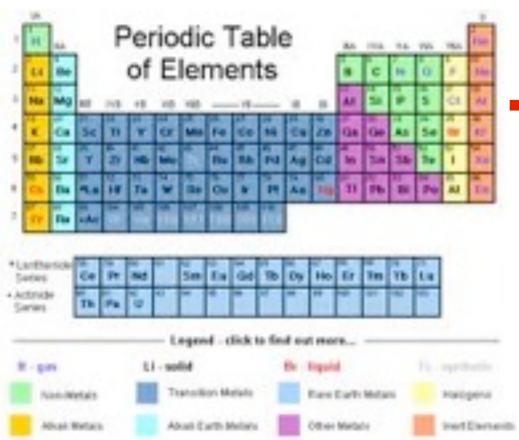
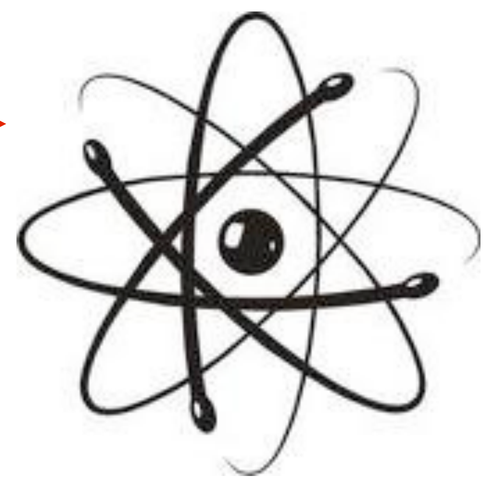
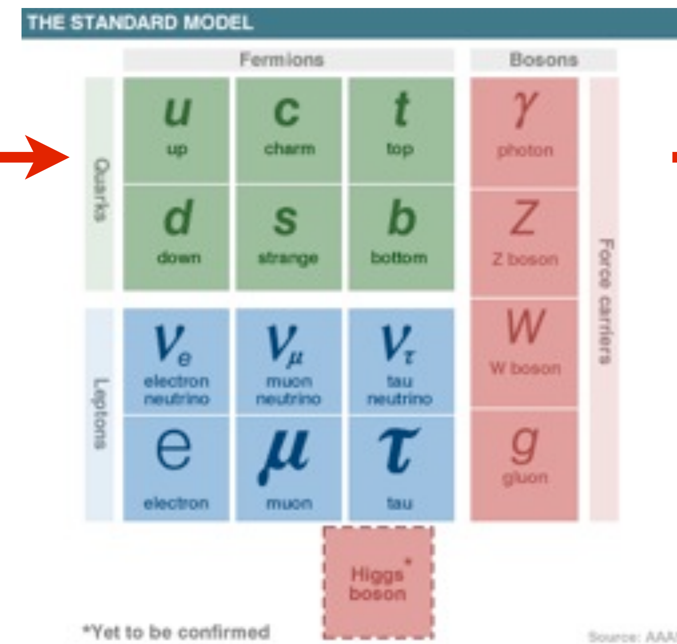
Can one of these galaxies be from the future?

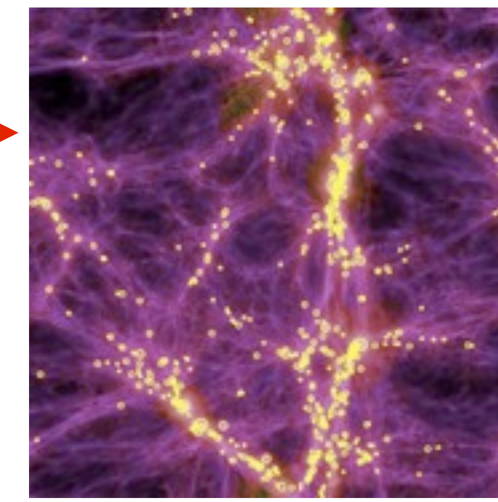
Can one of these galaxies be the Milky Way?

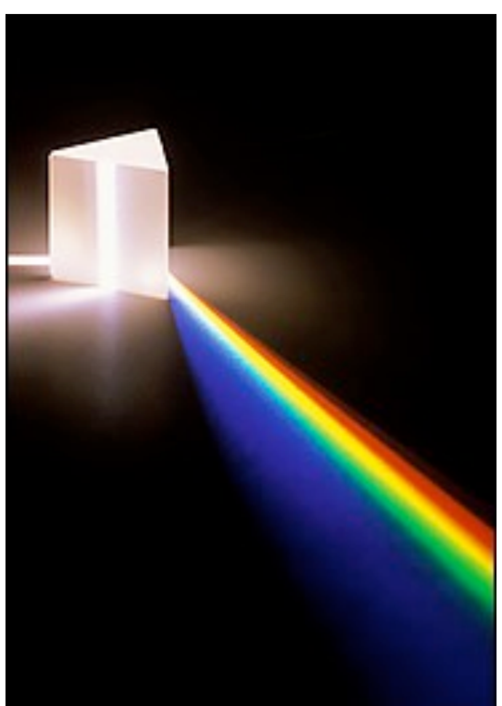
Lecture 2: Nature of Matter & Light



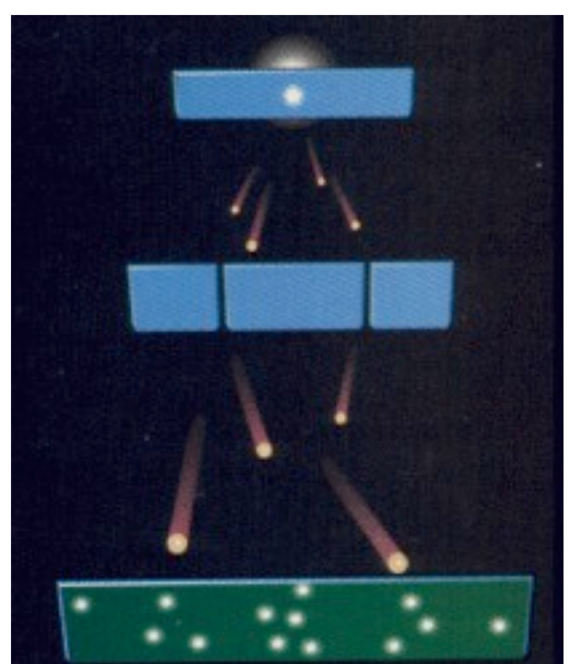




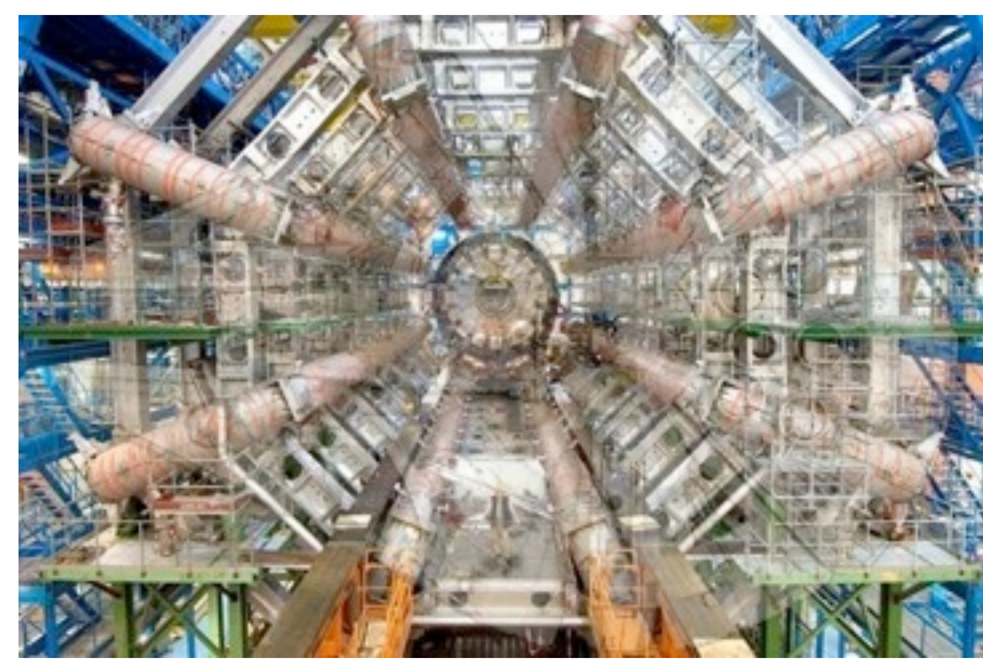




prism experiment



double slit experiment



Large Hadron Collider, CERN

The universe is made of **matter & light**.

