

Introdução à física de partículas



- Um pouco de história
- Dentro do átomo
- O Modelo padrão: forças e partículas
- Perguntas em aberto

Aparecimento da física moderna



Descrição do Universo: Egípcios (Nut Deusa dos Céus), ~2000 a.C.



SOMOS FEITOS DE QUÊ ?!

Thales de Mileto, séc.VII a.C.: tudo é água!

Empédocles, séc.V a.C.: os 4 elementos!



+a quintessência
(referida por Aristóteles
no séc.III a.C.)

+A-Tomos
(Leucipo e Demócrito,
séc. V a.C.)

(ideia de átomos tb. introduzida na Índia no séc. VI a.C.)

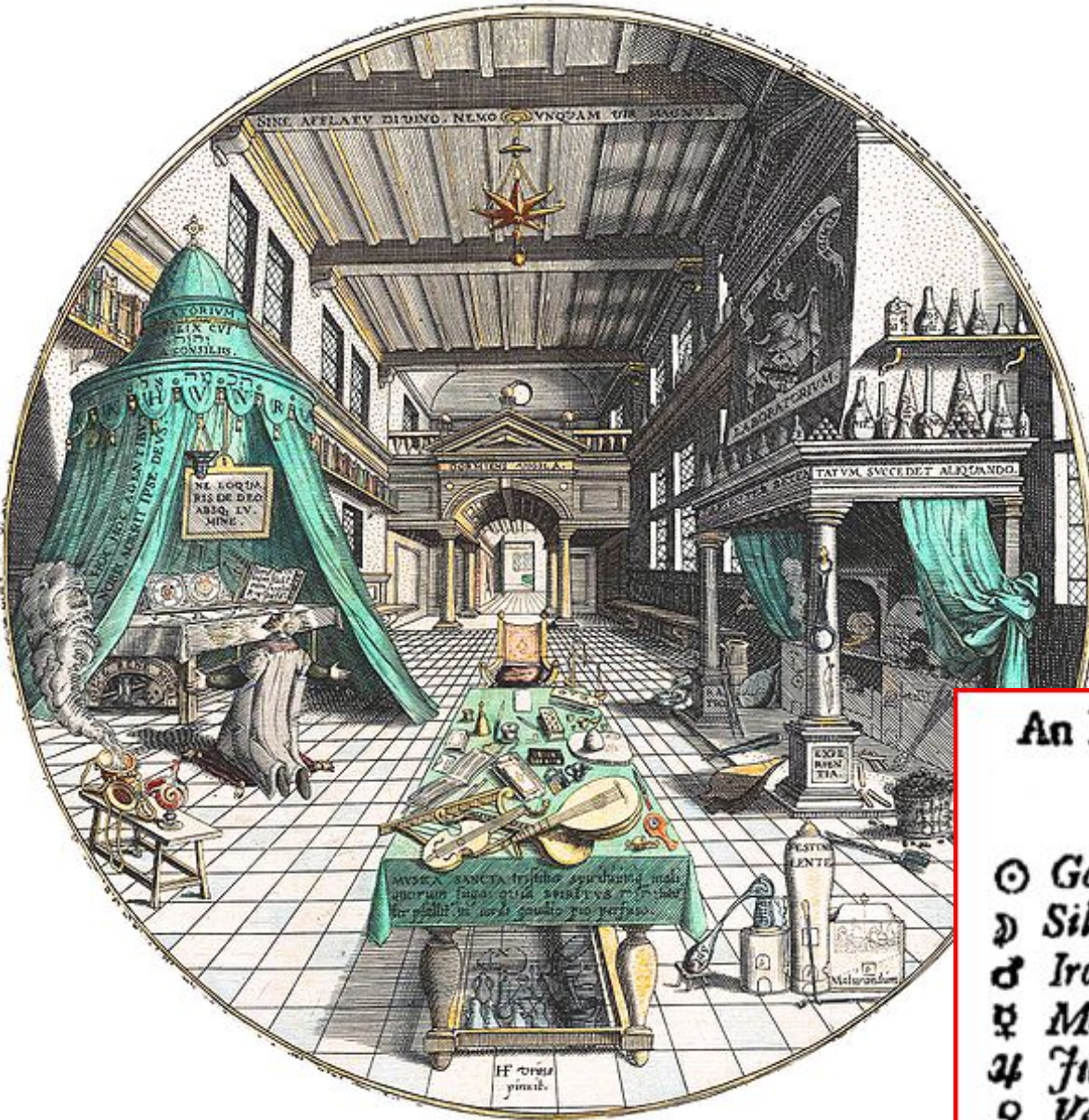


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Idade média, Europa:

EXPERIMENTAÇÃO!

Laboratório de Alquimista

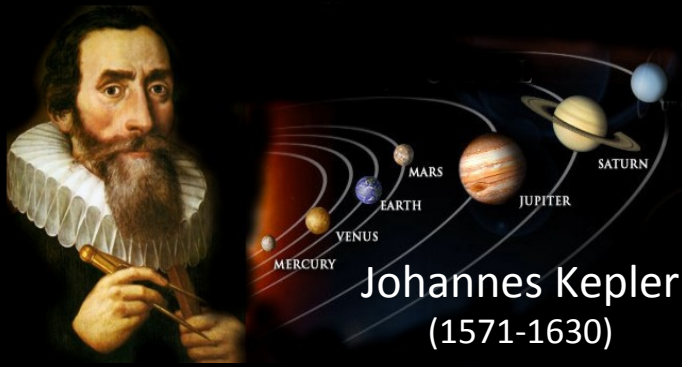


An Explication of the Characters which
are used in this Book.

☉ Gold.
☽ Silver.
♂ Iron.
♀ Mercury.
♃ Jupiter.
♀ Venus.
♄ Lead.
♁ Antimony.
✱ Sal armoniac.

A. F. *Aqua Fortis.*
A. R. *Aqua Regis.*
S. V. *Spirit of Wine.*
☿ *Sublimate,*
☿ *Precipitata.*
☿ *Amalgama.*
▽ *Water.*
△ *Fire,*

Idade moderna, Europa: EXPERIMENTAÇÃO $\approx$ TEORIA!

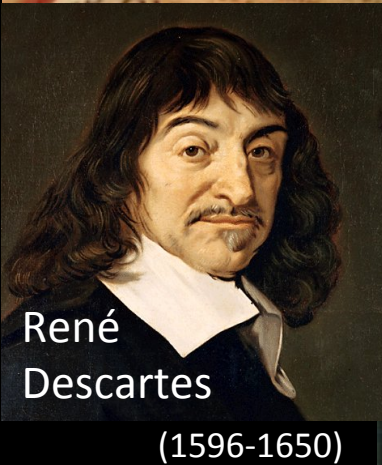


Johannes Kepler
(1571-1630)

Física!:

Princípios
Matemáticos
da Filosofia
da Natureza!

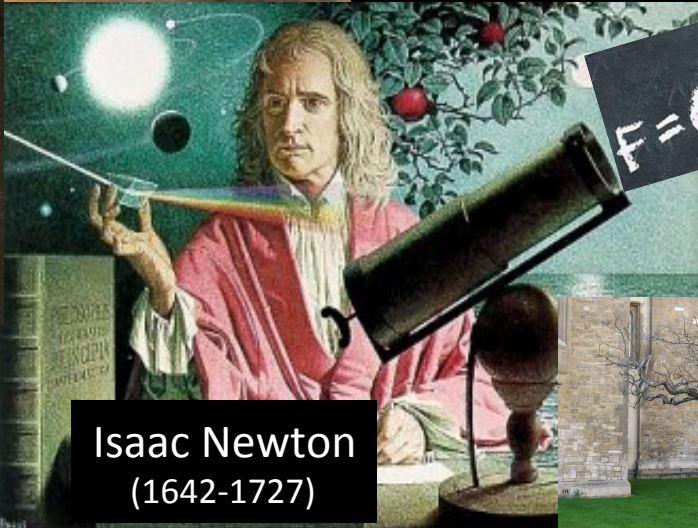
Galileo Galilei
(1564-1642)



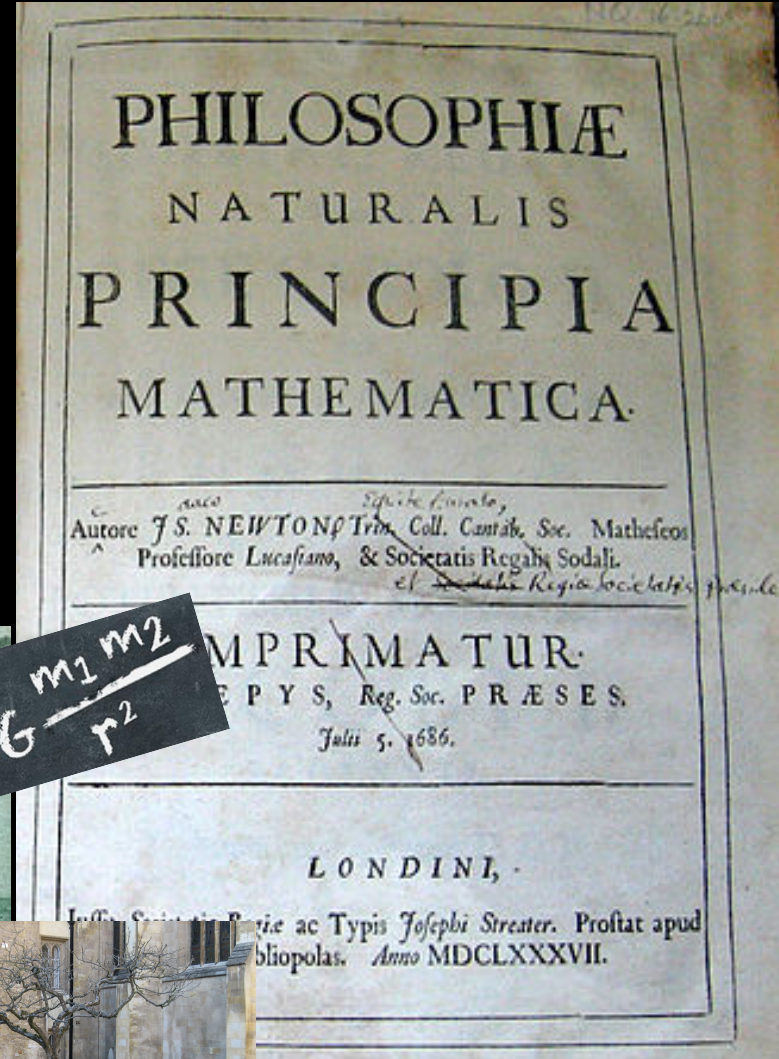
René
Descartes

(1596-1650)

