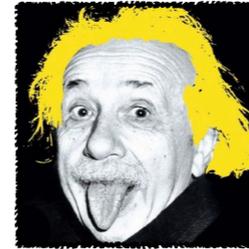


## Fisica delle Particelle, in Teoria ...

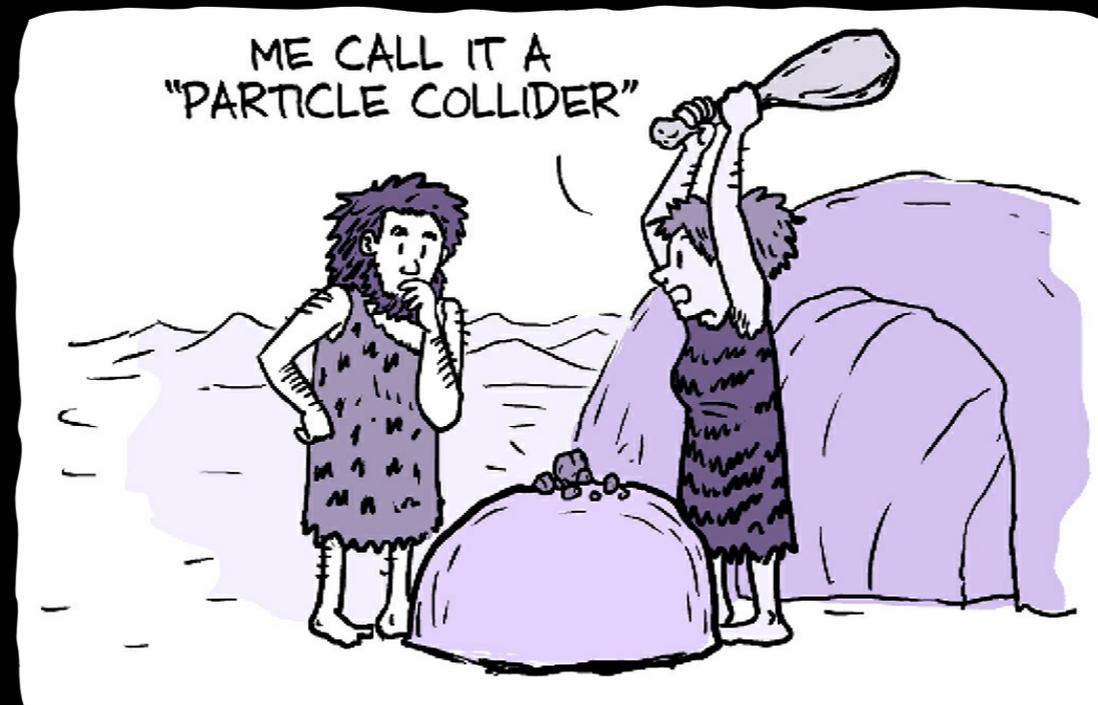


**MAURO VALLI**

---

INFN Rome





FISICI DELLE PARTICELLE AGLI ALBORI ...



... TEORICO?



... SPERIMENTALE!

# BIG QUESTIONS

- QUALE E' IL SIGNIFICATO DELL'ESISTENZA?
- COSA CI SARA' MAI OLTRE LA VITA?

CLASSICI DEL PENSIERO

Immanuel Kant

**Critica della  
ragion pura**

*a cura di Gustavo Bontadini*



Scholés

# BIG QUESTIONS

- QUALE E' IL SIGNIFICATO DELL'ESISTENZA?
- COSA CI SARA' MAI OLTRE LA VITA?
- LA VITA E' UN SOGNO ...  
... O I SOGNI AIUTANO A VIVERE?

**GIGI  
MARZULLO**

*Non ho capito la domanda*

**365** DUBBI E ROVELLI  
PER TUTTO L'ANNO

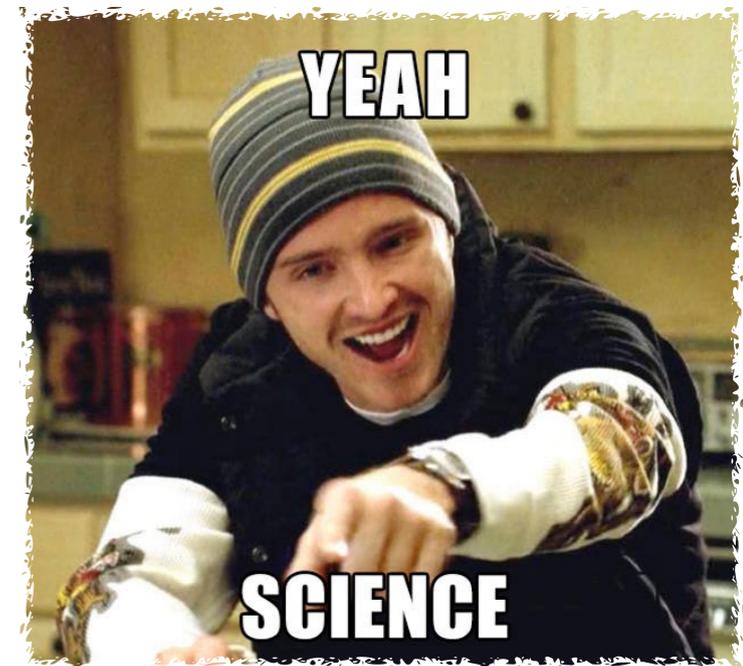


Rai Libri

# BIG QUESTIONS

- QUALE E' IL SIGNIFICATO DELL'ESISTENZA?
- COSA CI SARA' MAI OLTRE LA VITA?
- LA VITA E' UN SOGNO ...  
... O I SOGNI AIUTANO A VIVERE?

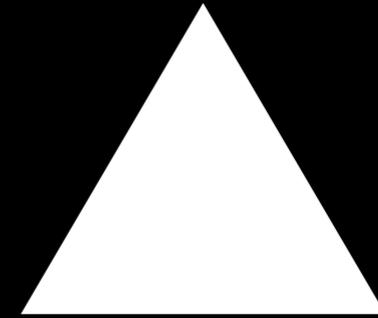
- DICHE COSA E' FATTO QUELLO CHE CI CIRCONDA?
- COME E' ORIGINATO E SI E' EVOLUTO L'UNIVERSO?



# IL METODO SCIENTIFICO

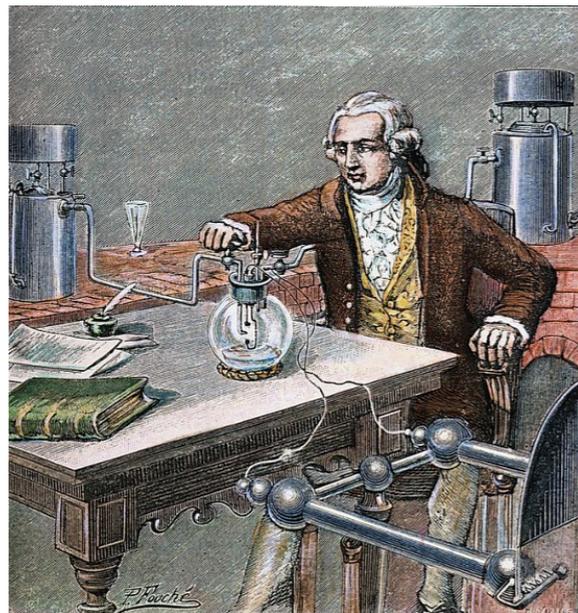


CONOSCENZA / PROGRESSO



TEORIA /  
PREDIZIONI

DATI /  
ESPERIMENTI



LAVOISIER : UN ELEMENTO  
E' UNA SOSTANZA NON  
SCOMPONIBILE NELLE VARIE  
REAZIONI CHIMICHE ...

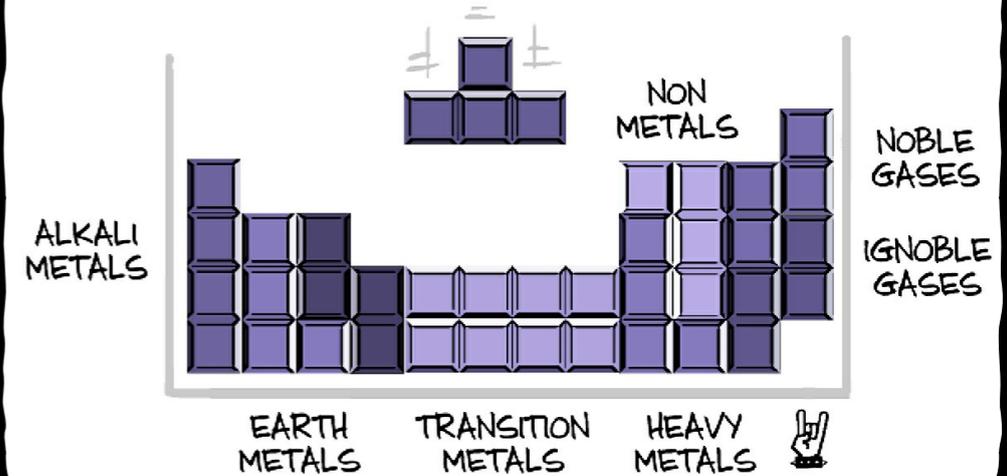
L'enorme varietà intorno a noi ... viene da solo un centinaio di elementi chimici!

### THE UNIVERSE:

- Me.
- You.
- That rock.
- That other rock.
- Those rocks over there.
- Etc.