The universe exists in **space & time**.

UNIVERSITY OF WATERLOO UNDERGRAD KRISTEN LEAL'S TIPS FOR SUCCESS IN THESE DAYS OF BIG CLASSES:

Don't sit at the back: It's harder to hear the professor and you are more likely to keep actively listening if the professor can see you.

Attend the tutorials: You'll get valuable face time with the teaching assistants,who are experts at what you're supposed to be learning.

Don't be afraid to participate: You're there to learn, and professors would rather someone try than everyone just sit there.

Ask questions: Professors welcome the opportunity to clarify what may be causing many students trouble.

Don't bring distractions to class: It's hard to resist the urge to use iPods, cellphones, and Facebook when the professor is far away and won't see you.

Find study partners: In a big class, you don't get much time with the professor to get your questions answered. A good supplement is finding a few people that you can work with. Usually a few heads are better than one.

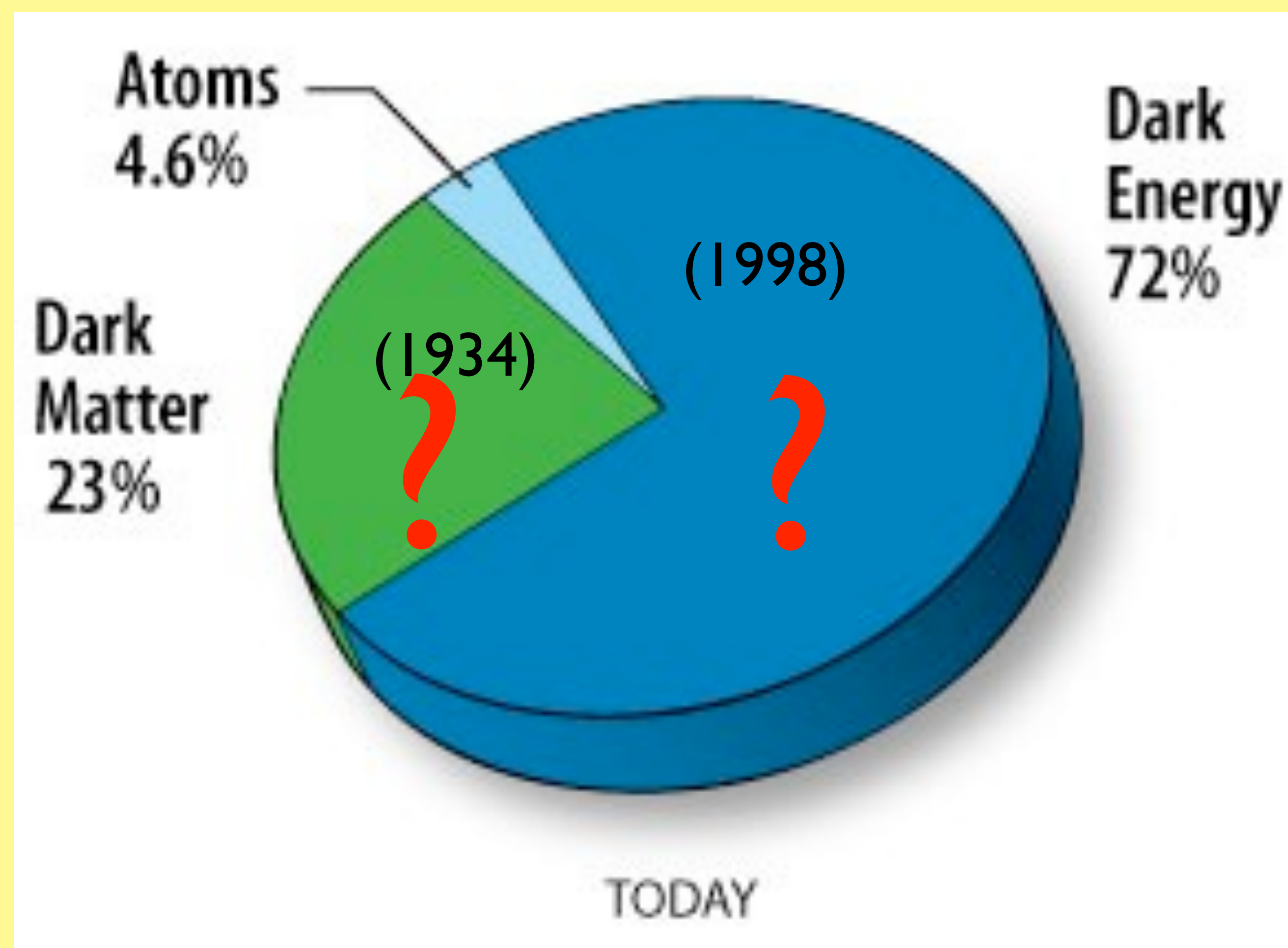
Do your research: If something isn't making sense, look to your textbook. If the textbook doesn't clear it up, do extra research, because not everything is going to come easily.

Keep up: with the lectures and readings. Falling behind is a death sentence.

2013 census of the universe:

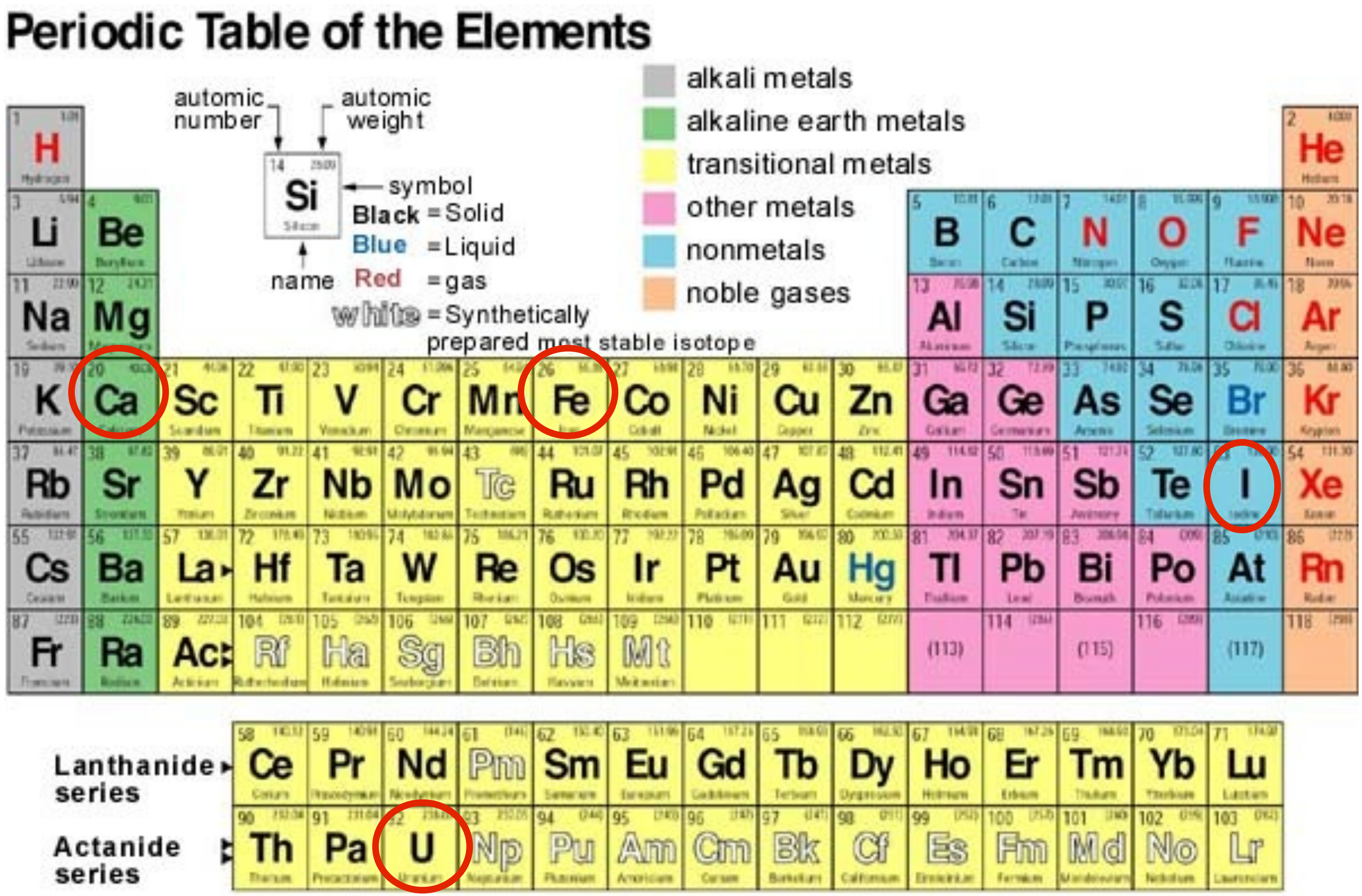
matter
= luminous matter
+ **dark** matter
+ **dark** energy

