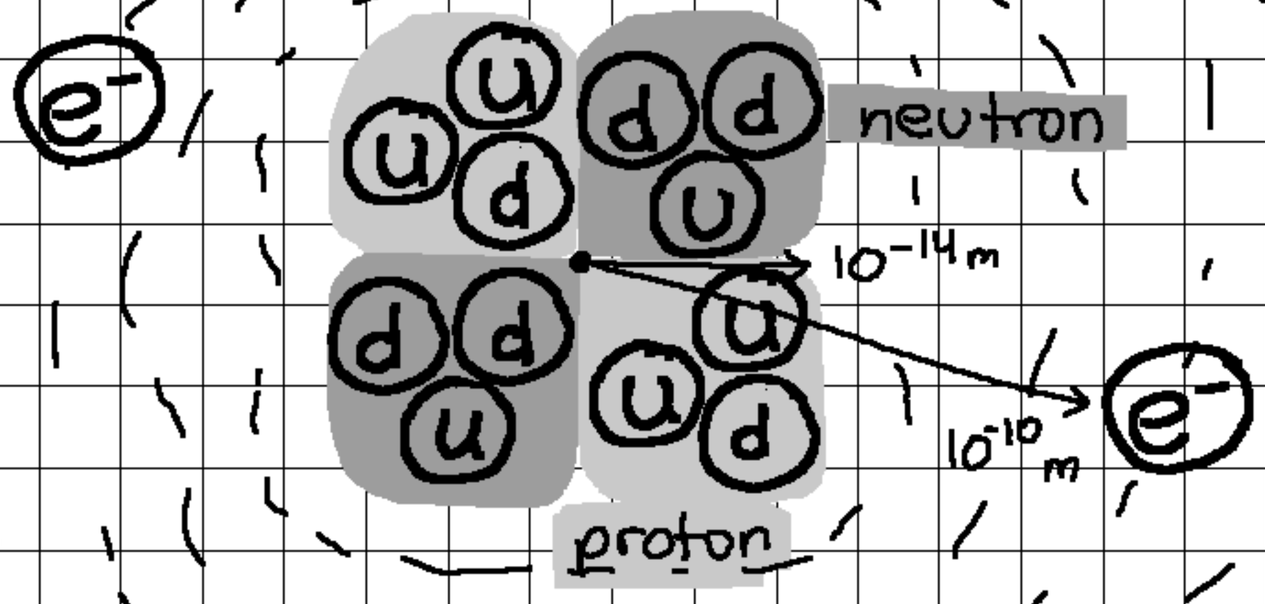
1.1 Matter

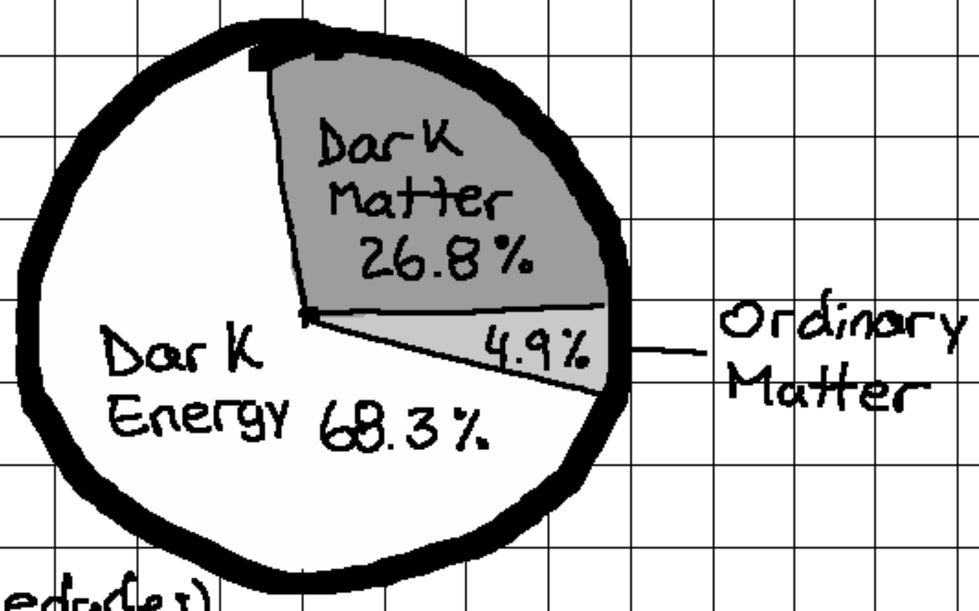
- Components of an atom:
  - Nucleous {positivly charged, $r = 10^{-14}$ m}
  - e^- cloud {negativly charged, $r = 1$ Å}
  - ↳ electron (leptons): elementary particle.
  - ↳ nucleous = protons + neutrons = quarks boud together by the strong force.



d u → Quarks

e^- → Leptons

- Contents of the Universe →



- Clasificación por Familias (según propiedades) y generaciones (según su masa)

