutron

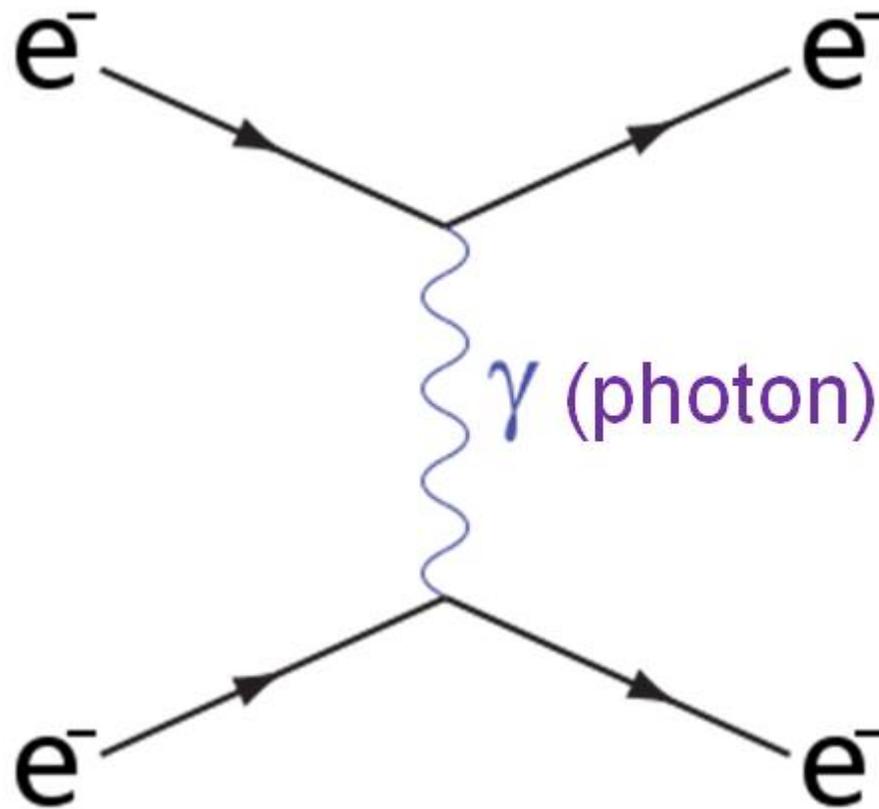
Weak force

Force	strength (within nucleus)	strength (outside nucleus)	exchange particle	Role
Strong	100	0	gluon	binds nucleus
Electro- magnetic	1	1	photon	binds atoms
Weak	10^{-5}	0	Z and W bosons	nuclear reactions
Gravity	10^{-43}	10^{-43}	graviton	large-scale structure

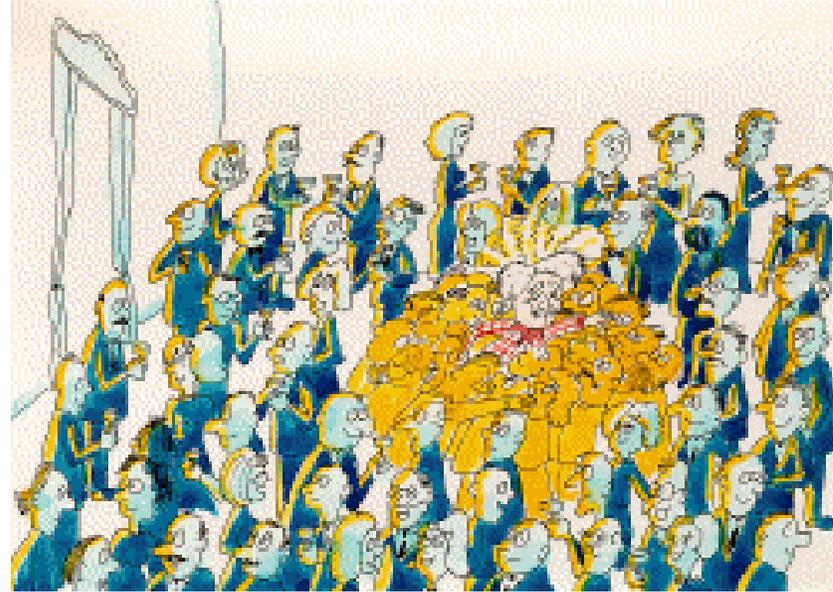
How do the Interaction Work???

