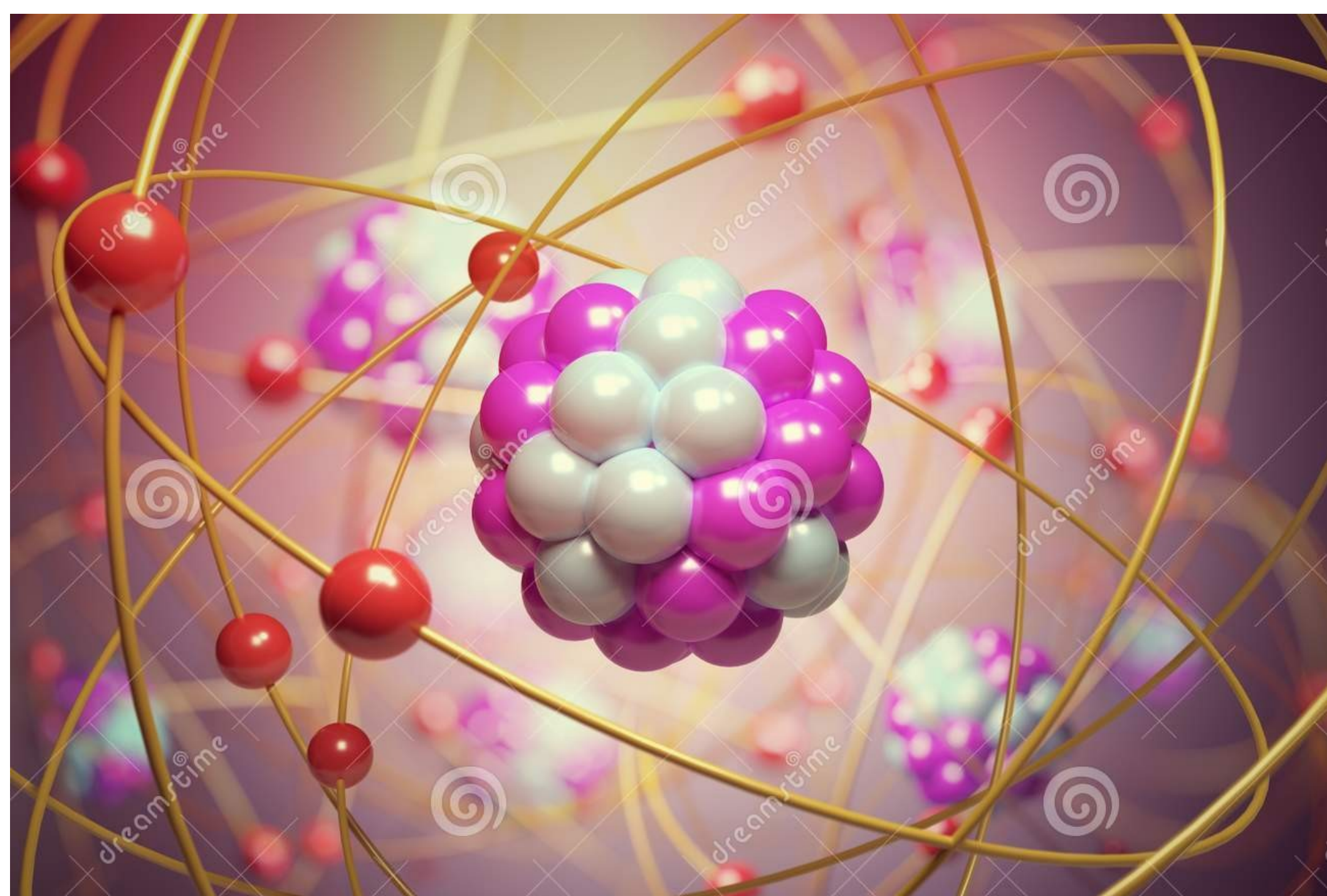
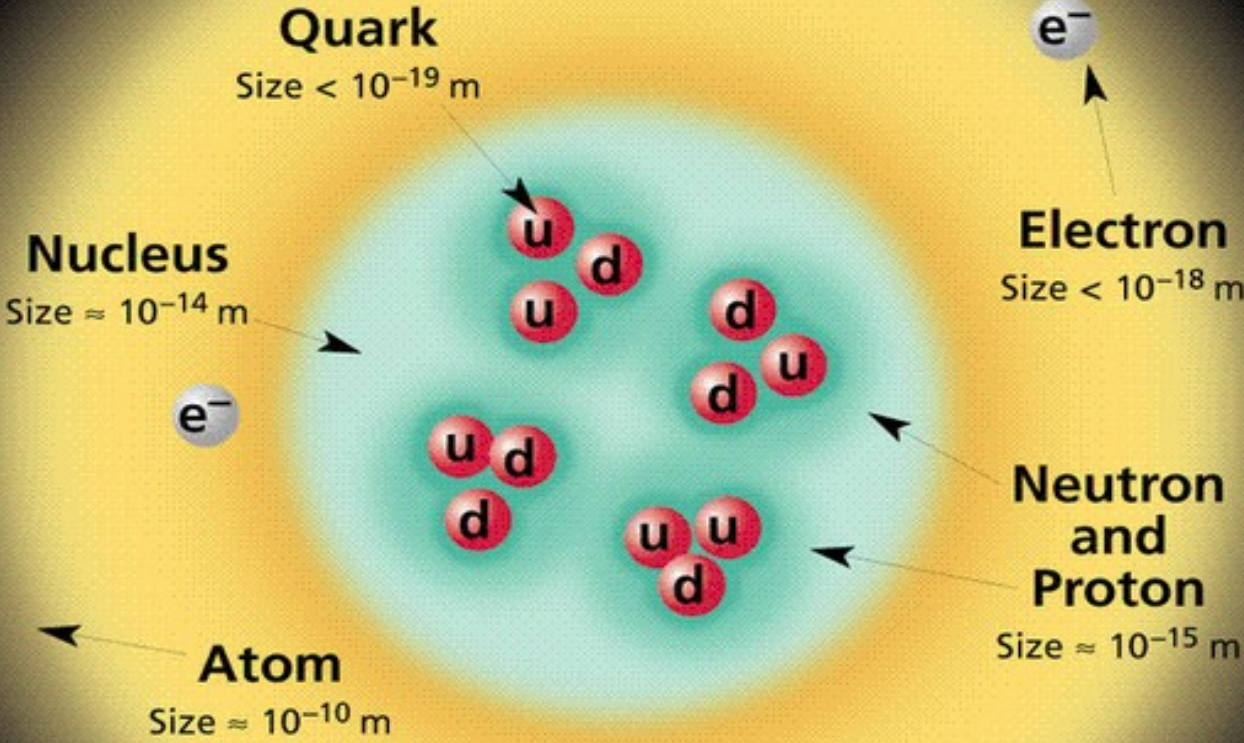


# Struttura della materia: Le particelle elementari.

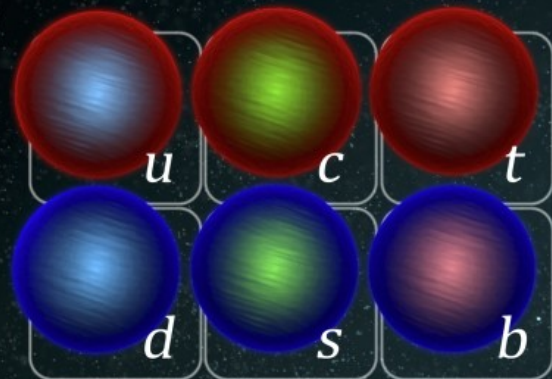


# Structure within the Atom

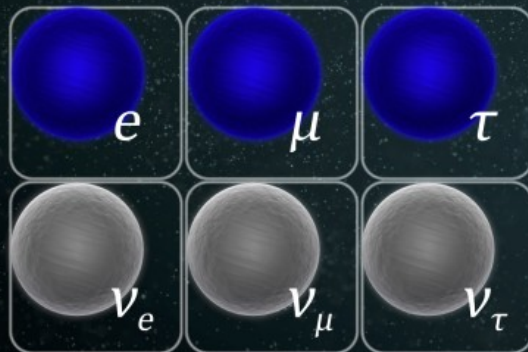


If the protons and neutrons in this picture were 10 cm across, then the quarks and electrons would be less than 0.1 mm in size and the entire atom would be about 10 km across.

