Stage Masterclass 2016

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Le costanti fondamentali della Natura e la Fisica Moderna

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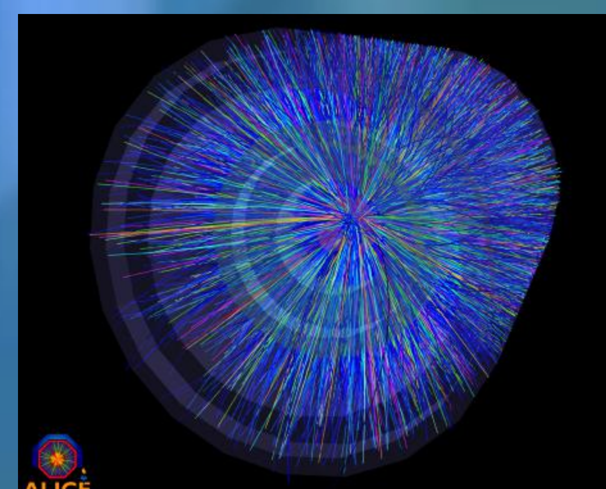
Schematicamente:

G

c

$\hbar$

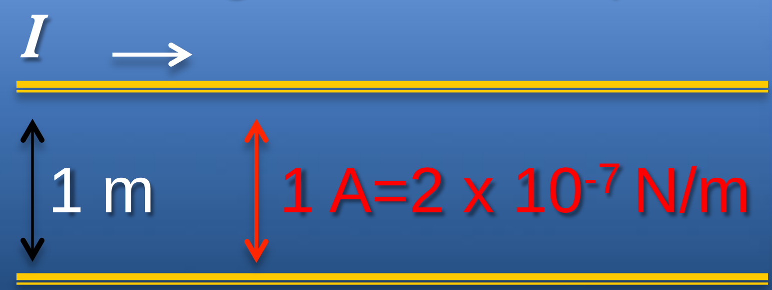


Sistemi di unità di misura

CGS (CM GR SEC)

- 1832 C. F. Gauss
- 1874 J. C. Maxwell & W. Thomson (EM Units)
- Sistemi meccanici: unità derivate E, F, P, …
- Elettromagnetismo: unità derivate (Q= $I \cdot t$)

U. El. magnetiche: Ampere



MKS (M KG SEC + EL.M)

- 1901 Proposto da G. Giorgi alla Ass.Elt.It
- 1940 Internationally adopted

Nuove unità fondamentali:

Coulomb, Candela, Kelvin, …

Sistema Internazionale

- 1960 11th Gen. Conf. Weights & Measures
- 2018 26th GCWM, redefinition Kg expected

7 unità fondamentali: MKS +

- AMPERE
- KELVIN
- CANDELA
- MOLE (added in 1971 - 11th GCWM)

Unità fondamentali e unità derivate

[Carica elettrica] Derivata:
Legge di Coulomb
E.g. F = 1 Newton, R = 1 m.

$$F = \frac{Q_1 Q_2}{R^2} \Rightarrow [Q] = [L]^{3/2} [M]^{1/2} [T]^{-1}$$

[Carica elettrica] Fondamentale
E.g. MKS + Unità di carica Q_e
Q_e = Carica elettrone

$$F = \frac{1}{4\pi \varepsilon_0} \frac{Q_1 Q_2}{R^2} \Rightarrow [\varepsilon_0] = Q_e^2 N^{-1} m^{-2}$$

Per ogni nuova unità fondamentale introdotta è necessaria una nuova "costante universale". Qui si è usata una Legge Fisica

Altri esempi

Unità Nautiche:

DISTANZA (X,Y): MIGLIO MARINO (NMI)
PROFONDITÀ (Z): BRACCIO (FTM -FATHOM)

Istropia dello spazio

$\Delta x = f\ \Delta z$ → $[f] = \text{nmi ftm}^{-1}$

Energia di una particella:
Eng. media degli atomi di un insieme:

JOULE (J)
GRADO KELVIN (K)

Teoria cinetica dei gas
$P V = N k T$

$E = k T$ → $[k] = J\ K^{-1}$

Minimo numero di unità di misura ?

Sembra sia 3....

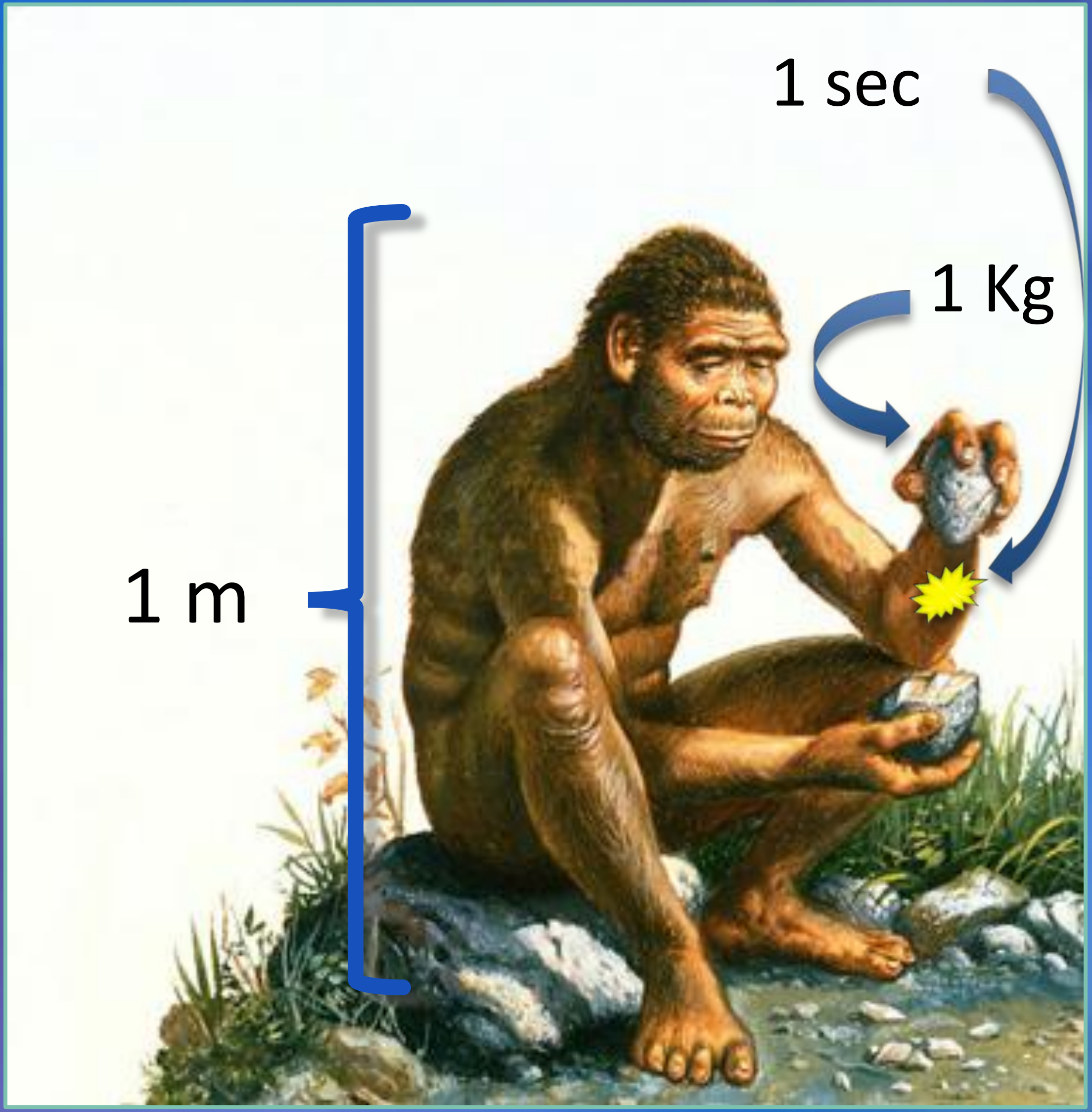
Spazio (metro) - **Massa** (kilo) - **Tempo** (sec)

Assumerò (per ora) che siano 3

Prima domanda:

Quantitativamente, perchè 1 metro, 1 kilo, 1 secondo ?

