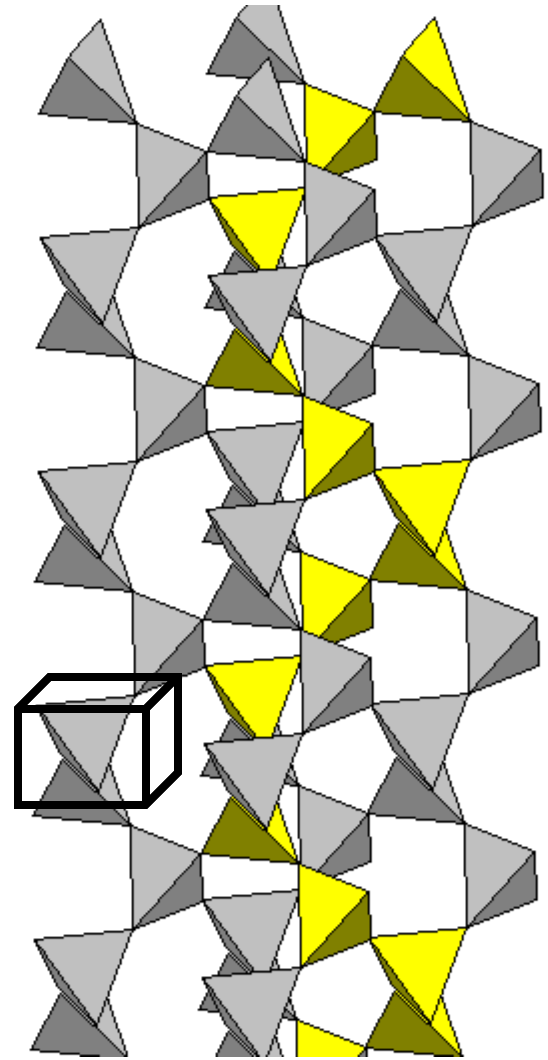
A Short History of the Universe

- The universe in a grain of sand
- Particles and forces
- The Big Bang
- Early history of the universe
- Nucleosynthesis

Molecular Level

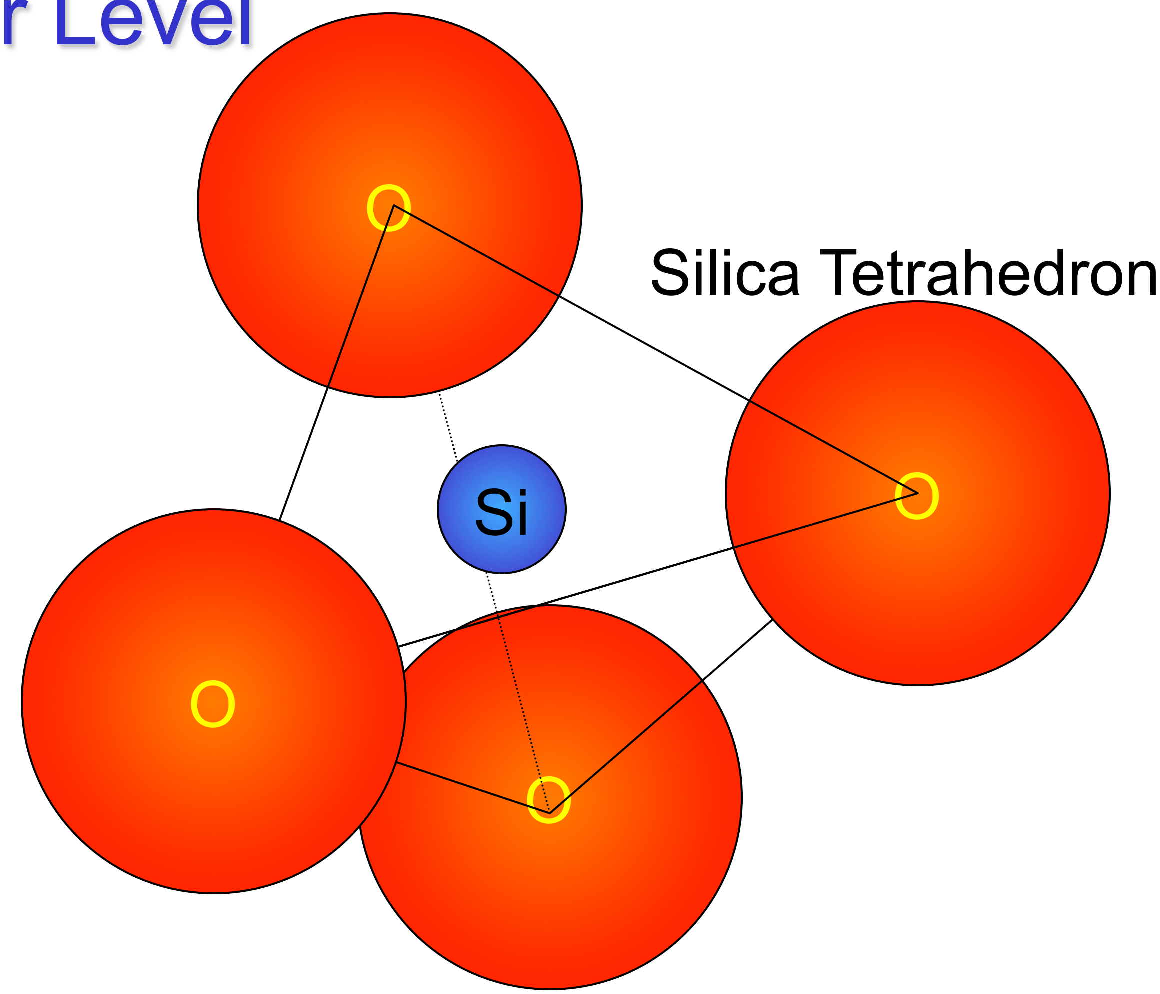
Quartz – SiO_2

Composed of linked spirals of silica tetrahedrons



http://www.uwgb.edu/dutchs/PETROLGY/QuartzStruc.HTM

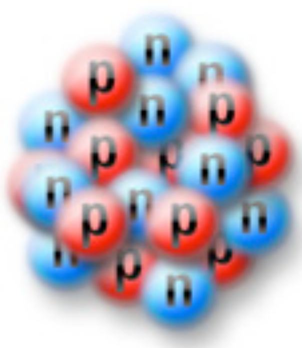
Molecular Level



Each tetrahedron is made of one silicon atom bonded to four oxygen atoms

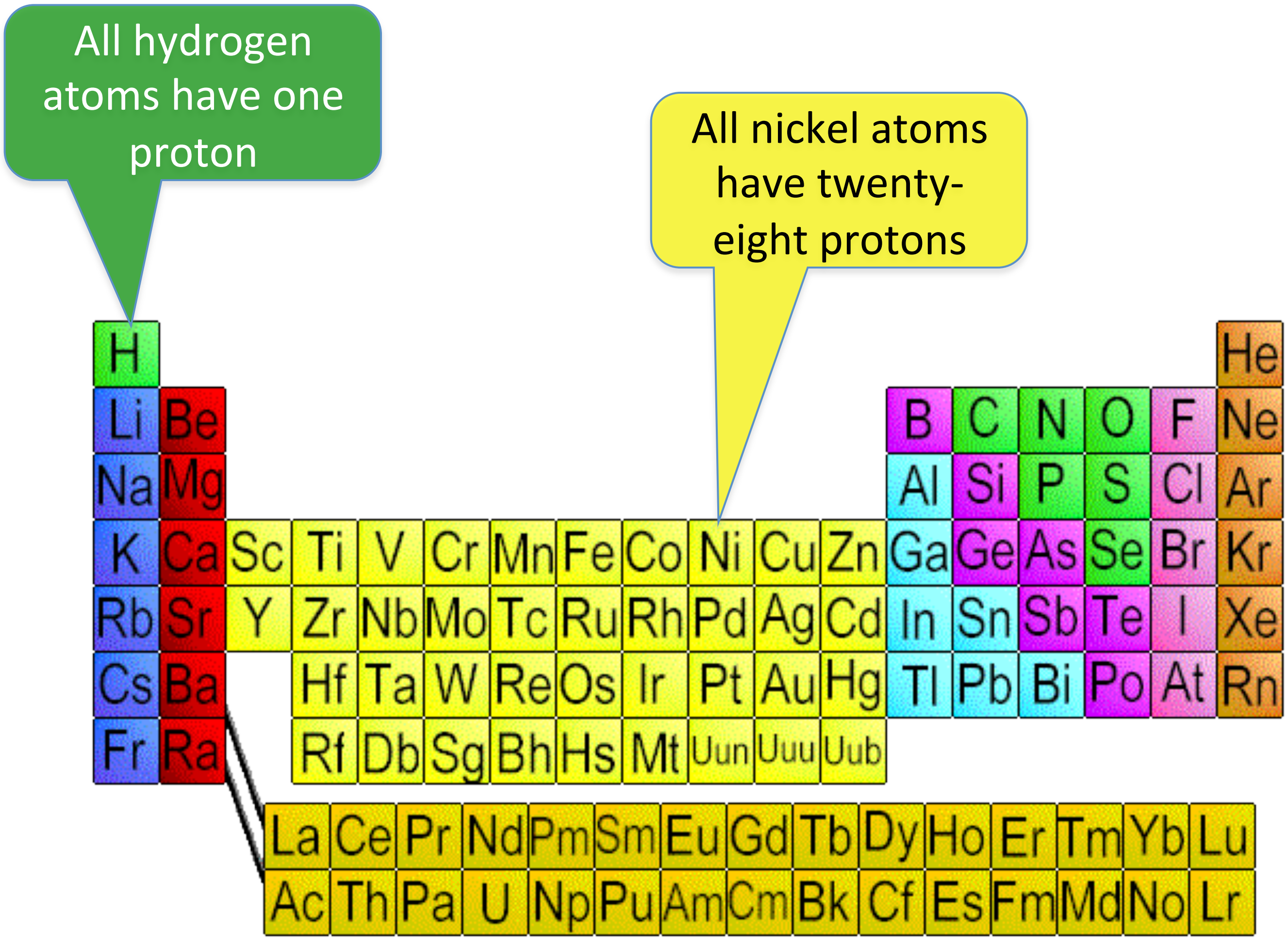
The atom is the fundamental particle of chemistry. It is composed of three smaller types of particles