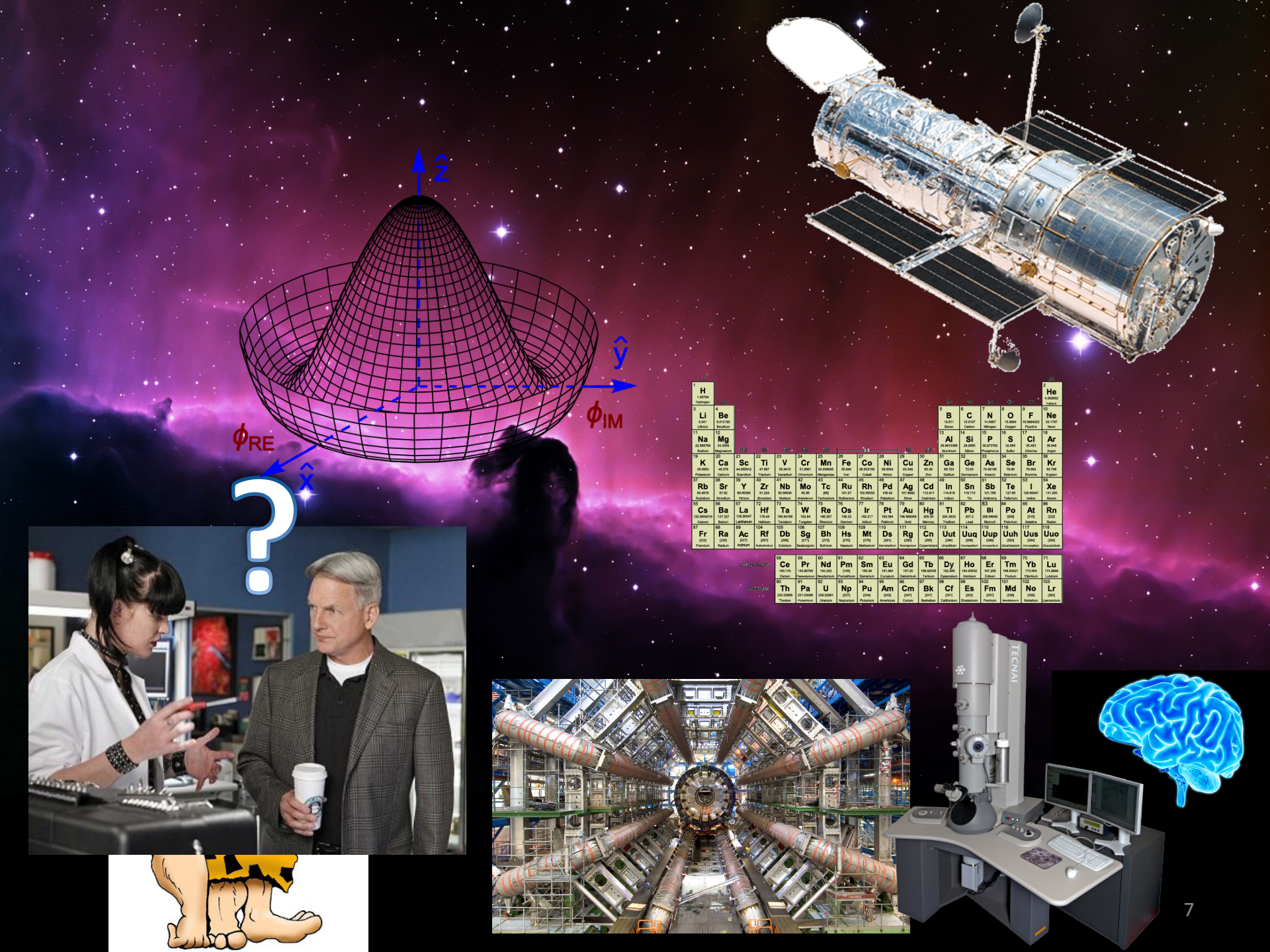
cogito
ergo sum



Isaac Newton
(1642-1727)