Homo Abilis (1.3-2.4 $x10^6$ yrs. ago)



Quantitativamente
un sistema di unità
"antropocentrico"

LUNGHEZZE: 1. Esperienza diretta

Factor (m)	Multiple	Value	Item
10^{-6}	1 micrometre (μm)	1 μm	also called one micron
		1–3 μm	particle size that a surgical mask removes at 80–95% efficiency[citation needed]
		6-8 μm	diameter of a red blood cell[12]
10^{-5}	10 μm	10 μm	typical size of a fog, mist or cloud water droplet. Chip 10 μm process in 1971.
		12 μm	width of acrylic fibre
		25.4 μm	1/1000 inch, commonly referred to as one thou or one mil
10^{-4}	100 μm	100 μm	average width of a strand of human hair[1]
		200 μm	typical length of *Paramecium caudatum*, a ciliate protist
		750 μm	maximum diameter of *Thiomargarita namibiensis*, the largest bacterium ever discovered
10^{-3}	1 millimetre (mm)	2.54 mm	1/10th inch; distance between pins in DIP (dual-inline-package) electronic components
		5 mm	length of average red ant
		7.62 mm	common military ammunition size
10^{-2}	1 centimetre (cm)	1.5 cm	length of a large mosquito
		2.54 cm	1 inch
		4.267 cm	diameter of a golf ball
10^{-1}	1 decimetre (dm)	10 cm	wavelength of the highest UHF radio frequency, 3 GHz
		30.48 cm	1 foot
		91.44 cm	1 yard
10^{5}	100 km	111 km	distance covered by one degree of latitude on Earth's surface
		163 km	length of the Suez Canal
		974.6 km	greatest diameter[14] of the dwarf planet,[note 1] Ceres

2. ASTRONOMICHE E COSMOLOGICHE

10^{16}	10 Pm	3.2616 light-years (3.0857×10^{16} m = 30.857 Pm)	1 parsec
		4.22 light-years = 39.9 Pm	distance to nearest star (Proxima Centauri)
		10.4 light-years = 98.4 Pm	as of September 2007, distance to nearest discovered extrasolar planet (Epsilon Eridani b)
10^{17}	100 Pm	20.4 light-years = 193 Pm	as of October 2010, distance to nearest discovered extrasolar planet with potential to support life as we know it (Gliese 581 d)
		65 light-years = 6.15×10^{17} m = 615 Pm	approximate radius of humanity's radio bubble, caused by high-power TV broadcasts leaking through the atmosphere into outer space
10^{18}	1 exametre (Em)	200 light-years = 1.9 Em	distance to nearby solar twin (HIP 56948), a star with properties virtually identical to our Sun [17]
10^{19}	10 Em	1,000 light-years = 9.46 Em or 9.46×10^{15} km	average thickness of Milky Way Galaxy[18] (1000 to 3000 ly by 21 cm observations[19])
10^{20}	100 Em	12,000 light-years = 113.5 Em or 1.135×10^{17} km	thickness of Milky Way Galaxy's gaseous disk[20]
10^{21}	1 zettametre (Zm)	100,000 light-years	diameter of galactic disk of Milky Way Galaxy[2]
		50 kiloparsecs	distance to SN 1987A, the most recent naked eye supernova
		52 kiloparsecs = 1.62×10^{21} m = 1.62 Zm	distance to the Large Magellanic Cloud (a dwarf galaxy orbiting the Milky Way)
		54 kiloparsecs = 1.66 Zm	distance to the Small Magellanic Cloud (another dwarf galaxy orbiting the Milky Way)
10^{22}	10 Zm	24 Zm = 2.5 million light-years = 770 kiloparsecs	distance to Andromeda Galaxy
		50 Zm (1.6 Mpc)	diameter of Local Group of galaxies
10^{23}	100 Zm	300–600 Zm = 10–20 megaparsecs	distance to Virgo cluster of galaxies
10^{24}	1 yottametre (Ym)	200 million light-years = 1.9 Ym = 61 megaparsecs	diameter of the Local Supercluster and the largest voids and filaments.
		550 million light-years ~170 megaparsecs ~5 Ym	diameter of the enormous Horologium Supercluster [21]
10^{25}	10 Ym	1.37 billion light years = 1.3×10^{25} m = 13 Ym	Length of the Sloan Great Wall, a giant wall of galaxies (galactic filament).[22]
10^{26}	100 Ym	1×10^{10} light-years = 9.5×10^{25} m = 95 Ym	estimated light travel distance to certain quasars
		9.2×10^{10} light years = 8.7×10^{26} m = 870 Ym	approx. diameter (comoving distance) of the visible universe[2]

3. Atomiche e Subatomiche

Factor (m)	Multiple	Value	Item
10^{-15}	1 femtometre (fm)	1.5 fm	size of an 11 MeV proton[5]
		2.81794 fm	classical electron radius[6]
			scale of the atomic nucleus[2][7]
10^{-14}	10 fm		
10^{-18}	1 attometre (am)		upper limit for the size of quarks and electrons
			sensitivity of the LIGO detector for gravitational waves
			upper bound of the typical size range for "fundamental strings"[2]
10^{-21}	1 zeptometre (zm)		Preons, hypothetical particles proposed as subcomponents of quarks and leptons; the upper bound for the width of a cosmic string in string theory.
		7 zm (7×10^{-21} metres)	effective cross section radius of high energy neutrinos[4]
		310 zm (3.10×10^{-19} metres)	de Broglie wavelength of protons at the Large Hadron Collider (4 TeV as of 2012)
10^{-24}	1 yoctometre (ym)	20 ym (2×10^{-23} metres)	effective cross section radius of 1 MeV neutrinos[3]
10^{-9}	1 nanometre (nm)	1 nm	diameter of a carbon nanotube[9]
		2.5 nm	Smallest transistor gate oxide thickness microprocessors (as of Jan 2007)
		6–10 nm	thickness of cell membrane
10^{-8}	10 nm	10 nm	thickness of cell wall in gram-negative bacteria[citation needed]
		40 nm	extreme ultraviolet wavelength
		90 nm	Human immunodeficiency virus (HIV) (generally, viruses range in size from 20 nm to 450 nm)
10^{-7}	100 nm	121.6 nm	wavelength of the Lyman-alpha line[10]
		380–435 nm	wavelength of violet light—see color and optical spectrum[11]
		625–740 nm	wavelength of red light[11]