Fermions matter constituents spin = 1/2, 3/2, 5/2						
Leptons spin = 1/2			Quarqs spin = 1/2			
Flavor	Mass GeV/c^2	Electric Charge	Flavor	Mass GeV/c^2	Electric Charge	
1° ν_L lightest neutrino*	$(0.0001-2)\cdot10^{-9}$	0	u up	0.002	2/3	Light Generation
1° e electron	0.000511	-1	d down	0.005	-1/3	
2° ν_M middle neutrino*	$(0.009-2)\cdot10^{-9}$	0	c charm	1.3	2/3	Medium Generation
2° μ muon	0.106	-1	s strange	0.1	-1/3	
3° ν_H heaviest neutrino*	$(0.05-2)\cdot10^{-9}$	0	t top	173	2/3	Heavy Generation
3° τ tau	1.777	-1	b bottom	4.2	-1/3	

Table:
- Neutrinos: produced in radioactive decays.
- Quarks: constituents of protons, neutrons and of all particles which we call hadrons.
- "Flavor": quantum number conserved by all interaction, except the weak interactions.

Hadrons:
- All particles which contain quarks.
- Sensitive to strong and nuclear interactions (unlike leptons)

↳ **Baryons:** bound states formed by 3 quarks (i.e. p, n → lightest atom nucleous)

↳ **Mesons:** quark + anti-quark (i.e. π, pion, lightest meson)

- obs: There are no hadrons made of top quarks bc t decays before it can form bounds with others.

Leptons:
- Elementary, not composed of other Known particles.

	Hadrons		Leptons	
	Baryons	Mesons	Charged	Neutral
u, d	p, n, Δ	$\pi, \eta, \rho, \omega, \ldots$	$e^{\pm}$	ν_L
s	$\Lambda, \Sigma, \Xi, \Omega$	K	$\mu^{\pm}$	ν_M
c	$\Lambda_c, \Sigma_c, \Xi_c, \Omega_{uc}$	$D, D_s, \eta_c, J/\psi, \chi_c$		
b	$\Lambda_b, \Sigma_b, \Xi_b, \Omega_{ub}$	$B, B_s, B_c, \Upsilon, \chi_b$	$\tau^{\pm}$	ν_H
t	—	—		

Strong Force: To be sensitive to this force, particles need "color charge" → only quarks.

$\langle p = uu, \; n = udd, \; \pi = u\bar{d} \rangle$

→ Leptons only interact with the em & week forces. they do not form long-lasting bonds among themselves

particles	Spin	# bar	# lept.	Q elec.	T, T_3 weak	C strong
Leptons						
ν_L, ν_M, ν_H	1/2	0	+1	0	1/2 , +1/2	0
e^-, μ^-, τ^-	1/2	0	+1	-1	1/2 , -1/2	0
Quarks						
u, c, t	1/2	+1/3	0	+2/3	1/2 , +1/2	R, G, B
d, s, b	1/2	+1/3	0	-1/3	1/2 , -1/2	R, G, B
Gauge Bosons						
γ	1	0	0	0	0	0
$Z, W^\pm$	1	0	0	0, ±1	1, (0, ±1)	0
Gluons	1	0	0	0	0	$C\bar{C}$
Vacuum						
Higgs	0	0	0	0	0	0

anti-particles	Spin	# bar	# lept.	Q elec.	T, T_3 weak	C strong
Leptons						
$\bar{\nu}_L, \bar{\nu}_M, \bar{\nu}_H$	1/2	0	-1	0	1/2 , -1/2	0
e^+, μ^+, τ^+	1/2	0	-1	+1	1/2 , +1/2	0
Quarks						
$\bar{u}, \bar{c}, \bar{t}$	1/2	-1/3	0	-2/3	1/2 , -1/2	$\bar{R}, \bar{G}, \bar{B}$
$\bar{d}, \bar{s}, \bar{b}$	1/2	-1/3	0	+1/3	1/2 , +1/2	$\bar{R}, \bar{G}, \bar{B}$
Gauge Bosons						
γ	1	0	0	0	0	0
$Z, W^\mp$	1	0	0	0, ∓1	1, (0, ∓1)	0
Gluons	1	0	0	0	0	$\bar{C}C$
Vacuum						
Higgs	0	0	0	0	0	0

*Same mass, opposite charges.

* **Weak charge**: "weak isospin", it has two components

$(T, T_3) \Rightarrow$ T: total lenght ok the weak isospin

T_3: its 3rd component.

→ Depends of the direction of the spin of the particle ⟹ it depends of the helicity of the particle.

* **Strong charge**: it has three components, colors

{R: Red, G: Green, B: Blue} → Quarks & Gluons

Quantum numbers conserved:

- Total **Baryon #**: # Baryons − # antibaryons = const.
  $\#q - \#\bar{q} = \text{const.}$

- Total **Lepton #**: # leptons − # antileptons = const.
  $\#(l^-, \nu_l) - \#(l^+, \bar{\nu}_l) = \text{const.}$

  * ν_e, ν_μ, ν_τ are mixed states of the particles ν_L, ν_M, ν_H

- **Charges** of all type:
  - Electric charge Q
  - Weak isospin (T, T_3)
  - Color $C = (R, G, B)$

- Flavor: conserved by → Strong & em interactions
  altered by ⟶ weak interactions.