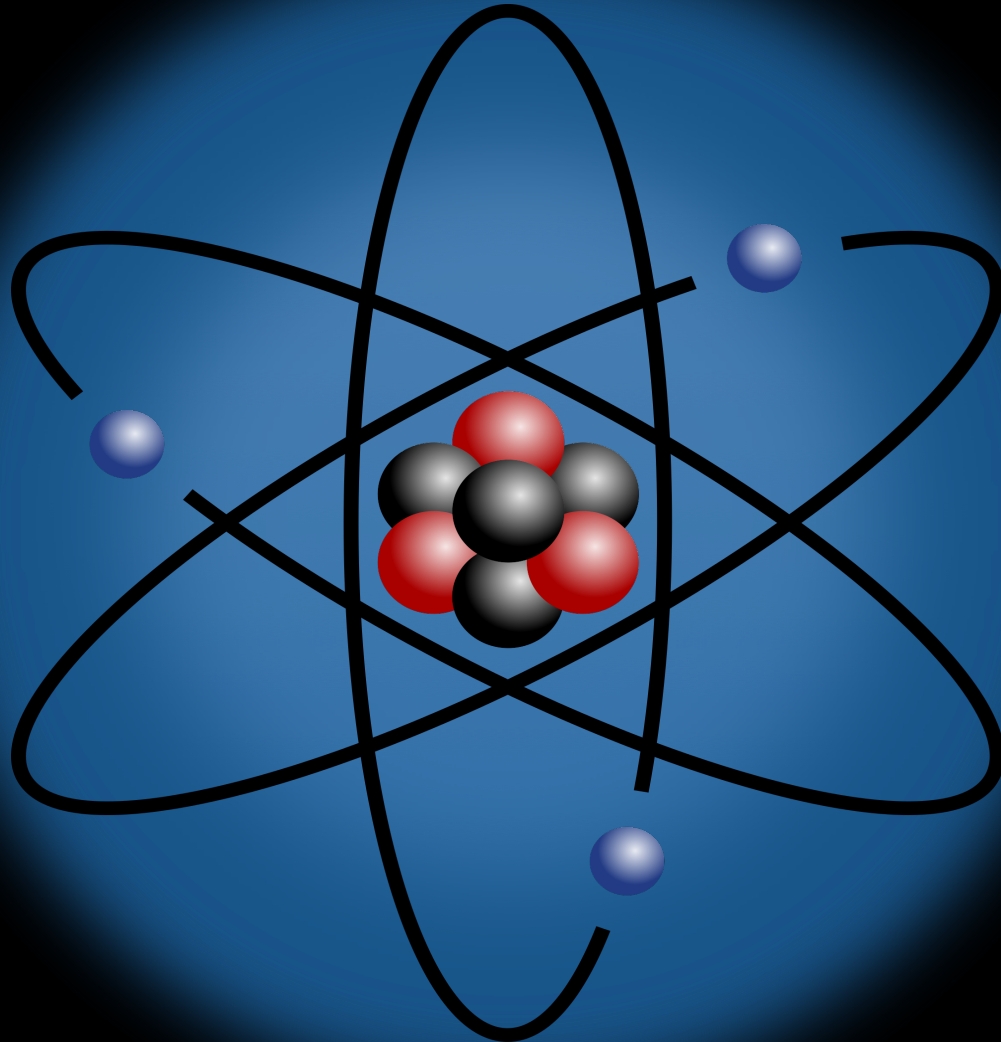


$$F = G \frac{m_1 m_2}{r^2}$$



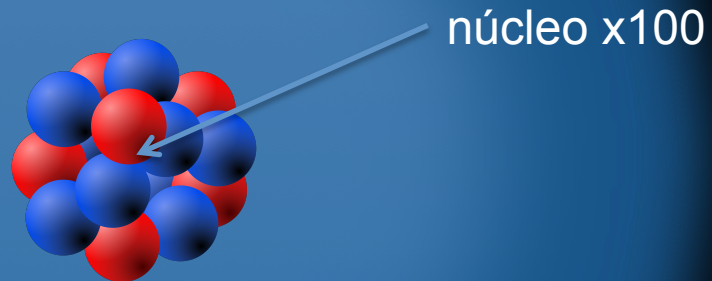
H 1.00794 Hydrogen												He 4.002602 Helium					
Li 6.941 Lithium	Be 9.012182 Beryllium											B 10.811 Boron	C 12.011 Carbon	N 14.00643 Nitrogen	O 15.999 Oxygen	F 18.9984032 Fluorine	Ne 20.1797 Neon
Na 22.98976928 Sodium	Mg 24.304 Magnesium											Al 26.9815385 Aluminum	Si 28.0855 Silicon	P 30.973761508 Phosphorus	S 32.06 Sulfur	Cl 35.453 Chlorine	Ar 39.948 Argon
K 39.0983 Potassium	Ca 40.078 Calcium	Sc 44.955912 Scandium	Ti 47.867 Titanium	V 50.9415 Vanadium	Cr 51.9961 Chromium	Mn 54.938044 Manganese	Fe 55.845 Iron	Co 58.933195 Cobalt	Ni 58.6934 Nickel	Cu 63.546 Copper	Zn 65.38 Zinc	Ga 69.723 Gallium	Ge 72.630 Germanium	As 74.921595 Arsenic	Se 78.96 Selenium	Br 79.904 Bromine	Kr 83.798 Krypton
Rb 85.4678 Rubidium	Sr 87.62 Strontium	Y 88.90584 Yttrium	Zr 91.224 Zirconium	Nb 92.90638 Niobium	Mo 95.94 Molybdenum	Tc 98 Technetium	Ru 101.07 Ruthenium	Rh 102.9055 Rhodium	Pd 106.36 Palladium	Ag 107.8682 Silver	Cd 112.411 Cadmium	In 114.818 Indium	Sn 118.710 Tin	Sb 121.757 Antimony	Te 127.6 Tellurium	I 126.905 Iodine	Xe 131.29 Xenon
Cs 132.90545196 Cesium	Ba 137.327 Barium	La 138.90471 Lanthanum	Hf 178.49 Hafnium	Ta 180.94788 Tantalum	W 183.84 Tungsten	Re 186.207 Rhenium	Os 190.23 Osmium	Ir 192.222 Iridium	Pt 195.083 Platinum	Au 196.966569 Gold	Hg 200.59 Mercury	Tl 204.3833 Thallium	Pb 207.2 Lead	Bi 208.980399 Bismuth	Po 209 Polonium	At 210 Astatine	Rn 222 Radon
Fr 223 Francium	Ra 226 Radium	Ac 227 Actinium	Th 232.0377 Thorium	Pa 231.03626 Protactinium	U 238.02891 Uranium	Np 237.048173 Neptunium	Pu 244.06422 Plutonium	Am 243.061381 Americium	Cm 247.070351 Curium	Bk 247.070351 Berkelium	Cf 251.0833 Californium	Es 252.0833 Einsteinium	Fm 257.1015 Fermium	Md 258.103892 Mendelevium	No 259.103892 Nobelium	Lr 260.103892 Lawrencium	

O átomo



O átomo

99.999 999 999 9% do
volume do átomo é
vazio!

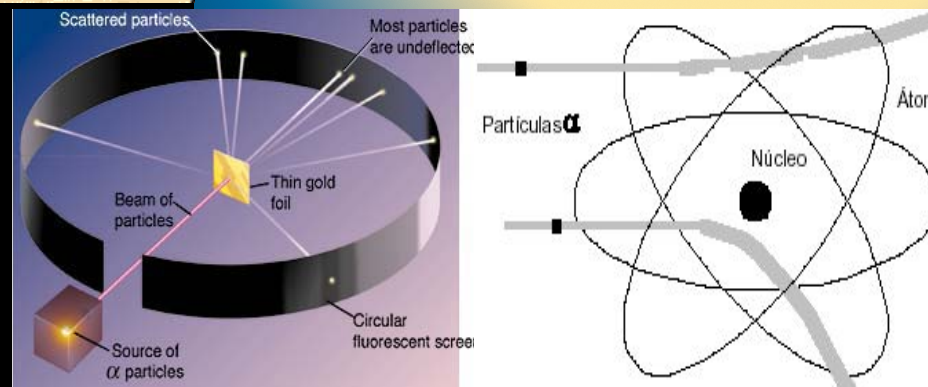
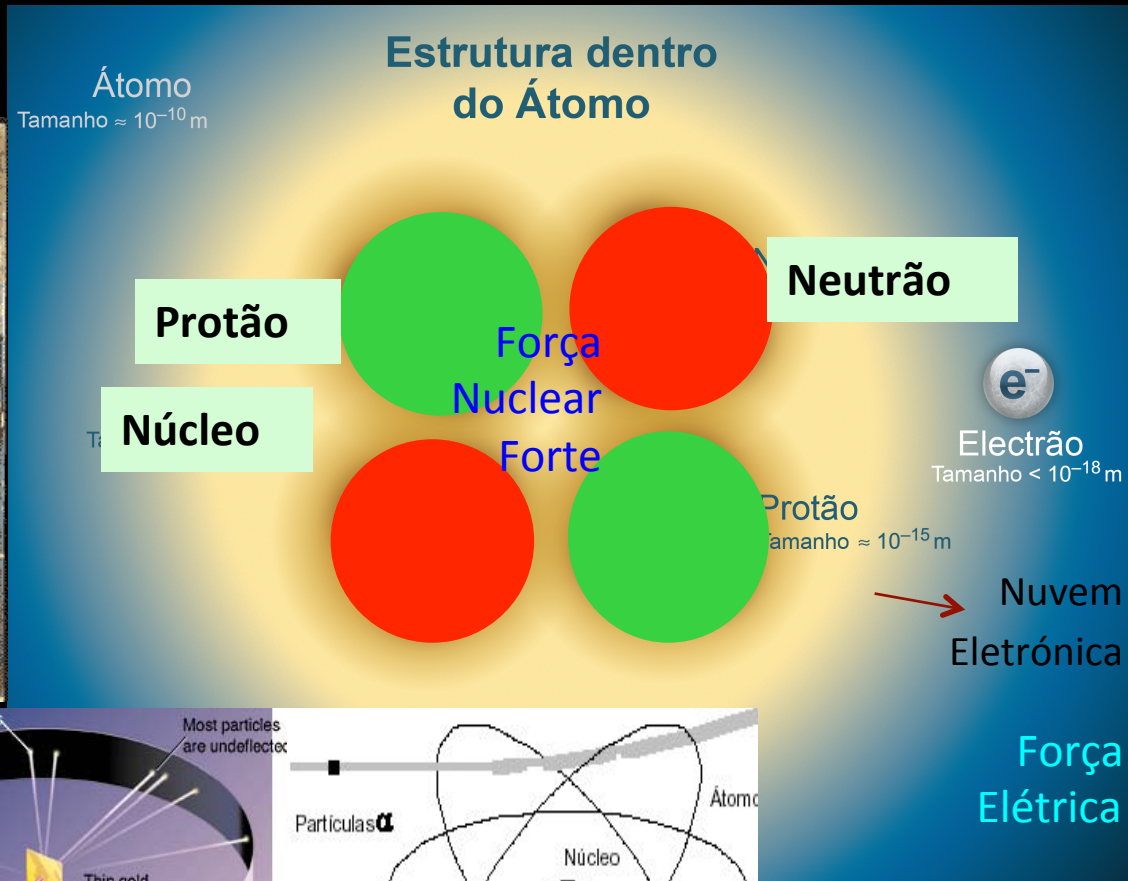
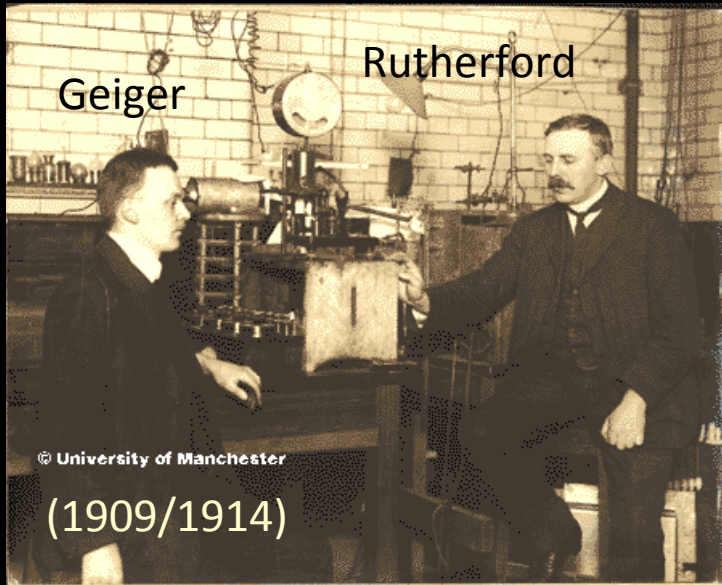


Uma questão de escala...



E os Núcleos ?!

Núcleos rodeados por
uma nuvem eletrónica!