Tempo: 1. Esperienza diretta

10^{-3}	1 millisecond	ms	One thousandth of one second	**4–8 ms**: typical seek time for a computer hard disk **100–400 ms** (=0.1–0.4 s): Blink of an eye[7] **18–300 ms** (=0.02–0.3 s): Human reflex response to visual stimuli	1 ms, 10 ms, 100 ms
10^{0}	1 second	s		**1 s**: 9,192,631,770 periods of the radiation corresponding to the transition between the two hyperfine levels of the ground state of the cesium-133 atom.[8] **60 s**: 1 minute	1 s, 10 s, 100 s
10^{3}	1 kilosecond (16.7 minutes)	ks		**3.6 ks**: 3600 s or 1 hour **86.4 ks**: 86 400 s or 1 day **604.8 ks**: 1 week	10^3 s, 10^4 s, 10^5 s
10^{6}	1 megasecond (11.6 days)	Ms		**2.6 Ms**: approximately 1 month **31.6 Ms**: approximately 1 year ≈ $10^{7.50}$ s	10^6 s, 10^7 s, 10^8 s
10^{9}	1 gigasecond (32 years)	Gs		**2.1 Gs**: average human life expectancy at birth (2011 estimate)[9] **3.16 Gs**: approximately 1 century **31.6 Gs**: approximately 1 millennium	10^9 s, 10^{10} s, 10^{11} s

2. Geologici e Cosmologici

10^{12}	1 terasecond (32 000 years)	Ts		**6 Ts**: time since the appearance of Homo sapiens (approximately)	10^{12} s, 10^{13} s, 10^{14} s
10^{15}	1 petasecond (32 million years)	Ps		**7.1–7.9 Ps**: 1 galactic year (225-250 million years)[10] **143 Ps**: the age of the Earth[11][12][13] **144 Ps**: the approximate age of the Solar system[14] and the Sun.[15] **430 Ps**: the approximate age of the Universe	10^{15} s, 10^{16} s, 10^{17} s
10^{18}	1 exasecond (32 billion years)	Es		**312 Es**: Estimated lifespan of a 0.1 solar mass red dwarf star.	10^{18} s, 10^{19} s, 10^{20} s
10^{21}	1 zettasecond (32 trillion years)	Zs		**3 Zs**: Estimated duration of Stelliferous Era. **9.8 Zs**:the lifetime of Brahma in Hindu mythology	10^{21} s, 10^{22} s, 10^{23} s
10^{24}	1 yottasecond (32 quadrillion years)	Ys		**1.6416 Ys**: Estimated half-life of the "stable" $^{209}_{83}Bi$ radioactive isotope. **6.616×10^{50} Ys**: Time required for a 1 solar mass black hole to evaporate completely due to Hawking radiation, if nothing more falls in.	10^{24} s, 10^{25} s, 10^{26} s and more

3. Elettronica e Particelle elementari

10^{-24}	1 yoctosecond	ys[2]	**Yoctosecond**, (*yocto-* + *second*), is one septillionth (short scale) of a second.	**0.3 ys**: mean life of the W and Z bosons.[3][4][a] **0.5 ys**: time for top quark decay, according to the Standard Model. **1 ys**: time taken for a quark to emit a gluon. **23 ys**: half-life of ^7H.	1 ys and less, 10 ys, 100 ys
10^{-21}	1 zeptosecond	zs	**Zeptosecond**, (*zepto-* + *second*), is one sextillionth (short scale) of one second.	**7 zs**: half-life of helium-9's outer neutron in the second nuclear halo. **17 zs**: approximate period of electromagnetic radiation at the boundary between gamma rays and X-rays. **300 zs**: approximate typical cycle time of X-rays, on the boundary between hard and soft X-rays. **500 zs**: current resolution of tools used to measure speed of chemical bonding[5]	1 zs, 10 zs, 100 zs
10^{-18}	1 attosecond	as	One quintillionth of one second	**12 attoseconds**: shortest measured period of time.[6]	1 as, 10 as, 100 as
10^{-15}	1 femtosecond	fs	One quadrillionth of one second	cycle time for 390 nanometre light, transition from visible light to ultraviolet	1 fs, 10 fs, 100 fs
10^{-12}	1 picosecond	ps	One trillionth of one second	**1 ps**: half-life of a bottom quark **4 ps**: Time to execute one machine cycle by an IBM Silicon-Germanium transistor	1 ps, 10 ps, 100 ps
10^{-9}	1 nanosecond	ns	One billionth of one second	**1 ns**: Time to execute one machine cycle by a 1 GHz microprocessor **1 ns**: Light travels 12 inches (30 cm)	1 ns, 10 ns, 100 ns
10^{-6}	1 microsecond	μs	One millionth of one second	sometimes also abbreviated *μ*sec **1 μs**: Time to execute one machine cycle by an Intel 80186 microprocessor **4–16 μs**: Time to execute one machine cycle by a 1960s minicomputer	1 μs, 10 μs, 100 μs

Massa: 1. Esperienza Diretta

Factor (kg)	Value	Item
	1 kg	One litre (0.001 m^3) of water[62]

Factor (kg)	Value	Item
10^{-6} milligram (mg)	2.5×10^{-6} kg	Mosquitoes, common smaller species (about 2.5 milligrams)[49]
10^{-5} centigram (cg)	1.1×10^{-5} kg	Small granule of quartz (2 mm diameter, 11 milligrams)[50]
	2×10^{-5} kg	Adult housefly (*Musca domestica*, 21.4 milligrams)[51]
10^{-4} decigram (dg)	$0.27–2.0 \times 10^{-4}$ kg	Range of amounts of caffeine in one cup of coffee (27–200 milligrams)[52]
	2×10^{-4} kg	Metric carat (200 milligrams)[53]
10^{-3} gram (g)	1×10^{-3} kg	One cubic centimeter of water (1 gram)[54]
	1×10^{-3} kg	US dollar bill (1 gram)[55]
	$\sim 1 \times 10^{-3}$ kg	Two raisins (approximately 1 gram)[56]
	8×10^{-3} kg	Coins of one Euro (7.5 grams) and one U.S. dollar (8.1 grams)[57]
10^{-2} decagram (dag)	$2–4 \times 10^{-2}$ kg	Adult mouse (*Mus musculus*, 20–40 grams)[58]
	1.4×10^{-2} kg	Amount of ethanol defined as one standard drink in the U.S. (13.7 grams)[59]
	2.8×10^{-2} kg	Ounce (avoirdupois) (28.35 grams)[53]
	4.7×10^{-2} kg	Mass equivalent of the energy that is called 1 megaton of TNT equivalent[53][60]
10^{-1} hectogram (hg)	0.1-0.2 kg	An orange (100–200 grams)[61]
	0.454 kg	Pound (avoirdupois) (454 grams)[53]