(living organisms, planets, stars, interstellar gas... everything that we know and love...)



our knowledge is inversely proportional to these percentages

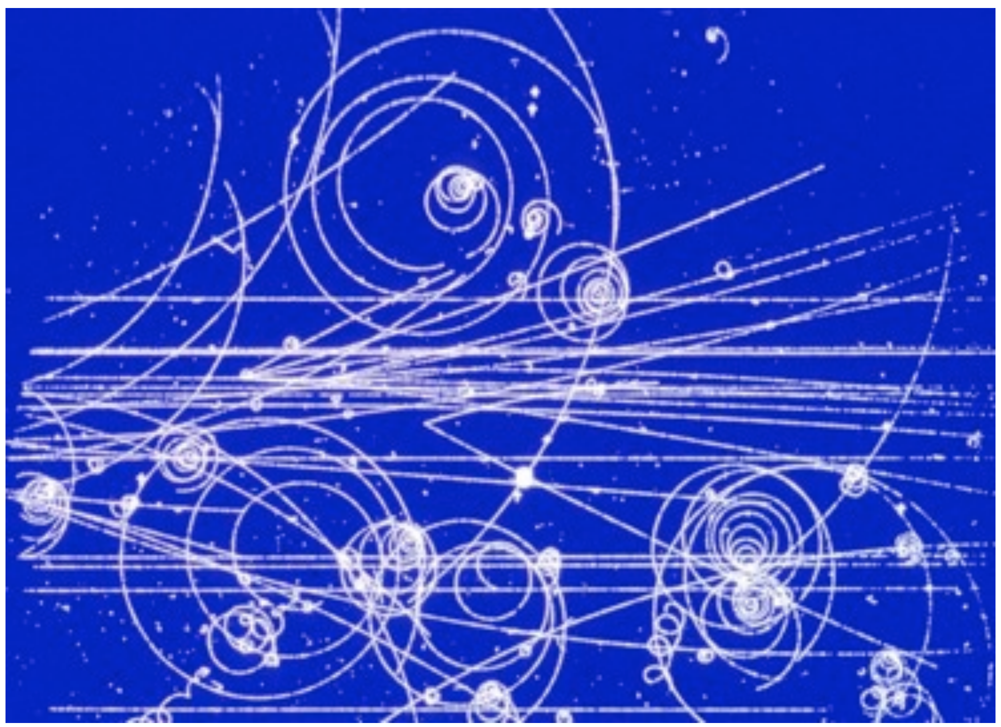
What is matter? What is luminous matter?

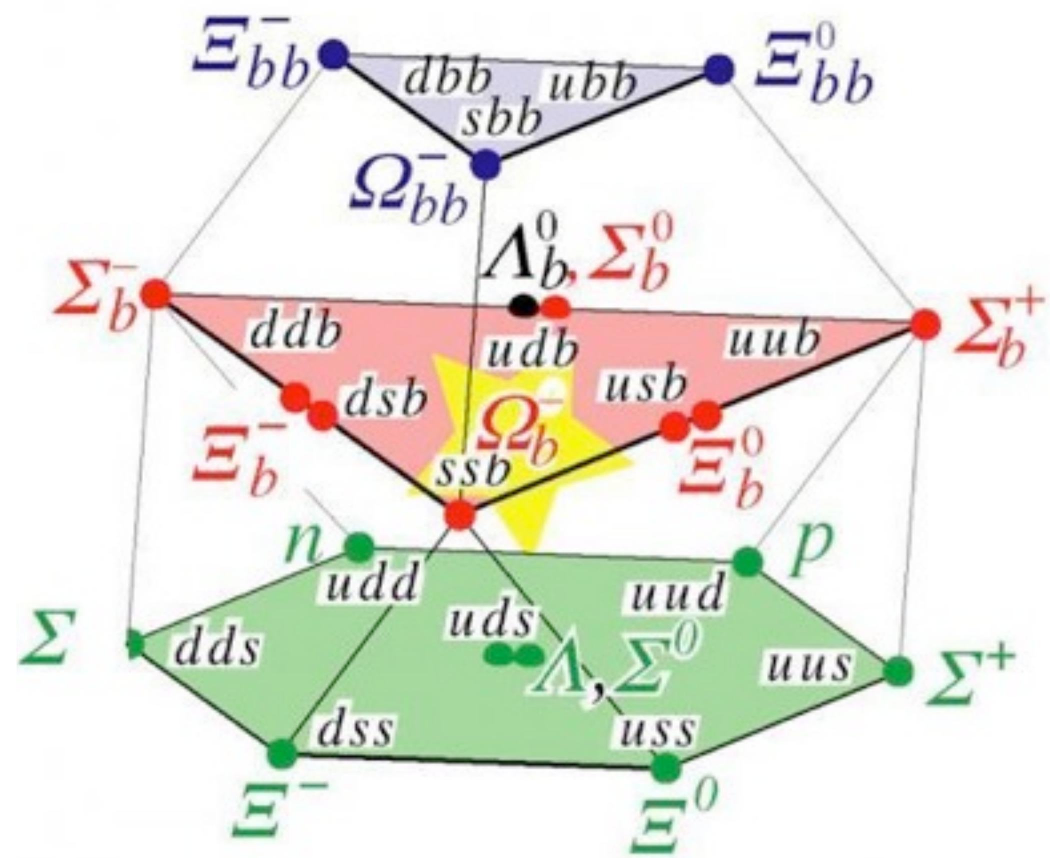


very heavy atoms are not stable

1940s: all atoms are made up of sub-atomic particles: electrons, protons, neutrons --- elementary?

1950s (post-war) particle accelerators brings to light many sub-atomic particles: anti-protons, pion, meson, kaon, lambda, sigma, Xi, omega, delta, epsilon....





This bewildering zoo of particles was distilled down in the 1970s to a very simple picture:

the "**standard model**"