Dentro do Núcleos Atômico

Quarks unidos por glúões

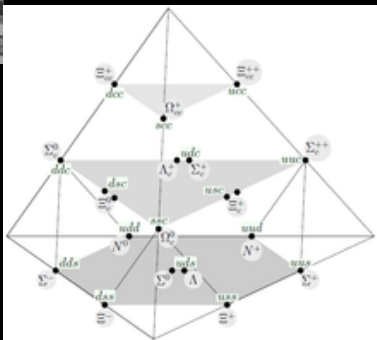
Gell-Mann



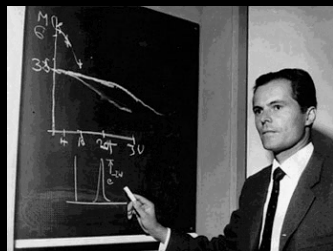
Feynmann



Ne'eman

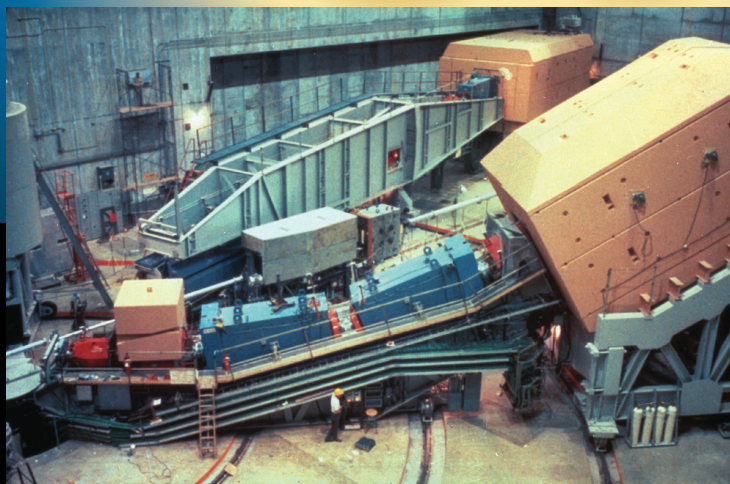


Hofstadter

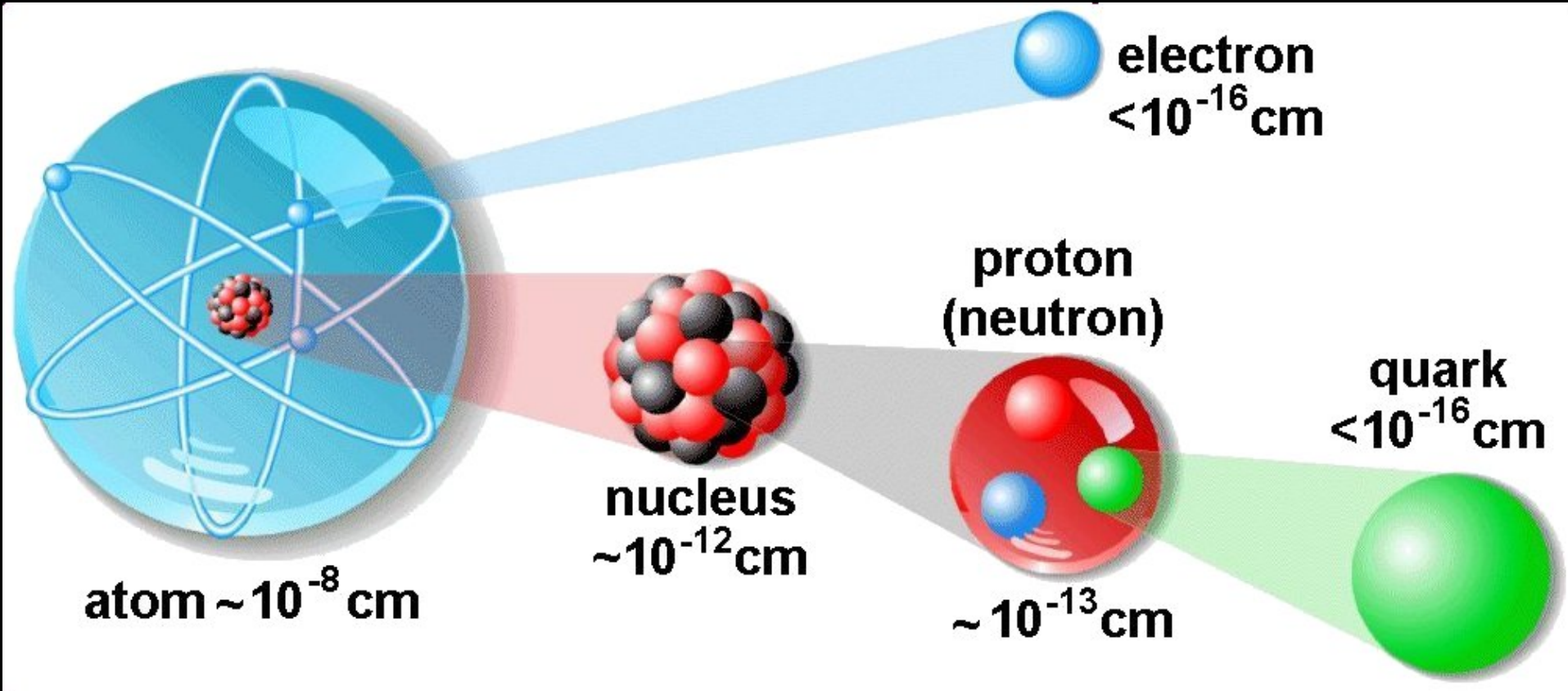


Zweig

Mössbauer



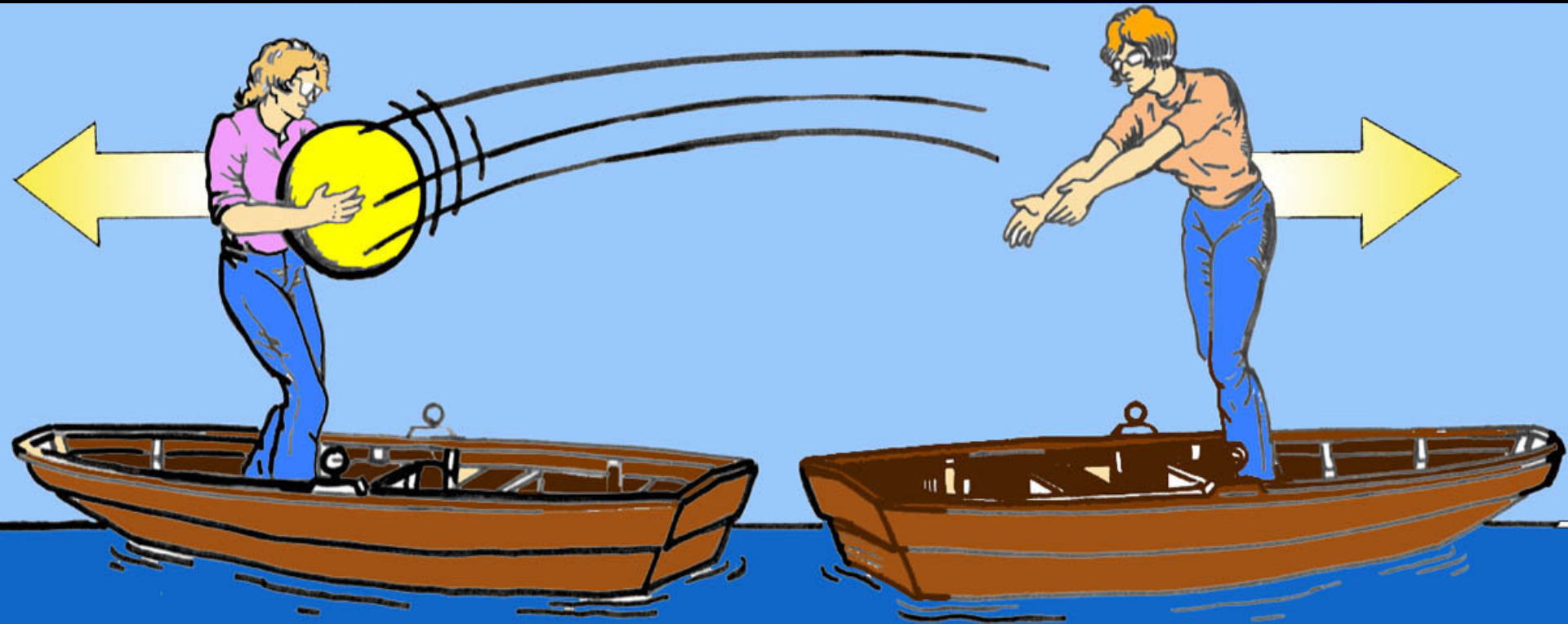
Do átomo às partículas fundamentais



As forças fundamentais

<i>Strong</i>	 Force which holds nucleus together	Strength 1	Range (m) 10^{-15} (diameter of a medium sized nucleus)	Particle gluons, π(nucleons)
<i>Electro-magnetic</i>		Strength $\frac{1}{137}$	Range (m) Infinite	Particle photon mass = 0 spin = 1
<i>Weak</i>	 neutrino interaction induces beta decay	Strength 10^{-6}	Range (m) 10^{-18} (0.1% of the diameter of a proton)	Particle Intermediate vector bosons W^+, W^-, Z_0, mass > 80 GeV spin = 1
<i>Gravity</i>		Strength 6×10^{-39}	Range (m) Infinite	Particle graviton ? mass = 0 spin = 2

As forças fundamentais



As forças fundamentais

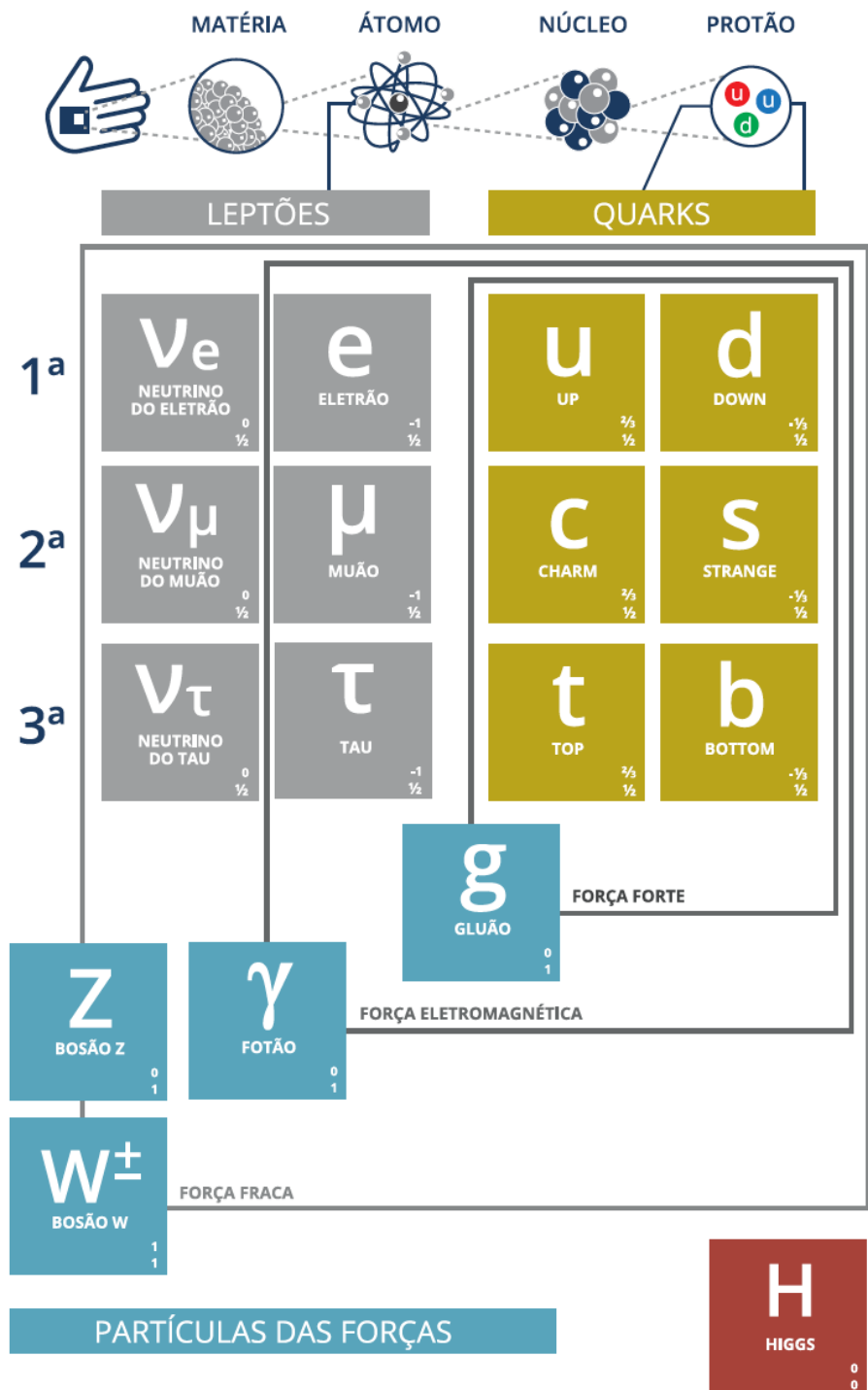
<i>Strong</i>		Force which holds nucleus together	Strength 1	Range (m) 10^{-15} (diameter of a medium sized nucleus)	Particle gluons, π (nucleons)
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<i>Gravity</i>			Strength 6×10^{-39}	Range (m) Infinite	Particle graviton ? mass = 0 spin = 2