### THE PERIODIC TABLE OF THE ELEMENTS (TETRIS VERSION)



## Tavola Periodica degli Elementi

Gruppo 1																	18	
Periodo 1	1.008 1312.0 2.20 1 H Idrogeno 1s <sup>1</sup>																	4.0026 2372.3 2 He Elio 1s <sup>2</sup>
2	6.94 520.2 0.98 3 Li Litio 1s <sup>2</sup> 2s <sup>1</sup>	9.0122 899.5 1.57 4 Be Berillio 1s <sup>2</sup> 2s <sup>2</sup>															20.180 2080.7 10 Ne Neon 1s <sup>2</sup> 2s <sup>2</sup> 2p <sup>6</sup>	
3	22.990 495.8 0.93 11 Na Sodio (Ne) 3s <sup>1</sup>	24.305 737.7 1.31 12 Mg Magnesio (Ne) 3s <sup>2</sup>															39.948 1520.6 18 Ar Argon (Ne) 3s <sup>2</sup> 3p <sup>6</sup>	
4	39.098 418.8 0.82 19 K Potassio (Ar) 4s <sup>1</sup>	40.078 589.8 1.00 20 Ca Calcio (Ar) 4s <sup>2</sup>	44.956 633.1 1.36 21 Sc Scandio (Ar) 3d <sup>1</sup> 4s <sup>2</sup>	47.867 658.8 1.54 22 Ti Titanio (Ar) 3d <sup>2</sup> 4s <sup>2</sup>	50.942 650.9 1.63 23 V Vanadio (Ar) 3d <sup>3</sup> 4s <sup>2</sup>	51.996 652.9 1.66 24 Cr Cromo (Ar) 3d <sup>5</sup> 4s <sup>1</sup>	54.938 717.3 1.55 25 Mn Manganese (Ar) 3d <sup>5</sup> 4s <sup>2</sup>	55.845 762.5 1.83 26 Fe Ferro (Ar) 3d <sup>6</sup> 4s <sup>2</sup>	58.933 726.5 1.83 27 Co Cobalto (Ar) 3d <sup>7</sup> 4s <sup>2</sup>	58.693 737.1 1.88 28 Ni Nichelio (Ar) 3d <sup>8</sup> 4s <sup>2</sup>	63.546 745.5 1.90 29 Cu Rame (Ar) 3d <sup>10</sup> 4s <sup>1</sup>	65.38 906.4 1.65 30 Zn Zinco (Ar) 3d <sup>10</sup> 4s <sup>2</sup>	69.723 578.8 1.81 31 Ga Gallio (Ar) 3d <sup>10</sup> 4s <sup>2</sup> 4p <sup>1</sup>	72.630 762.0 2.01 32 Ge Germanio (Ar) 3d <sup>10</sup> 4s <sup>2</sup> 4p <sup>2</sup>	74.922 947.0 2.18 33 As Arsenico (Ar) 3d <sup>10</sup> 4s <sup>2</sup> 4p <sup>3</sup>	78.971 941.0 2.55 34 Se Selenio (Ar) 3d <sup>10</sup> 4s <sup>2</sup> 4p <sup>4</sup>	79.904 1139.9 2.96 35 Br Bromo (Ar) 3d <sup>10</sup> 4s <sup>2</sup> 4p <sup>5</sup>	83.798 1350.8 3.00 36 Kr Kriptone (Ar) 3d <sup>10</sup> 4s <sup>2</sup> 4p <sup>6</sup>
5	85.468 403.0 0.82 37 Rb Rubidio (Kr) 5s <sup>1</sup>	87.62 549.5 0.95 38 Sr Stronzio (Kr) 5s <sup>2</sup>	88.906 600.0 1.22 39 Y Ittrio (Kr) 4d <sup>1</sup> 5s <sup>2</sup>	91.224 640.1 1.33 40 Zr Zirconio (Kr) 4d <sup>2</sup> 5s <sup>2</sup>	92.906 652.1 1.60 41 Nb Niobio (Kr) 4d <sup>4</sup> 5s <sup>1</sup>	95.95 684.3 2.16 42 Mo Molibdeno (Kr) 4d <sup>5</sup> 5s <sup>1</sup>	(98) 702.0 1.90 43 Tc Tecnezio (Kr) 4d <sup>5</sup> 5s <sup>2</sup>	101.07 712.3 1.55 44 Ru Rutenio (Kr) 4d <sup>7</sup> 5s <sup>1</sup>	102.91 719.7 2.28 45 Rh Rodio (Kr) 4d <sup>8</sup> 5s <sup>1</sup>	106.42 804.4 2.20 46 Pd Palladio (Kr) 4d <sup>10</sup>	107.87 731.0 1.93 47 Ag Argento (Kr) 4d <sup>10</sup> 5s <sup>1</sup>	112.41 867.8 1.69 48 Cd Cadmio (Kr) 4d <sup>10</sup> 5s <sup>2</sup>	114.82 558.3 1.78 49 In Indio (Kr) 4d <sup>10</sup> 5s <sup>2</sup> 5p <sup>1</sup>	118.71 708.6 1.96 50 Sn Stagno (Kr) 4d <sup>10</sup> 5s <sup>2</sup> 5p <sup>2</sup>	121.76 834.0 2.05 51 Sb Antimonio (Kr) 4d <sup>10</sup> 5s <sup>2</sup> 5p <sup>3</sup>	127.60 869.3 2.10 52 Te Tellurio (Kr) 4d <sup>10</sup> 5s <sup>2</sup> 5p <sup>4</sup>	126.90 1008.4 2.66 53 I Iodio (Kr) 4d <sup>10</sup> 5s <sup>2</sup> 5p <sup>5</sup>	131.29 1170.4 2.60 54 Xe Xenone (Kr) 4d <sup>10</sup> 5s <sup>2</sup> 5p <sup>6</sup>
6	132.91 375.7 0.79 55 Cs Cesio (Xe) 6s <sup>1</sup>	137.33 502.9 0.89 56 Ba Bario (Xe) 6s <sup>2</sup>	174.97 523.5 1.27 71 Lu Lutezio (Xe) 4f <sup>14</sup> 5d <sup>1</sup> 6s <sup>2</sup>	178.49 658.5 1.30 72 Hf Afnio (Xe) 4f <sup>14</sup> 5d <sup>2</sup> 6s <sup>2</sup>	180.95 761.0 1.50 73 Ta Tantalio (Xe) 4f <sup>14</sup> 5d <sup>3</sup> 6s <sup>2</sup>	183.84 770.0 2.36 74 W Tungsteno (Xe) 4f <sup>14</sup> 5d <sup>4</sup> 6s <sup>2</sup>	186.21 760.0 1.90 75 Re Renio (Xe) 4f <sup>14</sup> 5d <sup>5</sup> 6s <sup>2</sup>	190.23 840.0 2.20 76 Os Osmio (Xe) 4f <sup>14</sup> 5d <sup>6</sup> 6s <sup>2</sup>	192.22 880.0 2.28 77 Ir Iridio (Xe) 4f <sup>14</sup> 5d <sup>7</sup> 6s <sup>2</sup>	195.08 870.0 2.28 78 Pt Platino (Xe) 4f <sup>14</sup> 5d <sup>9</sup> 6s <sup>1</sup>	196.97 890.1 2.54 79 Au Oro (Xe) 4f <sup>14</sup> 5d <sup>10</sup> 6s <sup>1</sup>	200.59 1007.1 2.00 80 Hg Mercurio (Xe) 4f <sup>14</sup> 5d <sup>10</sup> 6s <sup>2</sup>	204.38 589.4 1.62 81 Tl Tallio (Xe) 4f <sup>14</sup> 5d <sup>10</sup> 6s <sup>2</sup> 6p <sup>1</sup>	207.2 715.6 2.33 82 Pb Piombo (Xe) 4f <sup>14</sup> 5d <sup>10</sup> 6s <sup>2</sup> 6p <sup>2</sup>	208.98 703.0 2.02 83 Bi Bismuto (Xe) 4f <sup>14</sup> 5d <sup>10</sup> 6s <sup>2</sup> 6p <sup>3</sup>	(210) 812.1 2.00 84 Po Polonio (Xe) 4f <sup>14</sup> 5d <sup>10</sup> 6s <sup>2</sup> 6p <sup>4</sup>	(210) 890.0 2.20 85 At Astatio (Xe) 4f <sup>14</sup> 5d <sup>10</sup> 6s <sup>2</sup> 6p <sup>5</sup>	(220) 1037.0 2.60 86 Rn Radone (Xe) 4f <sup>14</sup> 5d <sup>10</sup> 6s <sup>2</sup> 6p <sup>6</sup>
7	(223) 380.0 0.70 87 Fr Francio (Rn) 7s <sup>1</sup>	(226) 509.3 0.90 88 Ra Radio (Rn) 7s <sup>2</sup>	(262) 470.0 1.3 103 Lr Laurenzio (Rn) 5f <sup>14</sup> 6d <sup>1</sup> 7s <sup>2</sup>	(261) 580.0 1.4 104 Rf Rutherfordio (Rn) 5f <sup>14</sup> 6d <sup>2</sup> 7s <sup>2</sup>	(262) 580.0 1.4 105 Db Dubnio (Rn) 5f <sup>14</sup> 6d <sup>3</sup> 7s <sup>2</sup>	(266) 580.0 1.4 106 Sg Seaborgio (Rn) 5f <sup>14</sup> 6d <sup>4</sup> 7s <sup>2</sup>	(264) 580.0 1.4 107 Bh Bohrio (Rn) 5f <sup>14</sup> 6d <sup>5</sup> 7s <sup>2</sup>	(277) 580.0 1.4 108 Hs Hassio (Rn) 5f <sup>14</sup> 6d <sup>6</sup> 7s <sup>2</sup>	(268) 580.0 1.4 109 Mt Meitnerio (Rn) 5f <sup>14</sup> 6d <sup>7</sup> 7s <sup>2</sup>	(271) 580.0 1.4 110 Ds Darmstadtio (Rn) 5f <sup>14</sup> 6d <sup>8</sup> 7s <sup>2</sup>	(272) 580.0 1.4 111 Rg Roentgenio (Rn) 5f <sup>14</sup> 6d <sup>9</sup> 7s <sup>2</sup>	(285) 580.0 1.4 112 Cn Copernicio (Rn) 5f <sup>14</sup> 6d <sup>10</sup> 7s <sup>2</sup>	(284) 580.0 1.4 113 Nh Nihonio (Rn) 5f <sup>14</sup> 6d <sup>10</sup> 7s <sup>2</sup> 7p <sup>1</sup>	(289) 580.0 1.4 114 Fl Flerovio (Rn) 5f <sup>14</sup> 6d <sup>10</sup> 7s <sup>2</sup> 7p <sup>2</sup>	(288) 580.0 1.4 115 Mc Moscovio (Rn) 5f <sup>14</sup> 6d <sup>10</sup> 7s <sup>2</sup> 7p <sup>3</sup>	(292) 580.0 1.4 116 Lv Livermorio (Rn) 5f <sup>14</sup> 6d <sup>10</sup> 7s <sup>2</sup> 7p <sup>4</sup>	(294) 580.0 1.4 117 Ts Tennesso (Rn) 5f <sup>14</sup> 6d <sup>10</sup> 7s <sup>2</sup> 7p <sup>5</sup>	(294) 580.0 1.4 118 Og Oganesson (Rn) 5f <sup>14</sup> 6d <sup>10</sup> 7s <sup>2</sup> 7p <sup>6</sup>

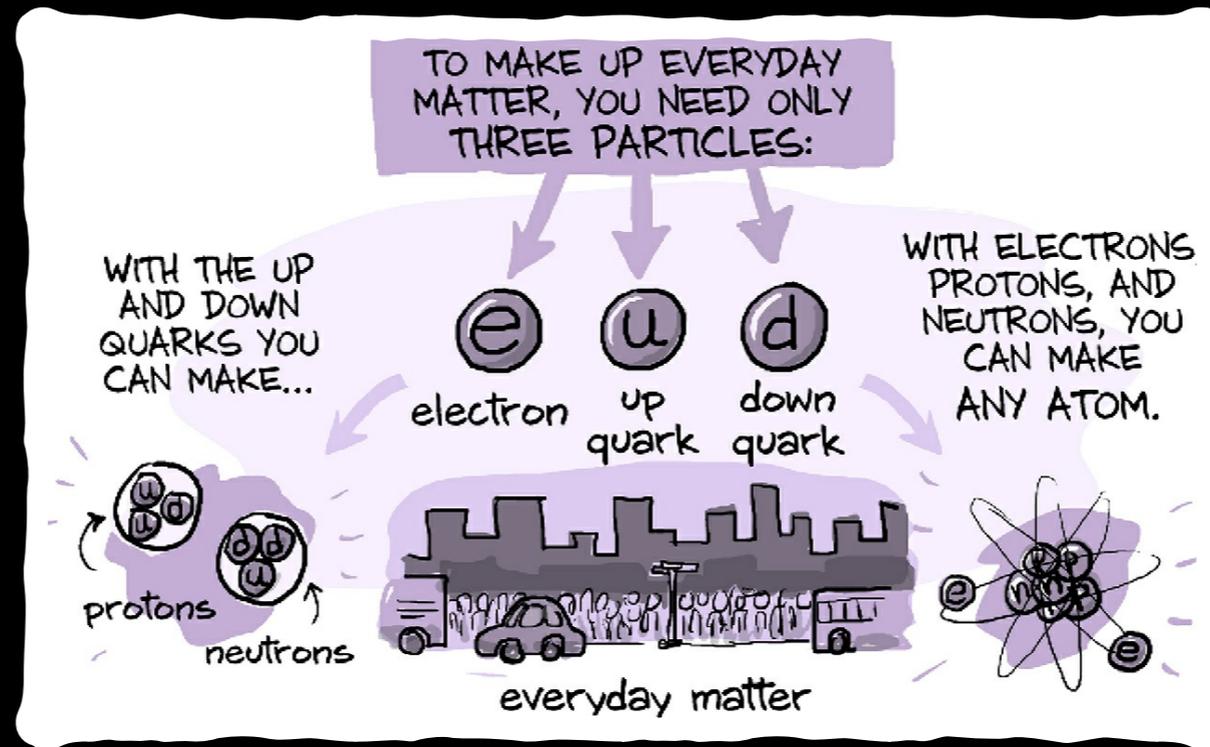
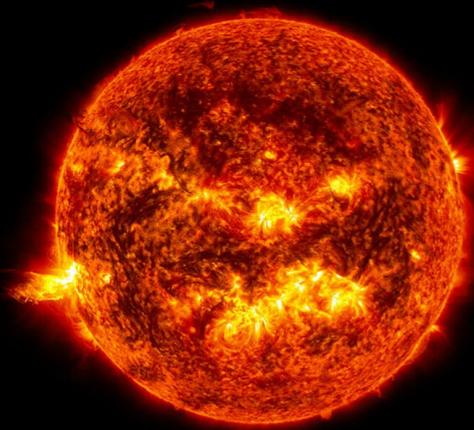