2. Terrestri

Factor (kg)	Value	Item
10^{12} petagram (Pg)	$0.8–2.1 \times 10^{12}$ kg	Global biomass of fish[98]
	4×10^{12} kg	World crude oil production in 2009 (3,843 Mt)[99]
	5.5×10^{12} kg	A teaspoon (5 ml) of neutron star material (5000 million tonnes)[100]
10^{13}	$1–100 \times 10^{13}$ kg	A 1–5 km tall mountain (very approximate)[101]
10^{14}	1.05×10^{14} kg	Global net primary production – the total mass of carbon fixed in organic compounds by photosynthesis each year on Earth[102]
	7.2×10^{14} kg	Total carbon stored in Earth's atmosphere[103]
10^{15} exagram (Eg)	2.0×10^{15} kg	Total carbon stored in the terrestrial biosphere[104]
	3.5×10^{15} kg	Total carbon stored in coal deposits worldwide[105]
10^{16}	1×10^{16} kg	951 Gaspra, the first asteroid ever to be closely approached by a spacecraft (rough estimate)[106]
	3.8×10^{16} kg	Total carbon stored in the oceans[107]
10^{17}	1.6×10^{17} kg	Prometheus, a shepherd satellite for the inner edge of Saturn's F Ring[108]

teragram (Tg)	6×10^{9} kg	Great Pyramid of Giza[90]
10^{10}	6×10^{10} kg	Amount of concrete in the Three Gorges Dam, the world's largest concrete structure[91][92]
10^{11}	$\sim 1 \times 10^{11}$ kg	The mass of a primordial black hole with an evaporation time equal to the age of the universe[93]
	2×10^{11} kg	Amount of water stored in London storage reservoirs (0.2 km^3)[94]
	4×10^{11} kg	Total mass of the human world population[67][95][96]
	5×10^{11} kg	Total biomass of Antarctic krill, probably the most plentiful animal species on the planet[97]

3. Astronomiche

Factor (kg)	Value	Item
10^{18} zettagram (Zg)	5.1×10^{18} kg	Earth's atmosphere[109]
	5.	
10^{19}	3	
	3	
10^{20}	9.	
10^{21} yottagram (Yg)	1.	
	1.	
	2.	
10^{22}	1.	
	2.	
	7.	
10^{23}	1.	
	1.	
	3.	
	6.4×10^{23} kg	Mars[121]

Factor (kg)	Value	Item
10^{24}	4.9×10^{24} kg	Venus[122]
	6.0×10^{24} kg	Earth[123]
10^{25}	3×10^{25} kg	Oort cloud[124]
	8.7×10^{25} kg	Uranus[125]
10^{26}	1.0×10^{26} kg	Neptune[126]
	5.7×10^{26} kg	Saturn[127]
10^{27}	1.9×10^{27} kg	Jupiter[128]
10^{28}	$2–14 \times 10^{28}$ kg	Brown dwarf stars (approximate)[129]
10^{29}	3×10^{29} kg	Barnard's Star, a nearby red dwarf star[130]

4. Astrofisiche e Cosmologiche

Factor (kg)	Value	Item
10^{30}	2×10^{30} kg	The Sun[131] (one solar mass or $M_\odot = 1.989 \times 10^{30}$ kg)
	2.8×10^{30} kg	Chandrasekhar limit ($1.4\ M_\odot$)[132][133]

Factor (kg)	Value	Item
10^{42}	1.2×10^{42} kg	Milky Way galaxy ($5.8 \times 10^{11}\ M_\odot$)[147]
	$2–3 \times 10^{42}$ kg	Local Group of galaxies, including the Milky Way ($1.29 \pm 0.14 \times 10^{12}\ M_\odot$)[147]
10^{43}		
10^{44}		
10^{45}	$1–2 \times 10^{45}$ kg	Local or Virgo Supercluster of galaxies, including the Local Group ($1 \times 10^{15}\ M_\odot$)[148]
10^{46}		
10^{47}		
10^{48}		
10^{49}		
10^{50}	3×10^{50} kg	Low end of the range for the estimated mass of the universe[149]
10^{51}		
10^{52}	3×10^{52} kg	Mass of the observable universe

5. Biologiche e microbiologiche

Factor (kg)	Value	Item
10^{-12} nanogram (ng)	1×10^{-12} kg	Average human cell (1 nanogram)[citation needed]
	$2–3 \times 10^{-12}$ kg	HeLa human cell[37][38]
	2×10^{-12} kg	Grain of birch pollen[39]

Factor (kg)	Value	Item
10^{-18} femtogram (fg)	1×10^{-18} kg	HIV-1 virus[23][24]
	4.7×10^{-18} kg	DNA sequence of length 4.6 Mbp, the length of the *E. coli* genome[25]
10^{-17}	~1×10^{-17} kg	Vaccinia virus, a large virus[26]
	1.1×10^{-17} kg	Mass equivalent of 1 joule[27]
10^{-16}	3×10^{-16} kg	*Prochlorococcus* cyanobacteria, the smallest (and possibly most plentiful)[28] photosynthetic organism on Earth[29][30]
10^{-15} picogram (pg)	1×10^{-15} kg	*E. coli* bacterium (wet weight)[31]
	6×10^{-15} kg	DNA in a typical diploid human cell (approximate)[32]
10^{-14}	2.2×10^{-14} kg	Human sperm cell[30][33]
	6×10^{-14} kg	Yeast cell (quite variable)[34][35]
10^{-13}	1.5×10^{-13} kg	*Dunaliella salina*, a green algae (dry weight)[36]

10^{-7}	1.5×10^{-7} kg	US RDA for iodine for adults[46]
	$2–3 \times 10^{-7}$ kg	Fruit fly (dry weight)[47][48]

6. Molecolari, Atomiche e Particelle

Factor (kg)	Value	Item
10^{-40}	4.2×10^{-40} kg	Mass equivalent of the energy of a photon at the peak of the spectrum of the cosmic microwave background radiation (0.235 meV/c^2)[citation needed]
10^{-36}	1.8×10^{-36} kg	One eV/c^2, the mass equivalent of one electronvolt[2]
	3.6×10^{-36} kg	Electron neutrino, upper limit on mass (2 eV/c^2)[3]
10^{-31}	9.11×10^{-31} kg	Electron (511 keV/c^2), the lightest elementary particle with a measured nonzero rest mass[4]
10^{-30}	3.0–5.5 $\times 10^{-30}$ kg	Up quark (as a current quark) (1.7–3.1 MeV/c^2)[5]
10^{-28}	1.9×10^{-28} kg	Muon (106 MeV/c^2)[6]
10^{-27} yoctogram (yg)	1.661×10^{-27} kg	Atomic mass unit (u) or dalton (Da)
	1.673×10^{-27} kg	Proton (938.3 MeV/c^2)[7][8]
	1.674×10^{-27} kg	Hydrogen atom, the lightest atom
	1.675×10^{-27} kg	Neutron (939.6 MeV/c^2)[9][10]
10^{-26}	1.2×10^{-26} kg	Lithium atom (6.941 u)
	3.0×10^{-26} kg	Water molecule (18.015 u)
	8.0×10^{-26} kg	Titanium atom (47.867 u)
10^{-25}	1.6×10^{-25} kg	Z boson (91.2 GeV/c^2)[11]
	1.8×10^{-25} kg	Silver atom (107.8682 u)
	3.1×10^{-25} kg	Top quark (173 GeV/c^2),[12] the heaviest known elementary particle
	3.2×10^{-25} kg	Caffeine molecule (194 u)
	3.5×10^{-25} kg	Lead-208 atom, the heaviest stable isotope known

Riassumendo

Scale:	Umana	della Natura
L/m	10^{-6}-10^{5}	10^{-24}-10^{26}
T/sec	10^{-3}-10^{9}	10^{-24}-10^{24}
M/Kg	10^{-6}-10^{5}	10^{-36}-10^{52}

Seconda domanda:

Perchè Spazio, Tempo e Massa ?