8 glúões (g)

fotão (γ)

$W^+ W^- Z^0$

gravitão?



Sumário... até agora

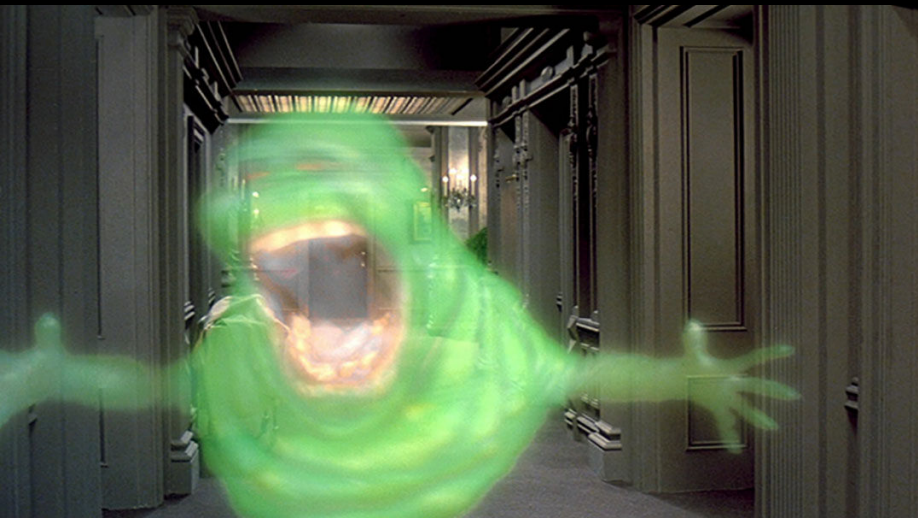
Além disso:

Por cada partícula fundamental existe uma anti-partícula (a antimatéria)

Para cada uma destas partículas, existe uma antipartícula de carga oposta (antimatéria)

PARTÍCULAS DE MATÉRIA

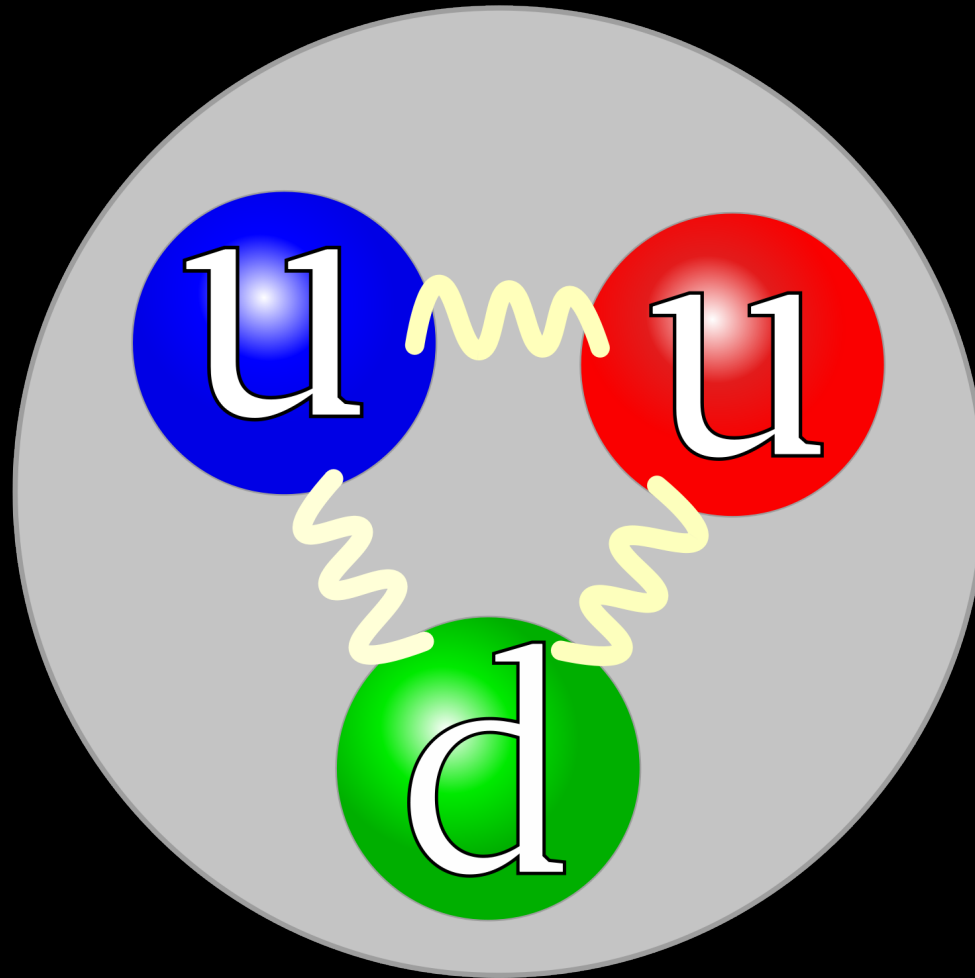
O Que está errado nestas imagens?