#### Note

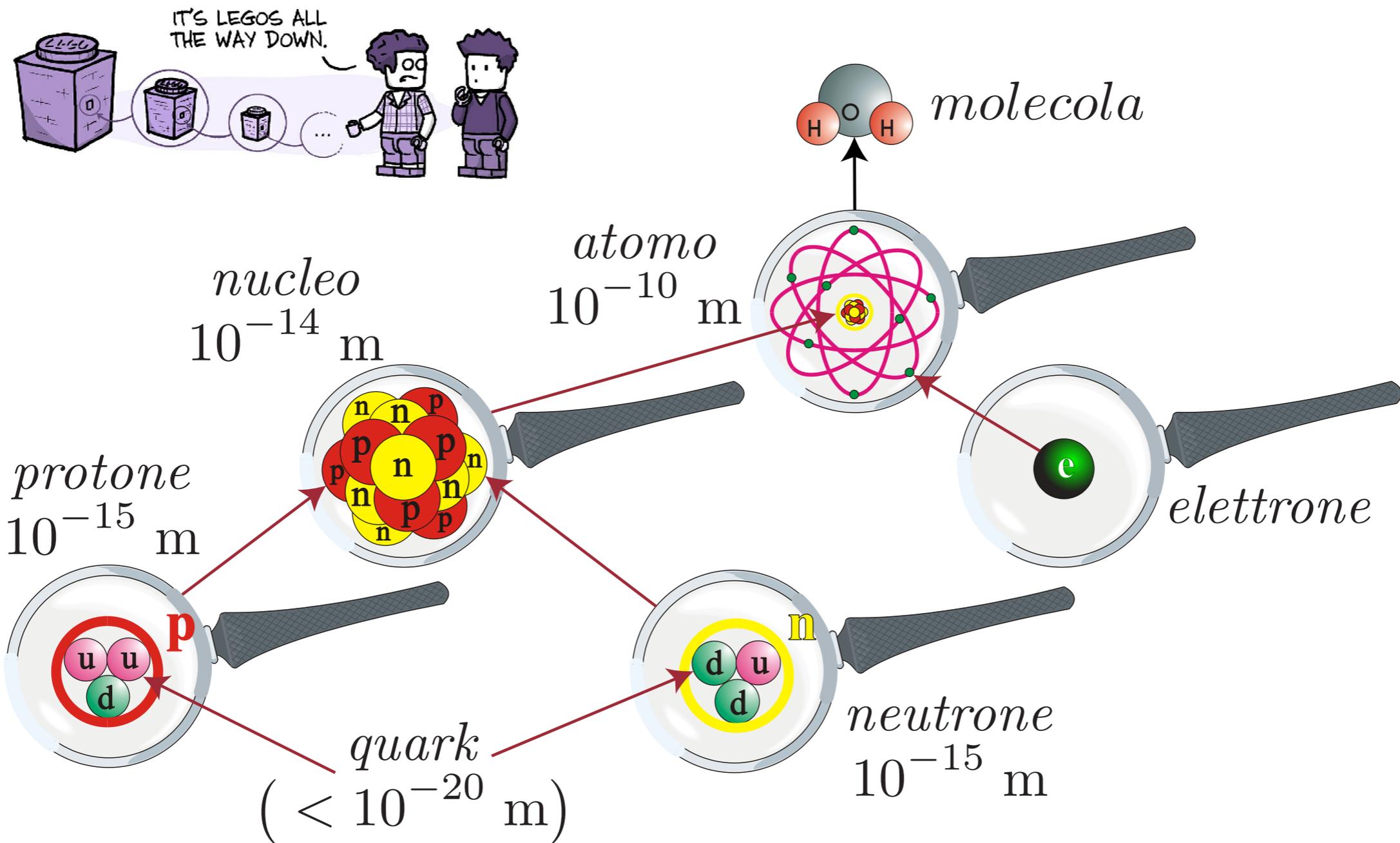
- 1 kJ/mol ≈ 0.0103636 eV
- tutti gli elementi sono implicati a avere l'ossidazione di zero.

- metalli alcalini
- metalli alcalino terrosi
- lantanoidi
- metalli di transizione
- proprietà sconosciute
- metalli di post-transizione
- metalloidi
- non metalli reattivi
- gas nobili
- attinoidi

# MATERIA << ORDINARIA >>



# DALLA MATERIA << ORDINARIA >> ...



... ALLA FISICA DELLE PARTICELLE!

L'ENORME VARIETÀ INTORNO A NOI ...  
... VIENE SOLO DA 3 PARTICELLE!

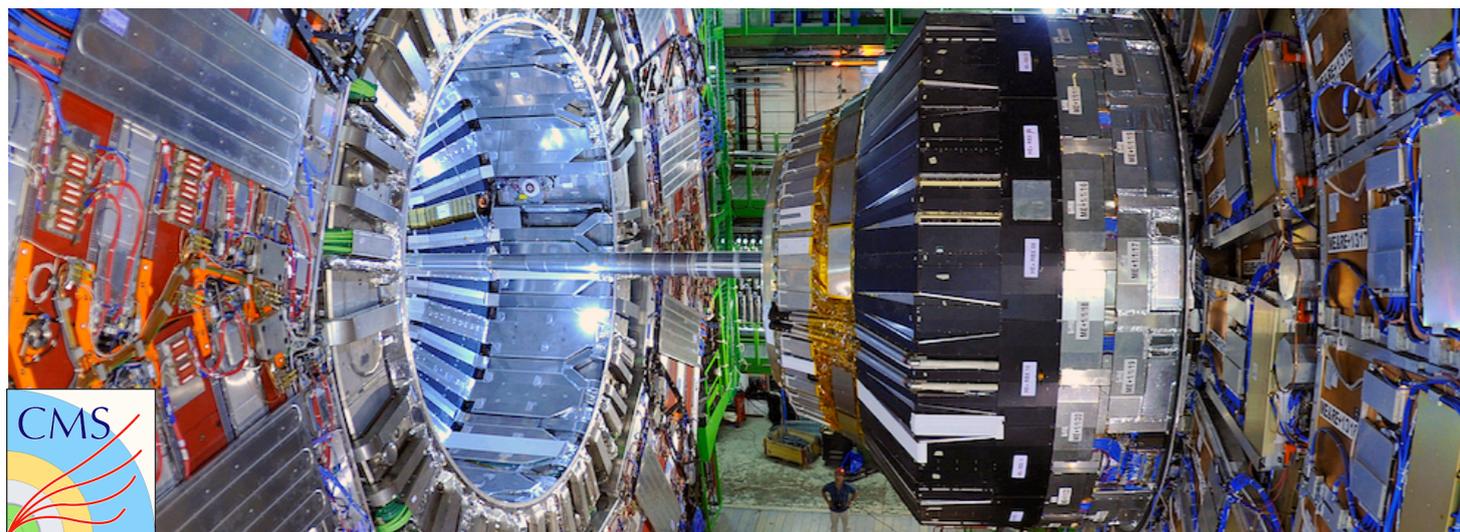
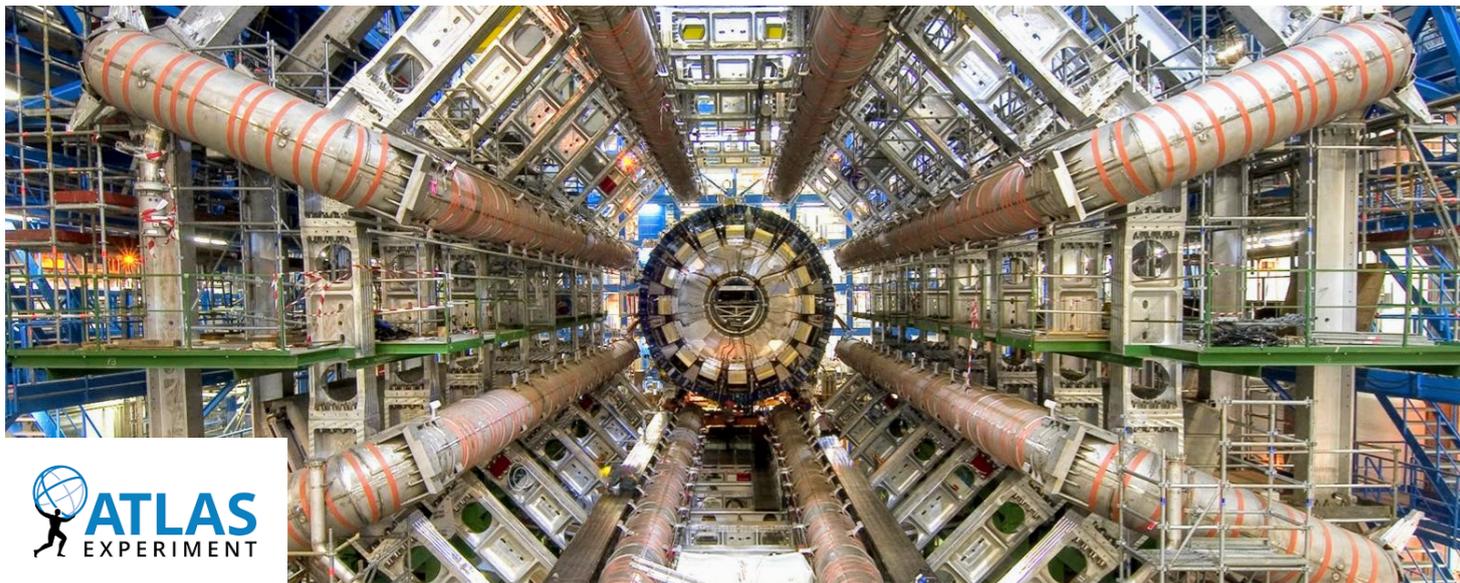


... UH-UUUH, MIITICO!!!

... BEH, SI' ... PERO', A DIRE IL VERO ... NON PROPRIO ...



# LA TAVOLA PERIODICA (QUELLA AGGIORNATA)



	$massa \rightarrow \approx 2.3 \text{ MeV}/c^2$ $carica \rightarrow \frac{2}{3}$ $spin \rightarrow \frac{1}{2}$	$\approx 1.275 \text{ GeV}/c^2$ $\frac{2}{3}$ $\frac{1}{2}$	$\approx 173.07 \text{ GeV}/c^2$ $\frac{2}{3}$ $\frac{1}{2}$
	<b>u</b> <i>up</i>	<b>c</b> <i>charm</i>	<b>t</b> <i>top</i>
Quark	$\approx 4.8 \text{ MeV}/c^2$ $-\frac{1}{3}$ $\frac{1}{2}$	$\approx 95 \text{ MeV}/c^2$ $-\frac{1}{3}$ $\frac{1}{2}$	$\approx 4.18 \text{ GeV}/c^2$ $-\frac{1}{3}$ $\frac{1}{2}$
	<b>d</b> <i>down</i>	<b>s</b> <i>strange</i>	<b>b</b> <i>bottom</i>
	$0.511 \text{ MeV}/c^2$ $-1$ $\frac{1}{2}$	$105.7 \text{ MeV}/c^2$ $-1$ $\frac{1}{2}$	$1.777 \text{ GeV}/c^2$ $-1$ $\frac{1}{2}$
	<b>e</b> <i>elettrone</i>	<b><math>\mu</math></b> <i>muone</i>	<b><math>\tau</math></b> <i>tauone</i>
Leptoni	$< 2.2 \text{ eV}/c^2$ $0$ $\frac{1}{2}$	$< 0.17 \text{ MeV}/c^2$ $0$ $\frac{1}{2}$	$< 15.5 \text{ MeV}/c^2$ $0$ $\frac{1}{2}$
	<b><math>\nu_e</math></b> <i>neutrino elettronico</i>	<b><math>\nu_\mu</math></b> <i>neutrino muonico</i>	<b><math>\nu_\tau</math></b> <i>neutrino tauonico</i>

# THE "FUNDAMENTAL" MATTER PARTICLES

1<sup>st</sup> GENERATION   2<sup>nd</sup> GENERATION   3<sup>rd</sup> GENERATION   CHARGE

QUARKS: 	UP 	CHARM 	TOP 	+2/3
	DOWN 	STRANGE 	BOTTOM 	-1/3
LEPTONS: 	ELECTRON 	MUON 	TAU 	-1
	$\nu_{\text{ELECTRON}}$ 	$\nu_{\text{MUON}}$ 	$\nu_{\text{TAU}}$ 	0

SOME MASS   MORE MASS   EVEN MORE MASS 

i) E' LA TABELLA << DEFINITIVA >> ?

ii) PERCHE' BEN DUE COPIE IN PIU' ?

... copie pesanti ... ed ancora più pesanti?!

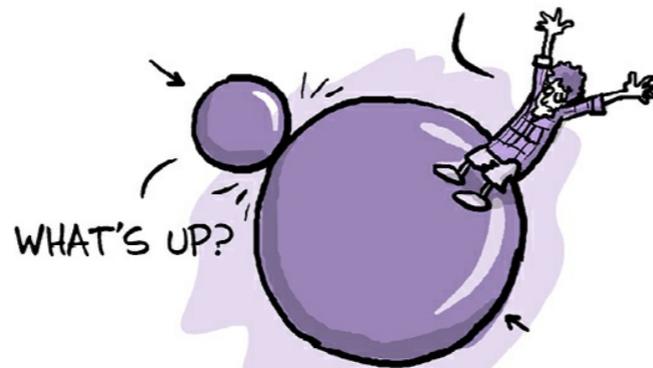
... particelle quark con carica frazionaria ?!

SONO QUESTI I MATTONCINI FONDAMENTALI  
PER COSTRUIRE IL NOSTRO UNIVERSO?

# Beh ... non ci scordiamo delle 4 FORZE FONDAMENTALI!

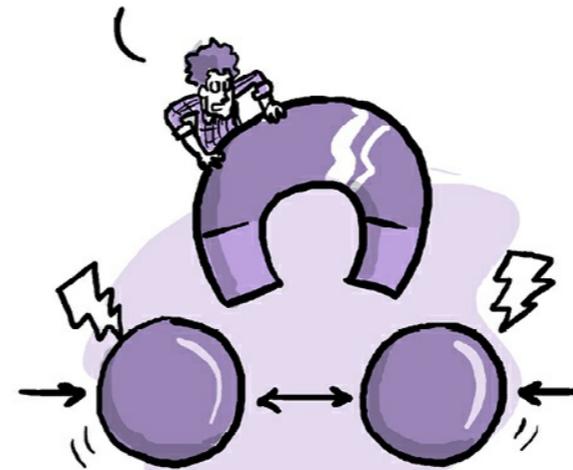
## THE 4 MAJOR WAYS THAT THINGS INTERACT:

IF YOU HAVE ANY MASS AT ALL, THINGS GET ATTRACTED.