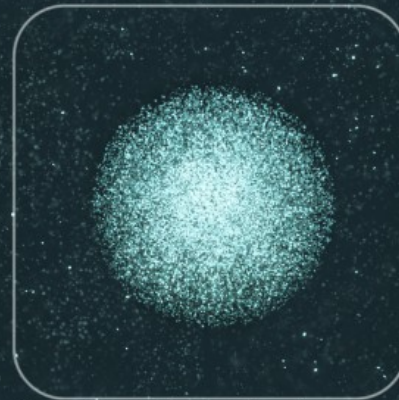
# Costituenti fondamentali della materia.



Quarks



Leptons



Higgs boson



Forces

|          |                               |                                 |                                  |                   |                               |
|----------|-------------------------------|---------------------------------|----------------------------------|-------------------|-------------------------------|
| mass →   | $\approx 2.3 \text{ MeV}/c^2$ | $\approx 1.275 \text{ GeV}/c^2$ | $\approx 173.07 \text{ GeV}/c^2$ | 0                 | $\approx 126 \text{ GeV}/c^2$ |
| charge → | 2/3                           | 2/3                             | 2/3                              | 0                 | 0                             |
| spin →   | 1/2                           | 1/2                             | 1/2                              | 1                 | 0                             |
|          | <b>u</b><br>up                | <b>c</b><br>charm               | <b>t</b><br>top                  | <b>g</b><br>gluon | <b>H</b><br>Higgs boson       |

|  |                               |                              |                                |                    |  |
|--|-------------------------------|------------------------------|--------------------------------|--------------------|--|
|  | $\approx 4.8 \text{ MeV}/c^2$ | $\approx 95 \text{ MeV}/c^2$ | $\approx 4.18 \text{ GeV}/c^2$ | 0                  |  |
|  | -1/3                          | -1/3                         | -1/3                           | 0                  |  |
|  | 1/2                           | 1/2                          | 1/2                            | 1                  |  |
|  | <b>d</b><br>down              | <b>s</b><br>strange          | <b>b</b><br>bottom             | <b>γ</b><br>photon |  |

|  |                         |                         |                         |                        |
|--|-------------------------|-------------------------|-------------------------|------------------------|
|  | $0.511 \text{ MeV}/c^2$ | $105.7 \text{ MeV}/c^2$ | $1.777 \text{ GeV}/c^2$ | $91.2 \text{ GeV}/c^2$ |
|  | -1                      | -1                      | -1                      | 0                      |
|  | 1/2                     | 1/2                     | 1/2                     | 1                      |
|  | <b>e</b><br>electron    | <b>μ</b><br>muon        | <b>τ</b><br>tau         | <b>Z</b><br>Z boson    |

|  |   |                                       |                                      |                        |
|--|---|---------------------------------------|--------------------------------------|------------------------|
|  | $< 2.2 \text{ eV}/c^2$                    | $< 0.17 \text{ MeV}/c^2$              | $< 15.5 \text{ MeV}/c^2$             | $80.4 \text{ GeV}/c^2$ |
|  | 0   | 0                                     | 0                                    | $\pm 1$                |
|  | 1/2                                       | 1/2                                   | 1/2                                  | 1                      |
|  | <b>ν<sub>e</sub></b><br>electron neutrino | <b>ν<sub>μ</sub></b><br>muon neutrino | <b>ν<sub>τ</sub></b><br>tau neutrino | <b>W</b><br>W boson    |

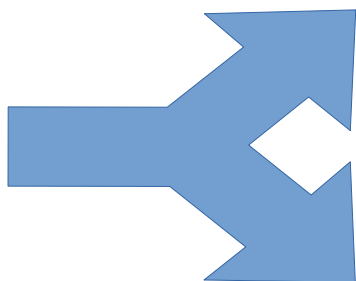
**QUARKS**

**LEPTONS**

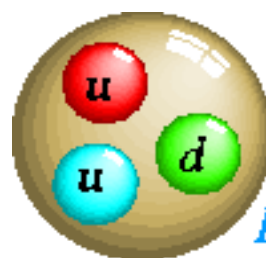
1 eV =  $1.6021 \times 10^{-19} \text{ J}$   
 1 e =  $1.602 \times 10^{-19} \text{ C}$   
 Sono uguali perché  $1 \text{ V} = 1 \text{ J/C}$

**GAUGE BOSONS**

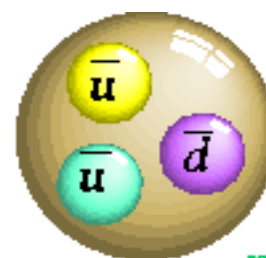
**ADRONI**



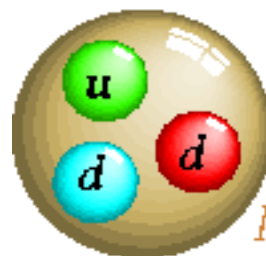
**BARIONI**



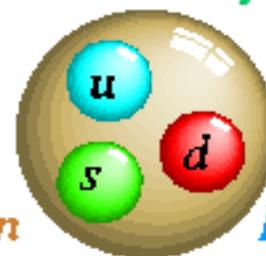
*Proton*



*Anti-proton*

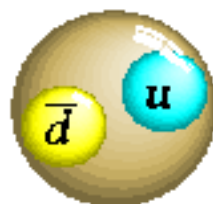


*Neutron*

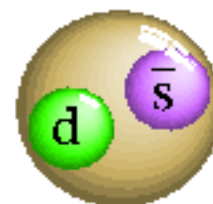


*Lambda*

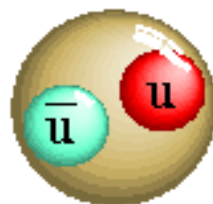
**MESONI**



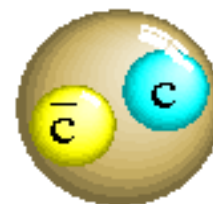
$\pi^+$



$K^0$

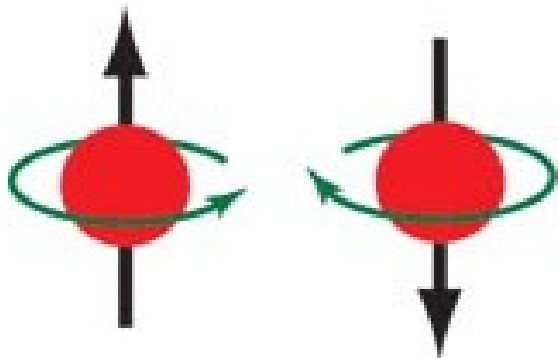


$\pi^0$

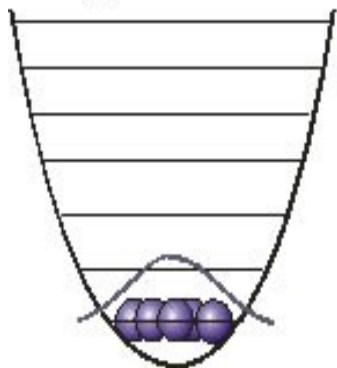


$J/\psi$

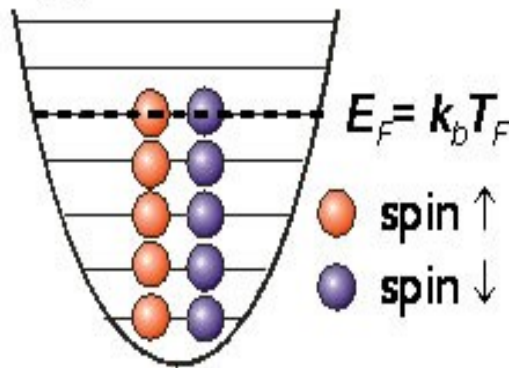
**SPIN: proprietà intrinseca delle particelle legata al momento angolare.**