Partiamo da un' altra domanda:

Come faccio a comunicare che sono in ritardo di 1 ora al "blind date" con un extraterrestre ?

Risposta: Ritarderò di 6.7772×10^{44}

rispetto al 8.0485×10^{60} stabilito

La Natura ci ha fornito

Tre “Costanti Fondamentali”

C — Velocità [L/T] — La massima velocità possibile fra due corpi in moto relativo: $2{,}998 \times 10^{8}$ m/sec

$\hbar$ — Azione [E · T] — Quanto di azione in meccanica quantistica: 6.626×10^{-34} J sec

G — $[L^3 / (M\,T^2)]$ — Costante di gravitazione Universale: 6.674×10^{-11} $N(m/Kg)^2$

Unità di Planck

Con c, h, G possiamo costruire unità fondamentali di lunghezza, tempo e massa:

Dimension	Expression	Value
Length (L)	$l_P = \sqrt{\frac{\hbar G}{c^3}}$	$1.616\,199(97) \times 10^{-35}$ m
Mass (M)	$m_P = \sqrt{\frac{\hbar c}{G}}$	$2.176\,51(13) \times 10^{-8}$ kg
Time (T)	$t_P = \frac{l_P}{c} = \frac{\hbar}{m_P c^2} = \sqrt{\frac{\hbar G}{c^5}}$	$5.391\,06(32) \times 10^{-44}$ s

Nelle di liste “ordini di grandezza”:

10^{-18}	1 attometre (am)		upper limit for the size of quarks and electrons
			sensitivity of the LIGO detector for gravitational waves
10^{-21}	1 zeptometre (zm)		Preons, hypothetical particles proposed as subcomponents of quarks and leptons;
		7 zm (7×10^{-21} metres)	effective cross section radius of high energy neutrinos[4]
		310 zm (3.10×10^{-19} metres)	de Broglie wavelength of protons at the Large Hadron Collider (4 TeV as of 2012)
10^{-24}	1 yoctometre (ym)	20 ym (2×10^{-23} metres)	effective cross section radius of 1 MeV neutrinos[3]

Planck Length

10^{-35}		1.62×10^{-35} m	Planck length; typical scale of hypothetical loop quantum gravity lengths smaller than this do not make any physical sense. Quantum foam is thought to exist at this level.

Planck Time

10^{-44}			**5.4×10^{-20} ys = 5.4×10^{-44} s**:	One Planck time $t_P = \sqrt{\hbar G/c^5} \approx 5.4\times10^{-44}$ s,[1] the time required for light to travel one Planck length, is the briefest physically meaningful span of time.

10^{-24}	1 yoctosecond	ys[2]	**Yoctosecond**, (*yocto-* + *second*), is one septillionth (short scale) of a second.	**0.3 ys**: mean life of the W and Z bosons.[3][4][a] **0.5 ys**: time for top quark decay, according to the Standard Model. **1 ys**: time taken for a quark to emit a gluon. **23 ys**: half-life of ^{7}H.	1 ys and less, 10 ys, 100 ys
10^{-21}	1 zeptosecond	zs	**Zeptosecond**, (*zepto-* + *second*), is one sextillionth (short scale) of one second.	**7 zs**: half-life of helium-9's outer neutron in the second nuclear halo. **17 zs**: approximate period of electromagnetic radiation at the boundary between gamma rays and X-rays. **300 zs**: approximate typical cycle time of X-rays, on the boundary between hard and soft X-rays. **500 zs**: current resolution of tools used to measure speed of chemical bonding[5]	1 zs, 10 zs, 100 zs
10^{-18}	1 attosecond	as	One quintillionth of one second	**12 attoseconds**: shortest measured period of time.[6]	1 as, 10 as, 100 as
10^{-15}	1 femtosecond	fs	One quadrillionth of one second	cycle time for 390 nanometre light, transition from visible light to ultraviolet	1 fs, 10 fs, 100 fs
10^{-12}	1 picosecond	ps	One trillionth of one second	**1 ps**: half-life of a bottom quark **4 ps**: Time to execute one machine cycle by an IBM Silicon-Germanium transistor	1 ps, 10 ps, 100 ps
10^{-9}	1 nanosecond	ns	One billionth of one second	**1 ns**: Time to execute one machine cycle by a 1 GHz microprocessor **1 ns**: Light travels 12 inches (30 cm)	1 ns, 10 ns, 100 ns
10^{-6}	1 microsecond	µs	One millionth of one second	sometimes also abbreviated *µsec* **1 µs**: Time to execute one machine cycle by an Intel 80186 microprocessor **4–16 µs**: Time to execute one machine cycle by a 1960s minicomputer	1 µs, 10 µs, 100 µs

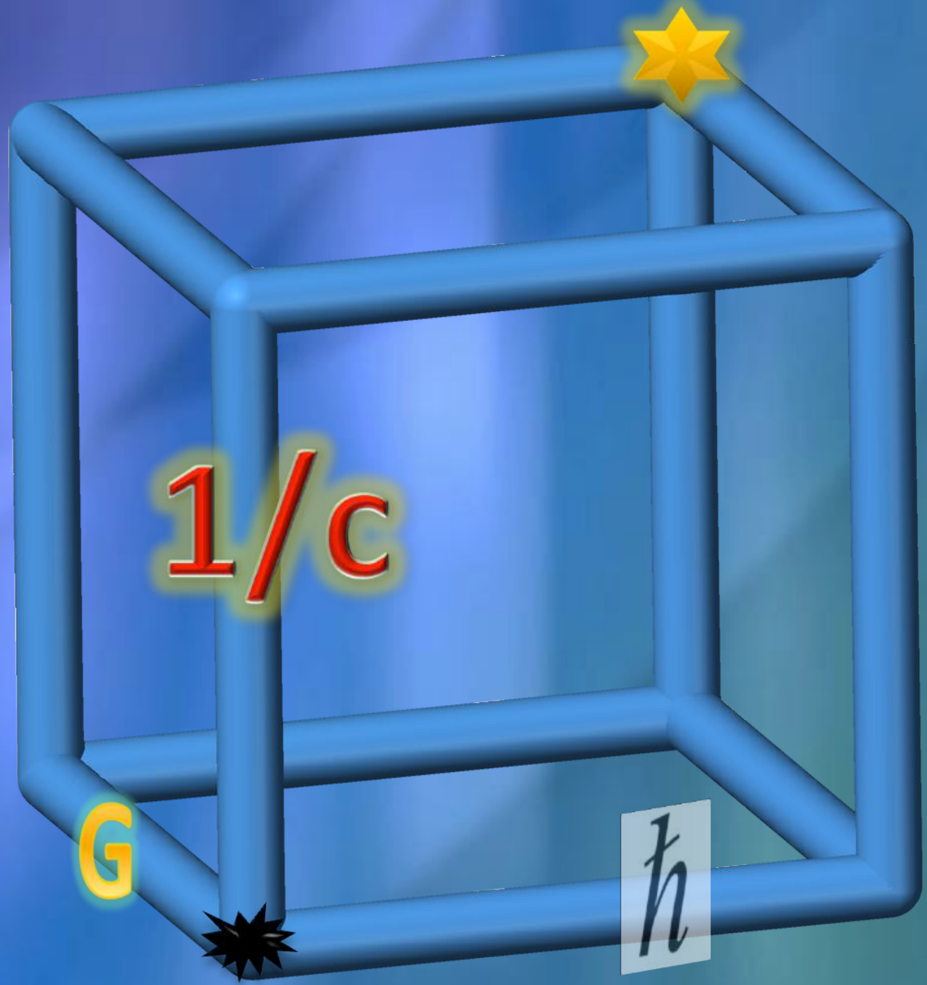
E la Massa di Planck ?