The interaction is mediated by “virtual” particle exchange

e.g. electromagnetism: photon exchange between electrically charged particles



How do Particle has Mass???



If the particle interacts with the **Higgs** particles it will be slowing down, which is in our macroscopic perception it acquires mass.

If it is not the case, the particle will be massless and move at the speed of light

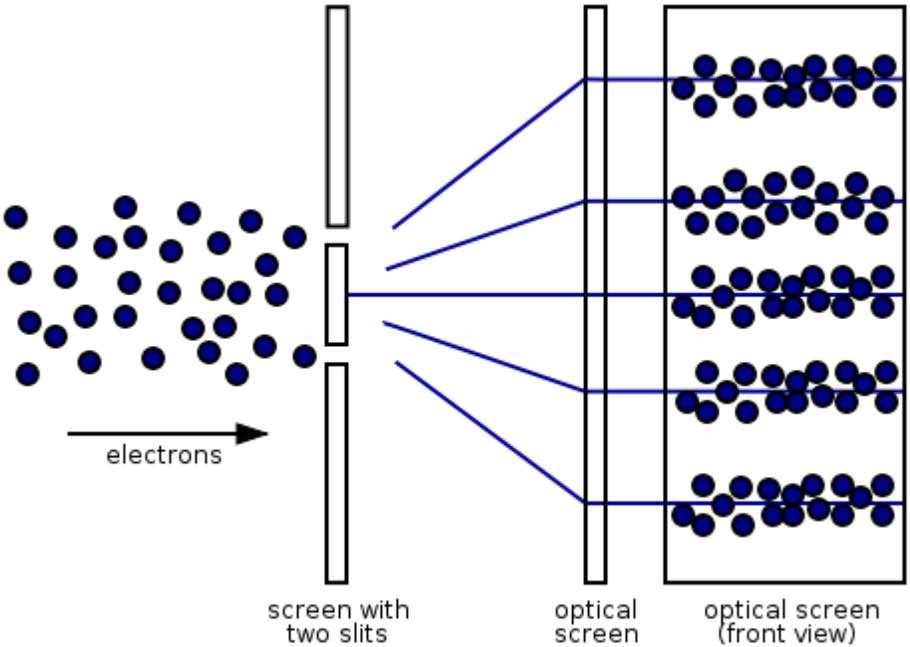
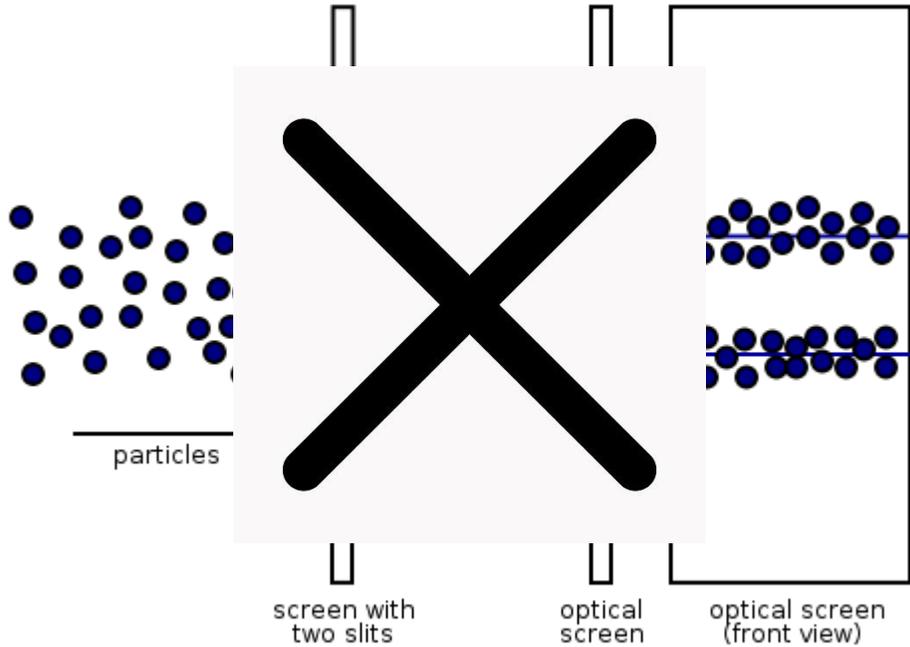
How do These Particles Behave???

...Described by the Quantum Theory...