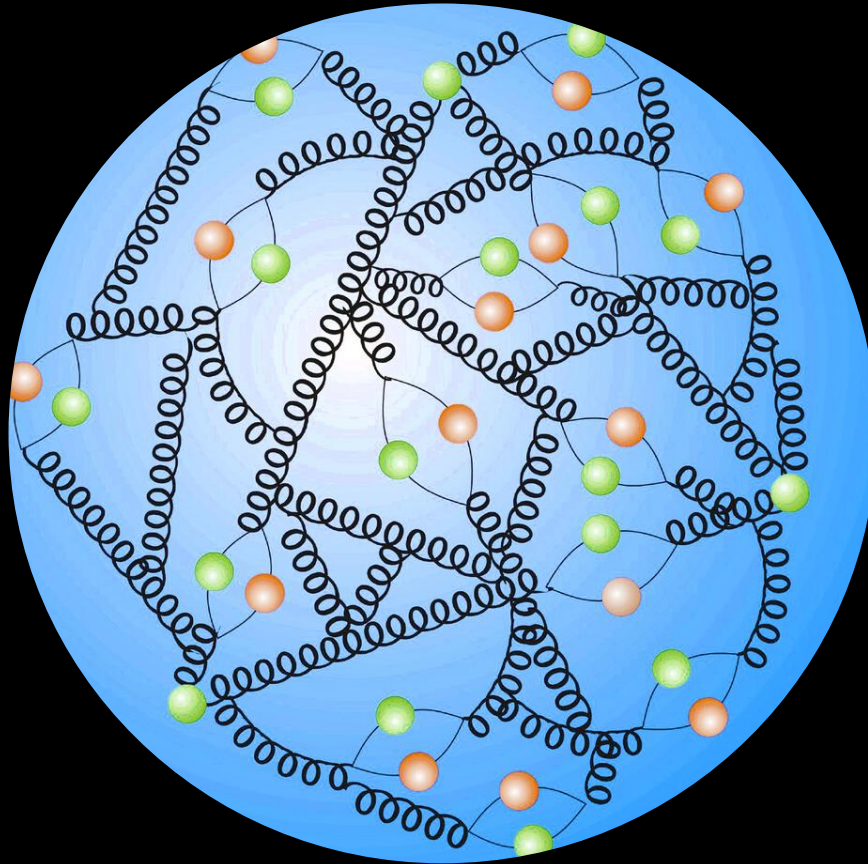
O Protão revisitado



O próton no modelo dos quarks



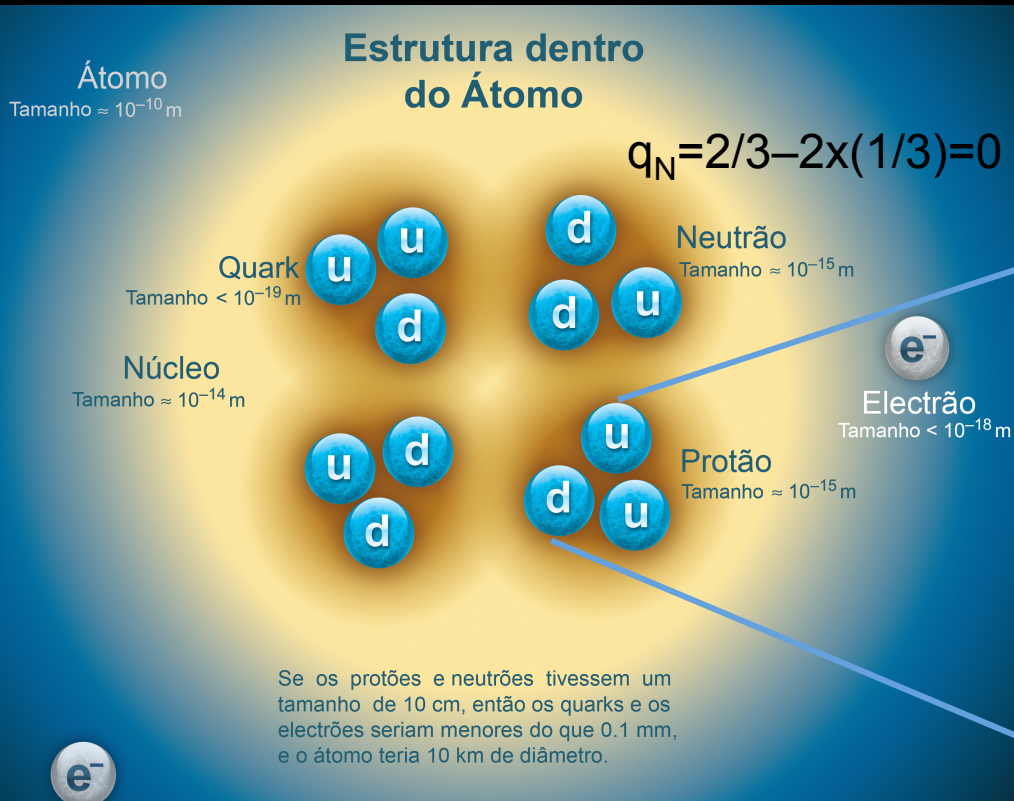
O próton tal como o conhecemos hoje



Quarks

Anti-Quarks Gluões

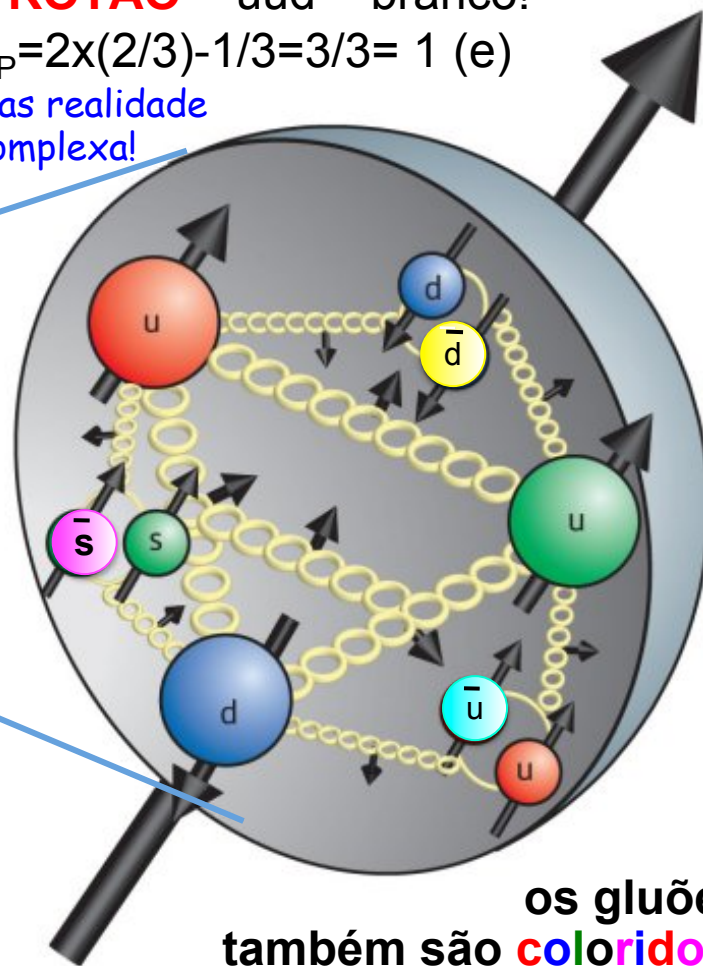
Nome Quark	Carga Eléctrica	Spin [h/(2π)]	"Cor" (r,g,b)
u (up)	+2/3 (e)	+1/2	● ● ●
d (down)	-1/3 (e)	+1/2	● ● ●



PROTÃO = uud = branco!

$$q_P = 2 \times (2/3) - 1/3 = 3/3 = 1 \text{ (e)}$$

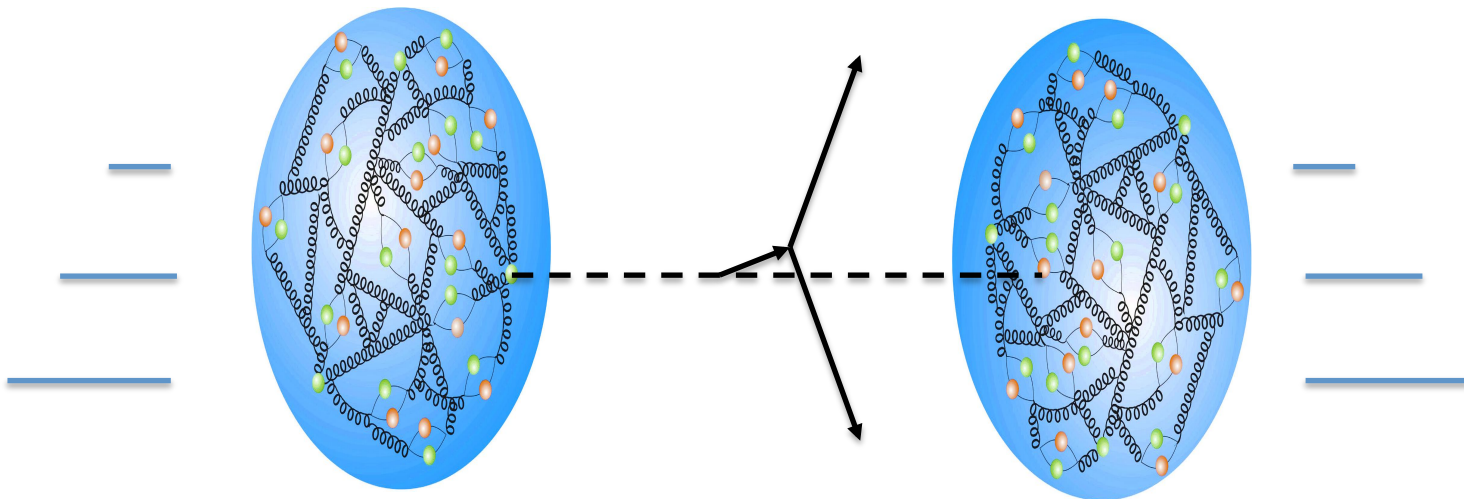
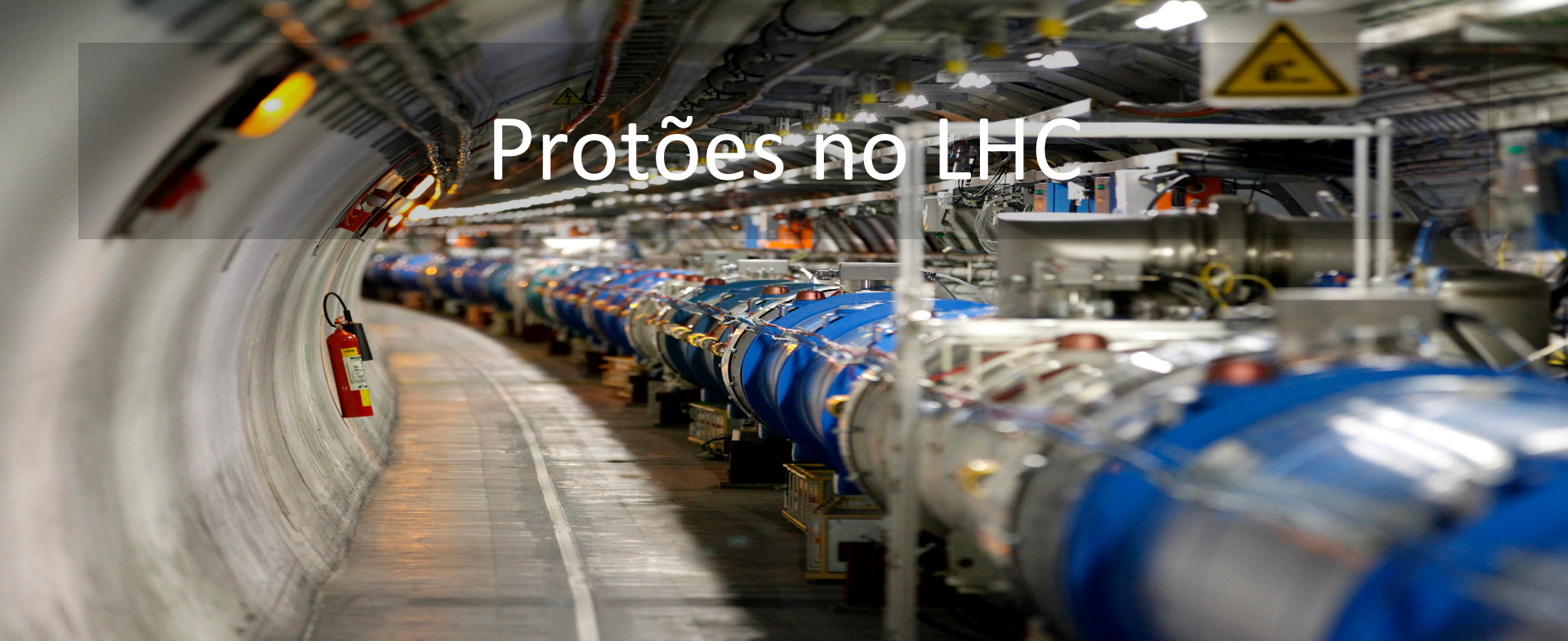
mas realidade complexa!