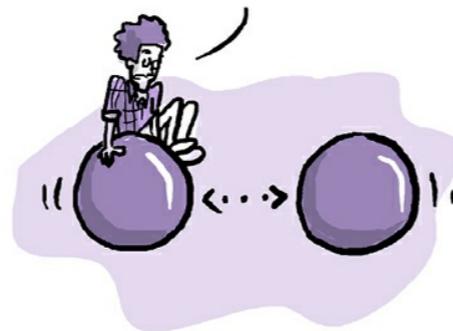


GRAVITY

TWO CHARGES ATTRACT OR REPEL EACH OTHER.

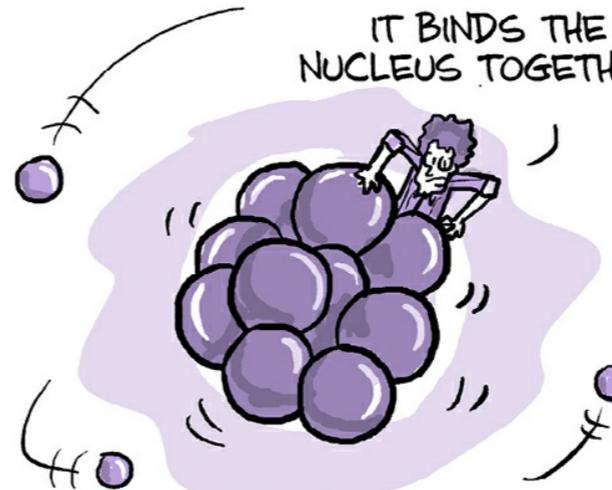


IT'S LIKE ELECTROMAGNETIC FORCES, BUT MUCH, MUCH WEAKER.



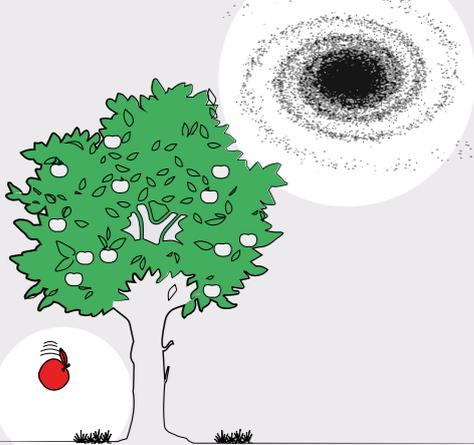
WEAK FORCE

IT BINDS THE NUCLEUS TOGETHER.

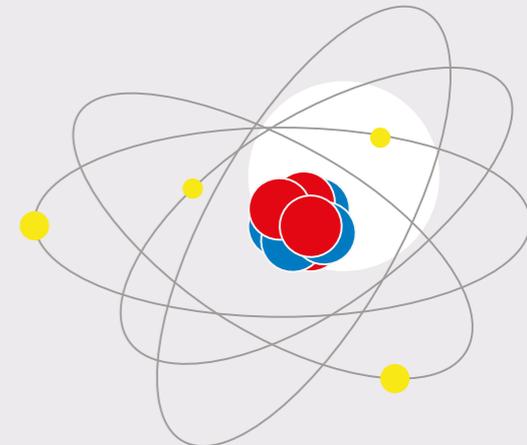


STRONG FORCE

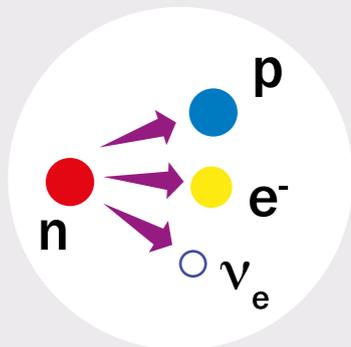
INTERAZIONE GRAVITAZIONALE  
Raggio d'azione infinito



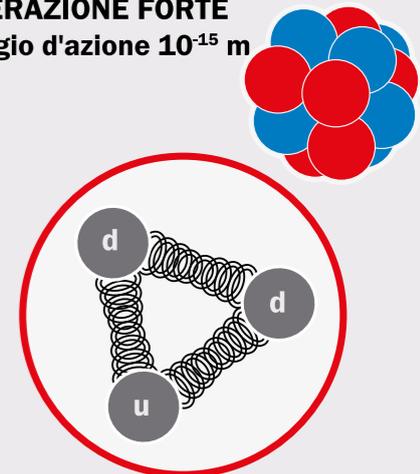
INTERAZIONE ELETTROMAGNETICA  
Raggio d'azione infinito

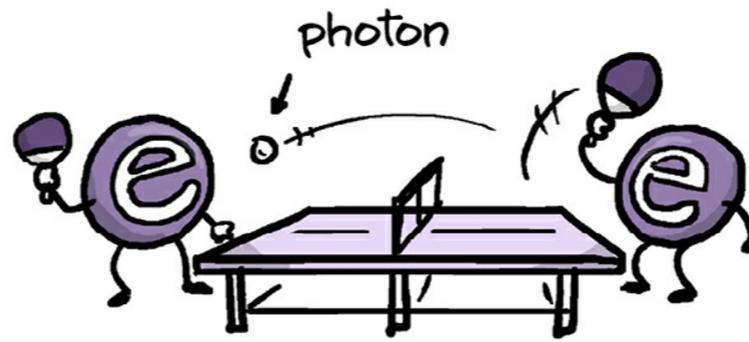


INTERAZIONE DEBOLE  
Raggio d'azione  $10^{-17}$  m



INTERAZIONE FORTE  
Raggio d'azione  $10^{-15}$  m



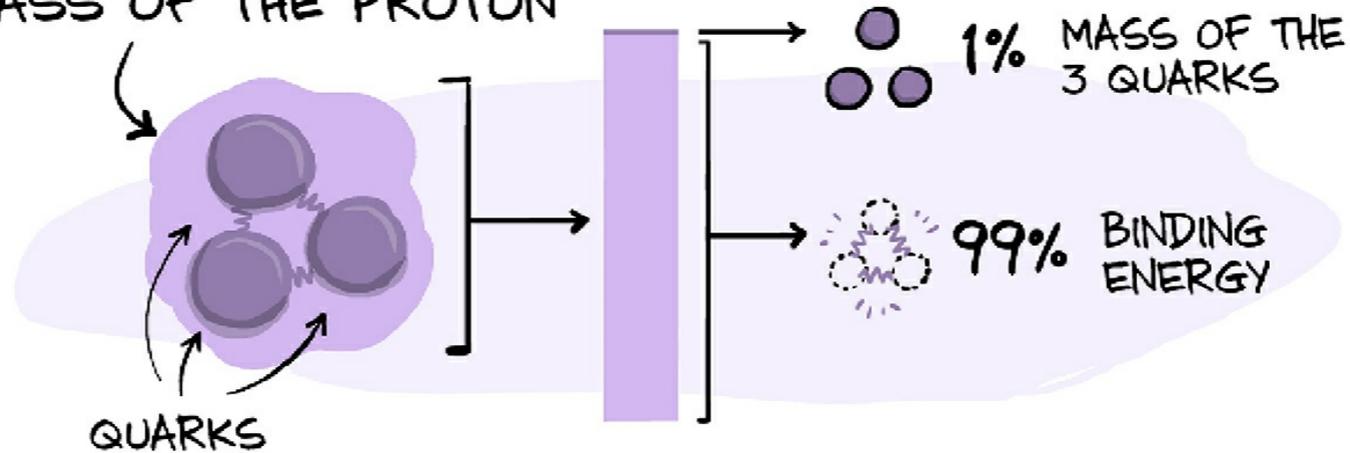


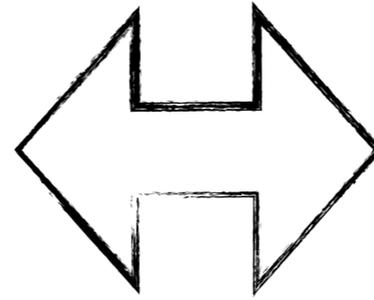
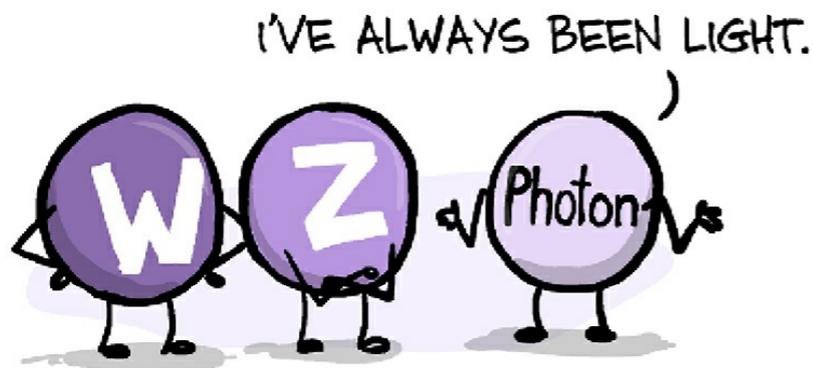
A NOT-THAT-INACCURATE DEPICTION OF PARTICLE FORCE INTERACTION