Electrons are negatively charged particles with very little mass that are attracted to the positively charged nucleus of the atom



Protons (positively charged particles) and neutrons (particles with no charge) are bound together in the relatively massive nucleus of the atom.

http://particleadventure.org/

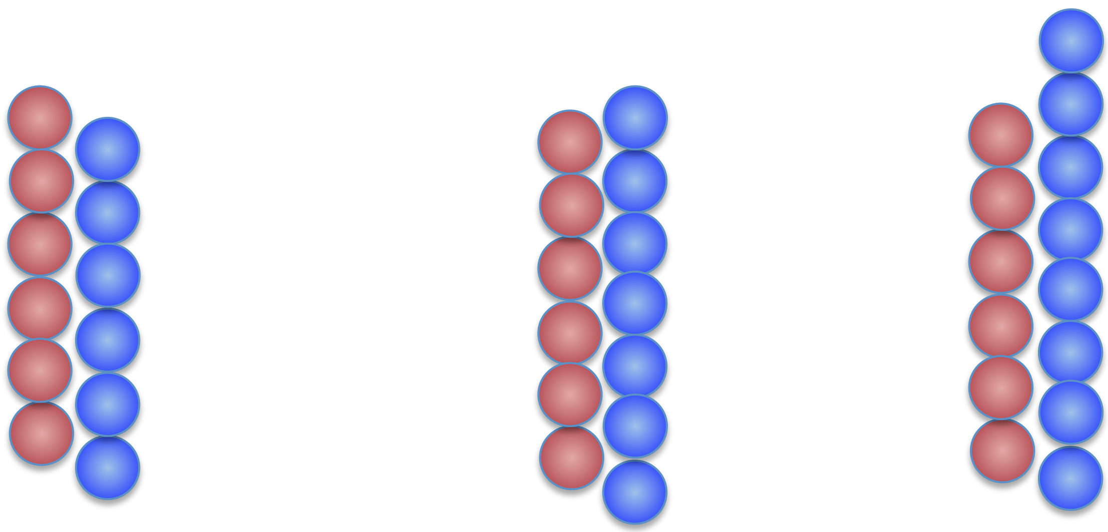


An element is all atoms with the same number of protons in the nucleus.

http://particleadventure.org/

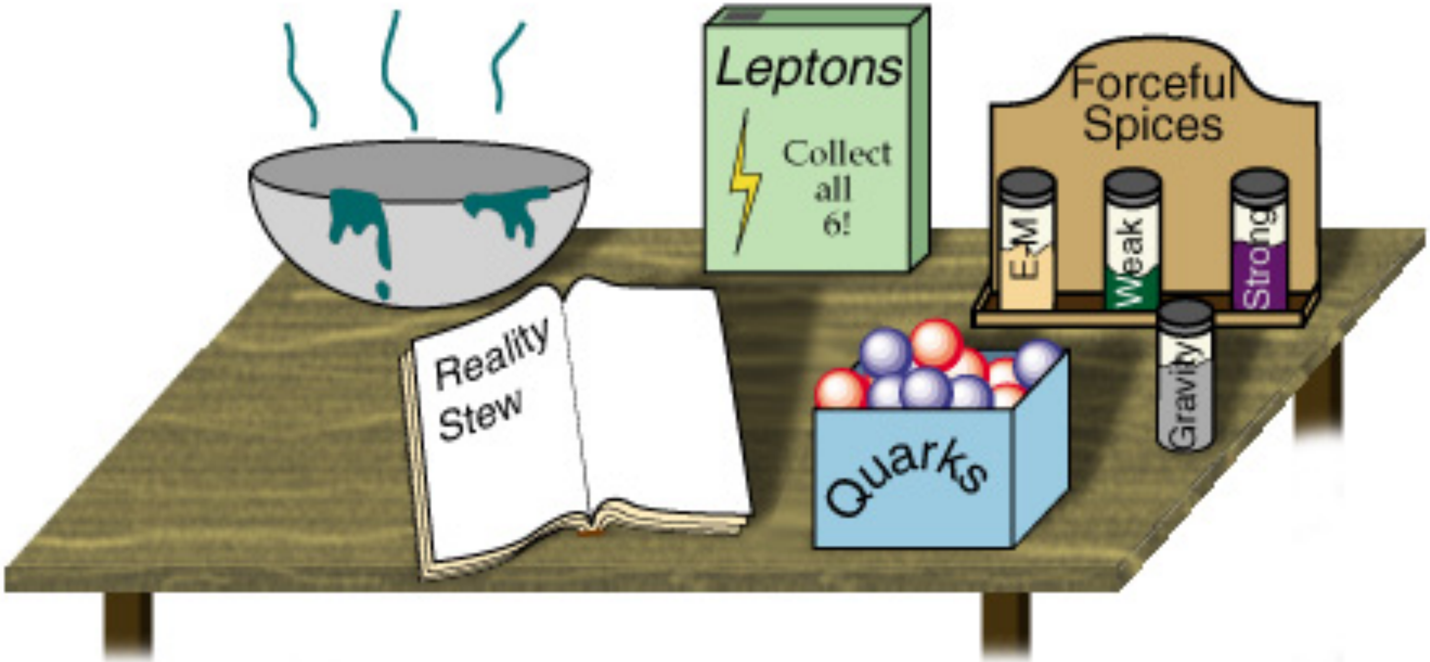
The number of neutrons in the nucleus can vary from atom to atom in an element. These variations, called isotopes, have different atomic weights, and some are not stable, and thus can radioactively decay. The isotopes are chemically identical.

All carbon atoms have six protons



Carbon-12 has 6 neutrons	Carbon-13 has 7 neutrons	Carbon-14 has 8 neutrons
Stable	*Stable*	*UNSTABLE!*

Sub-Atomic Level



Protons and neutrons are made up of *fundamental particles* called quarks. Electrons are fundamental particles.

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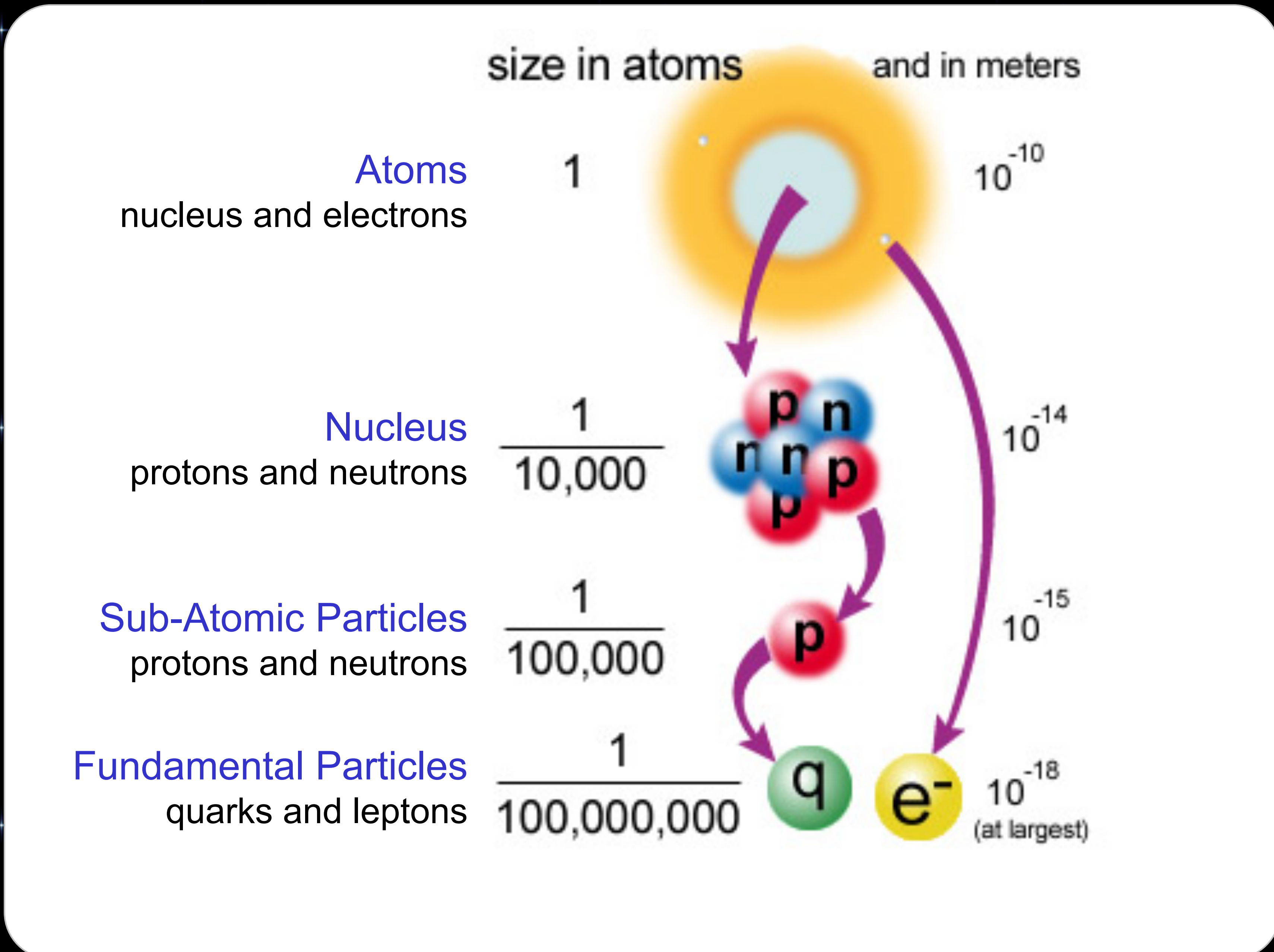