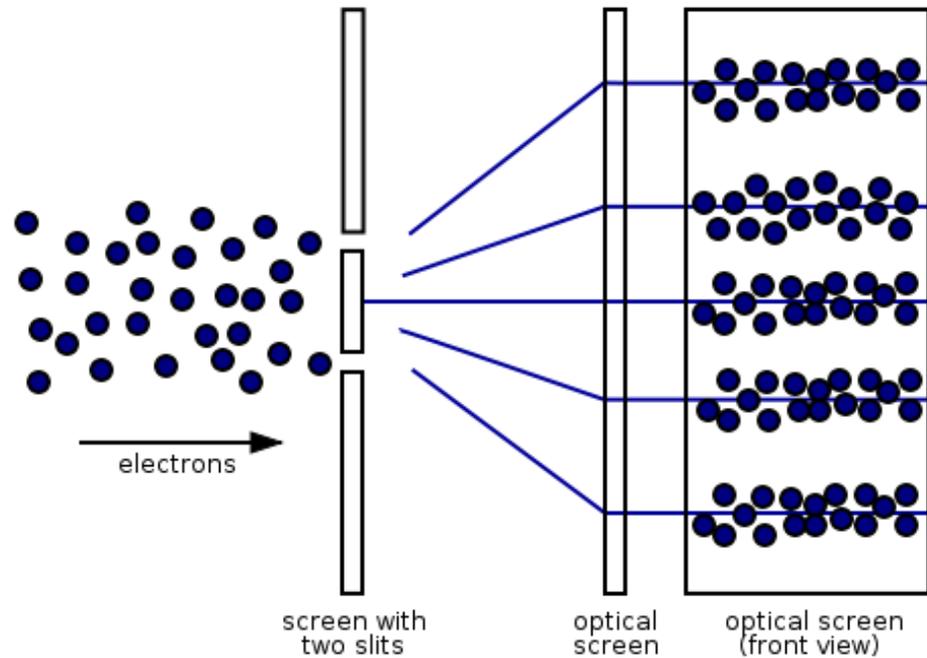
Richard P. Feynman: “..it is safe to say that **no body understands** quantum theory.”

Weird Double Slit Experiment...



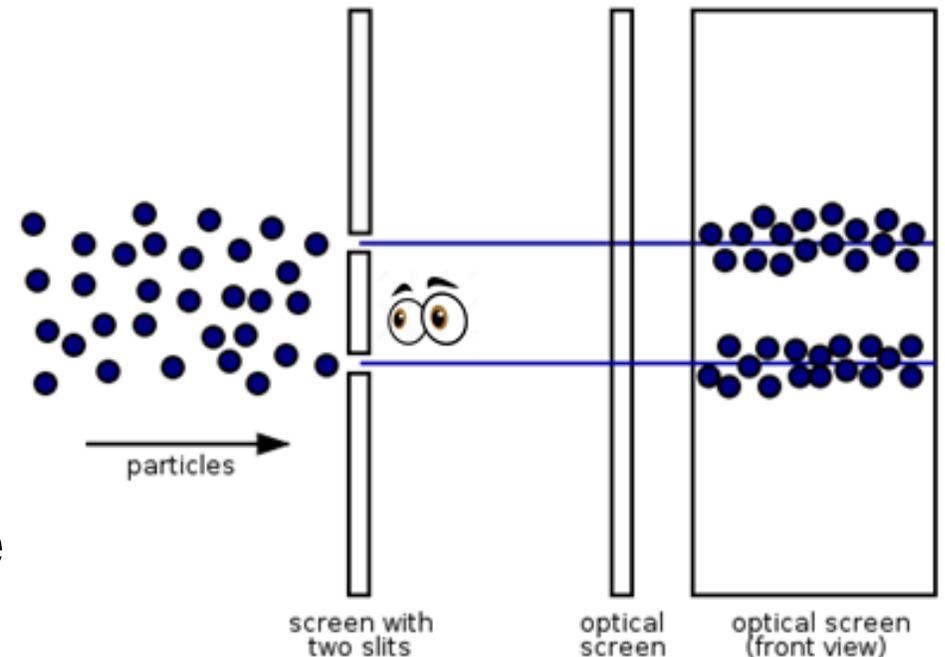
Particles exhibit wave behavior

Weird Behavior...



An electron can be in both slits simultaneously due to **quantum coherence!**...