(a) BEC



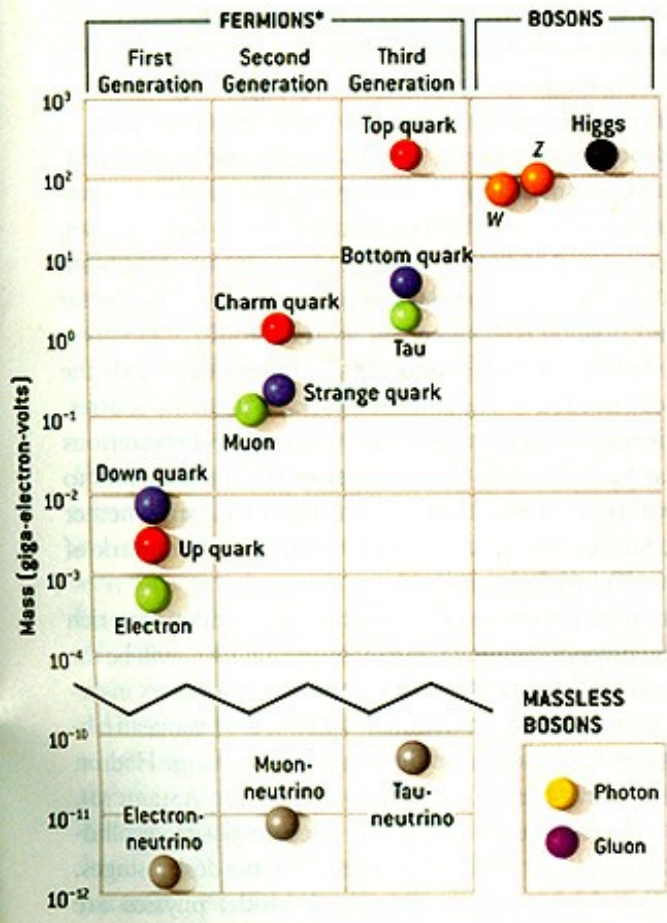
(b) Fermi sea



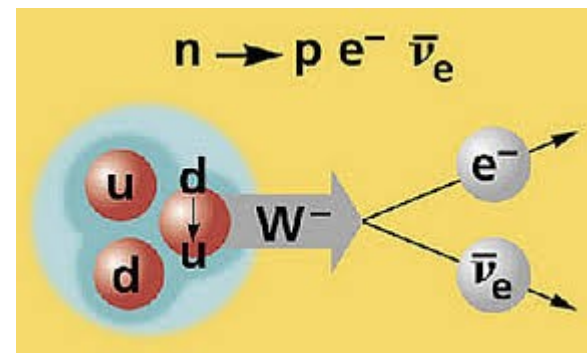
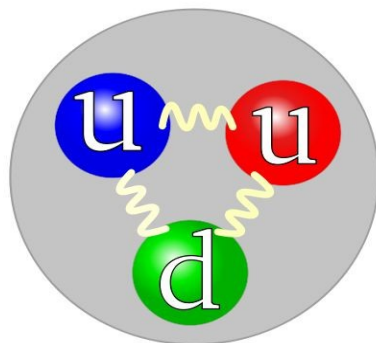
| Fermions          |  | Bosons                                      |              |
|-------------------|--|---|--------------|
| Leptons<br>Quarks | Spin<br>$\frac{1}{2}$                          | Carrier<br>Bosons<br>$\gamma W^+ W^- Z^0 g$ | Spin<br>1    |
| Baryons<br>(qqq)  | $\frac{1}{2}, \frac{3}{2}, \frac{5}{2}, \dots$ | Mesons<br>(q $\bar{q}$ )                    | 0, 1, 2, ... |

**Principio di esclusione di Pauli: due fermioni non possono occupare simultaneamente lo stesso stato quantico. Importante per la struttura elettronica degli atomi. I bosoni invece si.**

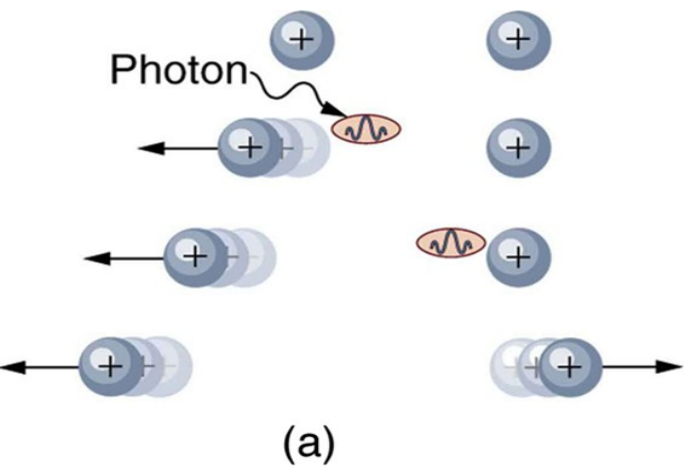
**BEC: Bose Einstein condensation, a bassa temperatura i bosoni si concentrano in un singolo stato.**



## Decadimento beta, interazione debole.

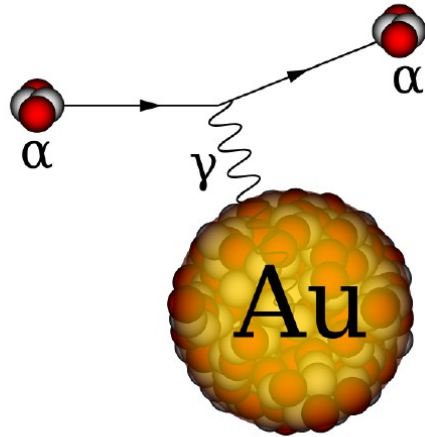


| Force                   | Diagram | Strength            | Range (m)  | Particle  |
|-------------------------|---------|---------------------|--|---|
| <b>Strong</b>           |         | 1                   | $10^{-15}$<br>(diameter of a medium sized nucleus) | gluons, $\pi$ (nucleons)  |
| <b>Electro-magnetic</b> |         | $\frac{1}{137}$     | Infinite   | photon<br>mass = 0<br>spin = 1  |
| <b>Weak</b>             |         | $10^{-6}$           | $10^{-18}$<br>(0.1% of the diameter of a proton)   | Intermediate vector bosons $W^+$ , $W^-$ , $Z_0$ ,<br>mass > 80 GeV<br>spin = 1 |
| <b>Gravity</b>          |         | $6 \times 10^{-39}$ | Infinite   | graviton ?<br>mass = 0<br>spin = 2  |