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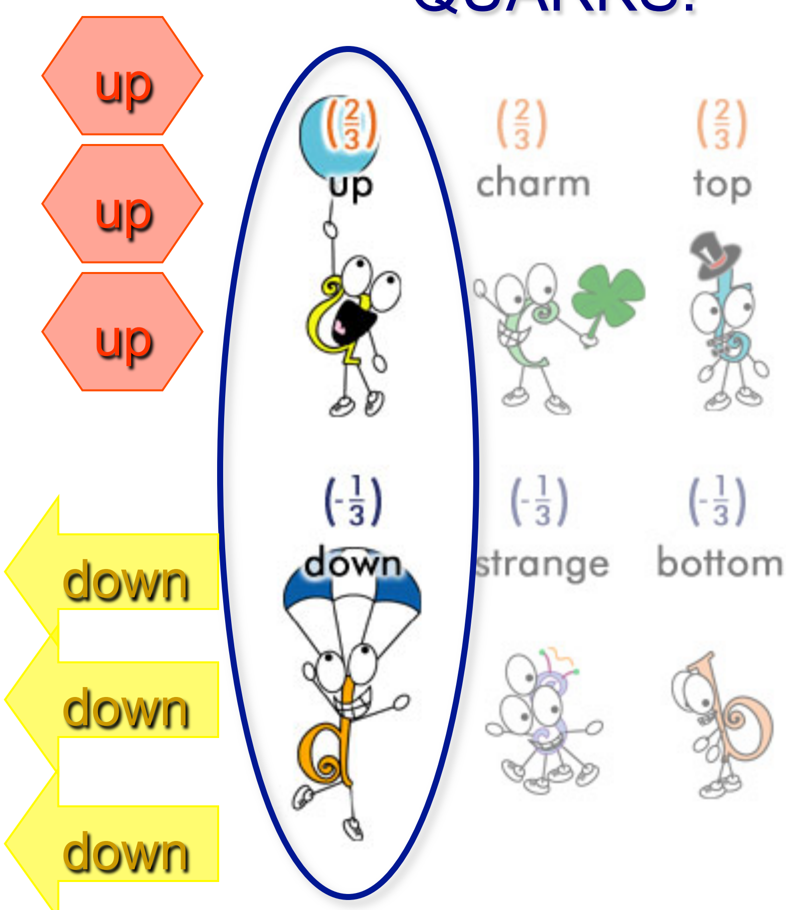
QUARKS!



Fundamental Particles

Each quark has a fractional electrical charge. They combine to form sub-atomic particles

Proton

up + *up* + *down*

(+2/3)+(+2/3)+(-1/3) = +1 charge

Neutron

up + *down* + *down*

(+2/3)+(-1/3)+(-1/3) = no charge

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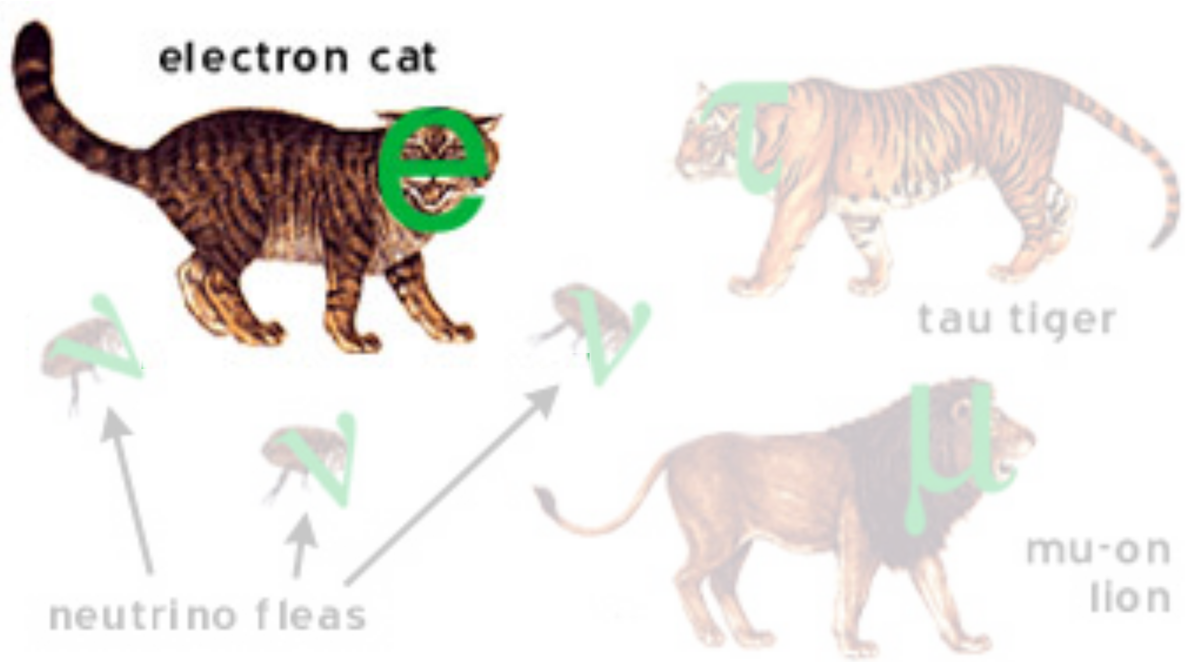
Fundamental Particles



LEPTONS!

Electrons are the most important lepton.

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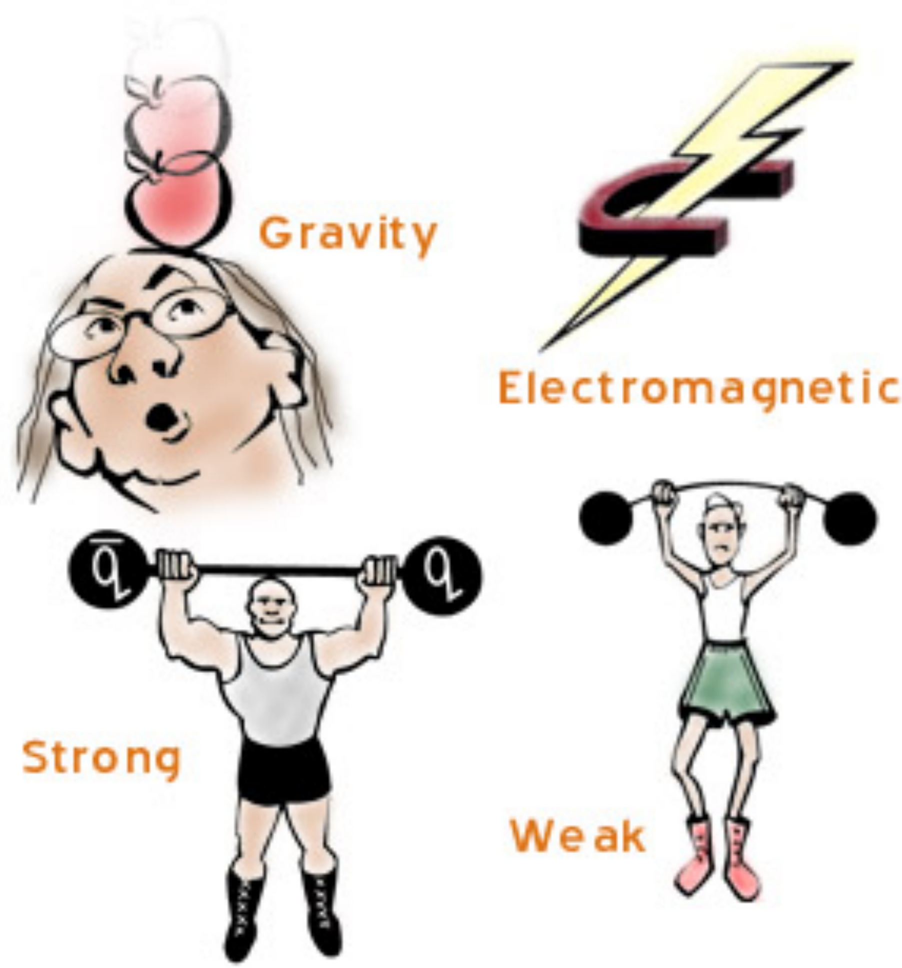
Forces