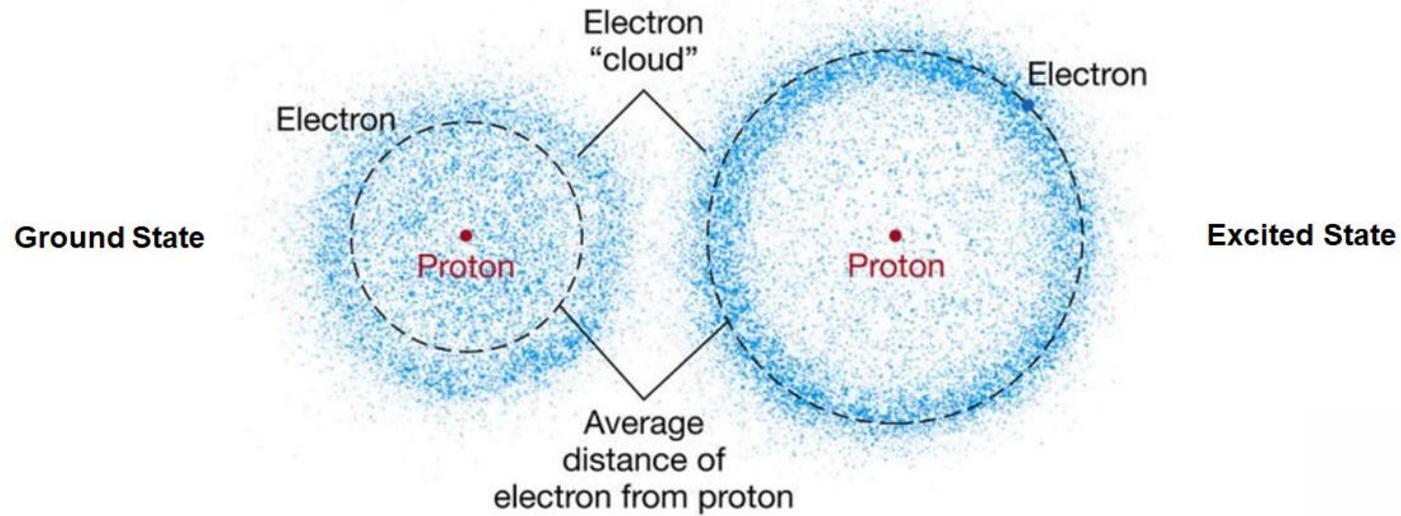
This feature disappears when one puts a detector on one slit, i.e. the particles are restored to behave like ordinary particles.



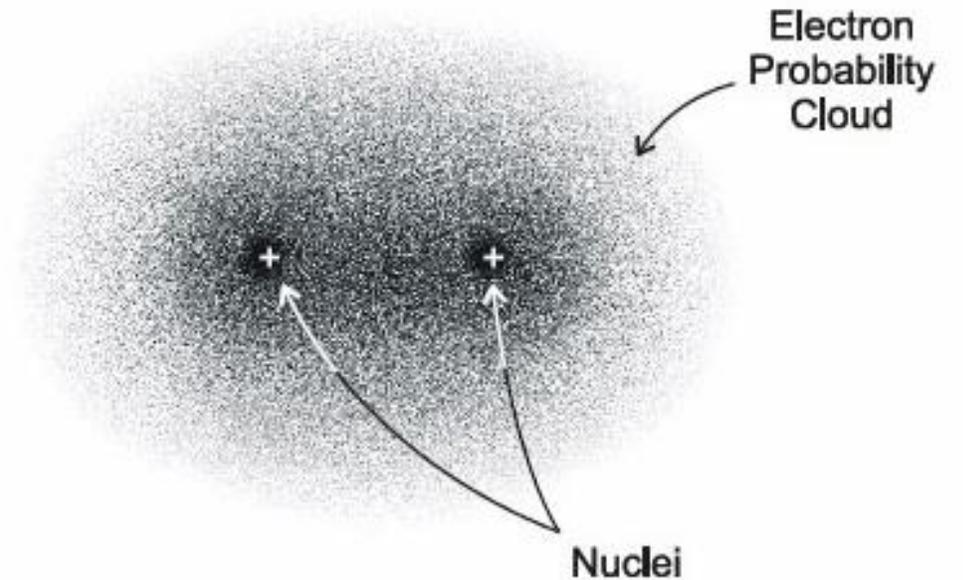
First weirdness: Uncertainty Principle (Causality Violation)...

- One cannot measure any property of a particle without interacting with it in some way.
- This introduces an inherent uncertainty into the result.
- One can never measure all the properties exactly.
- If one measures the particle position exactly, then it loses the information of its momentum, and vice versa.
- In specific conditions, a particle can be in two places simultaneously.