Factor (kg)	Value	Item
10^{-12} nanogram (ng)	1×10^{-12} kg	Average human cell (1 nanogram)[citation needed]
	$2–3 \times 10^{-12}$ kg	HeLa human cell[37][38]
	8×10^{-12} kg	Grain of birch pollen[39]
10^{-11}		
10^{-10}	2.5×10^{-10} kg	Grain of maize pollen[40]
	3.5×10^{-10} kg	Small grain of sand (0.063 mm diameter, 350 nanograms)
10^{-9} microgram (μg)	3.6×10^{-9} kg	Human ovum[30][41]
	2.4×10^{-9} kg	US RDA for vitamin B12 for adults[42]
10^{-8}	1.5×10^{-8} kg	US RDA for vitamin D for adults[43]
	$\sim 2 \times 10^{-8}$ kg	Uncertainty in the mass of the International Prototype Kilogram (IPK) (±~20 μg)[citation needed]
	2.2×10^{-8} kg	Planck Mass
	$\sim 7 \times 10^{-8}$ kg	One eyebrow hair (approximate)[45]
10^{-7}	1.5×10^{-7} kg	US RDA for iodine for adults[46]
	$2–3 \times 10^{-7}$ kg	Fruit fly (dry weight)[47][48]

Perchè M_P è "molto grande" ? (categoria "esperienza diretta")

NO ! SIAMO NOI AD ESSERE "INCOMPRENSIBILMENTE LEGGERI" !

Bronstein cube

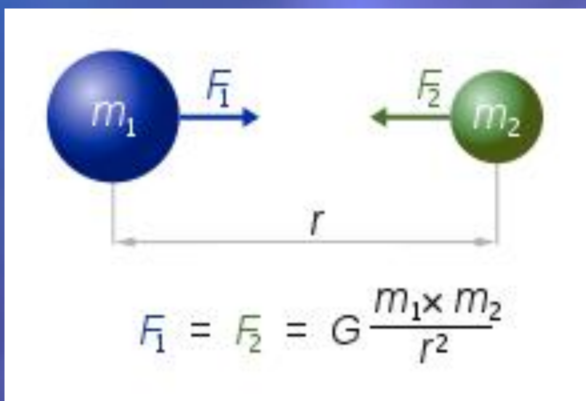


$G = h = 1/c = 0$

$c \to \infty$ $1/c \to 0$

La fisica che conoscete (h=1/c=0)

GRAVITÀ NEWTONIANA



G

Meccanica classica ….

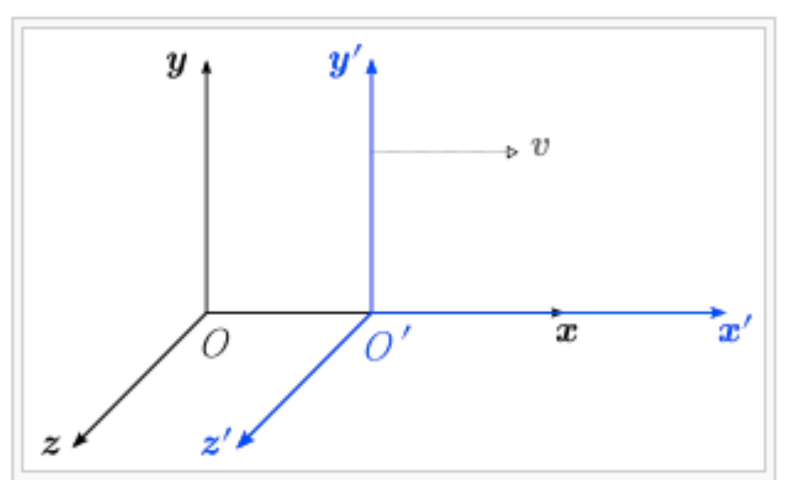
s = v. t

F = m a

G=h=1/c=0

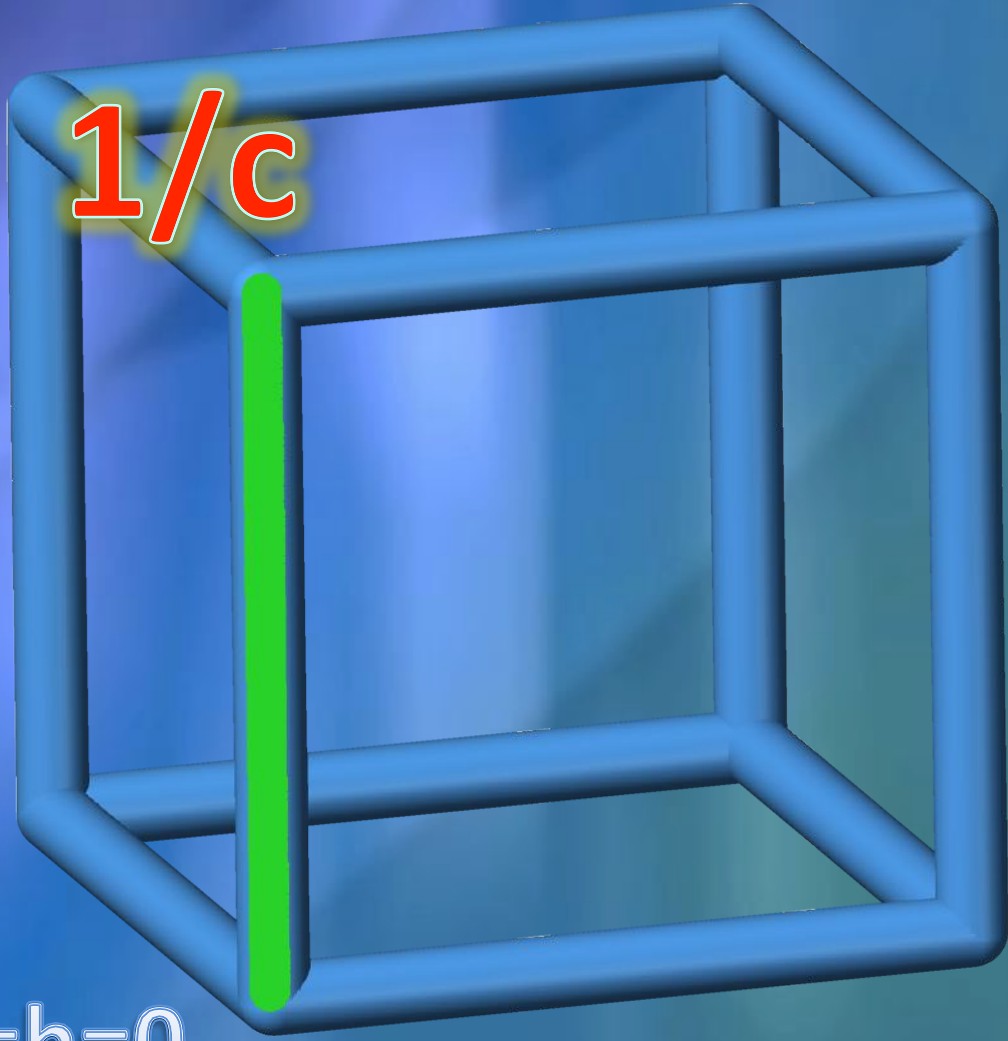
La relatività speciale: $1/c \neq 0$

Trasformazioni di Lorentz



$$t' = \gamma(t - vx/c^2)$$
$$x' = \gamma(x - vt)$$

$$\gamma = \frac{1}{\sqrt{1 - \frac{v^2}{c^2}}}$$



G=h=0

Elettromagnetismo (una teoria relativistica)