# standard model particle interactions

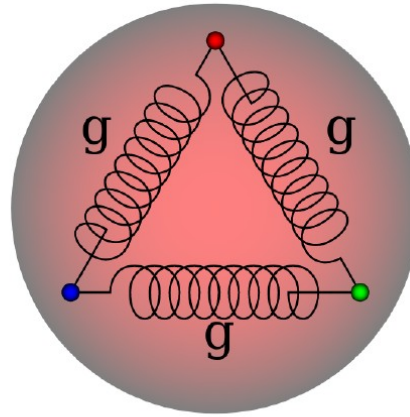
electromagnetic  
(charge)



alpha particle scattering  
in the gold foil experiment

interaction mediated  
by photons

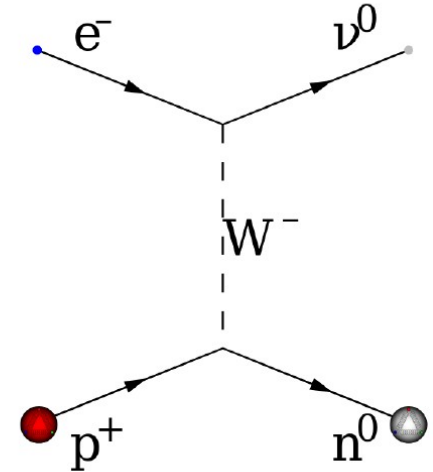
strong  
(color)



quarks bound together  
within a proton

interaction mediated  
by gluons

weak  
(flavor)



reverse beta decay

interaction mediated  
by W and Z particles

**Modello standard NON include la gravità quindi non è una teoria unificata completa.**



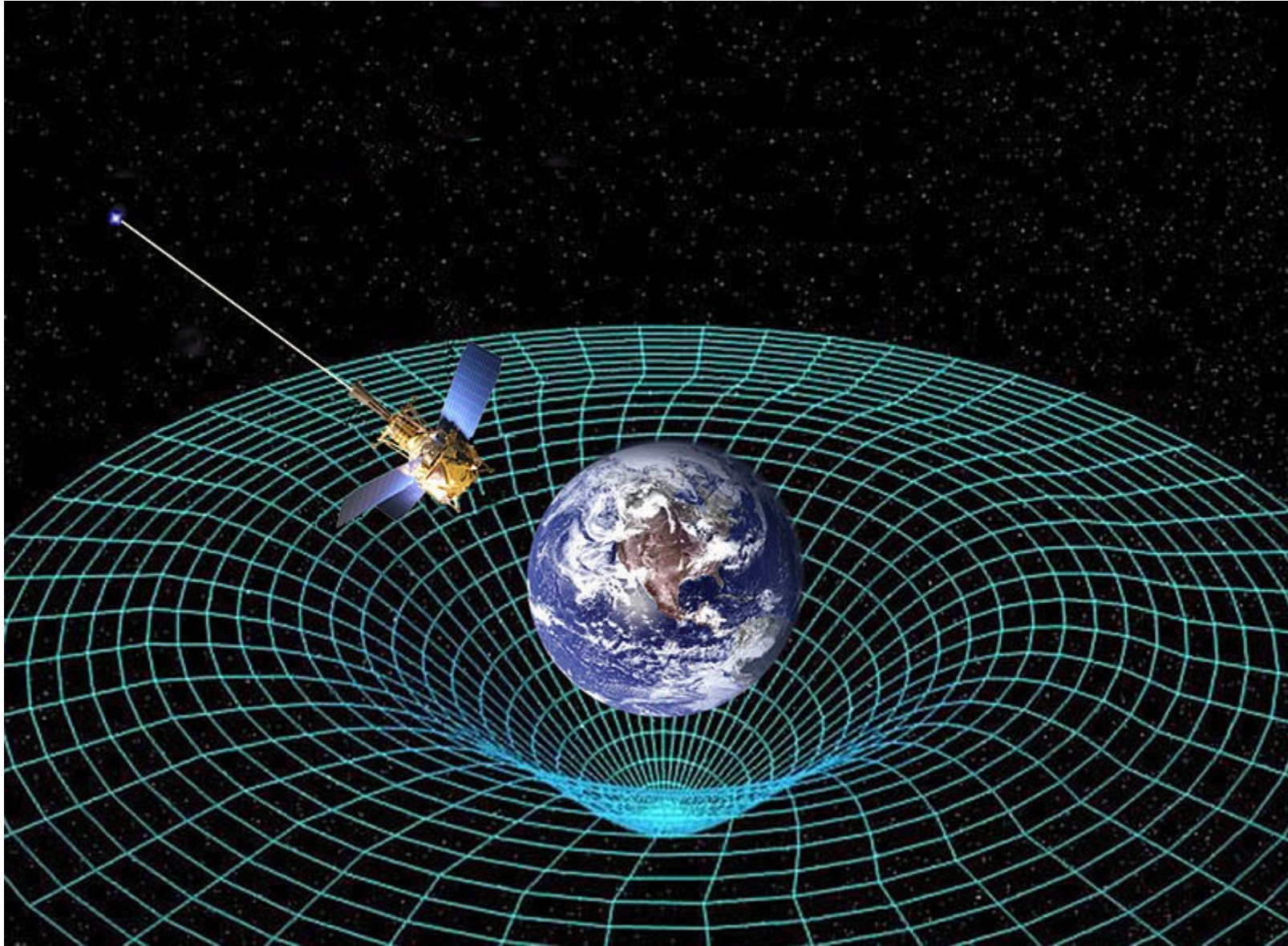
# GRAVITY

## UNIVERSO:

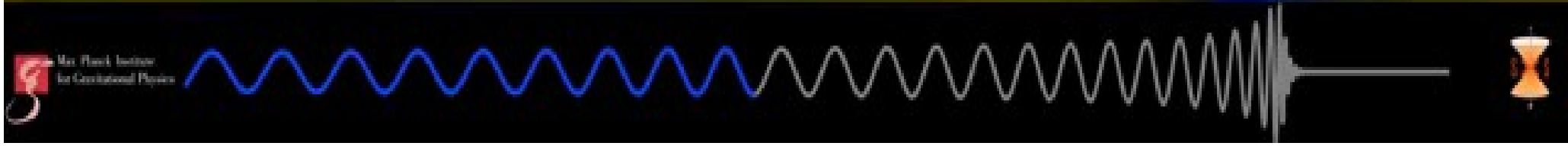
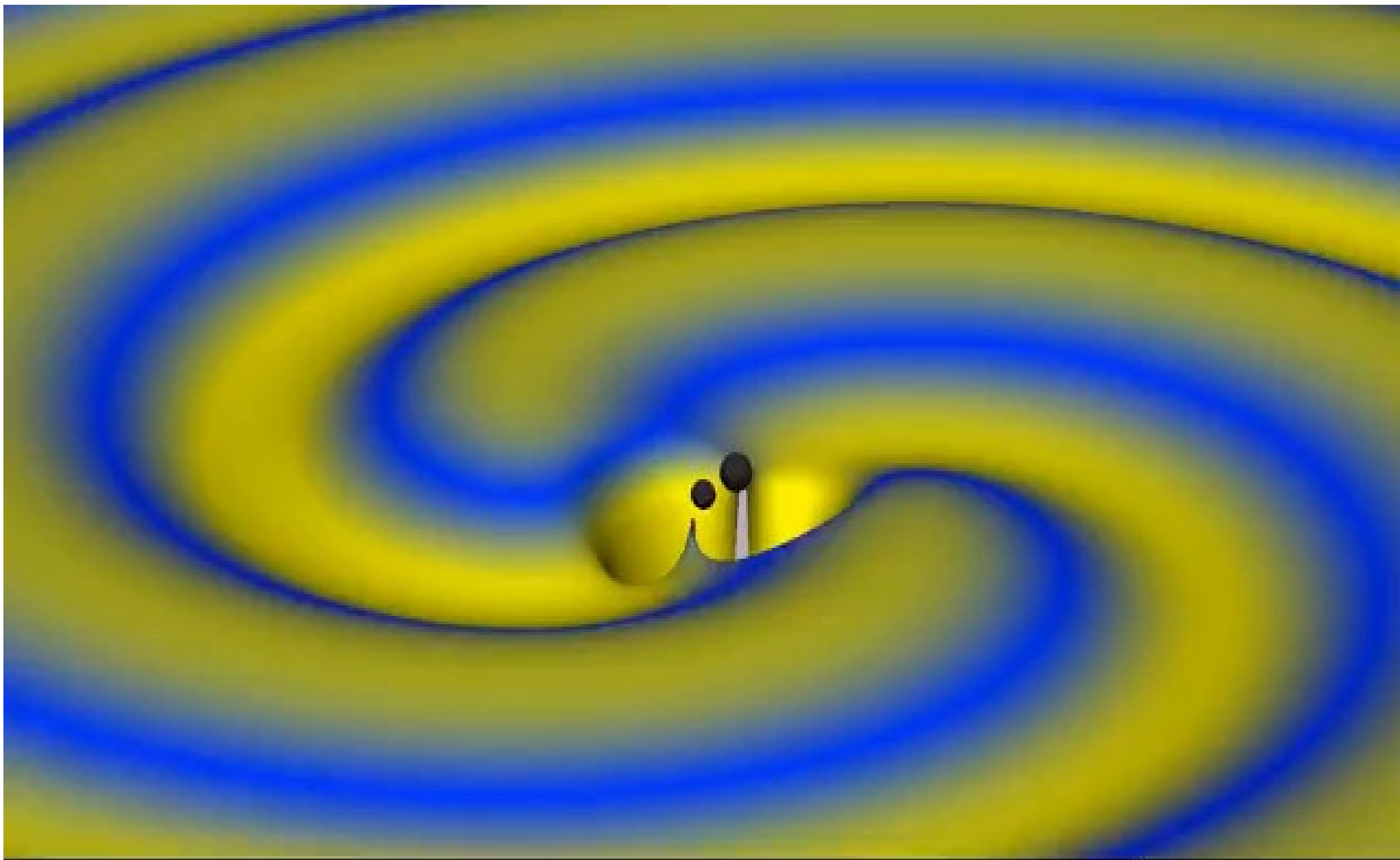
- $10^{22}$ - $10^{24}$  Stelle
- $\sim 10^{11}$ - $10^{12}$   
galassie
- Via Lattea  
 $\sim 10^{11}$ - $10^{12}$  stelle