## FORCE CARRIER PARTICLES

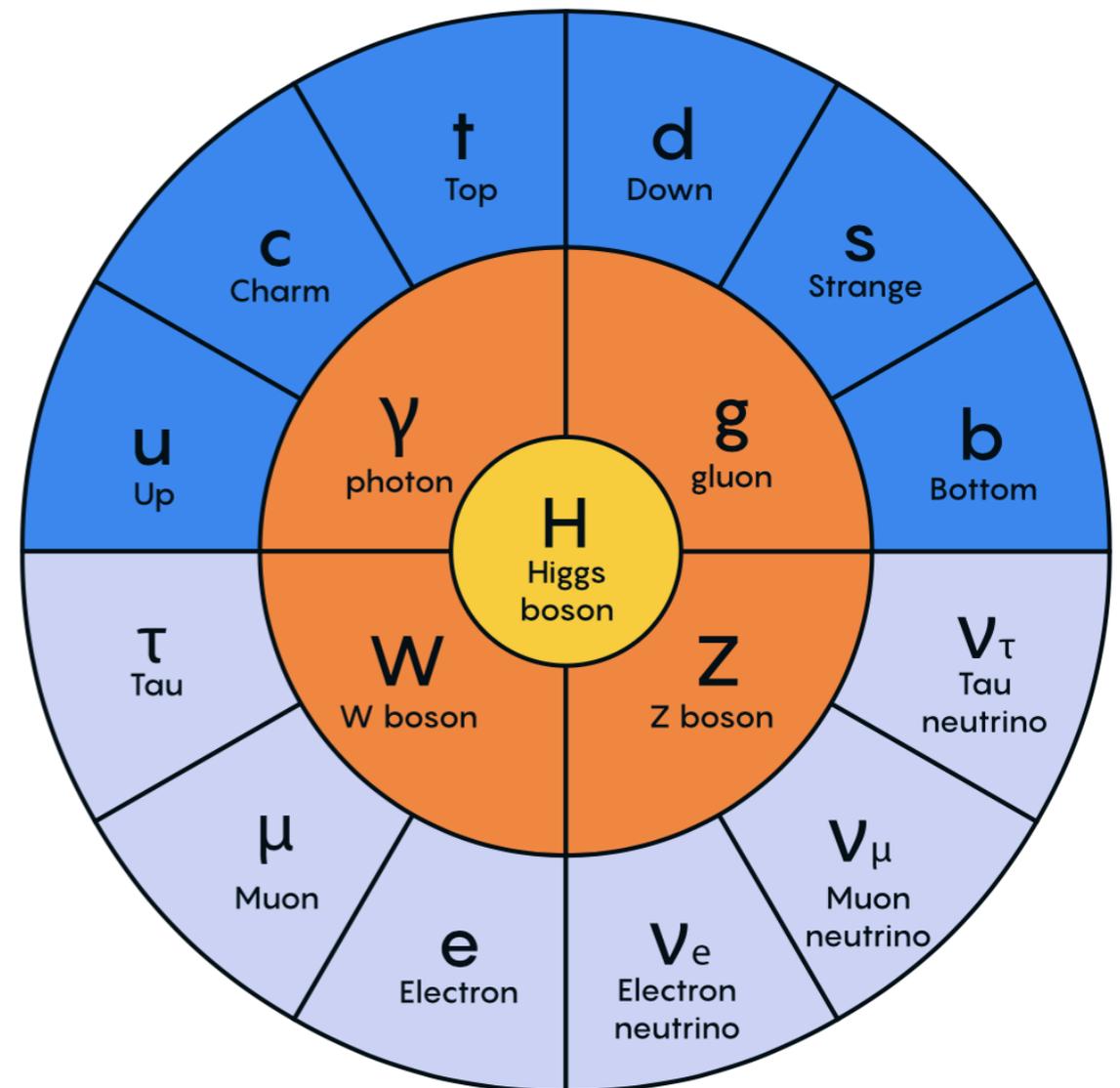
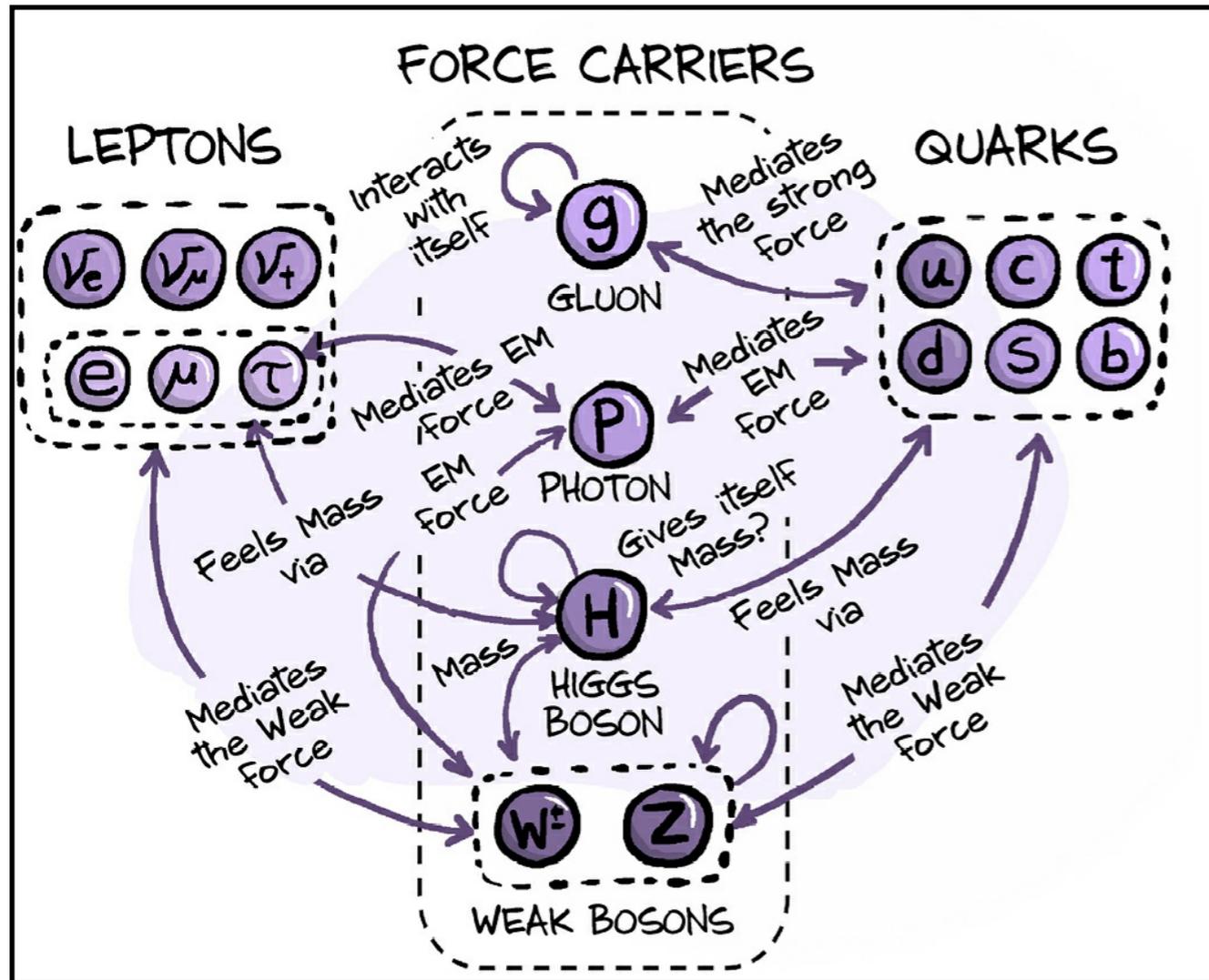
FORCE PARTICLE	FORCE IT TRANSMITS
 PHOTON	ELECTROMAGNETIC FORCE
 W, Z BOSONS	WEAK FORCE
 GLUON	STRONG FORCE

### MASS OF THE PROTON





# IL BOSONE DI HIGGS COMPLETA IL MODELLO STANDARD!



# ALLA BASE DEL MODELLO STANDARD, LE SIMMETRIE



**SIMMETRIA  
CILINDRICA**

INVARIANZA  
SOTTO  
ROTAZIONI  
INTORNO  
ALL'ASSE  
DEL CILINDRO



**SIMMETRIA  
SFERICA**

INVARIANZA  
SOTTO ROTAZIONI  
INTORNO A UN  
QUALUNQUE ASSE



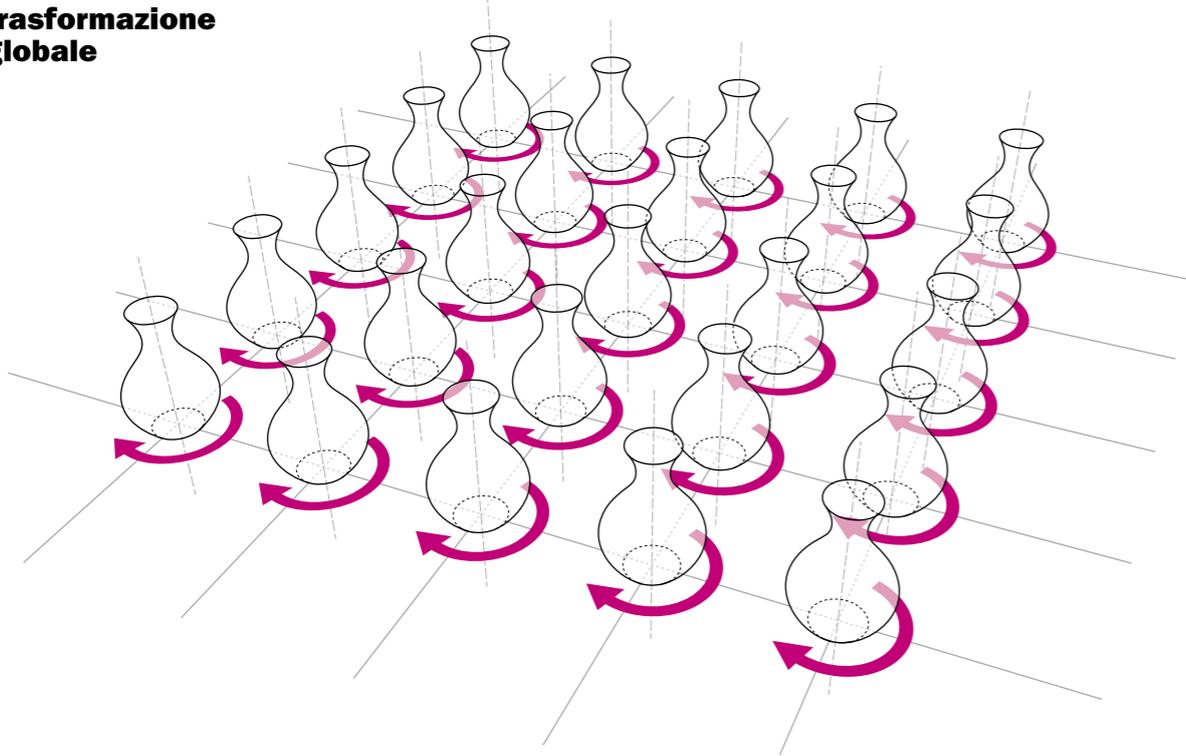
M  
I  
L  
E  
V  
A



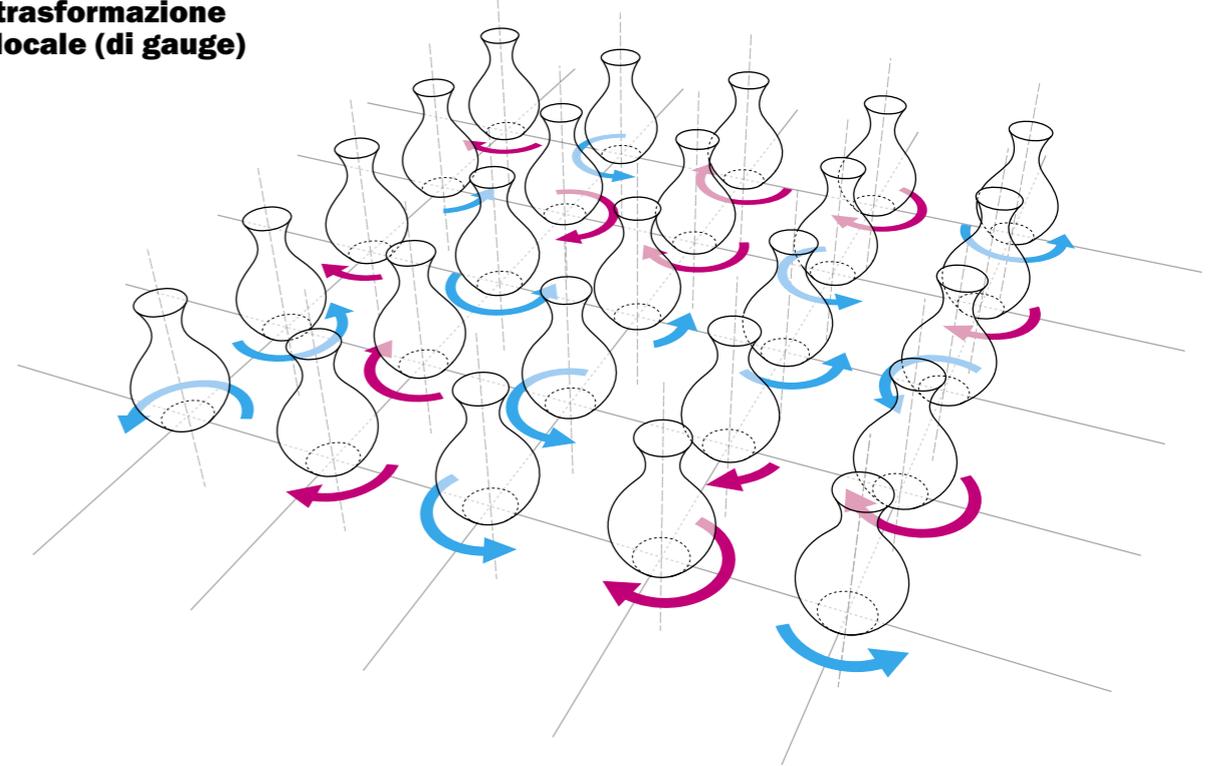
M  
A  
R  
I  
C

# ALLA BASE DEL MODELLO STANDARD, LE SIMMETRIE

trasformazione globale



trasformazione locale (di gauge)

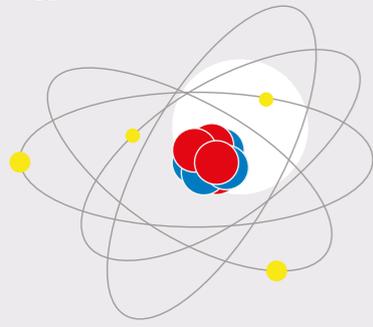


M  
I  
L  
E  
V  
A

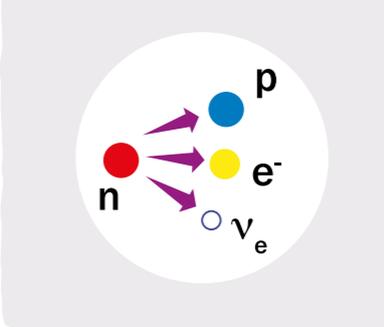


M  
A  
R  
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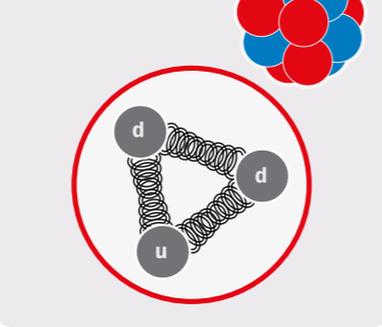
**INTERAZIONE ELETTROMAGNETICA**  
Raggio d'azione infinito



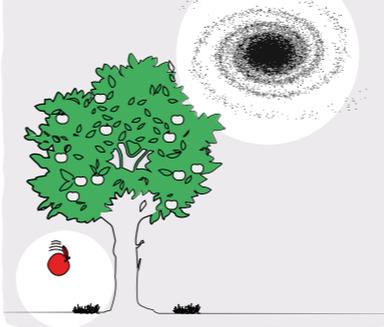
**INTERAZIONE DEBOLE**  
Raggio d'azione  $10^{-17}$  m