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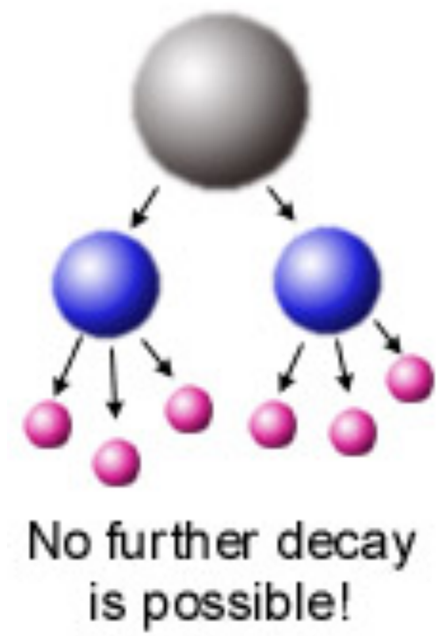
Weak Nuclear Force

Responsible for holding more massive quarks and leptons together



More massive fundamental particles rapidly decay to more stable, lower mass particles (e.g., tau to muon to electron)

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Strong Nuclear Force

Holds quarks together in sub-atomic particles

Attraction is caused by differences in "quark color" (which has nothing to do with real color)

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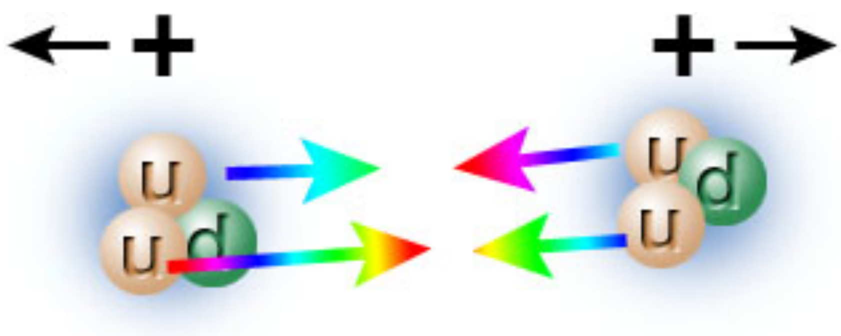
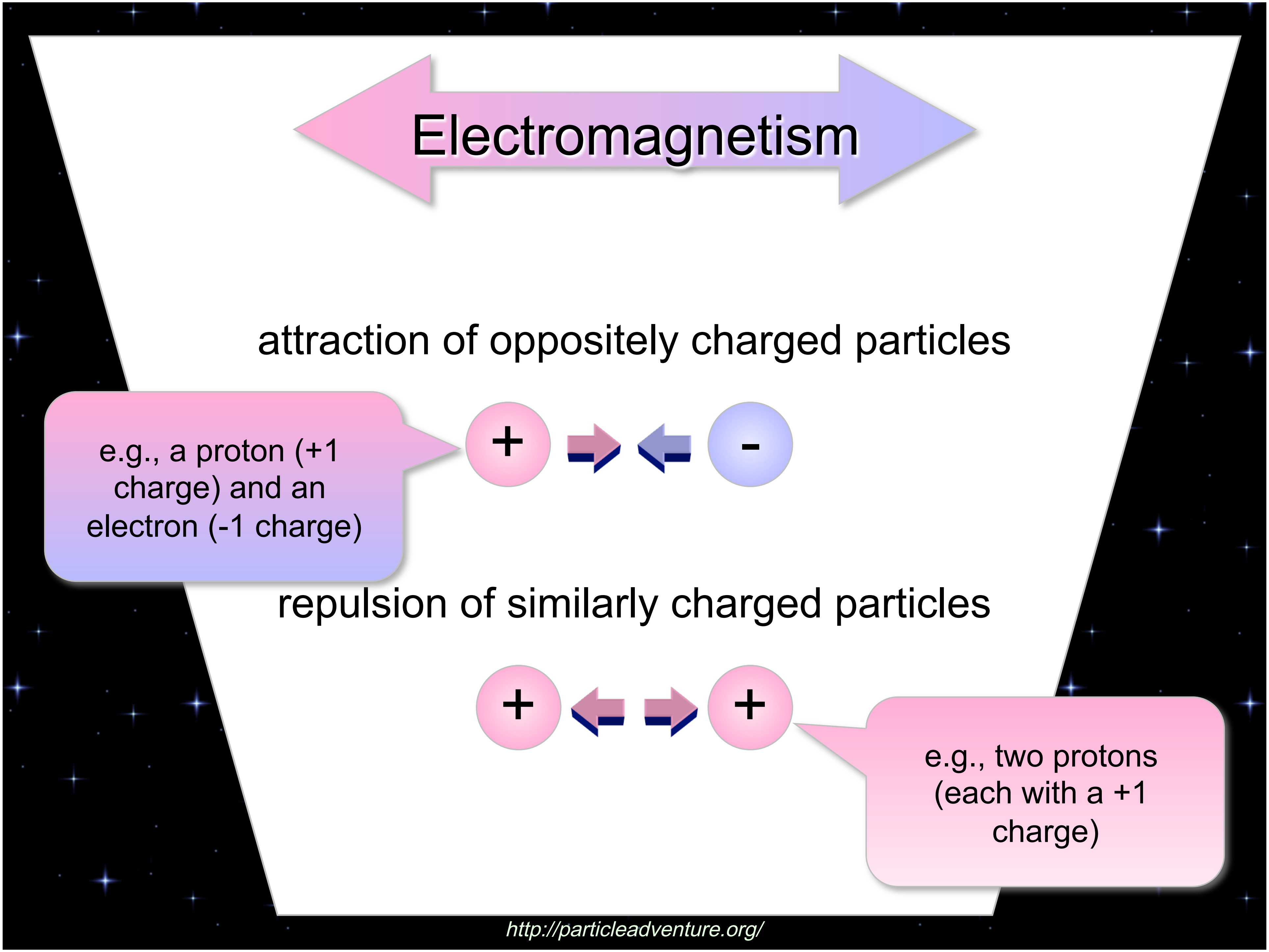
Residual Strong Nuclear Force

Holds nucleus together



"Color" attraction between quarks overcomes electromagnetic repulsion, but only over very small distances

http://particleadventure.org/


Electromagnetism
attraction of oppositely charged particles
e.g., a proton (+1 charge) and an electron (-1 charge)
+
-
repulsion of similarly charged particles
+
+
e.g., two protons (each with a +1 charge)
http://particleadventure.org/

Electromagnetism

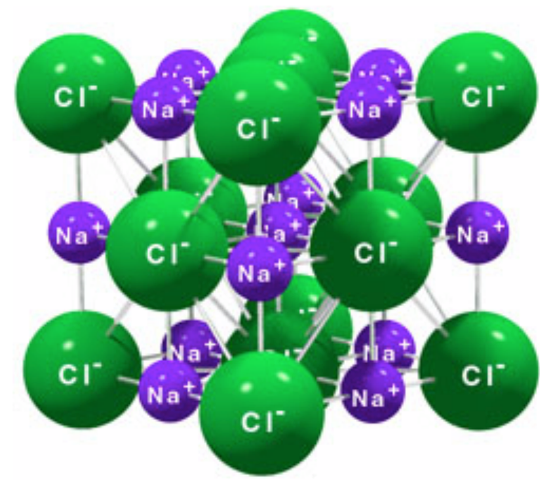
Atoms bond together to make molecules, which are described with chemical formulas. Molecular structures can be simple, or very complex.