## Spazio-tempo curvo

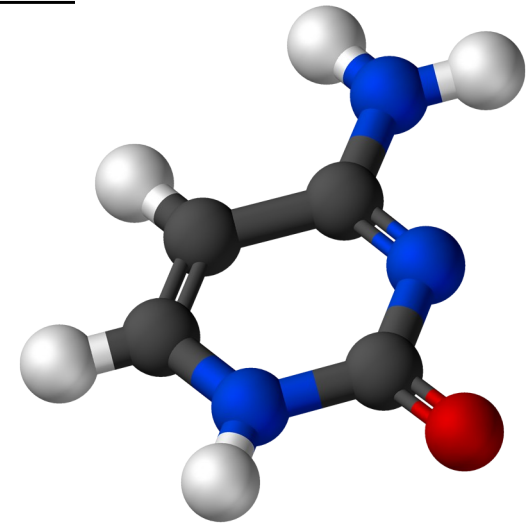


$$G^{\mu\nu} = 8\pi T^{\mu\nu}$$

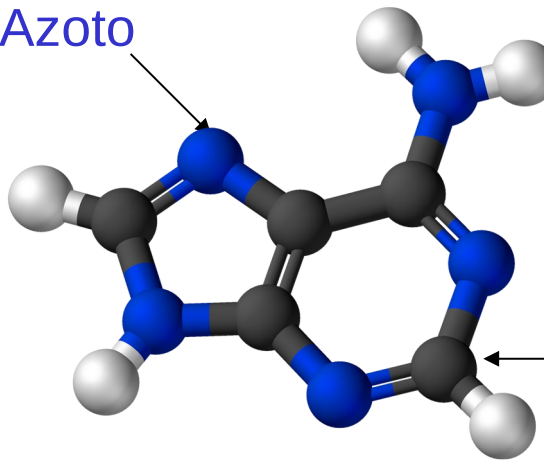


# FORZE ELETTROMAGNETICHE

Il nucleotide **Citosina**



Azoto

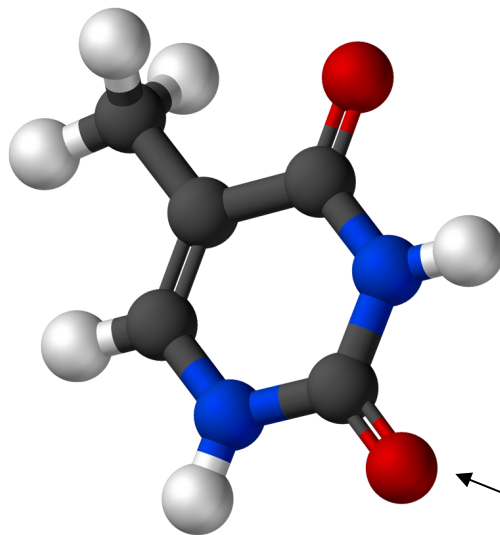


Idrogeno

Il nucleotide **Adenina**