Luminous matter - Part I: quarks & leptons

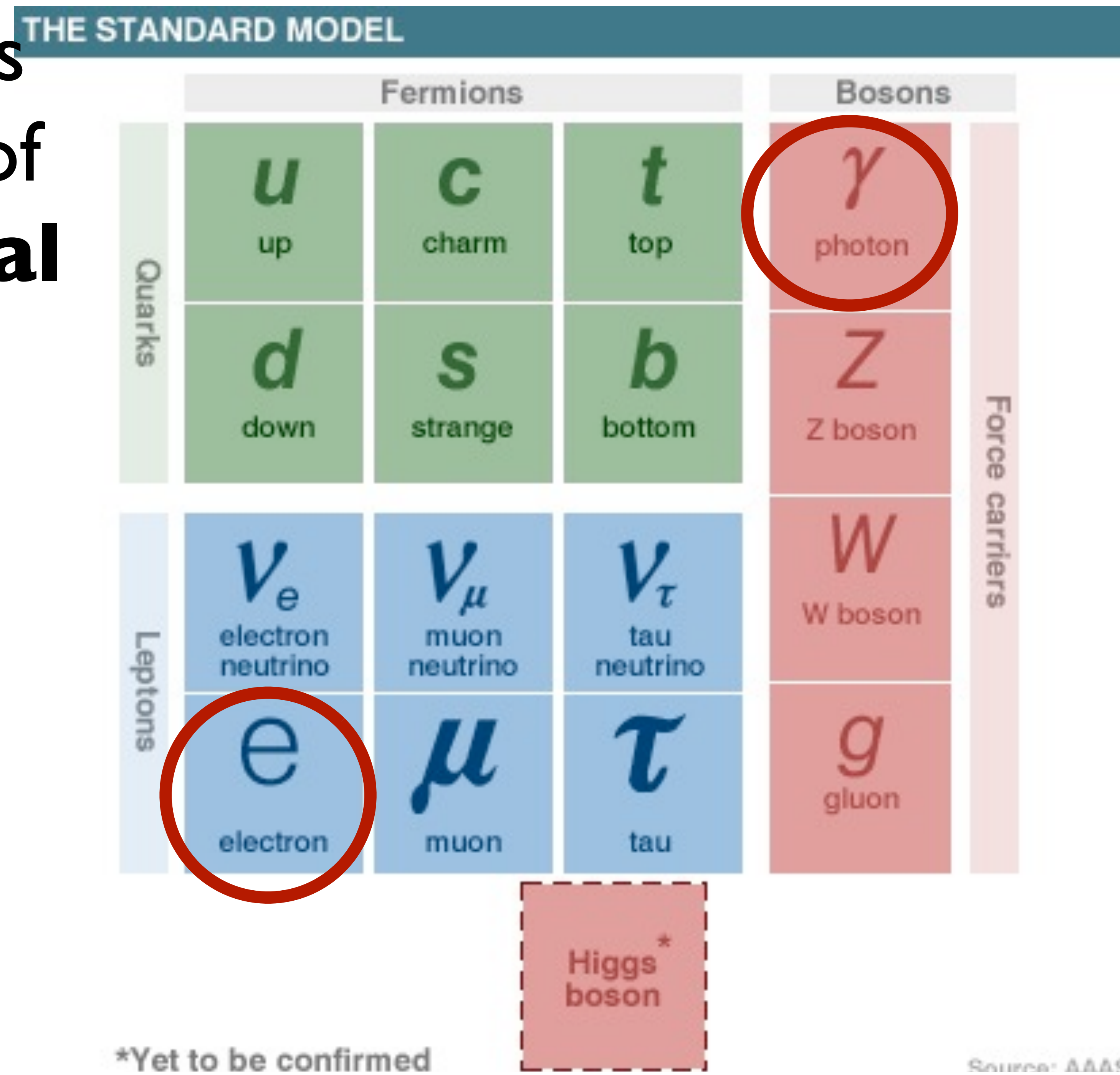
in the **standard model** of particle physics, all luminous matter is constructed out of a handful of "**fundamental particles**"

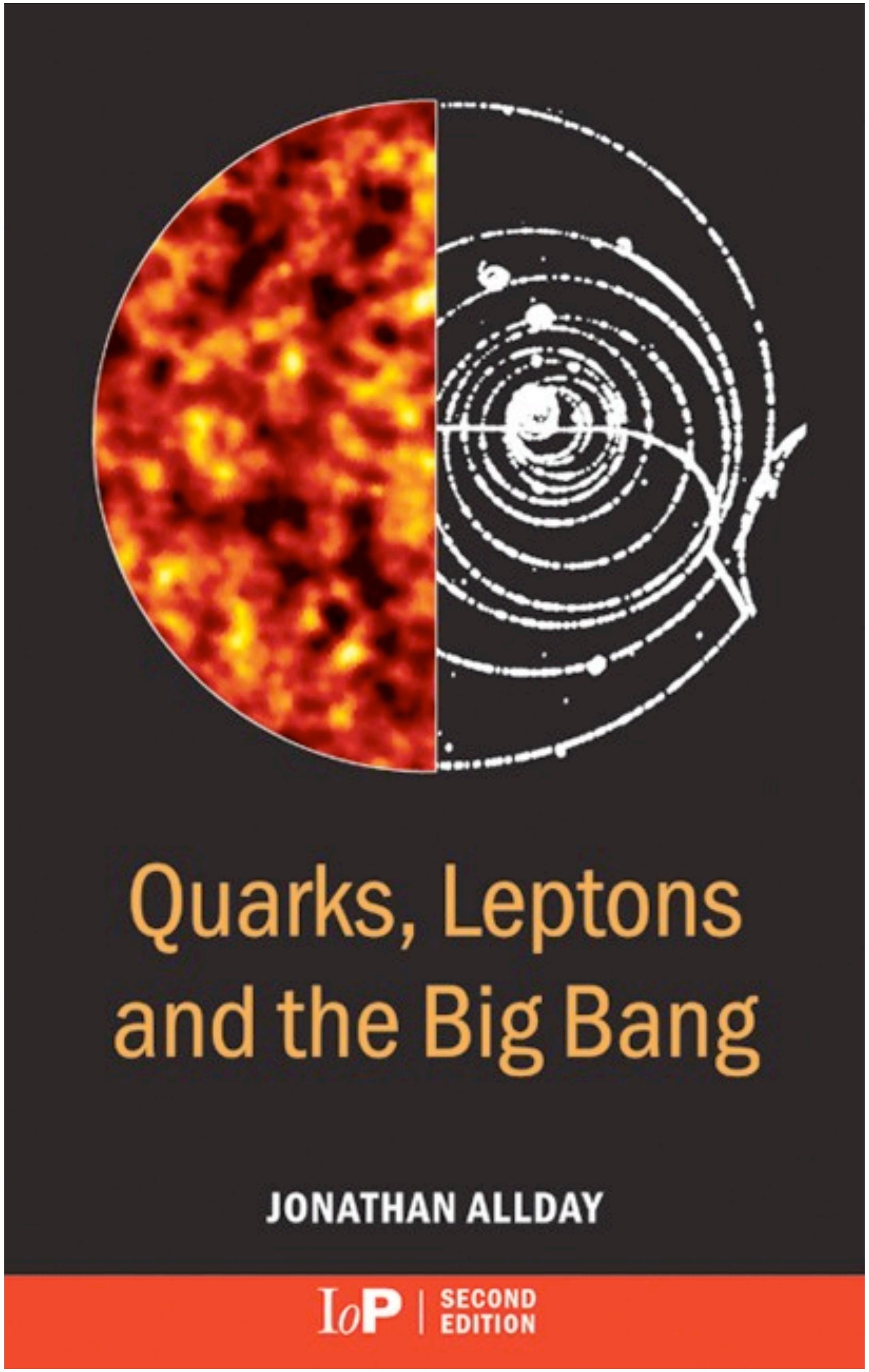
these explains all known atoms, subatomic particles, **AND** their interactions (forces).

The standard model has stood many tests over the past 40 years.

It's our most advanced tool to understand the nature of matter and light.