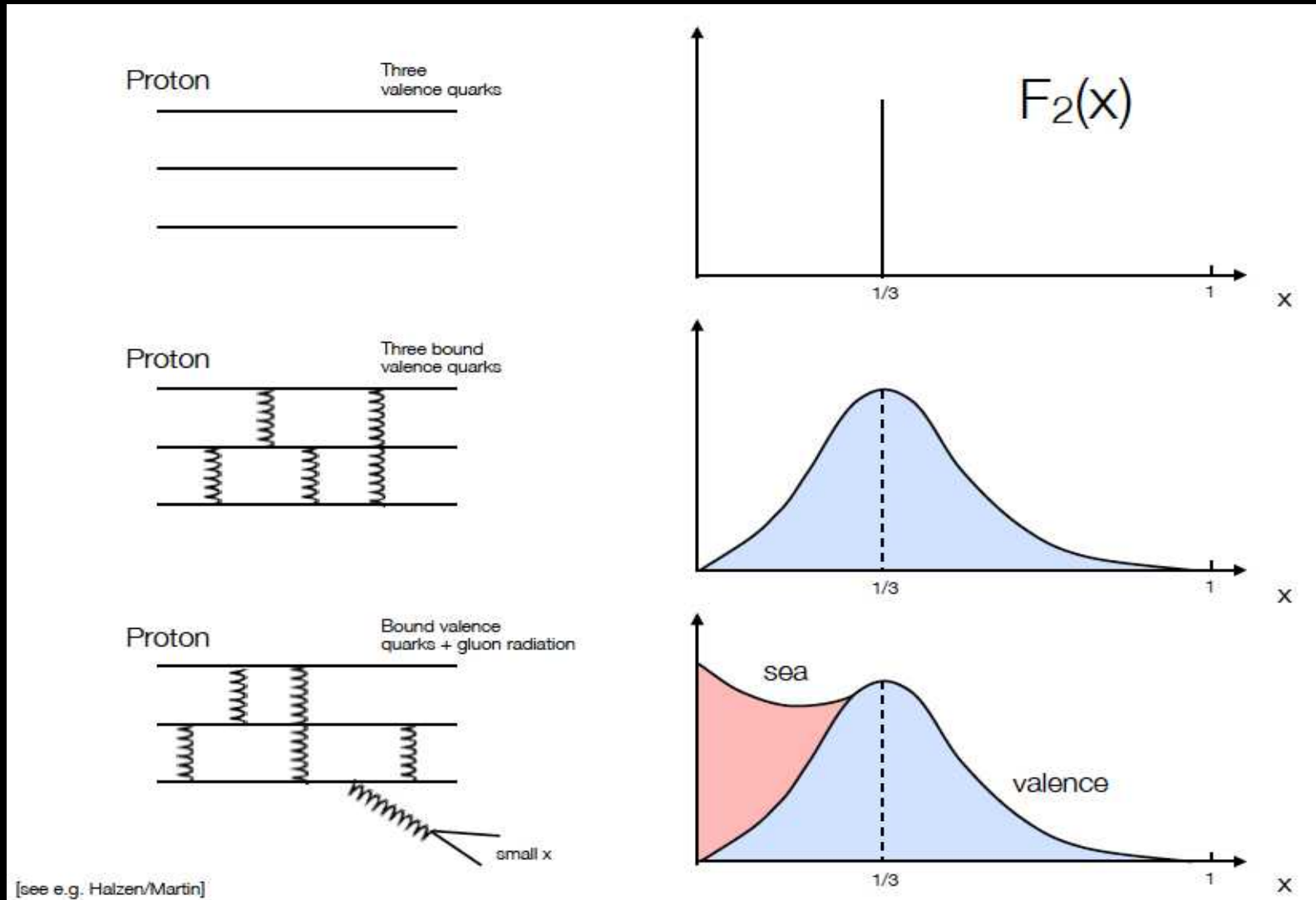
os gluões também são coloridos

Contudo, $m_p = 0,938 \text{ GeV}/c^2 \approx 1 \text{ GeV} \gg \Sigma m_q$

Protões no LHC



Como se distribui a energia dentro dos prótons

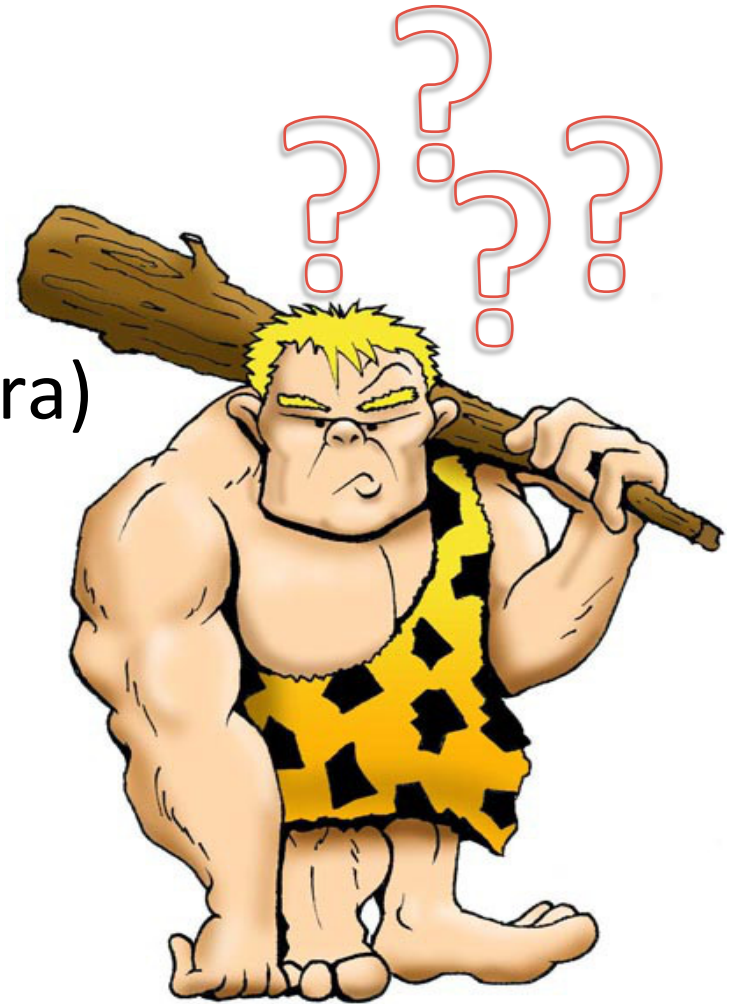


x = fracção da energia do próton levada por cada quark ou

A seguir:

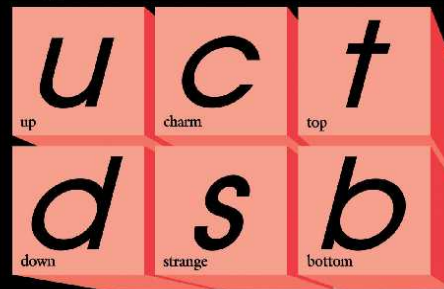
- Neutrinos (quarta-feira)
- O bóson de Higgs (sexta-feira)

Perguntas??

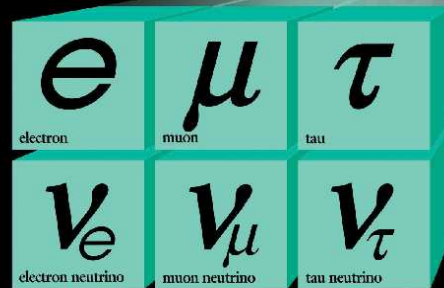
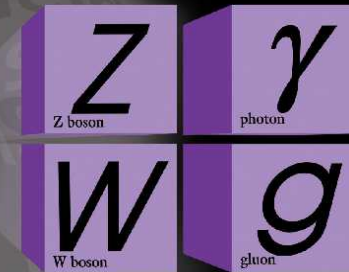


E agora, já sabemos tudo?