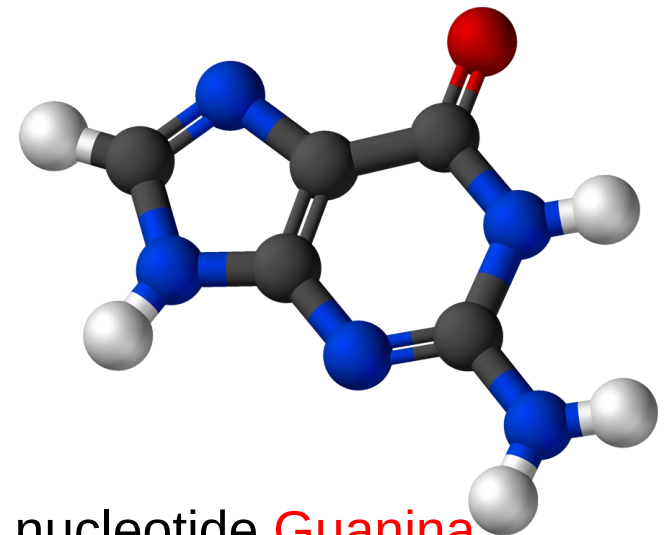
Carbonio

Il nucleotide **Timina**

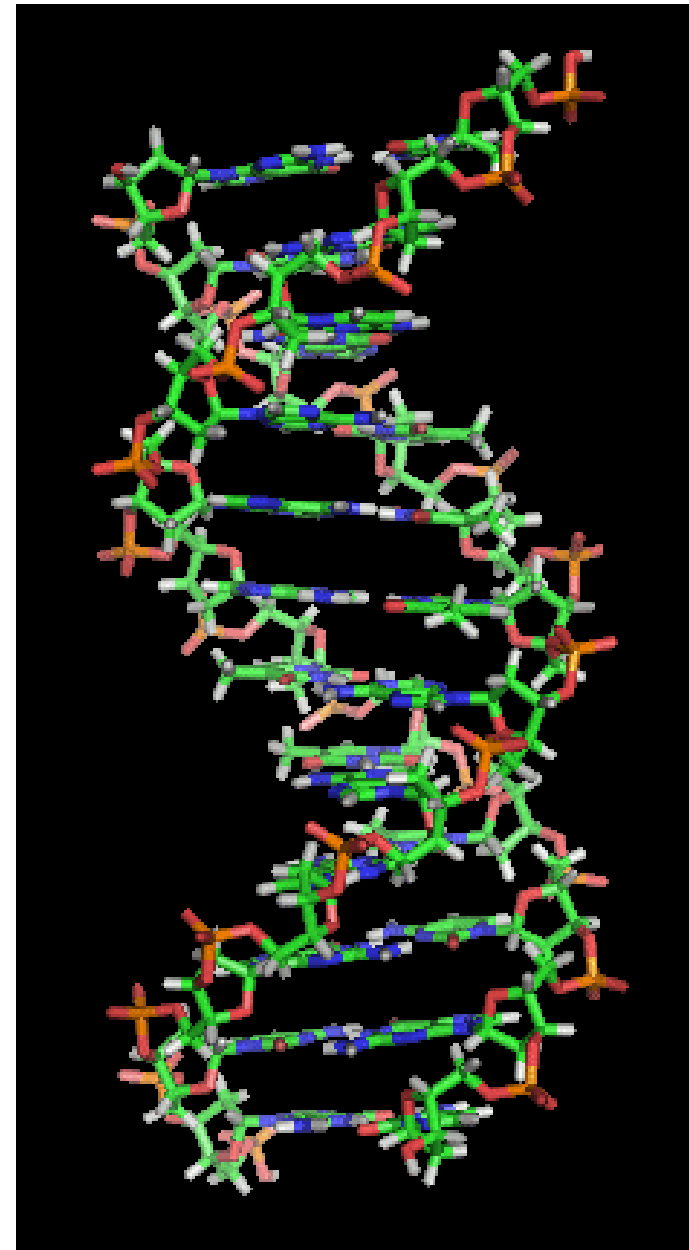
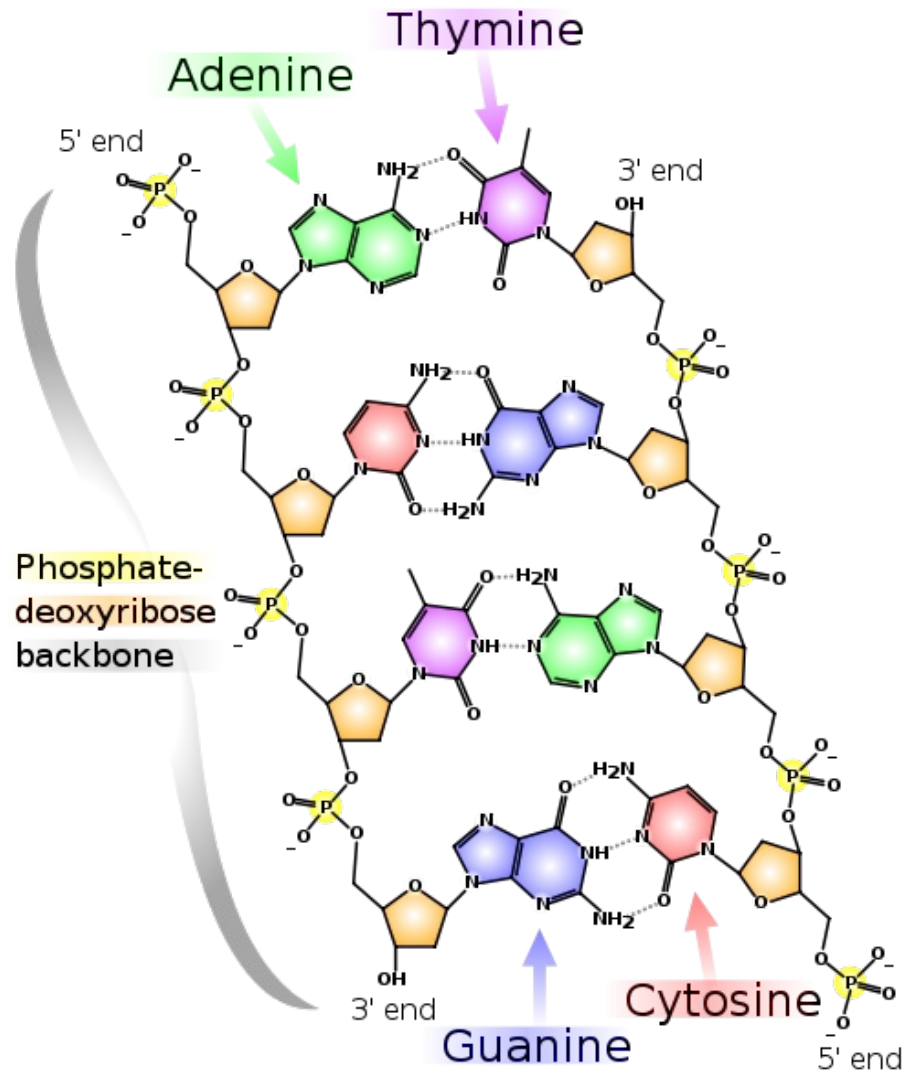


Ossigeno

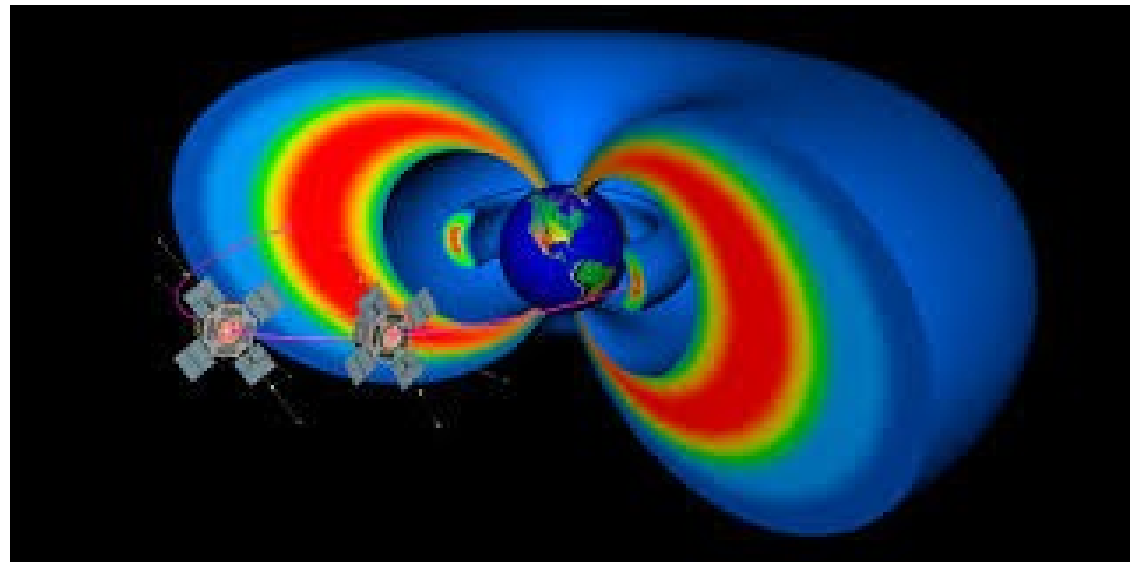
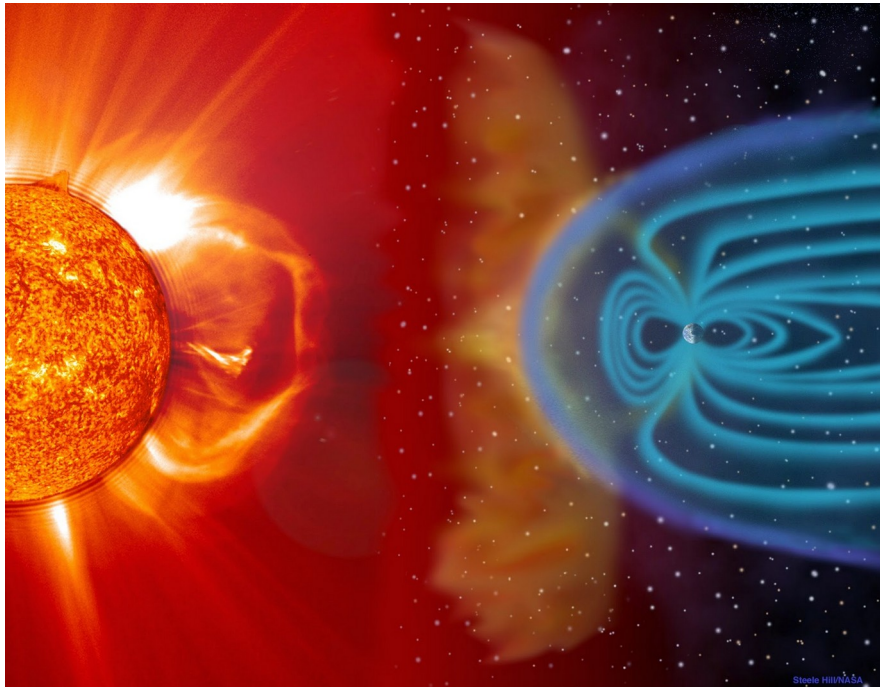
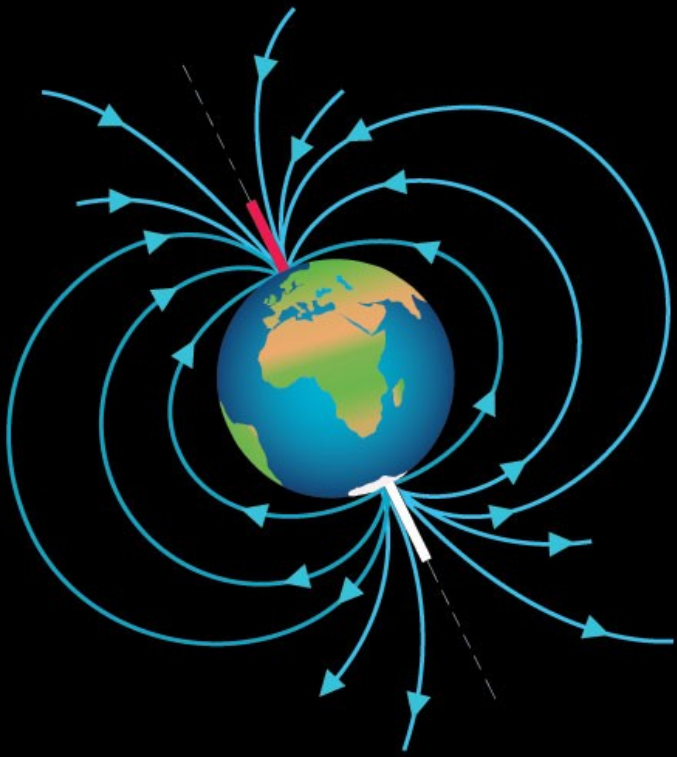
Il nucleotide **Guanina**