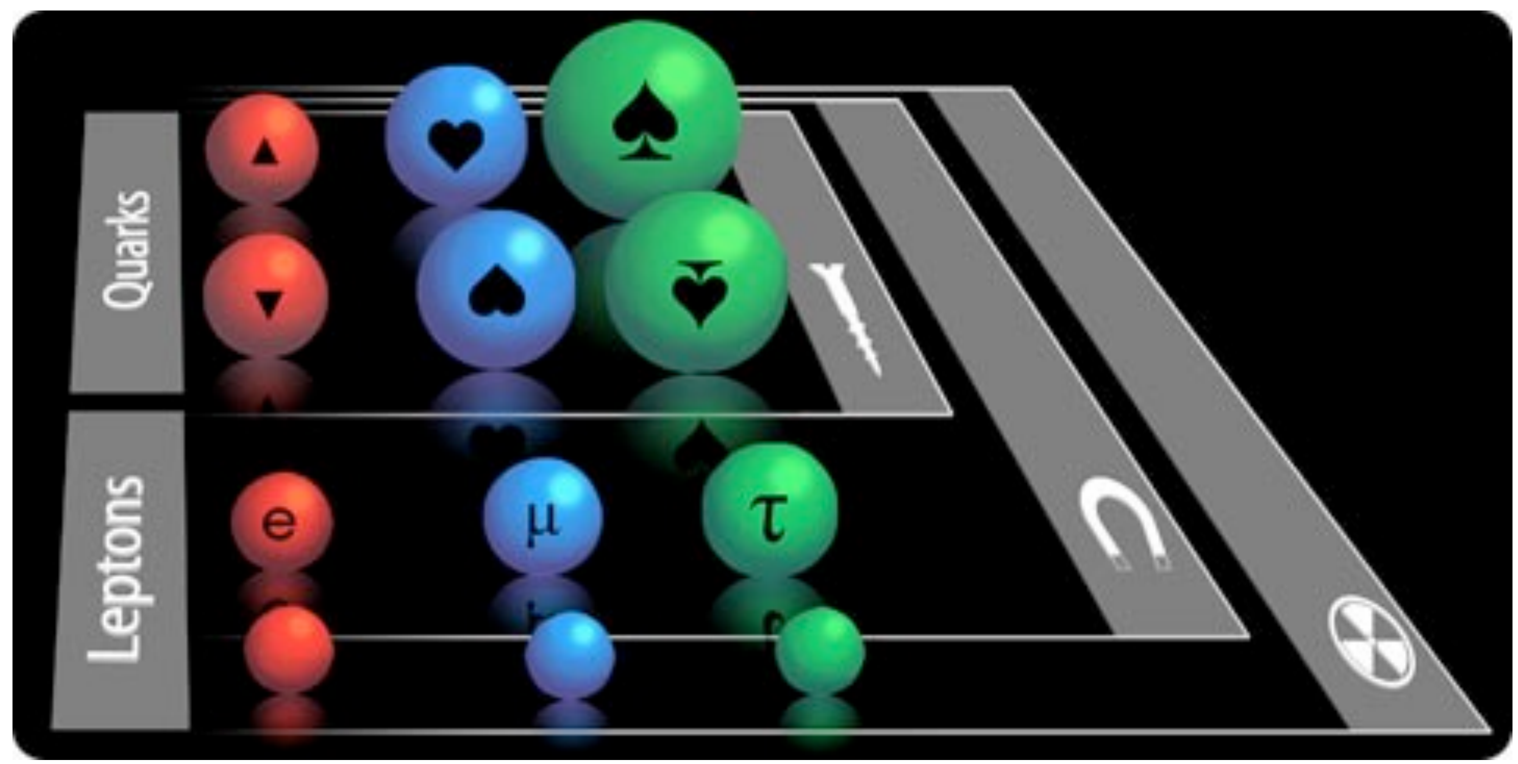
But it is NOT the ultimate theory.





fundamental = ‘uncuttable’

most matter on Earth is made up of
- up quarks
- down quarks
- electrons



Wednesday, January 16, 2013

Quarks

The term "quark" was coined by Murray Gell-Mann from Finnegan's Wake by James Joyce. The line "Three quarks for Muster Mark..." appears in the book. Gell-Mann received the 1969 Nobel Prize for his work in classifying elementary particles.

Charge	1st Generation	2nd Generation	3rd Generation
+2/3	up (u)	charm (c)	top (t)
-1/3	down (d)	strange (s)	bottom (b)

first proposed in 1960s, which simplified/clarified our material world

all 6 have since been observed in accelerators

no more

a quarks is not divisible

- quarks are grouped into "generations" based on their properties
- more massive as one moves from 1st to 3rd
- most matter is made up of 1st generation quarks
- at present the universe has very few heavy quarks

- quarks have fractional electric charges and come with colors

$E = m c^2$

1 Gev = 10^9 electron volt = 1.6×10^{-10} Joule
1 Gev/c^2 = 1.8×10^{-24} g ~ 1 proton mass

Physical Properties of Quarks

Charge	1st generation	2nd generation	3rd generation
+2/3	up ~ 0.002 GeV/c^2	charm ~ 1.58 GeV/c^2	top ~ 180 GeV/c^2
-1/3	down ~ 0.005 GeV/c^2	strange ~ 0.1GeV/c^2	bottom ~ 4.58 GeV/c^2

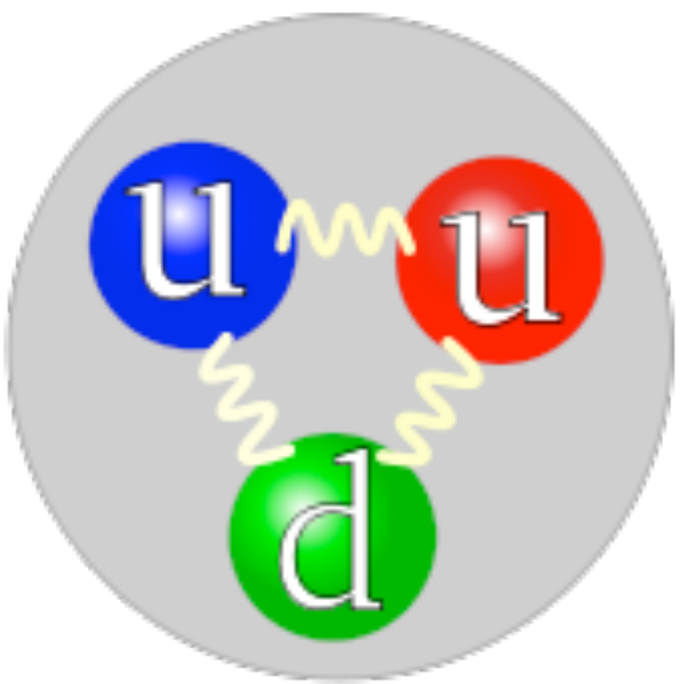
- Note how mass increases along generations.
- Masses are only approximate! Hard to pin down since you can't find an isolated quark, and the individual masses have to be deduced from the masses of the composite particles the quarks form.
- For example, it's hard to work out how much of the mass of a proton, say, is due to the masses of the quarks inside it and how much is due to the energy of the interactions between the quarks inside it.
- The top quark has the mass of a decent sized molecule!

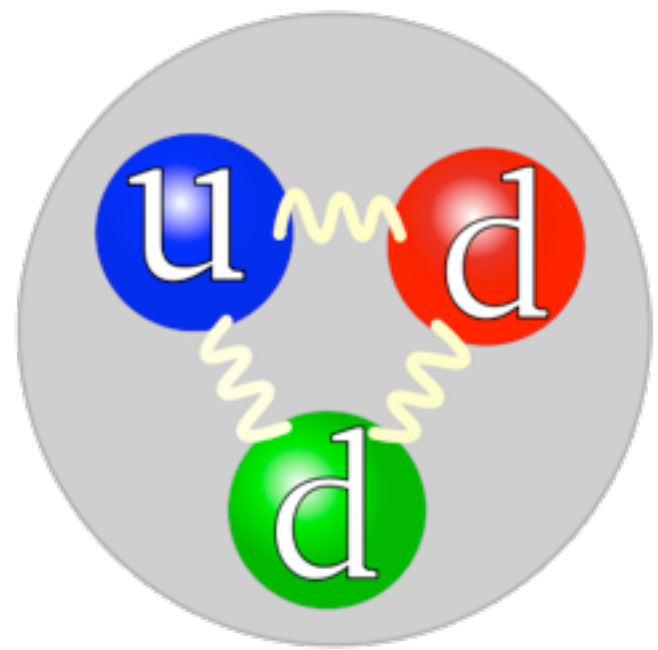
Does GOD write down these values? The Standard Model posits that elementary particles derive their masses from the Higgs mechanism, which is related to the unobserved Higgs boson.