Caffeine

1,3,7-trimethyl-1H-purine-2,6(3H,7H)-dione

$C_8H_{10}N_4O_2$

Table Salt



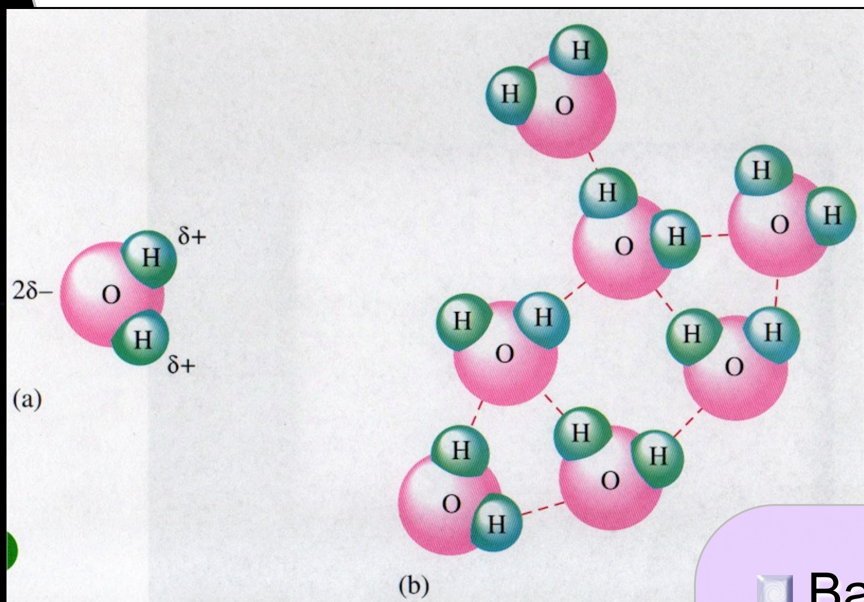
Sodium Chloride

NaCl

http://www.mylot.com/w/image/2435174.aspx

http://www.chemistry.wustl.edu/~edudev/LabTutorials/Water/PublicWaterSupply/PublicWaterSupply.html

Electromagnetism



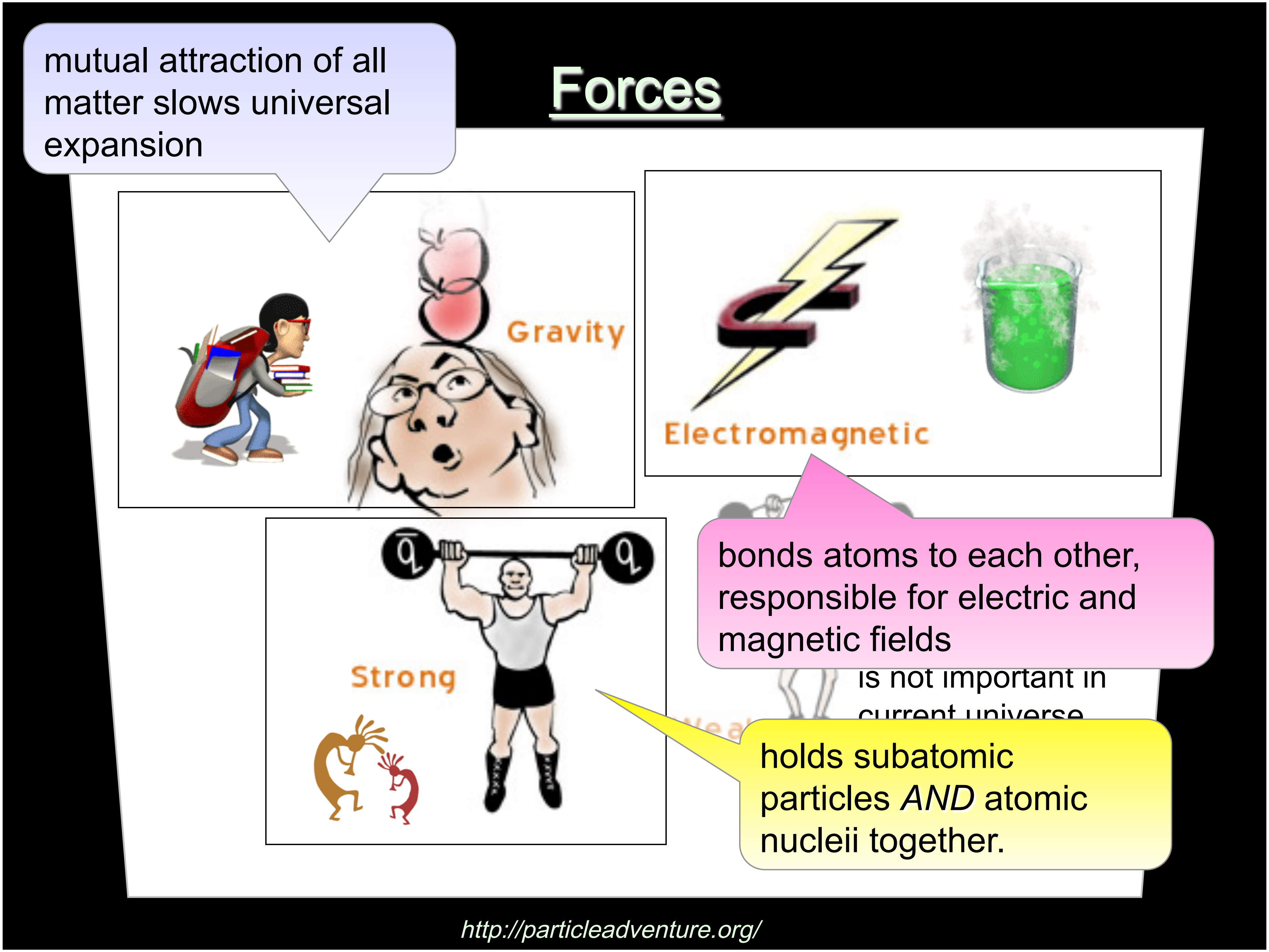
- Basis of all chemistry
- Responsible for properties of phases of matter
- Prevents everyone in this room from falling to the center of the Earth

Gravity

Gravity is a property of matter – any object with mass also exerts gravitational attraction.

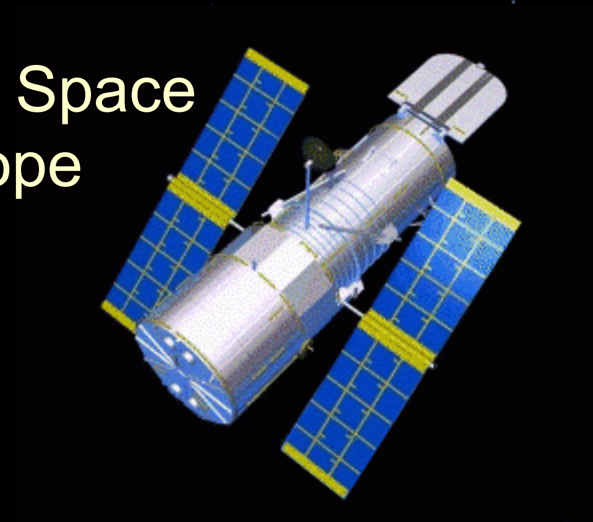
All objects attract each other gravitationally, with more massive objects exerting greater force.

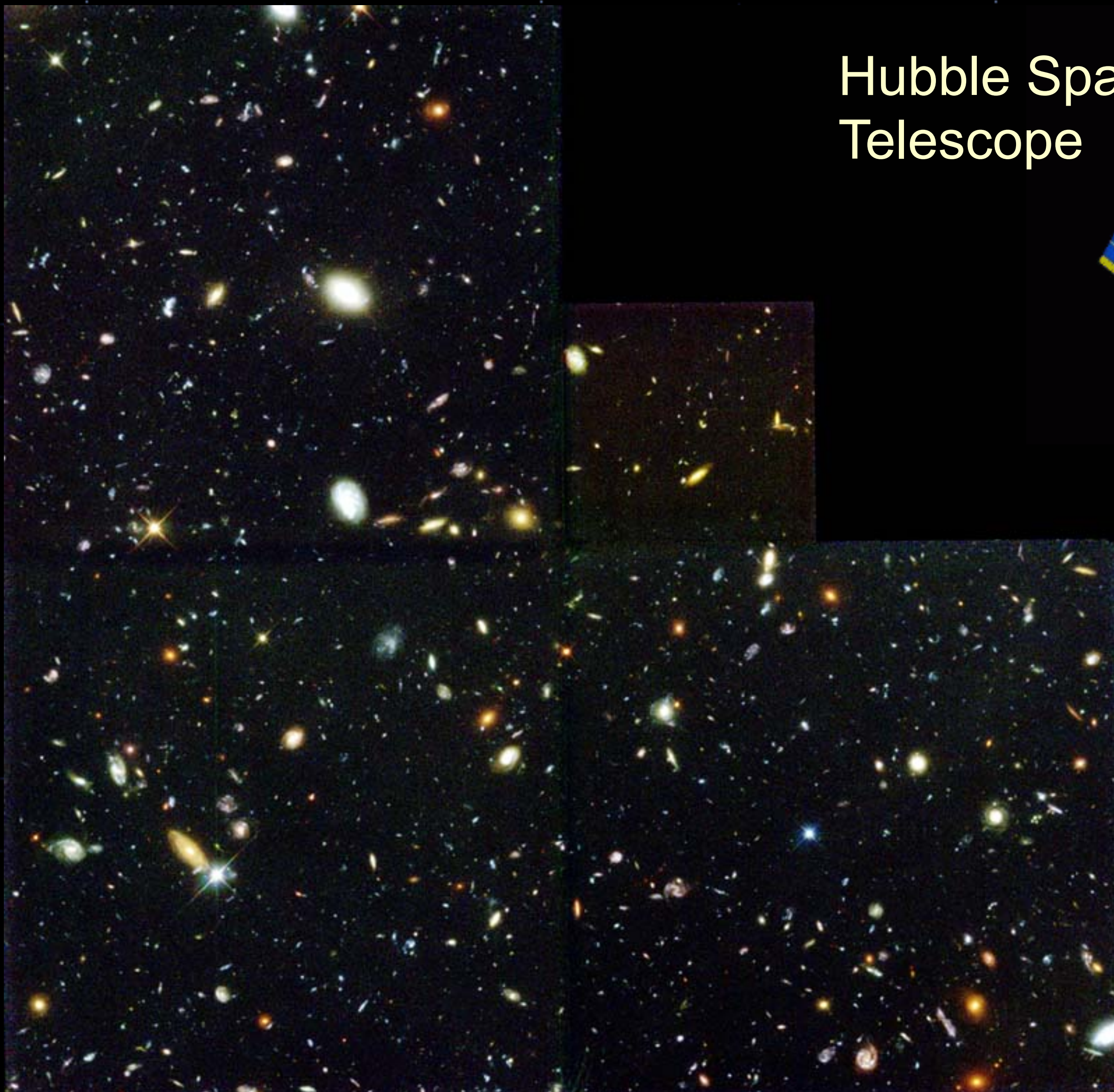
It has been hypothesized that mass warps space in a higher dimension, thus causing objects to be attracted to each other.