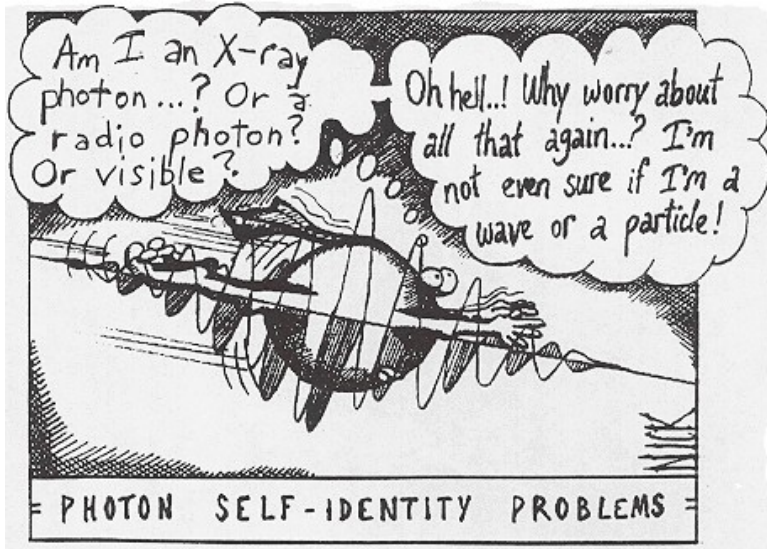
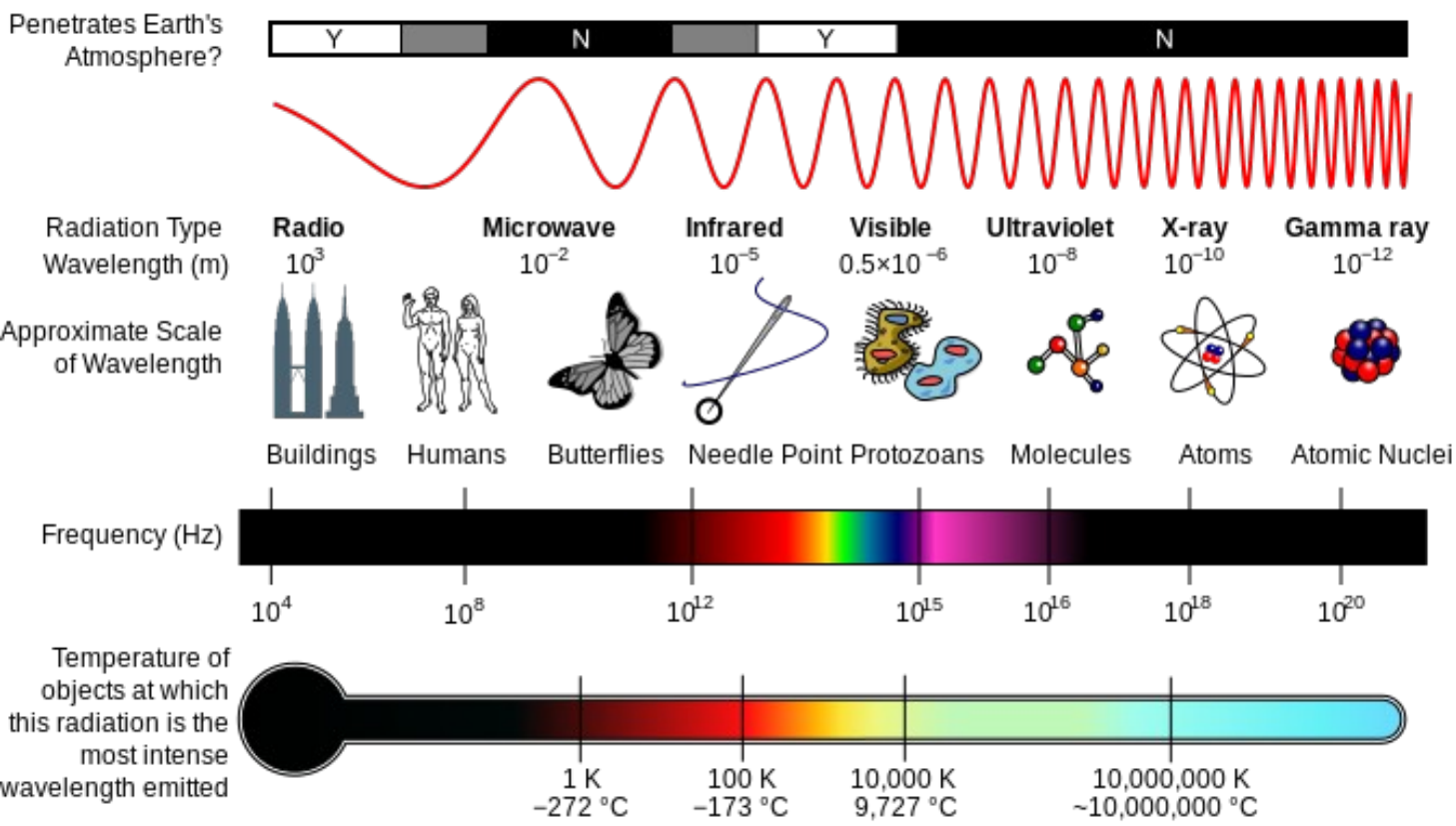
# DNA



**Campo magnetico terrestre:  
protegge la vita tramite la  
magnetosfera, mette a rischio  
quella degli astronauti nelle fasce  
di Van Allen.**