“*Three quarks for Muster Mark...*”

The most common examples of combinations of quarks

Proton: uud (2/3 + 2/3 -1/3 =total charge of +1)
Neutron: udd (2/3 -1/3 -1/3 =total charge of 0)



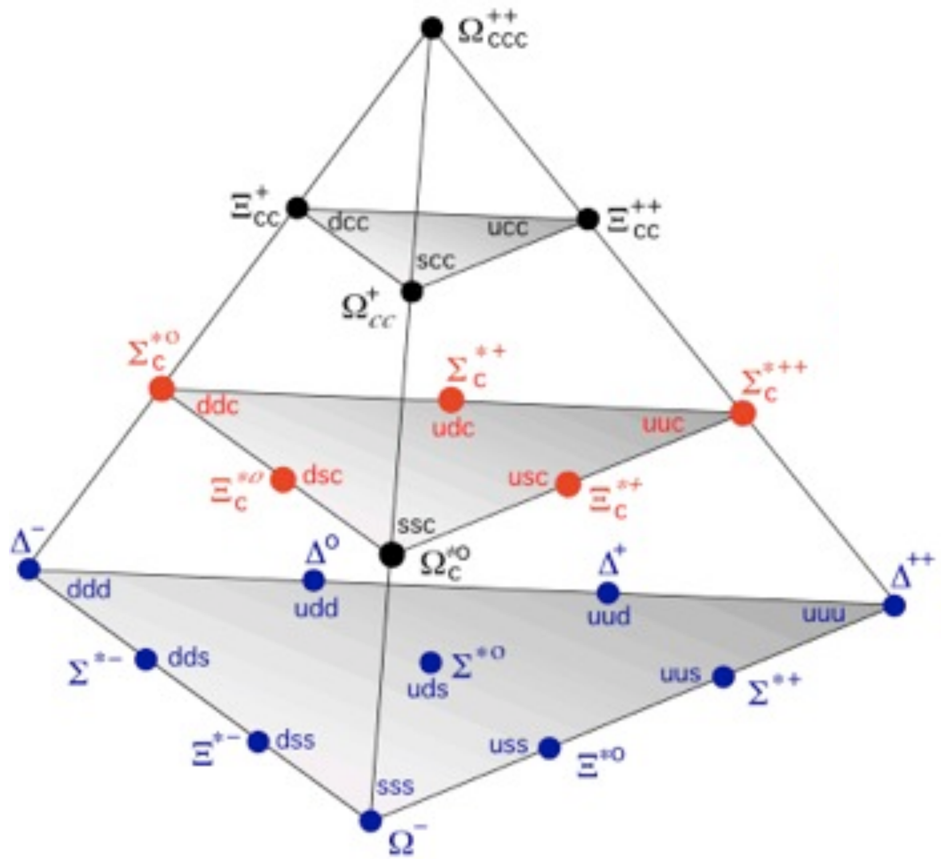


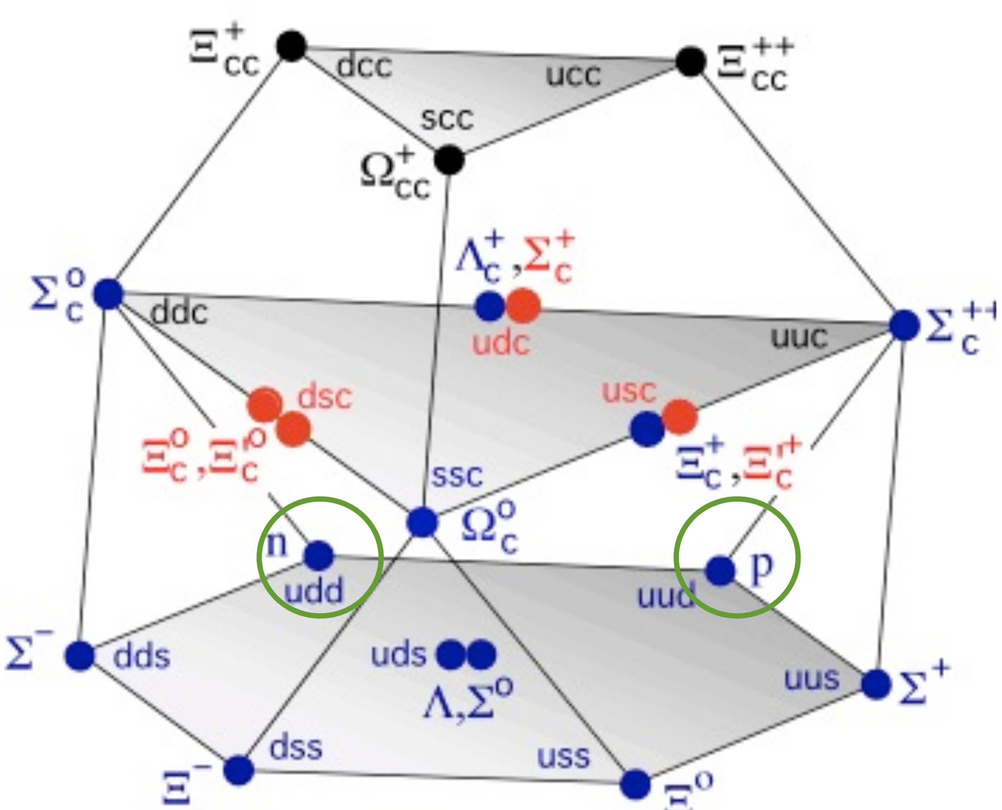
6 Quarks make a (particle) zoo

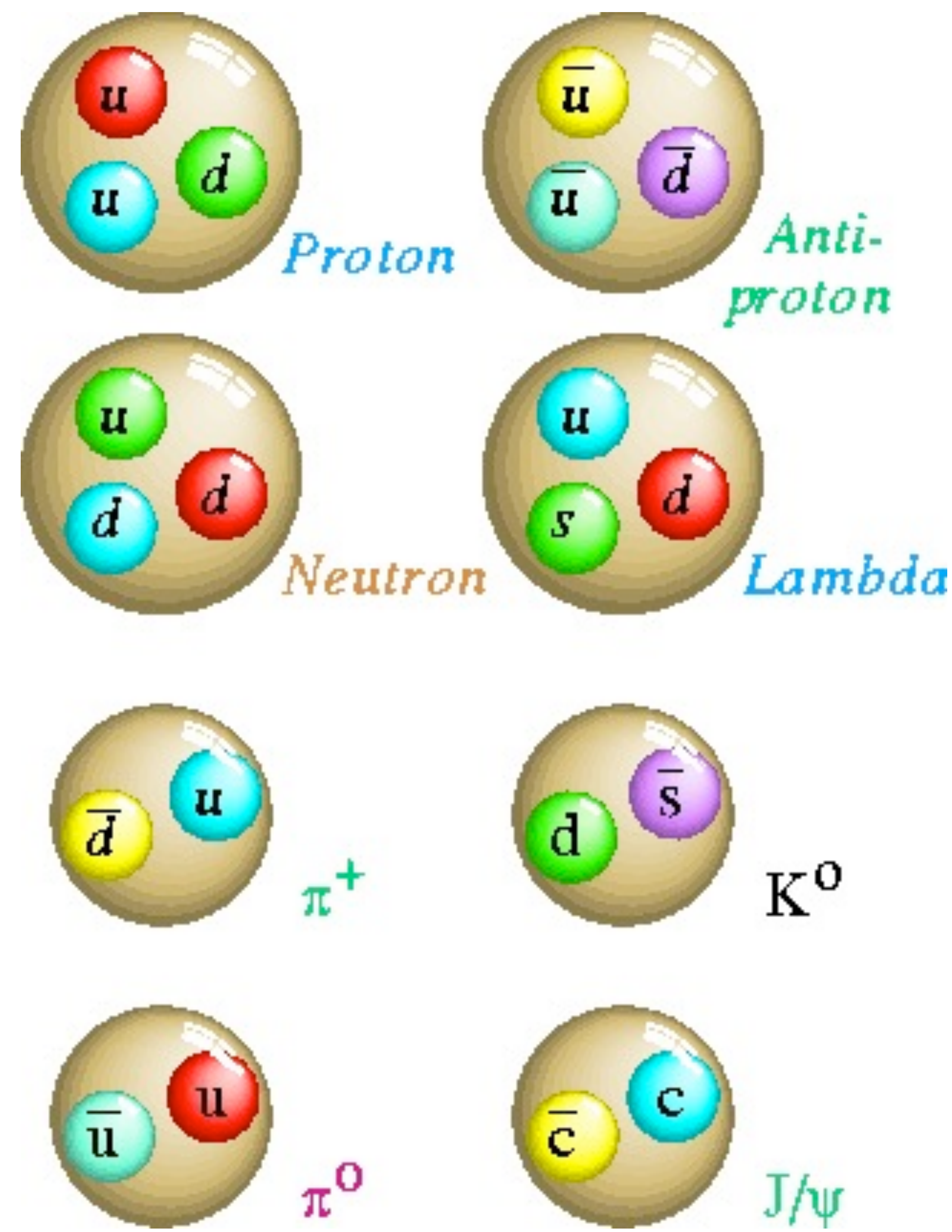
hadron = quark combinations

Baryon = three quark combinations

meson = quark + anti-quark







Leptons

→ Greek, 'fine, small'

charge	1st Generation	2nd Generation	3rd Generation
-1	electron (e^-)	muon (μ^-)	tau (τ^-)
0	electron-neutrino (ν_e)	muon-neutrino (ν_μ)	tau-neutrino (ν_τ)