Quarks



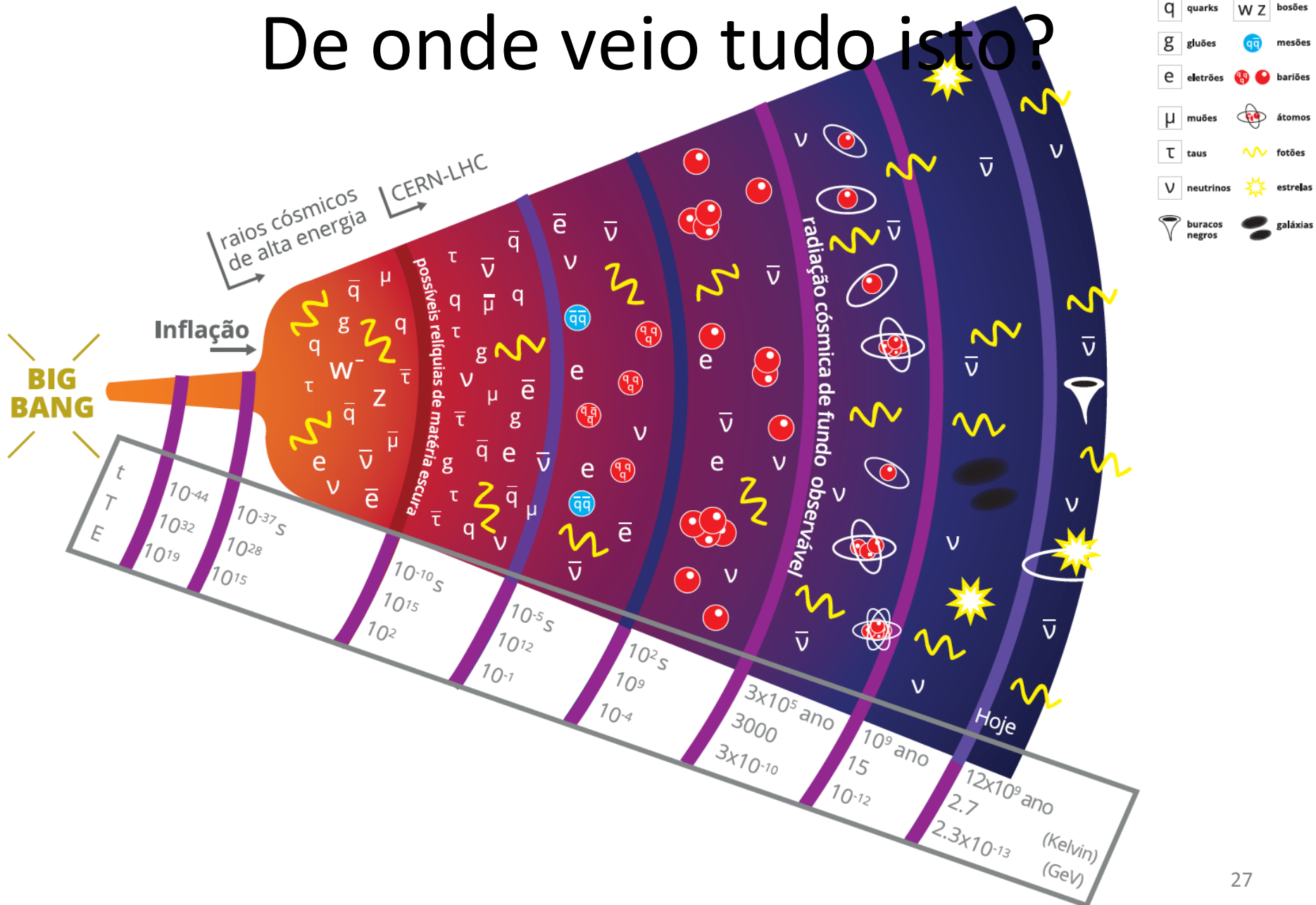
Forces



Leptons



De onde veio tudo isto?



O Modelo Padrão

Leptons

Electric Charge

Tau	-1	0	Tau Neutrino
Muon	-1	0	Muon Neutrino
Electron	-1	0	Electron Neutrino

Strong

Gluons (8)

Quarks

Mesons Baryons

Nuclei

Electromagnetic

Photon

Atoms
Light
Chemistry
Electronics

Quarks

Electric Charge

Bottom	-1/3	2/3	Top
Strange	-1/3	2/3	Charm
Down	-1/3	2/3	Up

each quark: R B G 3 colours

Gravitational

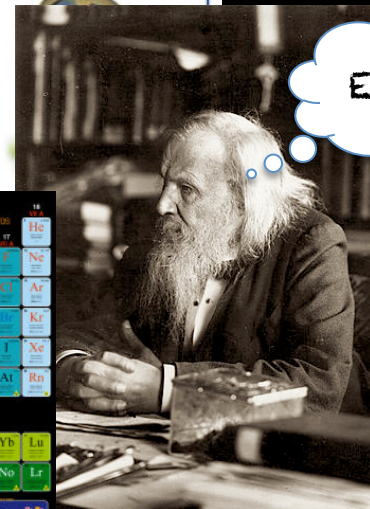
Graviton ?

Solar
Galaxy
Black

Weak

Bosons (W,Z)

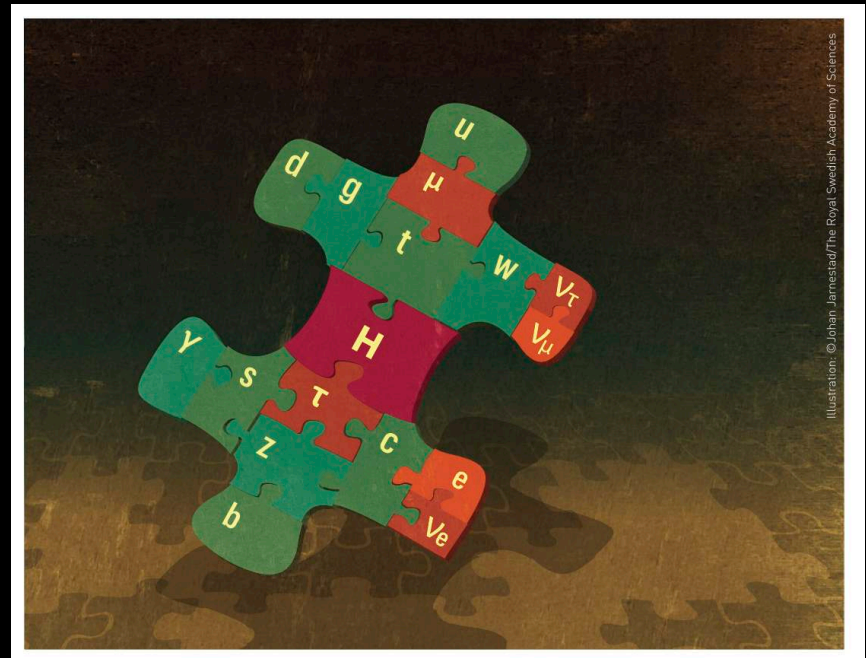
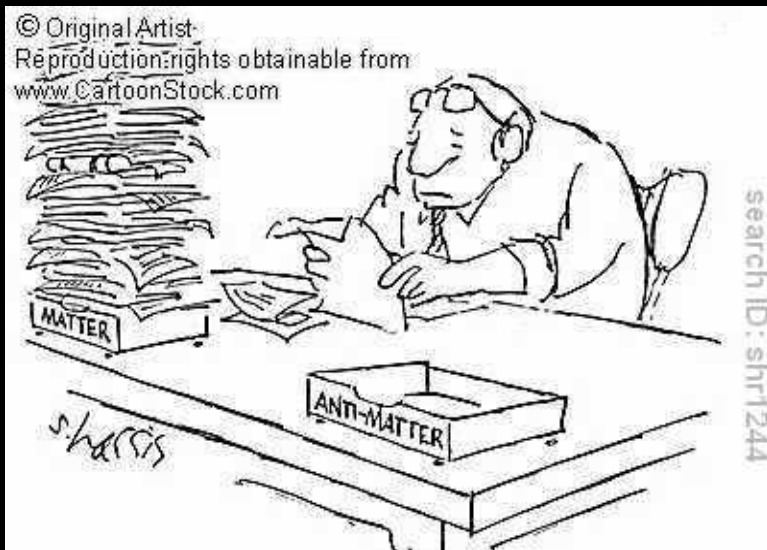
THE PERIODIC TABLE OF THE ELEMENTS



EW! EW!

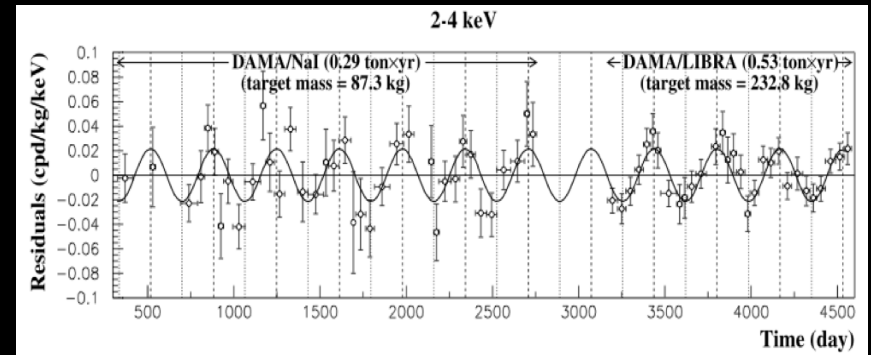
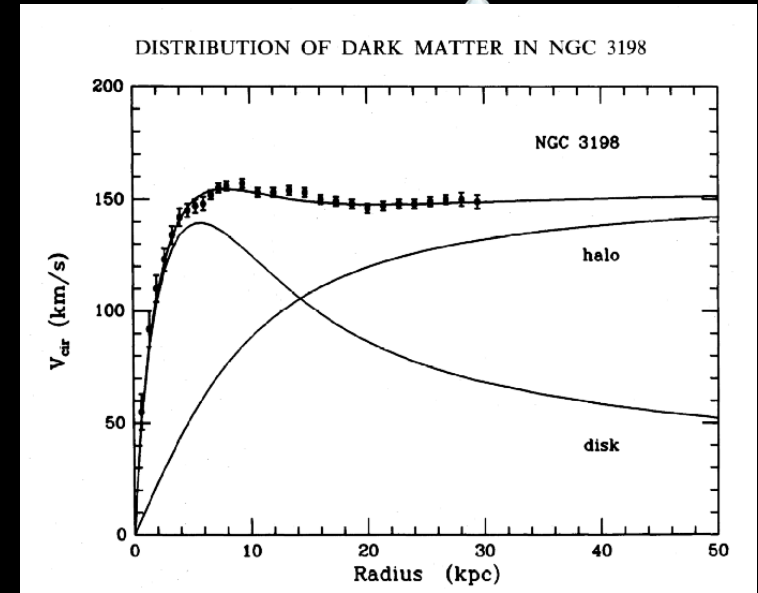
E agora?...

- O Modelo Standard NÃO pode ser o puzzle completo!
- Há uma dinâmica subjacente ao mecanismo de Higgs?
- Porque é que a força das interações e as massas das partículas são tão diferentes?
- E porque é que a expansão do universo é acelerada? Energia escura!
- União das forças a alta energia?
- Para onde foi a antimatéria?
- O que é a matéria escura



Matéria Escura

- A sua existência no Universo é clara:
 - Rotação de galáxias
 - Espectro da radiação de fundo
 - Microlensing
- Mas **não sabemos o que é!**



Unificação das interações?