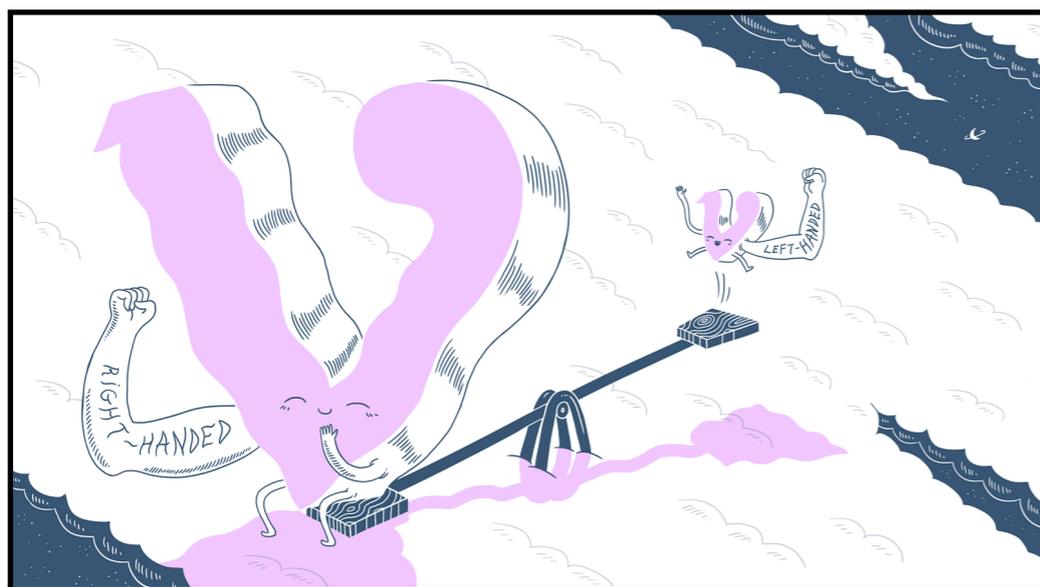
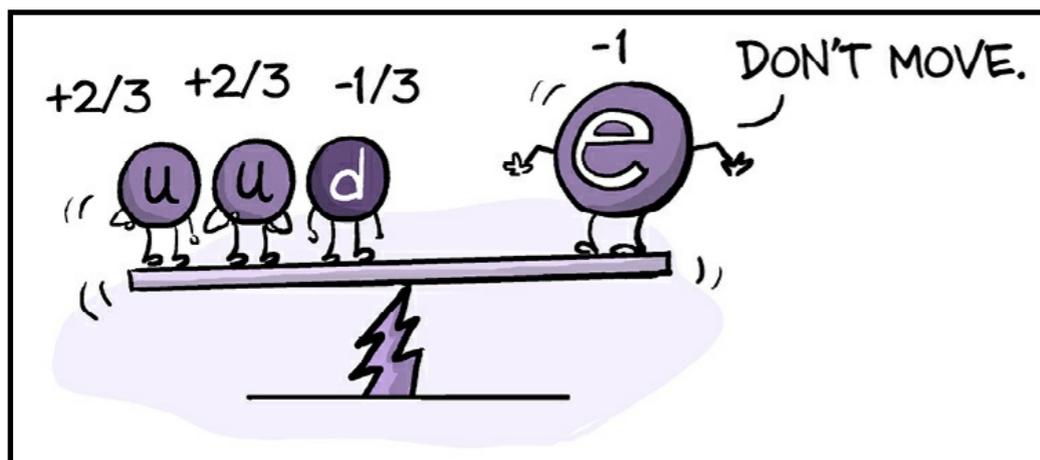
**INTERAZIONE FORTE**  
Raggio d'azione  $10^{-15}$  m