- the number of (different) leptons is the same as that of quarks
- for the first row, the mass increases with generation
- we can currently only set limits on the neutrino mass


Don’t just stand there.
Let those neutrinos through.
Not that you have a choice. Trillions of these particles from the Sun pass through you every second at nearly the speed of light.
www.CoolCosmos.net

Luminous matter - Part II: forces

forces are interactions between particles,
forces are carried out by “force mediators” -- particles of their own

The Four **Basic** Forces in Nature

Name	Strength	Range	What?	mediated by
Strong	1	10^{-15} m	Holds atomic nucleus together	g gluon
Electromagnetism	1/137	Infinite	Holds you together	γ photon
Weak	10^{-5}	10^{-17} m	Breaks atoms apart	Z Z boson W W boson
Gravity	10^{-39}	Infinite	Holds Universe together	

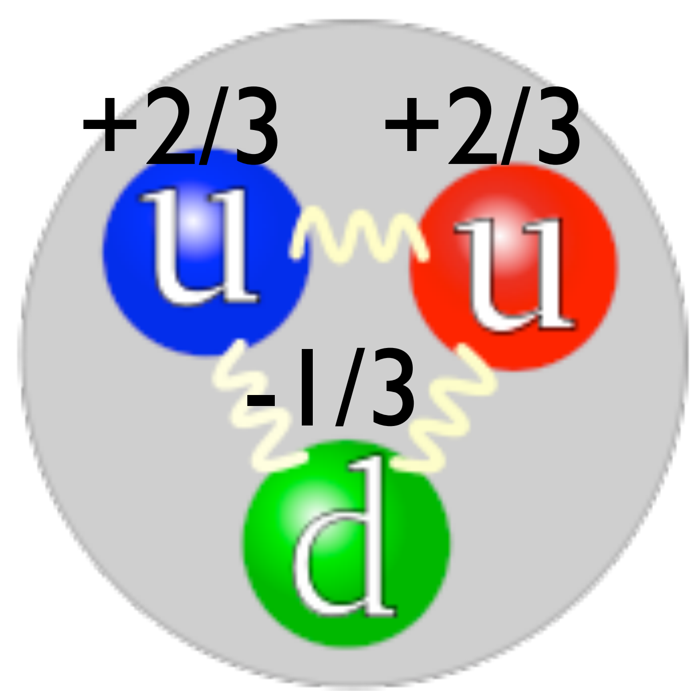
forces we deal with daily

- what about force to push open a door? friction force? nuclear binding force?.....
- gravity doesn’t yet fit into the ‘standard model’

The Strong Force

- The strong force acts only between quarks: it binds quarks to form composite particles (e.g., protons, neutrons).
- It is a very short range force: acts over 10^{-15}m.
- Two protons 1 m apart have zero strong force, and repel each other with electromagnetic force 10^{36} times stronger than gravitational attraction.

but if pushed close enough
.... form stable nuclei
... mediated by 'gluon'



Strong force is short-ranged. This explains...

Name	Strength	Range
Strong	1	10^{-15} m

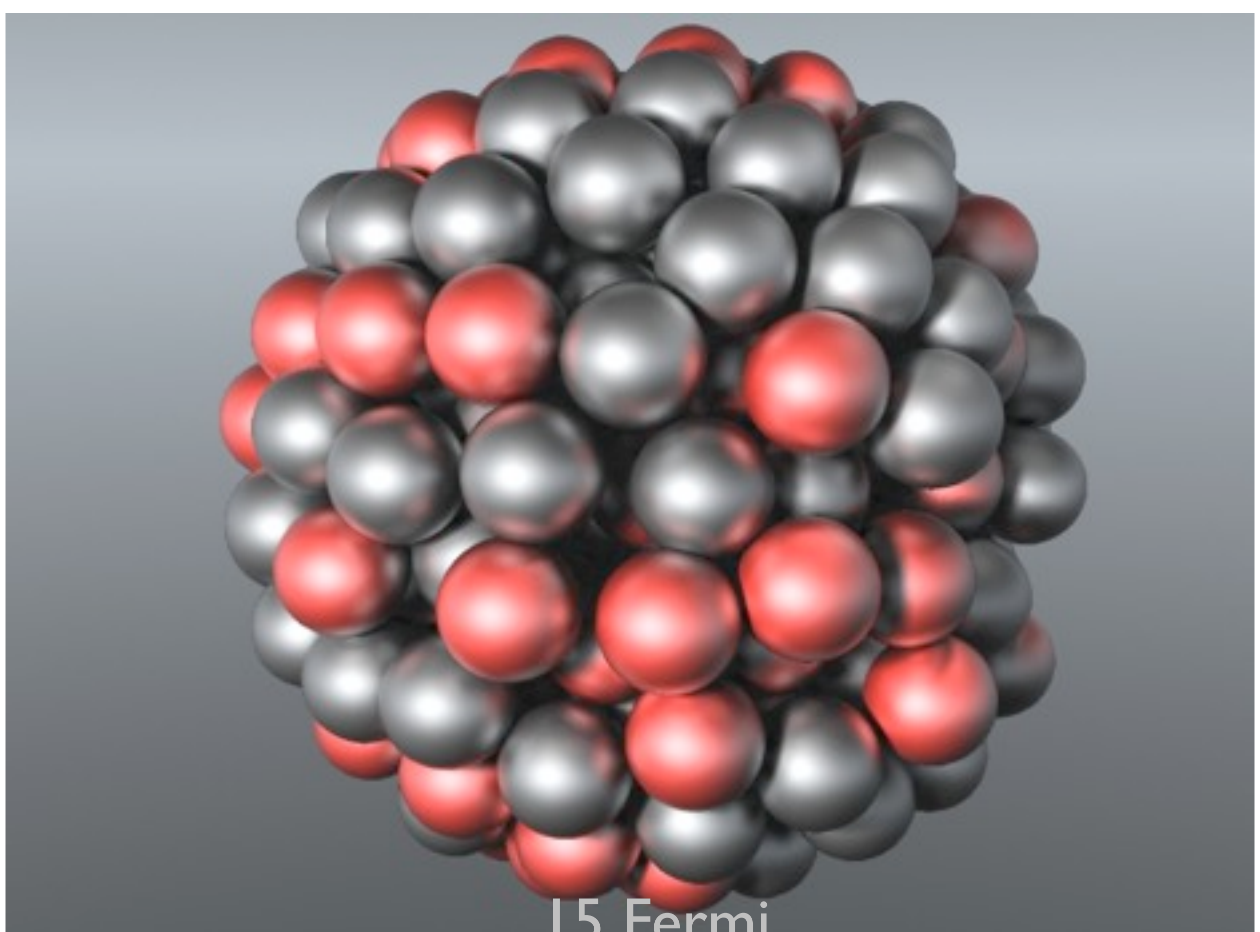
(1 Fermi)