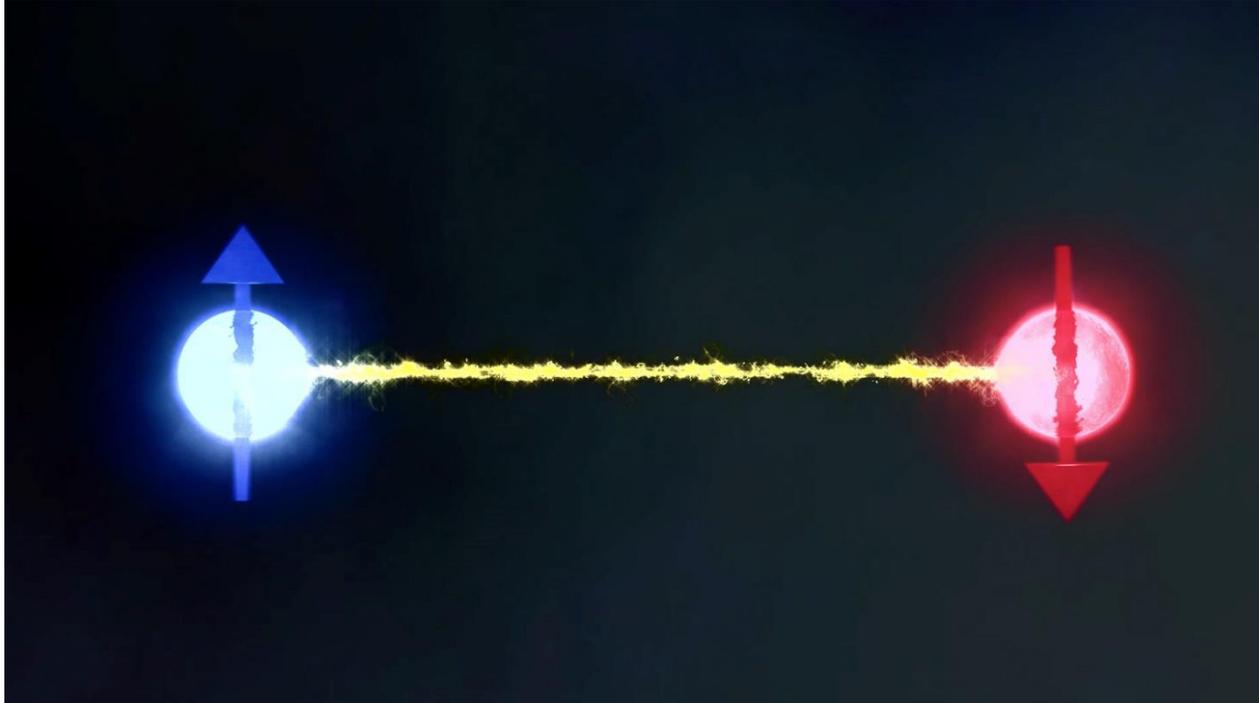
Electron in Hydrogen Atom & Molecule...



We can only predict the probability of an electron to be in certain position



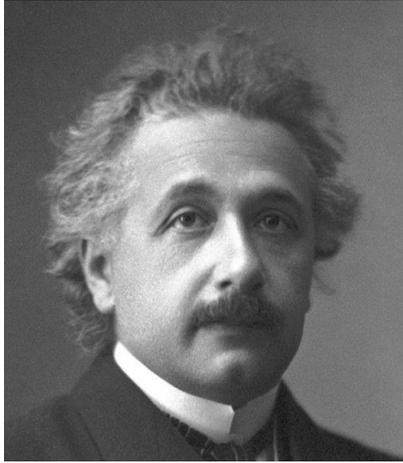
Second Weirdness: Entanglement (Non-Realism)...



Two particles with the same state function is entangled to each other.

Measurement of one particle will immediately affect the other one, no matter how far they are separated, indicating non-locality and no pre-existing condition to occur (non-realism).

Albert Einstein...