# Onde elettromagnetiche

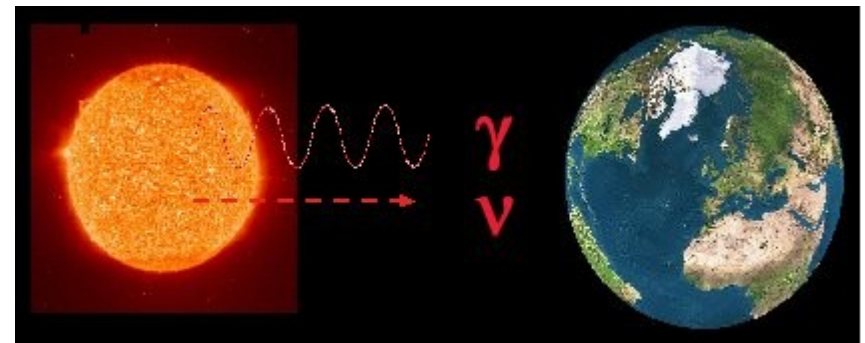
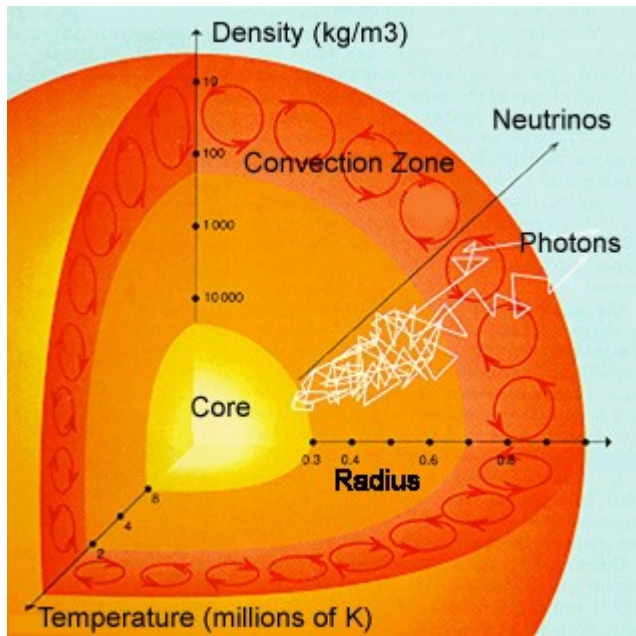


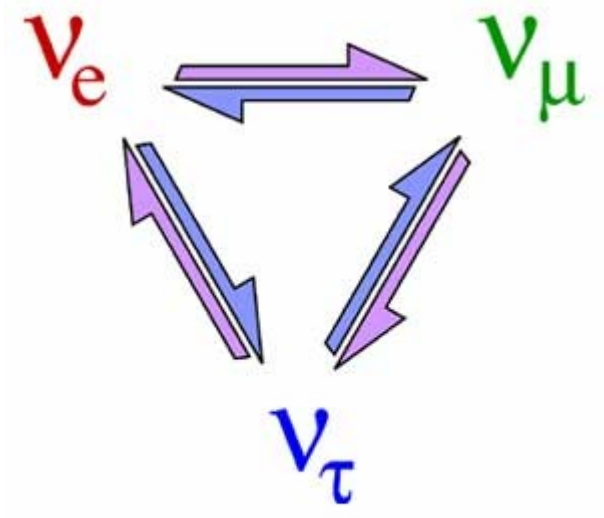
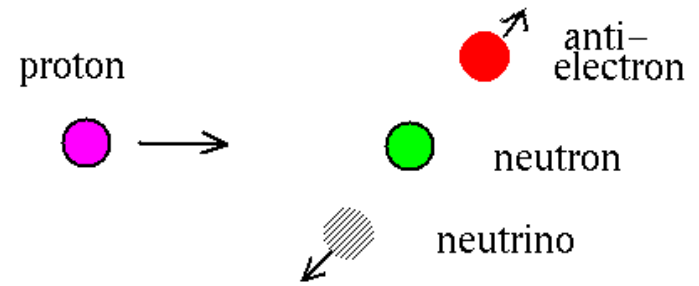
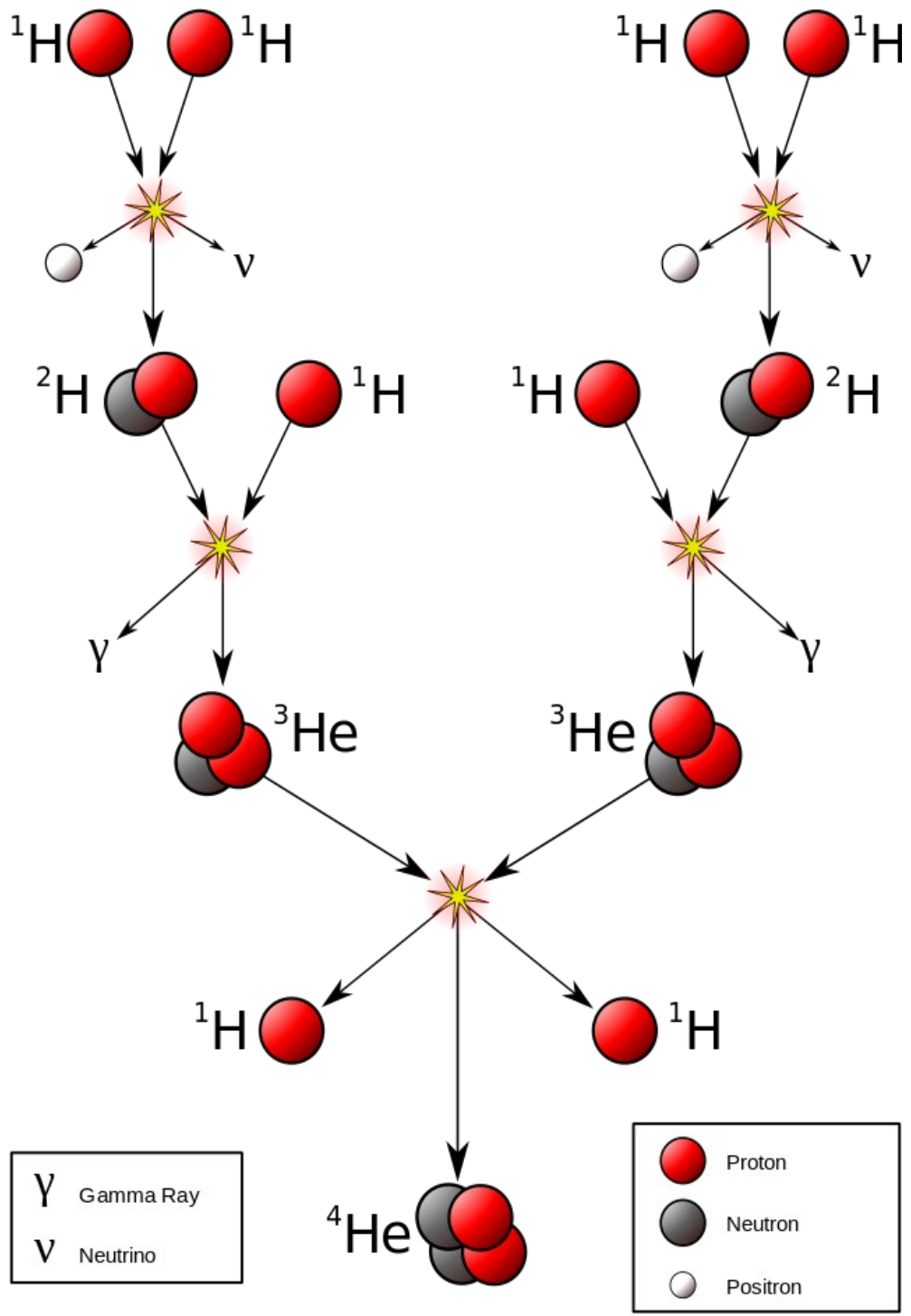
# INTERAZIONE FORTE E DEBOLE:





# Interazione debole: i neutrini solari





The periodic change of neutrino flavor from one type into another is referred to as neutrino oscillations.

## **Questioni non risolte dal modello standard:**

**1) Che cos'è la 'dark matter'?**

**2) Che cosa è successo all'antimateria dopo il big bang (l'attuale universo è fatto di materia ma le equazioni sono simmetriche)**

**3) Come includere la gravità nelle teorie quantistiche?**