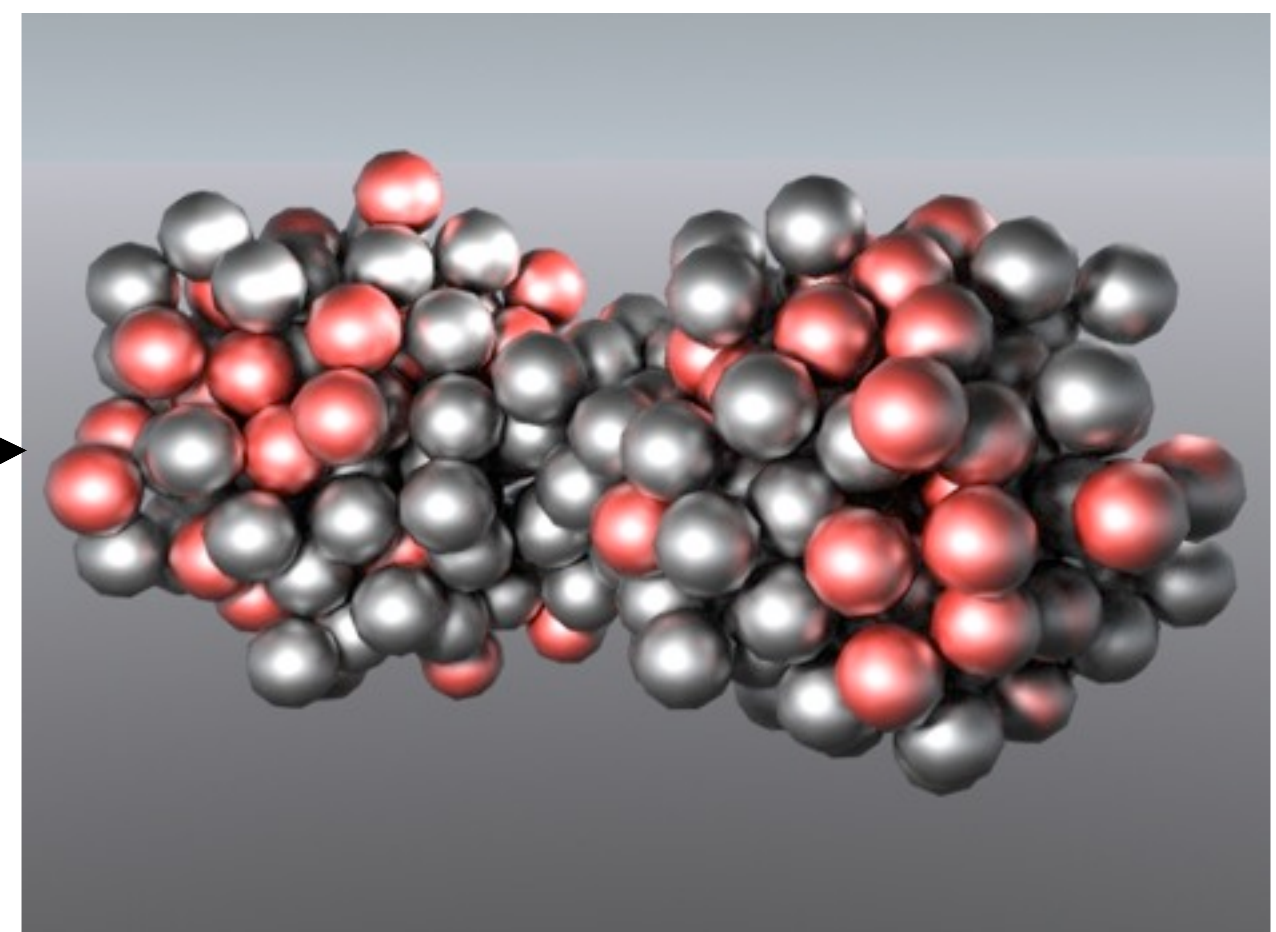
Heaviest Atom possible:

Nuclear force, the attractive force that binds proton and neutron together to form larger nucleus, is a residual force of the strong force.

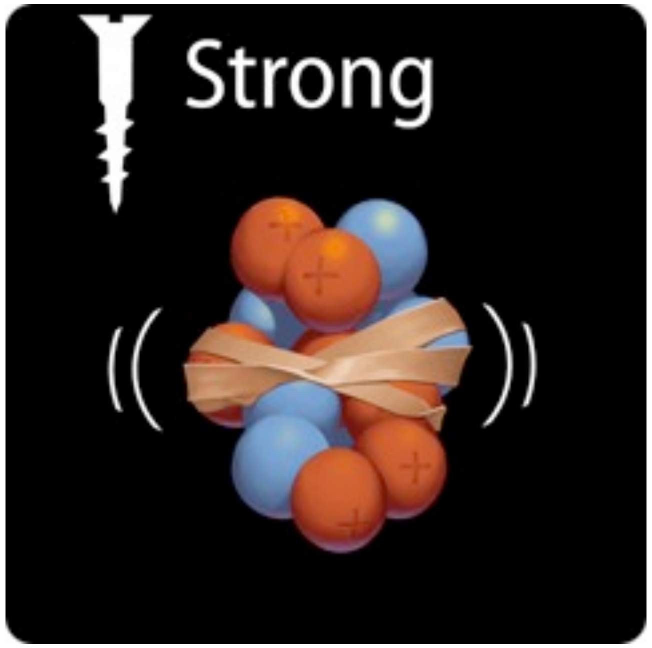
For nucleus that is too large, strong force loses out to EM repulsion between protons.

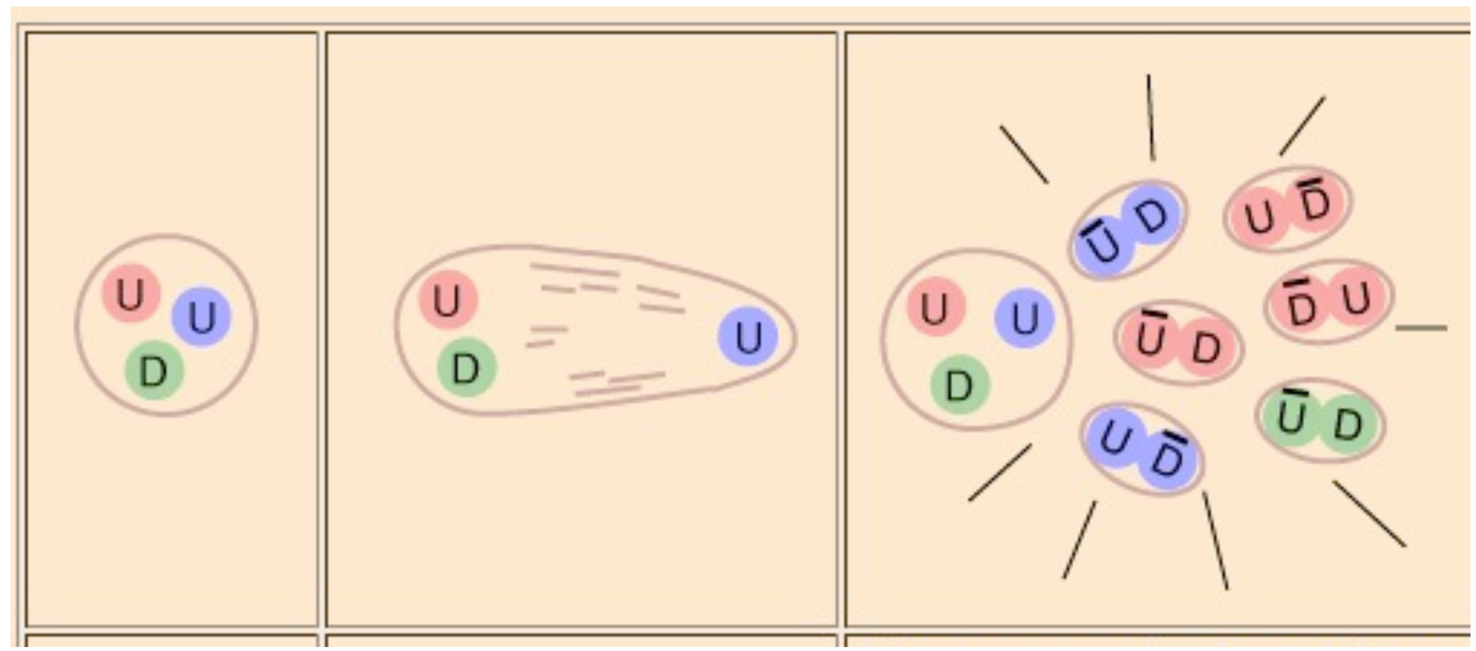
Uranium nucleus is near the edge. It fissions easily, lucky for us.





Quarks have been bound up since the Universe was 10^{-6} seconds old ('Quark Confinement') Why aren't there any naked quarks?





- gluons are force carrier for the strong force.
- As quarks are torn apart, the gluon field gets stronger. When quarks become so far apart that we may observe them in isolation, the gluon field contains enough energy to make new quark pairs (quark-antiquark). $E = m c^2$.
- So the energy expended in attempting to separate the quarks has resulted in the production of other hadrons, no free quarks.
- As a result, we can only calculate properties of quarks by looking at their conglomerates.
- But in the dense & hot early universe, we have quark-gluon soup. Hadrons unstable.

Summary of Concepts:

1) fundamental particles

6 quarks + 6 leptons + 4 bosons (force mediators) + Higgs?

2) fundamental forces

short range: strong & weak

long range: EM & gravity (tangible)