Forces
mutual attraction of all matter slows universal expansion
Gravity
Electromagnetic
bonds atoms to each other, responsible for electric and magnetic fields
is not important in
current universe
Strong
holds subatomic particles *AND* atomic nucleii together.
http://particleadventure.org/

So how did the universe get to be this way?

Hubble Space Telescope





Hubble Deep Field **HST WFPC2**

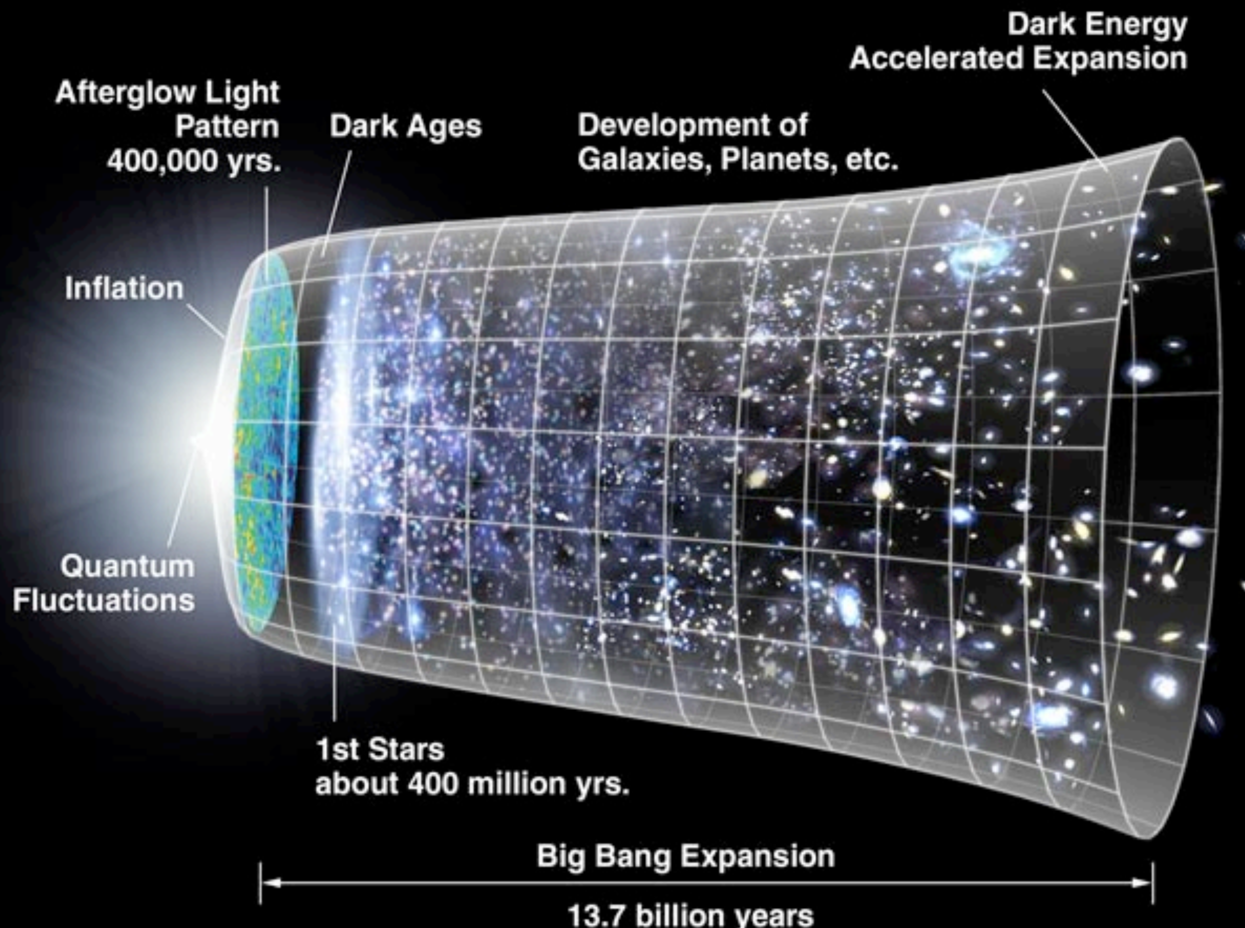
ST ScI OPO January 15, 1996 R. WIlliams and the HDF Team (ST ScI) and NASA

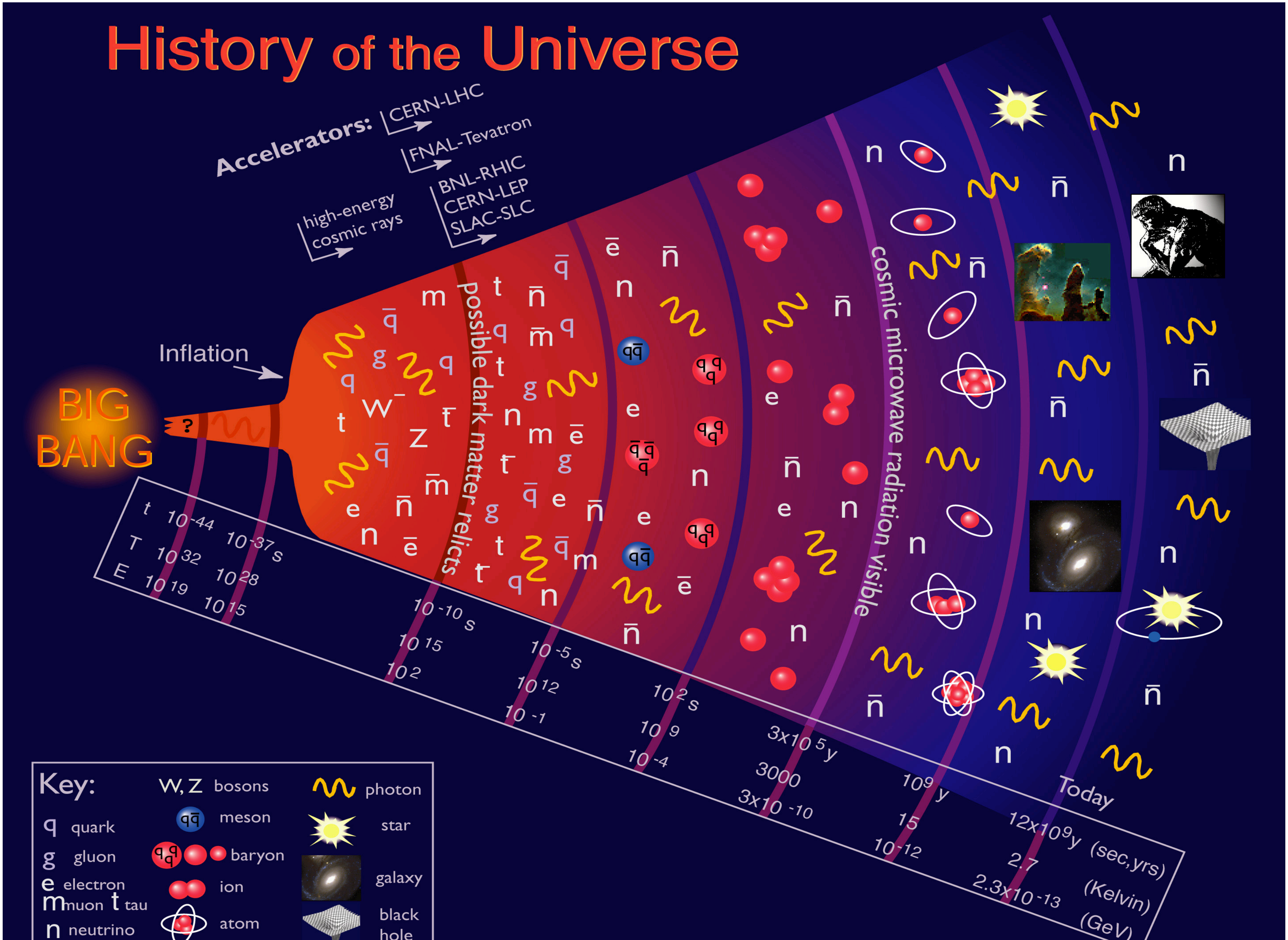
Mapping to Date:

Millions of galaxies

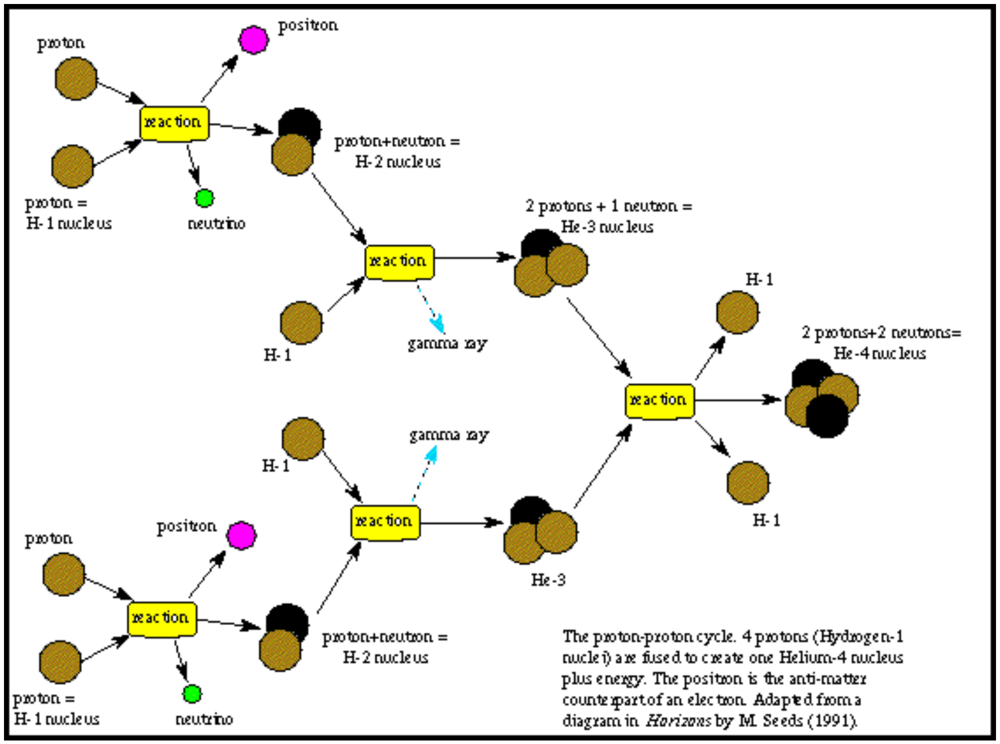
- Humans have observed only a small portion of the Universe, but other than our members of our own galaxy and our galaxy's nearest neighbors, all objects we have observed are moving away from us.
- There's nothing wrong with us - the objects are moving away from each other, too. In other words, the universe appears to be expanding.
- If we run the tape backwards, and re-compress the universe, there was a time (12-14 billion years ago), when the entire universe was unimaginably dense and small.
- The event that led to the expansion from that dense universe is called the "Big Bang."

The leading hypothesis in cosmology is that the universe today is the result of expansion after the Big Bang.




History of the Universe
Accelerators:
CERN-LHC
FNAL-Tevatron
BNL-RHIC
CERN-LEP
SLAC-SLC
high-energy cosmic rays
Inflation
BIG BANG
possible dark matter relicts
cosmic microwave radiation visible
t 10^-44 10^-37 s 10^-10 s 10^-5 s 10^2 s 3x10^5 y 10^9 y 12x10^9 y (sec,yrs)
T 10^32 10^28 10^15 10^12 10^9 3000 15 2.7 (Kelvin)
E 10^19 10^15 10^2 10^-1 10^-4 3x10^-10 10^-12 2.3x10^-13 (GeV)
Today
Key:
q quark
g gluon
e electron
m muon t tau
n neutrino
W, Z bosons
meson
baryon
ion
atom
photon
star
galaxy
black hole

Nucleosynthesis – Making New Elements



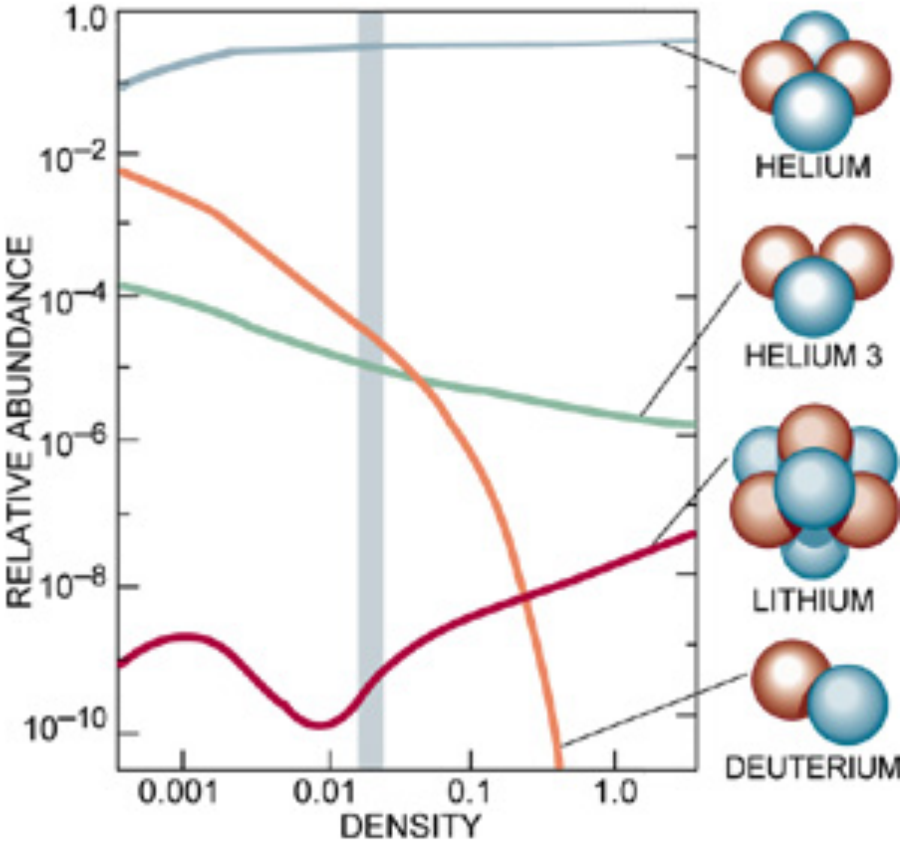
Hydrogen Fusion

Given enough energy, protons can “hit” each other hard enough for the strong nuclear force to overcome electromagnetic repulsion.

In the modern universe, hydrogen fusion takes place in the hearts of stars. It is also the basis of thermonuclear bombs.