Vettori: $\vec{a} = (a_x, a_y, a_z)$; $\vec{a} \cdot \vec{b} = \sum_{i=1}^{3} a_i b_i = a_i b_i$

Invarianza delle equazioni rispetto rotazioni spaziali

Equazioni di Maxwell (1864)

$$\begin{cases} \nabla \cdot \mathbf{E} = \rho \\ \nabla \times \mathbf{E} = -\frac{\partial \mathbf{B}}{\partial t} \\ \nabla \cdot \mathbf{B} = 0 \\ \nabla \times \mathbf{B} = \mathbf{J} + \frac{\partial \mathbf{E}}{\partial t} \end{cases}$$

Quadrivettori: (1905)

$a_\mu = (a_0, a_x, a_y, a_z)$; $a.b = a_\mu b^\mu$

Invarianza rispetto trasf. di Lorentz

Eq. Maxwell in forma covariante

$$\frac{\partial F^{\mu\nu}}{\partial x^\nu} = J^\mu$$

El. Magnetismo: Notazioni Covarianti

Field Strength tensor:

$$F^{\mu\nu} = \begin{bmatrix} 0 & -E_x & -E_y & -E_z \\ E_x & 0 & -B_z & B_y \\ E_y & B_z & 0 & -B_x \\ E_z & -B_y & B_x & 0 \end{bmatrix}$$

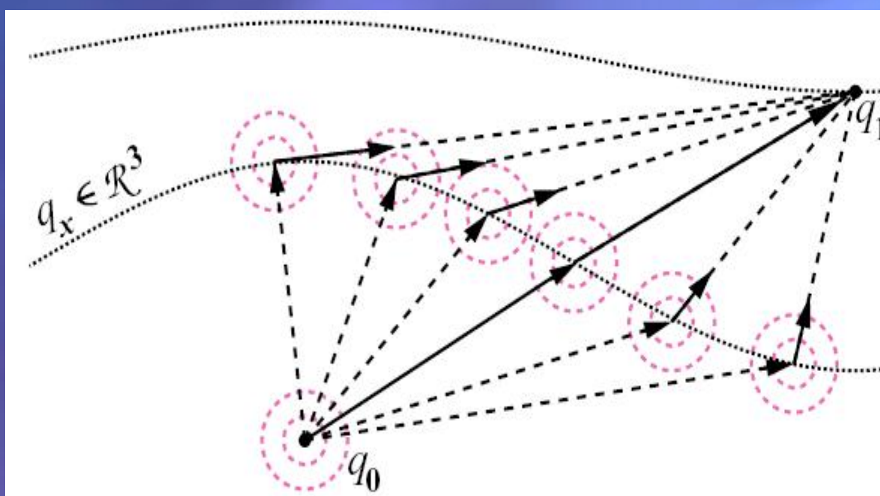
Quadri-corrente:

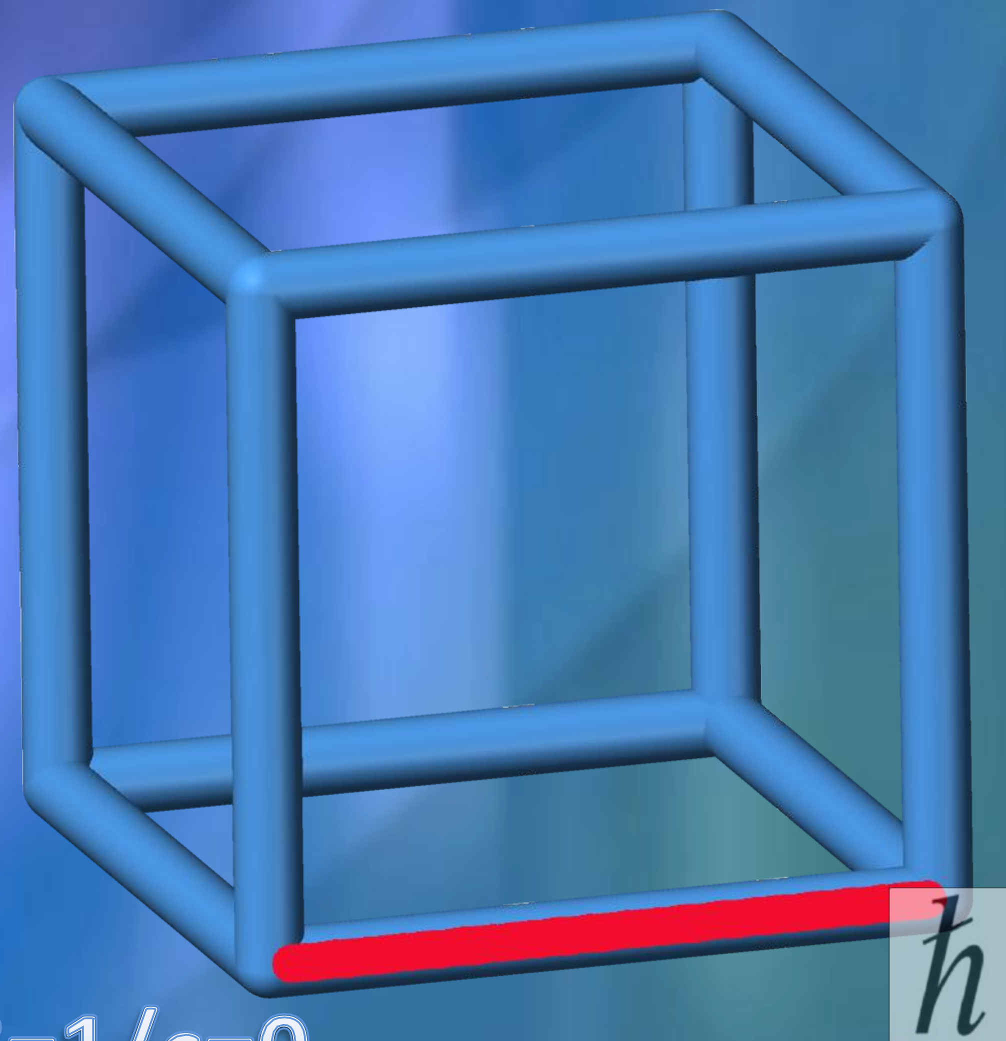
$$J^{\mu} = (\varrho, J_x, J_y, J_z)$$

Quadri-divergenza:

$$\frac{\partial}{\partial x^{\alpha}} = \left(\frac{\partial}{\partial t}, \ \nabla \right) = \partial_{\alpha}$$