**INTERAZIONE GRAVITAZIONALE**  
Raggio d'azione infinito



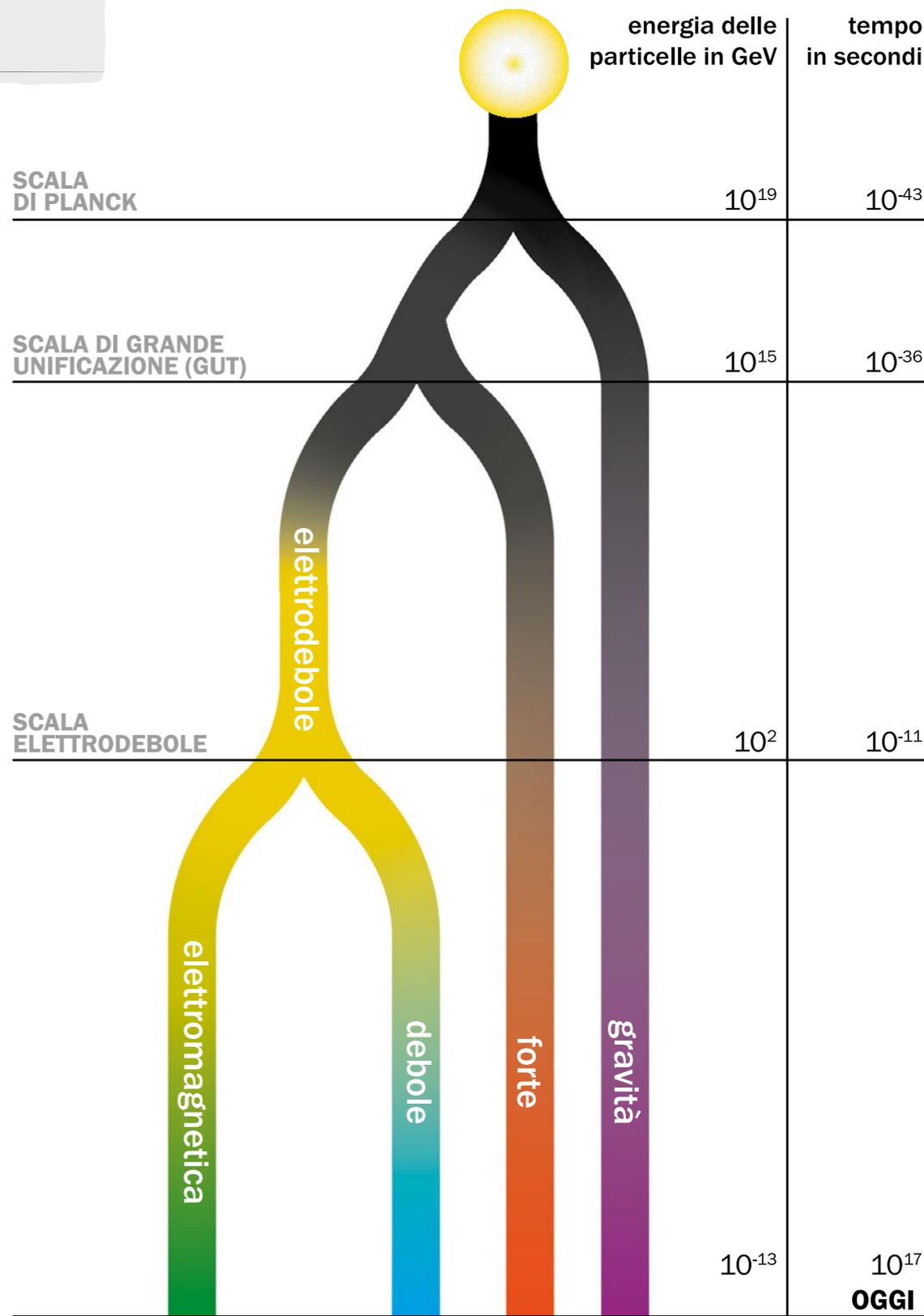
# OLTRE IL MODELLO STANDARD: LA GRANDE UNIFICAZIONE

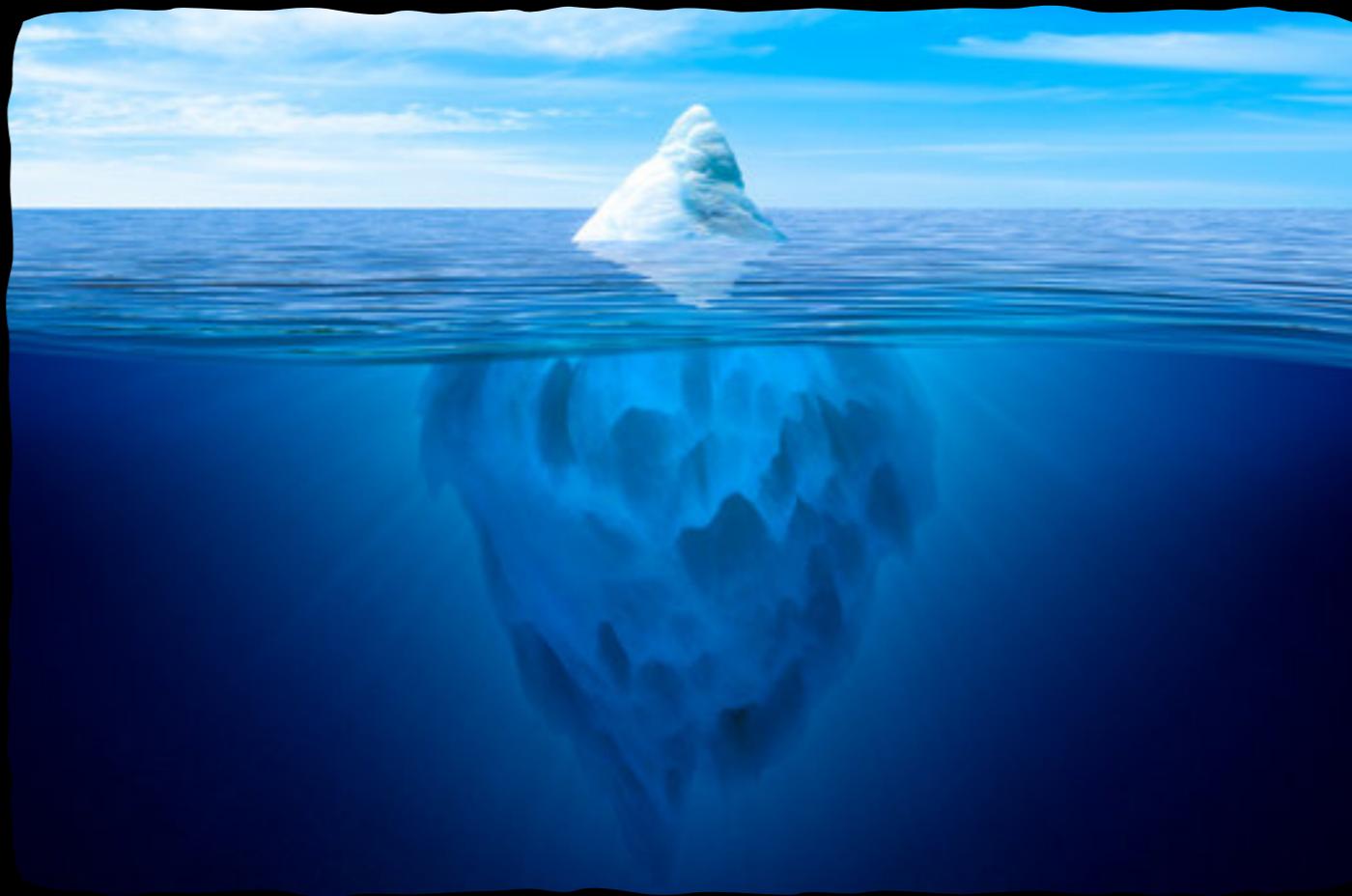


SCALA DI PLANCK

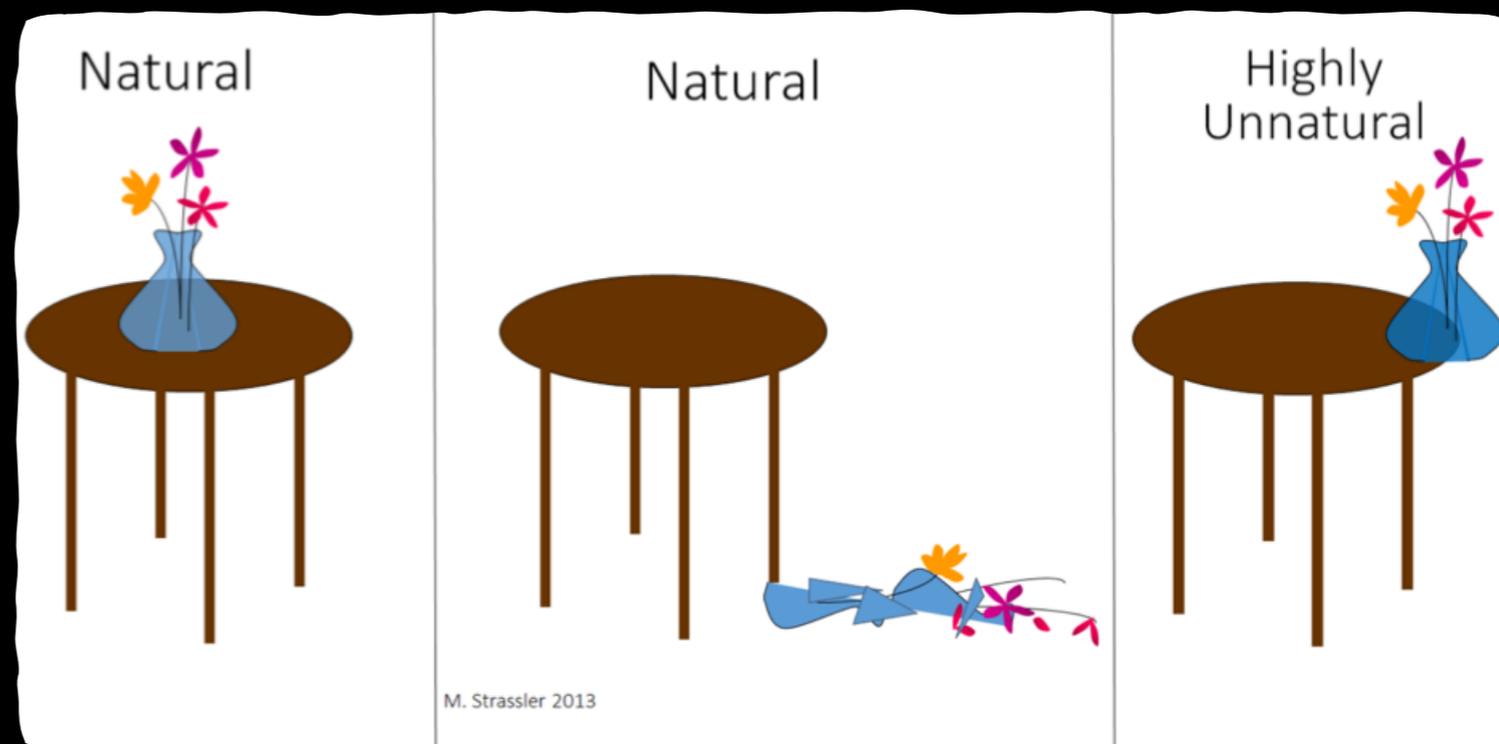
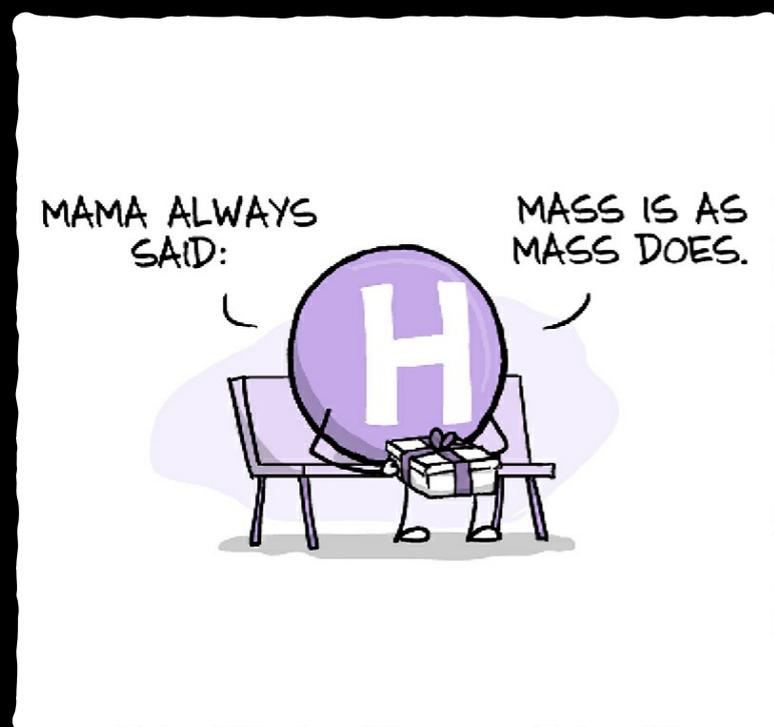
SCALA DI GRANDE UNIFICAZIONE (GUT)

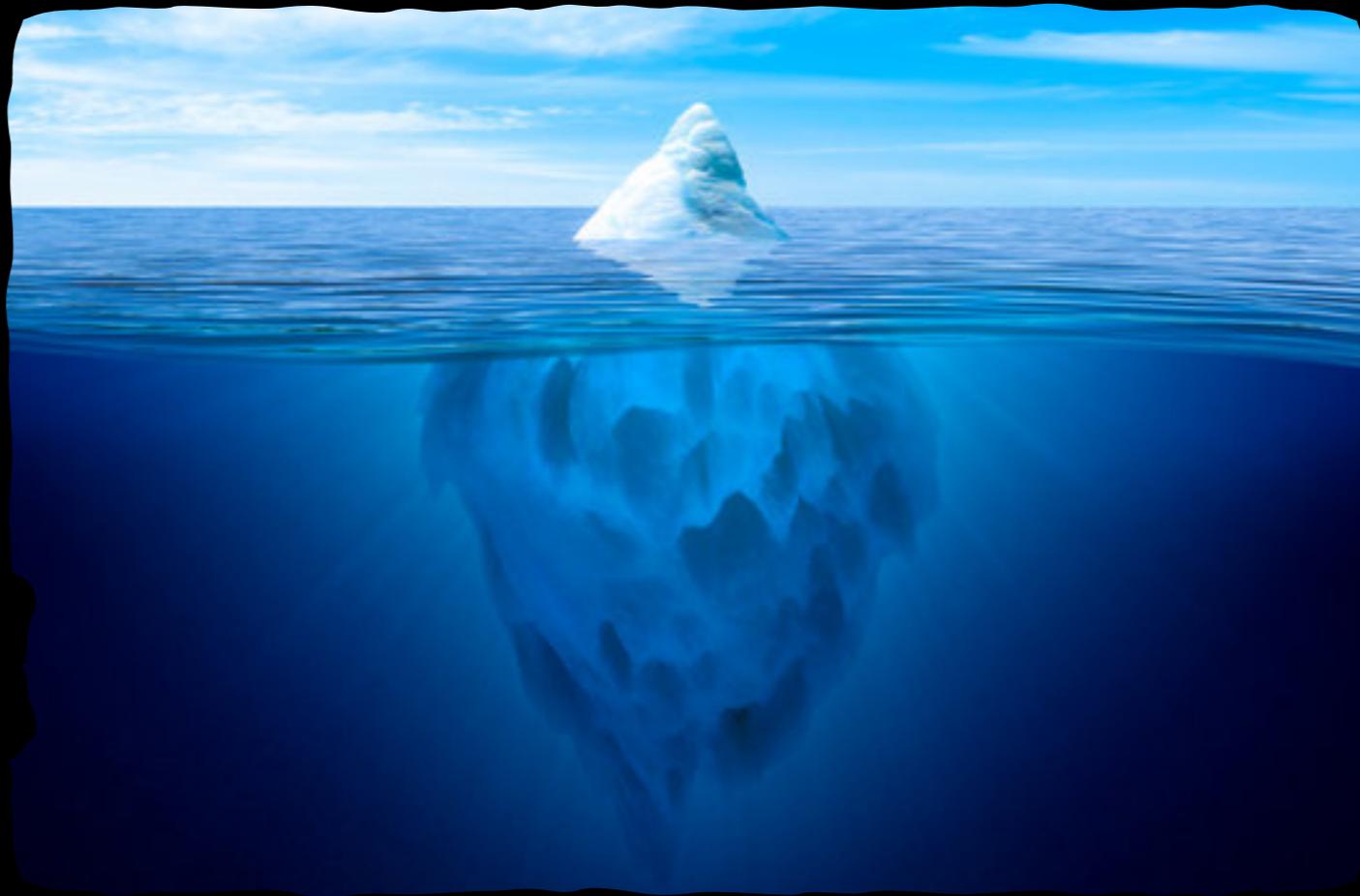
SCALA ELETTRODEBOLE





# IL MODELLO STANDARD: SOLO LA PUNTA DI UN ICEBERG?

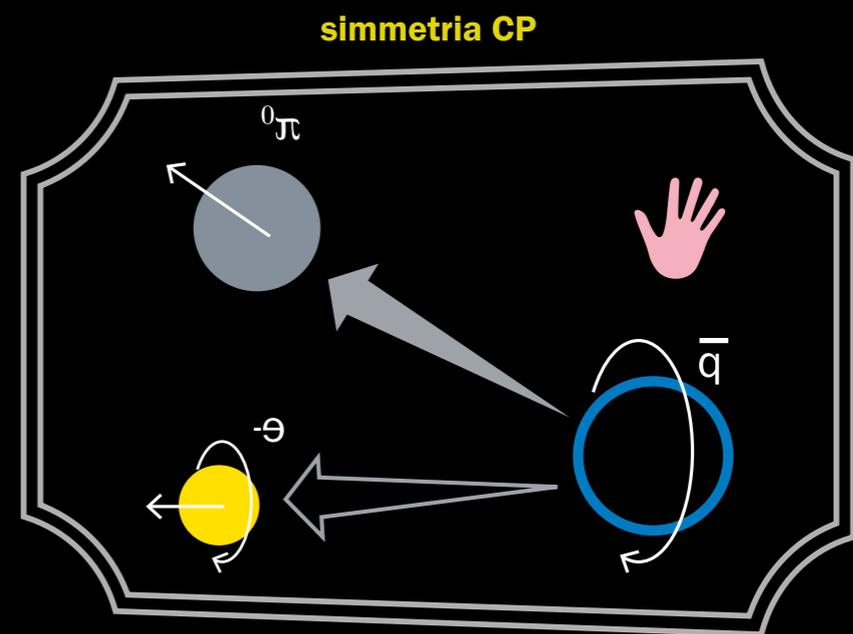
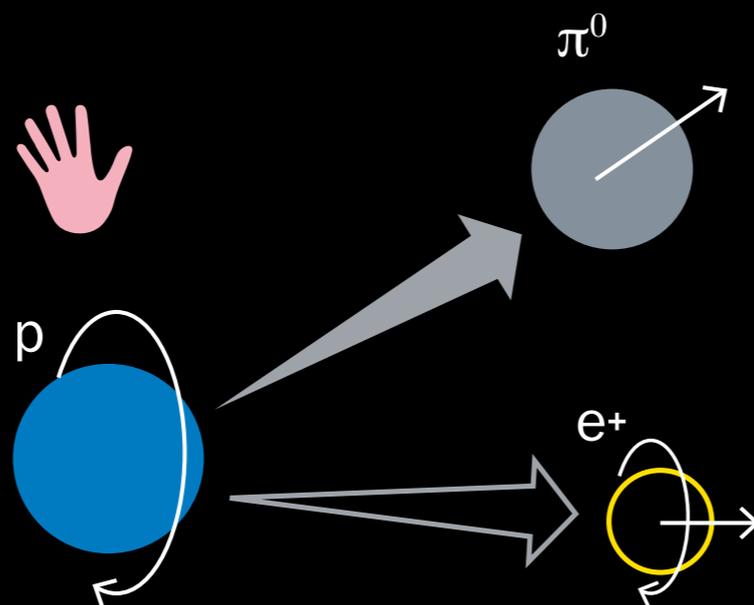