http://www.astronomynotes.com/

Big Bang Elements

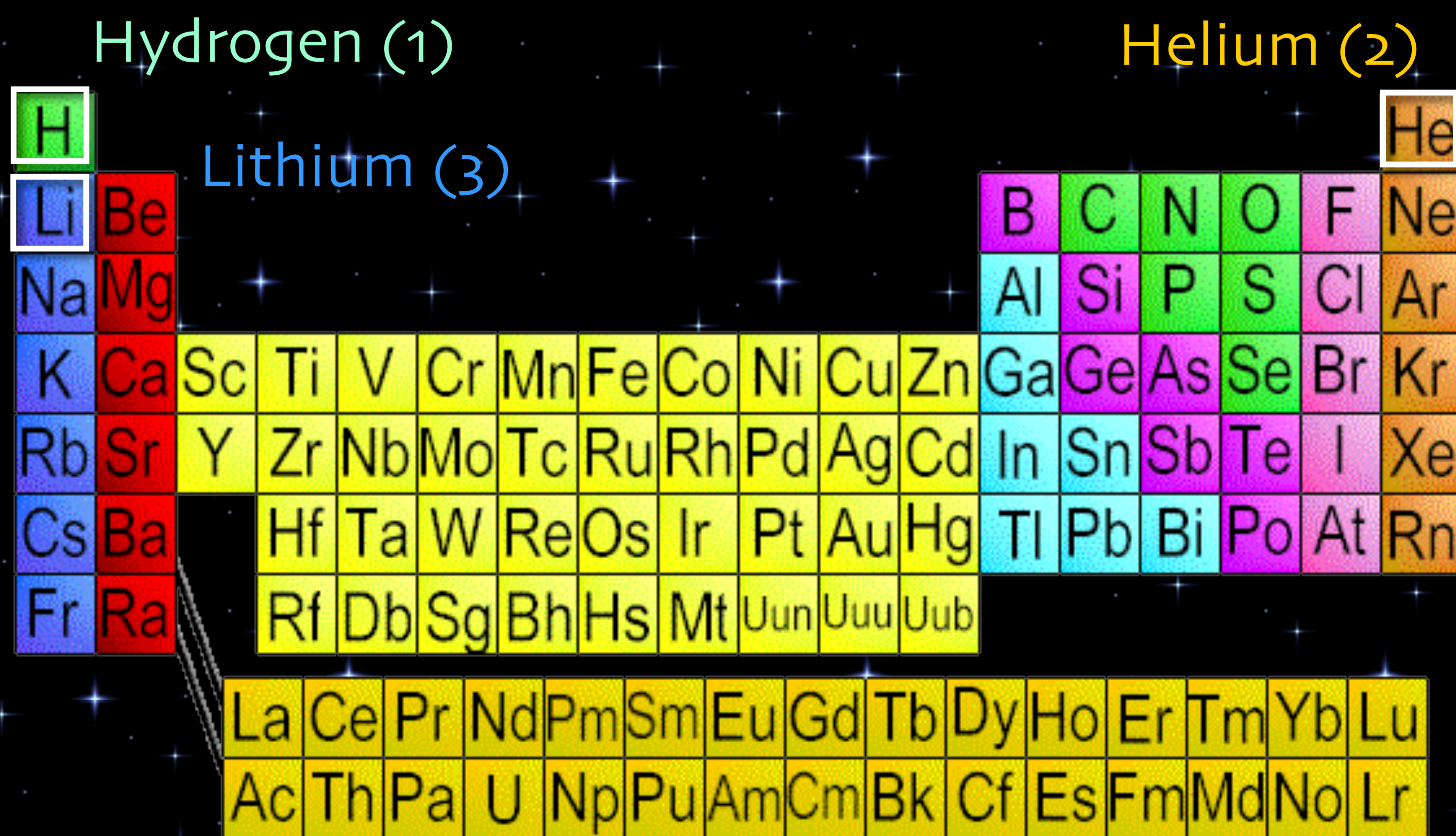


Baryons (protons and neutrons) formed at a time when there was still lots of energy available to shoot them around.

As the baryons knocked into each other, some stuck, forming isotopes of the elements hydrogen, helium and lithium.

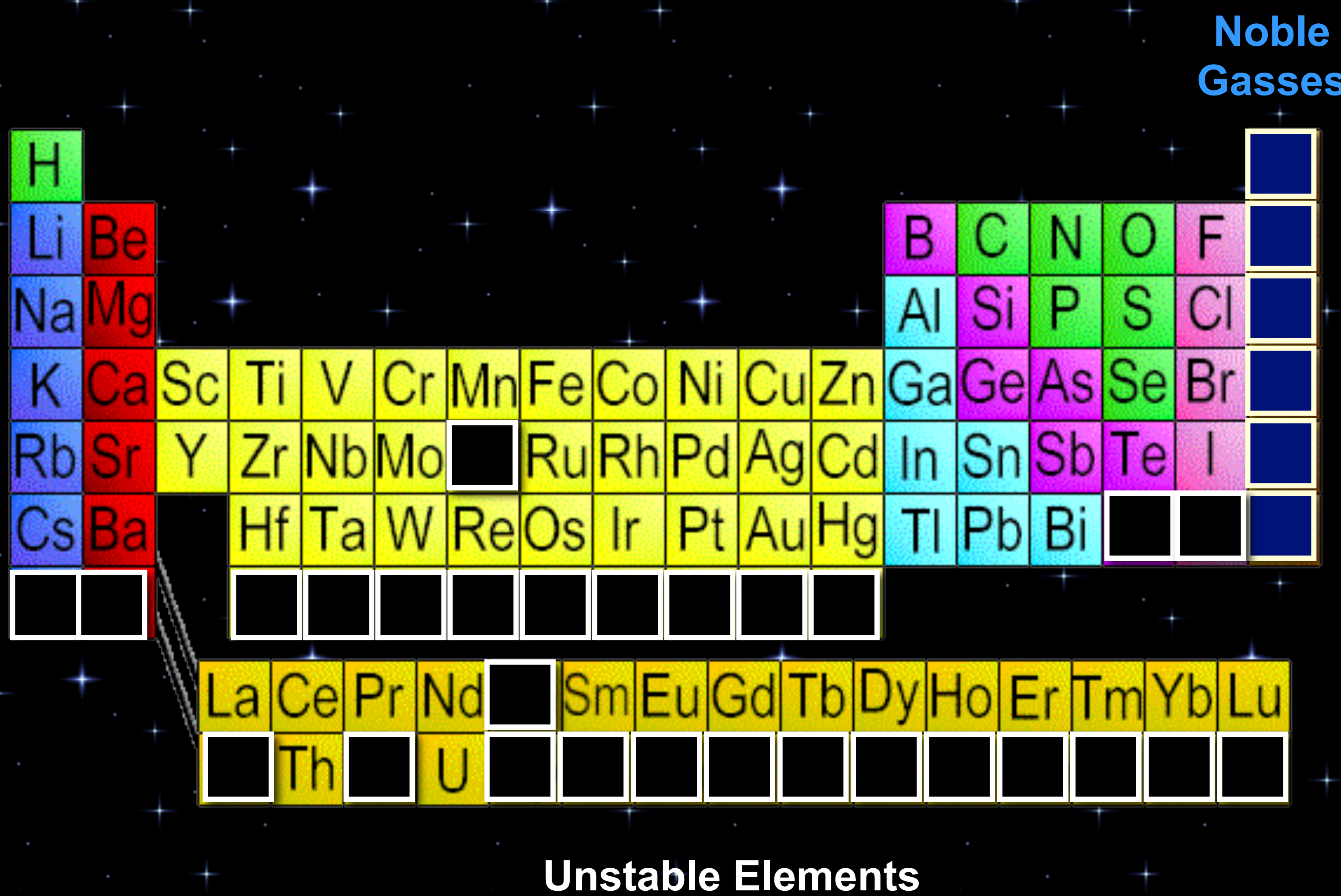
There was not enough energy to form heavier elements.

Big Bang Elements

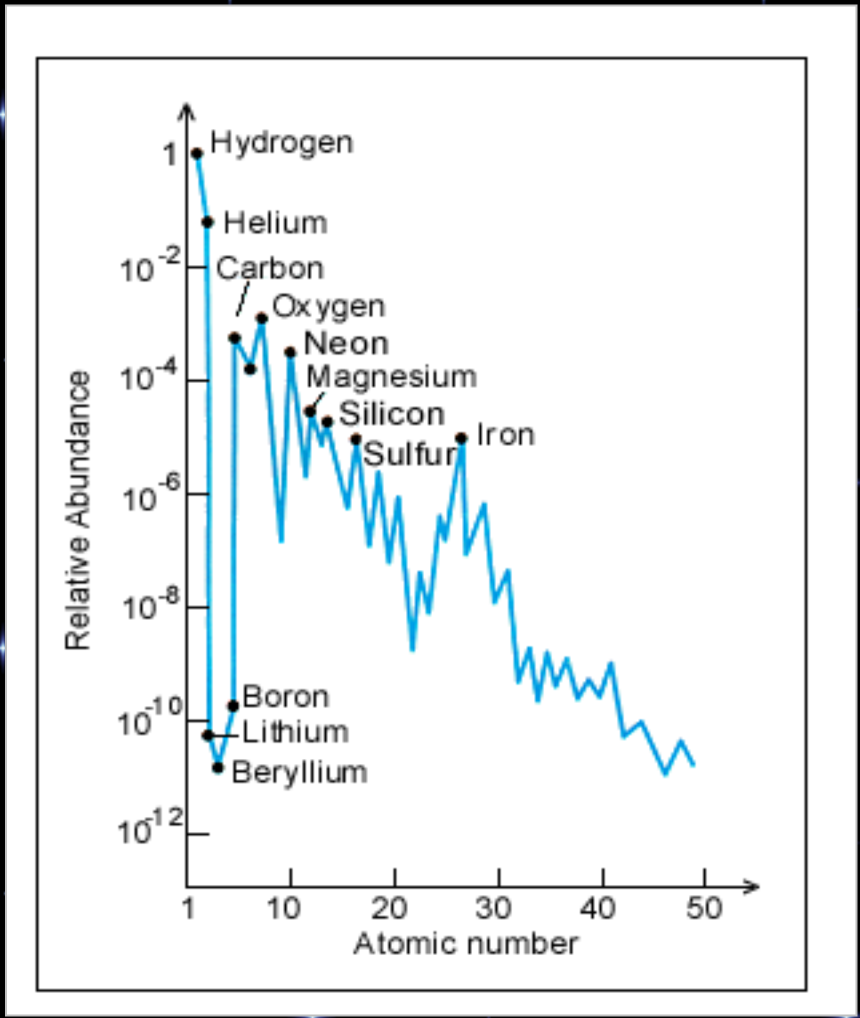


Elements formed during and soon after the Big Bang.

Elements of the Earth's Crust



Composition of Star Nebulae



H	1,000,000
He	98,000
O	850
Ne	120
N	100
Fe	47
Na	2
Other	100

The modern, visible universe is still primarily hydrogen and helium, but with other elements

These elements were not made during the Big Bang, and must have been assembled in the billions of years since then.

http://www.astronomynotes.com/

Post-Big Bang Elements

Where were (and are!) these heavier elements formed?

Both in the hearts of living stars and during some of their explosive deaths…