1. “Do you really believe the moon is not there when you are not looking at it?” – realism –
2. “God doesn’t play dice” – determinism –

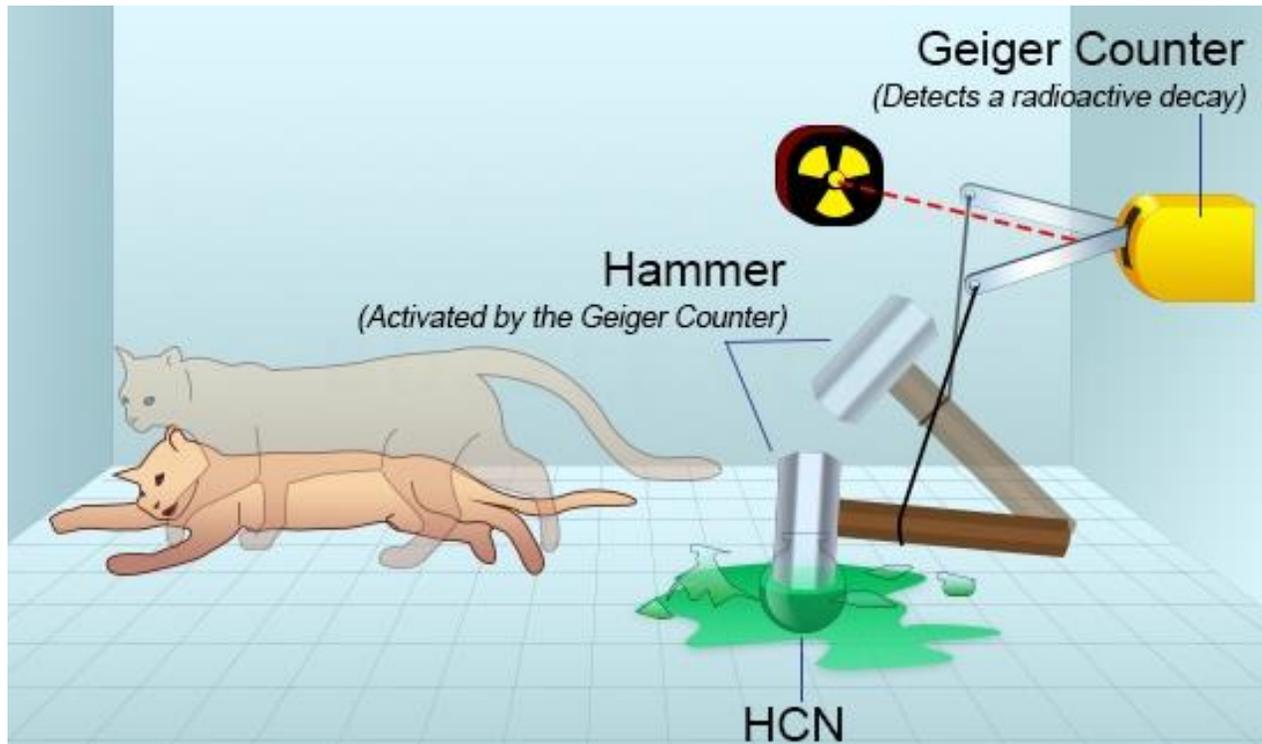
Niels Bohr...



1. “Yes, it can be” – no realism –
2. “Stop telling God what to do” – indeterminism –

“COPENHAGEN INTERPRETATION”

Third Weirdness: Schrödinger Cat Paradox...



The radiative nuclei can be either decaying or not, and this leads to the condition of either dead or alive cat.

The definite state of the cat is said to be in a superposition of dead and alive probability, until one making a measurement.

What is Reality???

According to the Copenhagen Interpretation and Bell - Leggett Inequality Violation:

“There is no pre-existing physical reality (realism) of a system until one conducts measurement to it.”

Then what is reality?

“Something that we will never understand”

<Gerard t'Hooft, Physics Nobel Laureate 1999>

Why We Live in Deterministic World???

The transition from indeterminism to determinism is due to **quantum decoherence** process, where the coherence state function of an isolated quantum system is entangled with its environment (e.g. measurement).

Albert Szent-Györgyi...

"As scientists attempt to understand a living system, they move down from dimension to dimension, from one level of complexity to the next lower level. I followed this course in my own studies. I went from anatomy to the study of tissues, then to electron microscopy and chemistry, and finally to quantum mechanics (**theory**). This downward journey through the scale of dimensions has its irony, for in my search for the secret of life, I ended up with atoms and electrons, which have no life at all (**with weird indeterministic and non-realism behaviors**). Somewhere along the line life has run out through my fingers. So, in my old age, I am now retracing my steps, trying to fight my way back"

Conclusion???. . .

We have been trying to learn about the nature of the world of atomic scale. It seems its dynamics is God's business and He only gives us little clue but it's useful enough..



**...Now I Know That I
Knew Nothing...**

...Thank You...