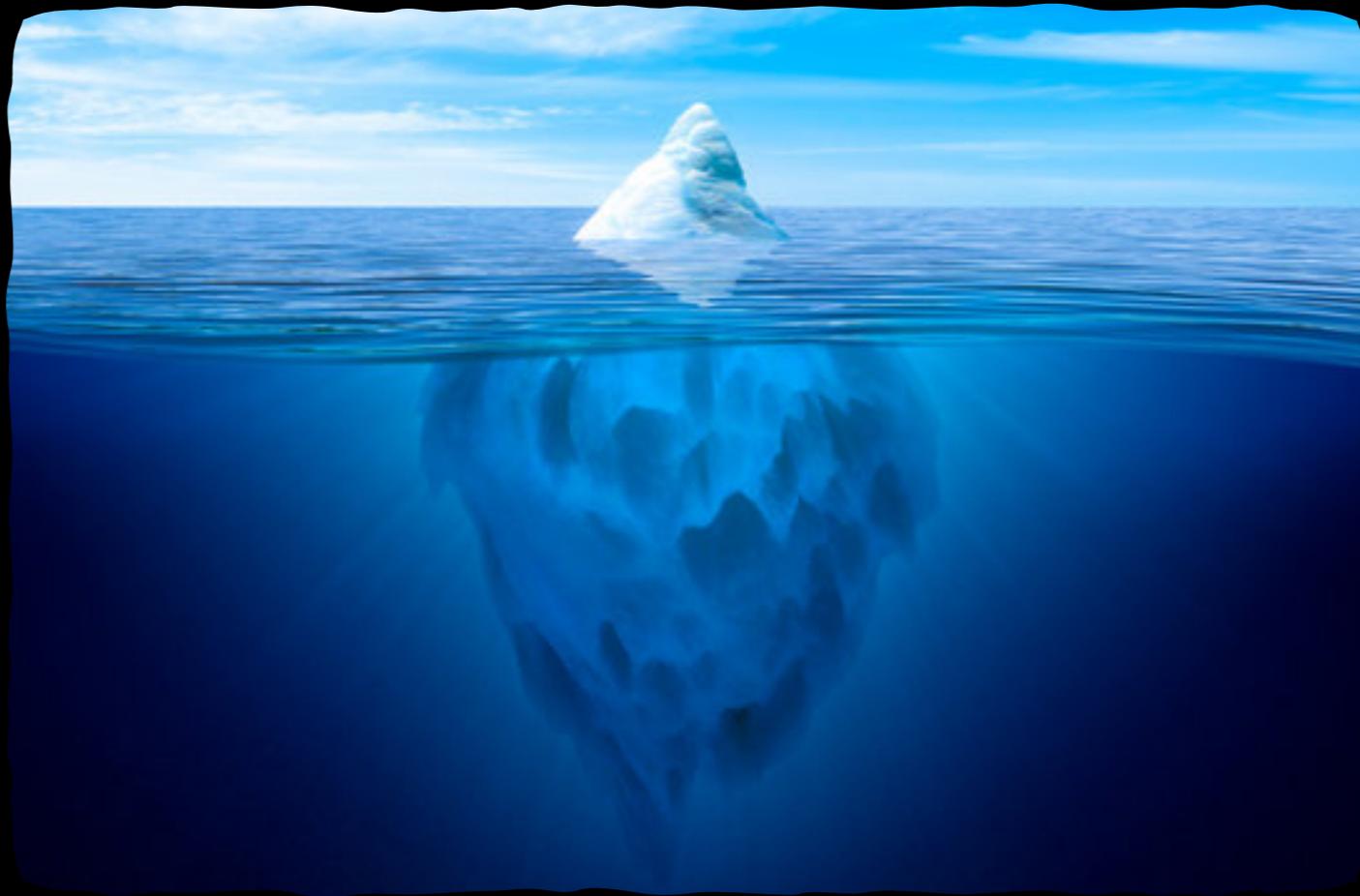


# IL MODELLO STANDARD: SOLO LA PUNTA DI UN ICEBERG?

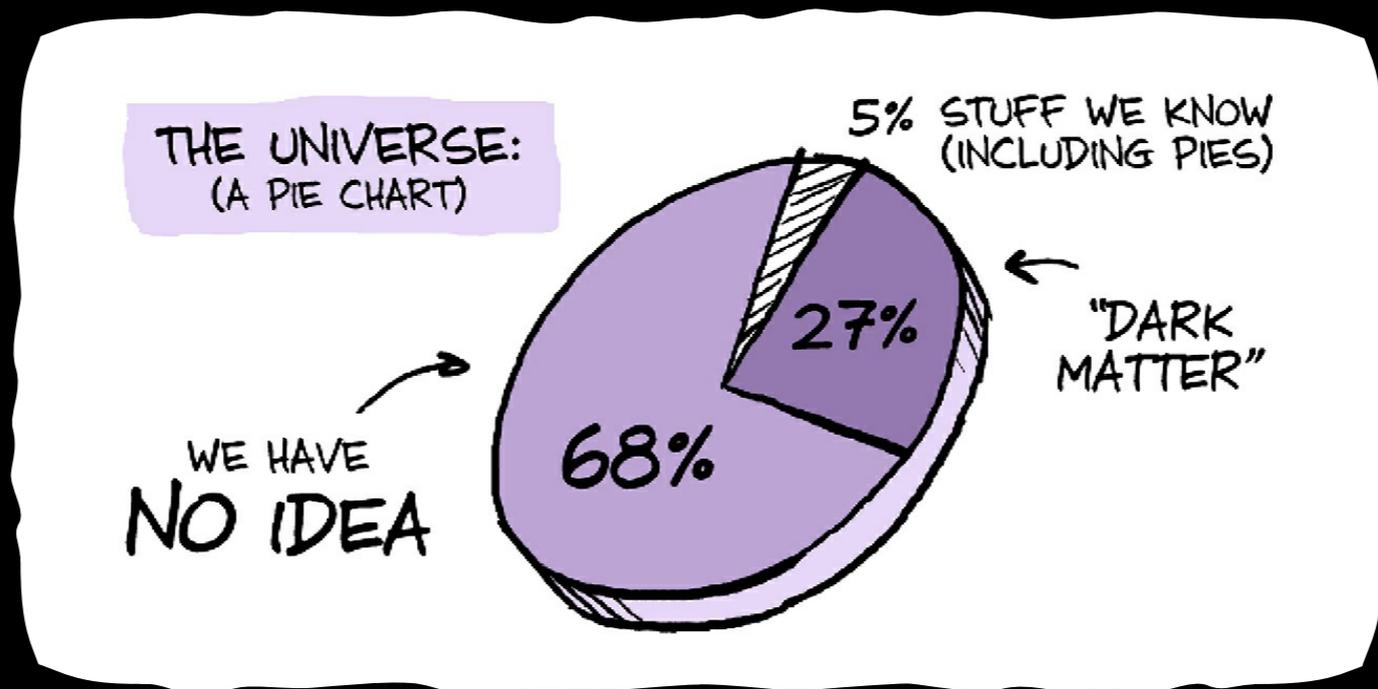


A. Sakharov





IL MODELLO STANDARD: SOLO LA PUNTA DI UN ICEBERG?  
PROBABILMENTE SÌ!!!

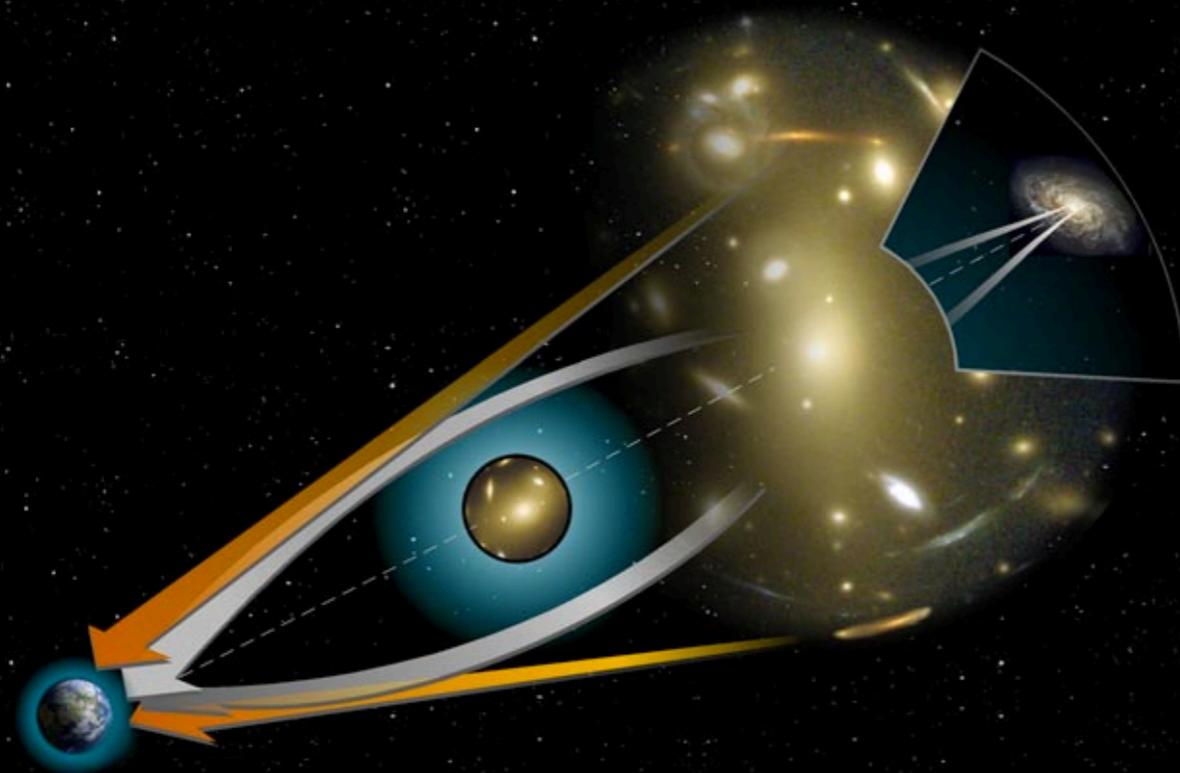
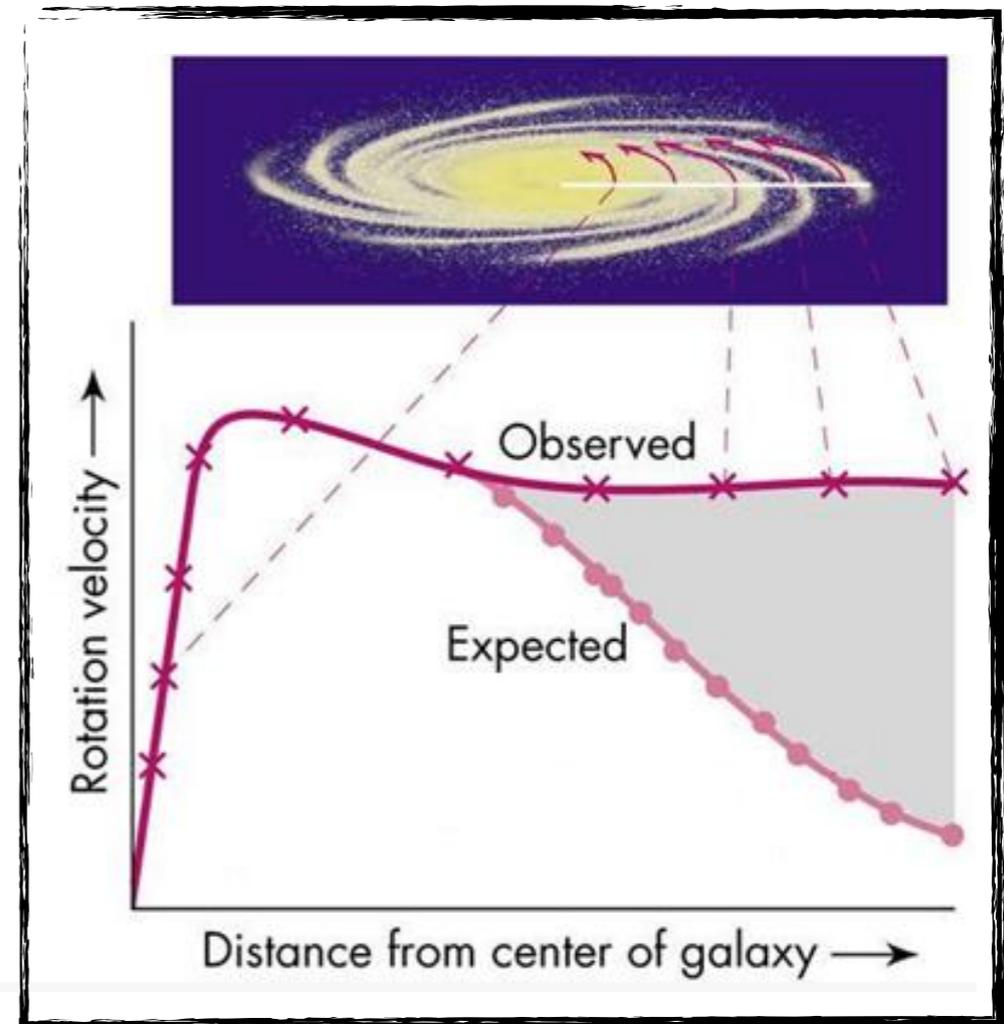


# COSA E' LA MATERIA OSCURA?

Un mistero ancora tutto da scoprire ...



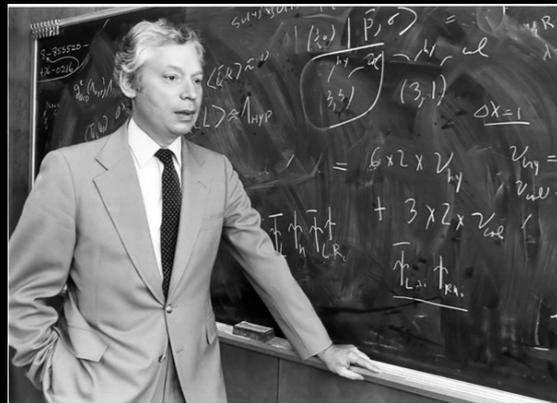
#MANTRA-DI-OGGI: **CERCARE OVUNQUE!**



**DARK MATTER**

- GRAVITY
- ELECTROMAGNETISM
- WEAK FORCE
- STRONG FORCE





Lo sforzo di capire l'universo è tra le pochissime cose che innalzano la vita umana al di sopra del livello di una farsa, conferendole un po' della dignità di una tragedia.

*Steven Weinberg*