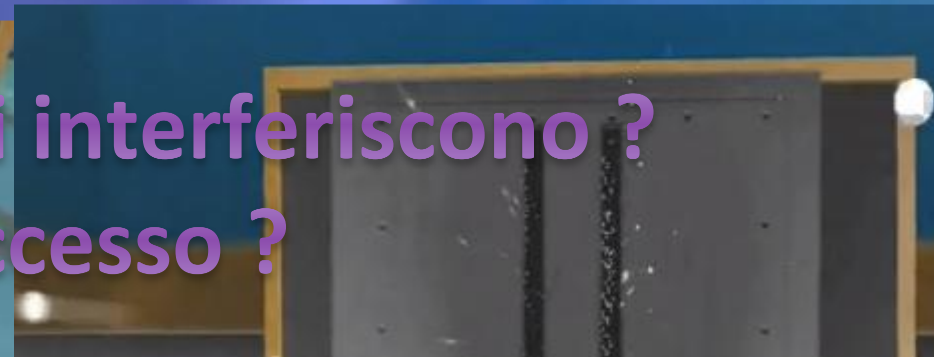
Meccanica Quantistica: h ≠ 0





G=1/c=0

Interferenza quanto meccanica



Perche' gli elettroni interferiscono ?

Cos' è successo ?

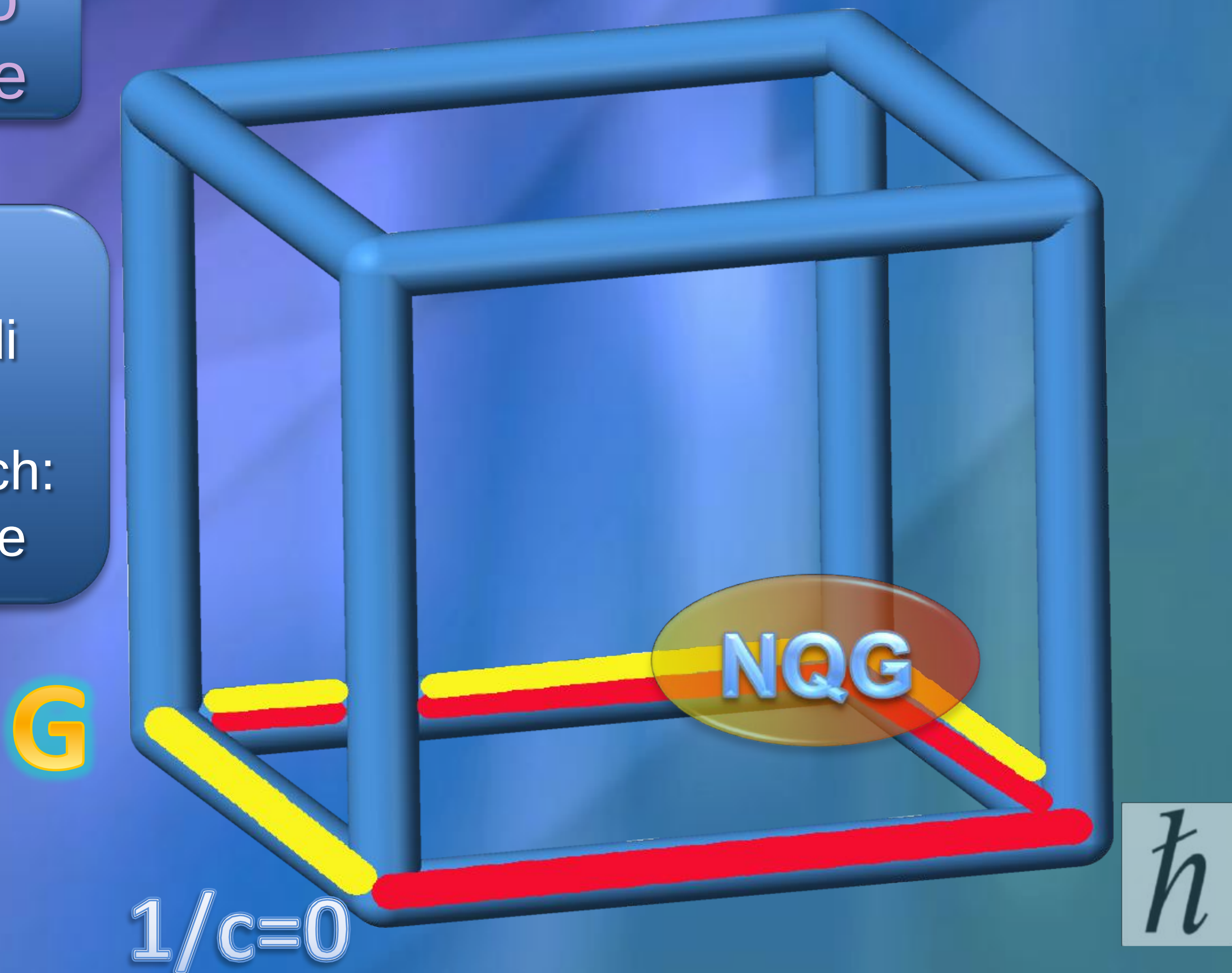
$$
\begin{aligned}
B(x''t''\tau'';x't'\tau') = {} & \frac{1}{C(\epsilon)}\prod_{n=1}^{N-1}\int\frac{d\bar{x}_n}{C(\epsilon)}\exp\left\{\frac{-i\epsilon}{\hbar}\sum_{n=1}^{N}\left[\frac{m}{2}\left(\frac{\bar{x}_n-\bar{x}_{n-1}}{\epsilon}\right)^2-V\left(\frac{\bar{x}_n+\bar{x}_{n-1}}{2}\right)\right]\right\} \\
& \cdot\frac{1}{C(\epsilon)}\prod_{n=1}^{N-1}\int\frac{dx_n}{C(\epsilon)}\exp\left\{\frac{i\epsilon}{\hbar}\sum_{n=1}^{N}\left[\frac{m}{2}\left(\frac{x_n-x_{n-1}}{\epsilon}\right)^2-V\left(\frac{x_n+x_{n-1}}{2}\right)\right]\right\} \\
= {} & \frac{1}{|C(\epsilon)|^2}\iint\frac{d\bar{x}_1\,dx_1}{|C(\epsilon)|^2}\iint\frac{d\bar{x}_2\,dx_2}{|C(\epsilon)|^2}\cdots\iint\frac{d\bar{x}_{N-1}\,dx_{N-1}}{|C(\epsilon)|^2} \\
& \times\exp\left\{\frac{i\epsilon}{\hbar}\sum_{n=1}^{N}\left(\frac{m}{2}\left[\left(\frac{x_n-x_{n-1}}{\epsilon}\right)^2-\left(\frac{\bar{x}_n-\bar{x}_{n-1}}{\epsilon}\right)^2\right]\right.\right. \\
& \left.\left.-\left[V\left(\frac{x_n+x_{n-1}}{2}\right)-V\left(\frac{\bar{x}_n+\bar{x}_{n-1}}{2}\right)\right]\right)\right\}. \qquad (23)
\end{aligned}
$$

Gravità Newtoniana Quantistica $G,h \neq 0$

Teoria poco interessante

Gravità:
Masse grandi

Quantum Mech:
Masse piccole



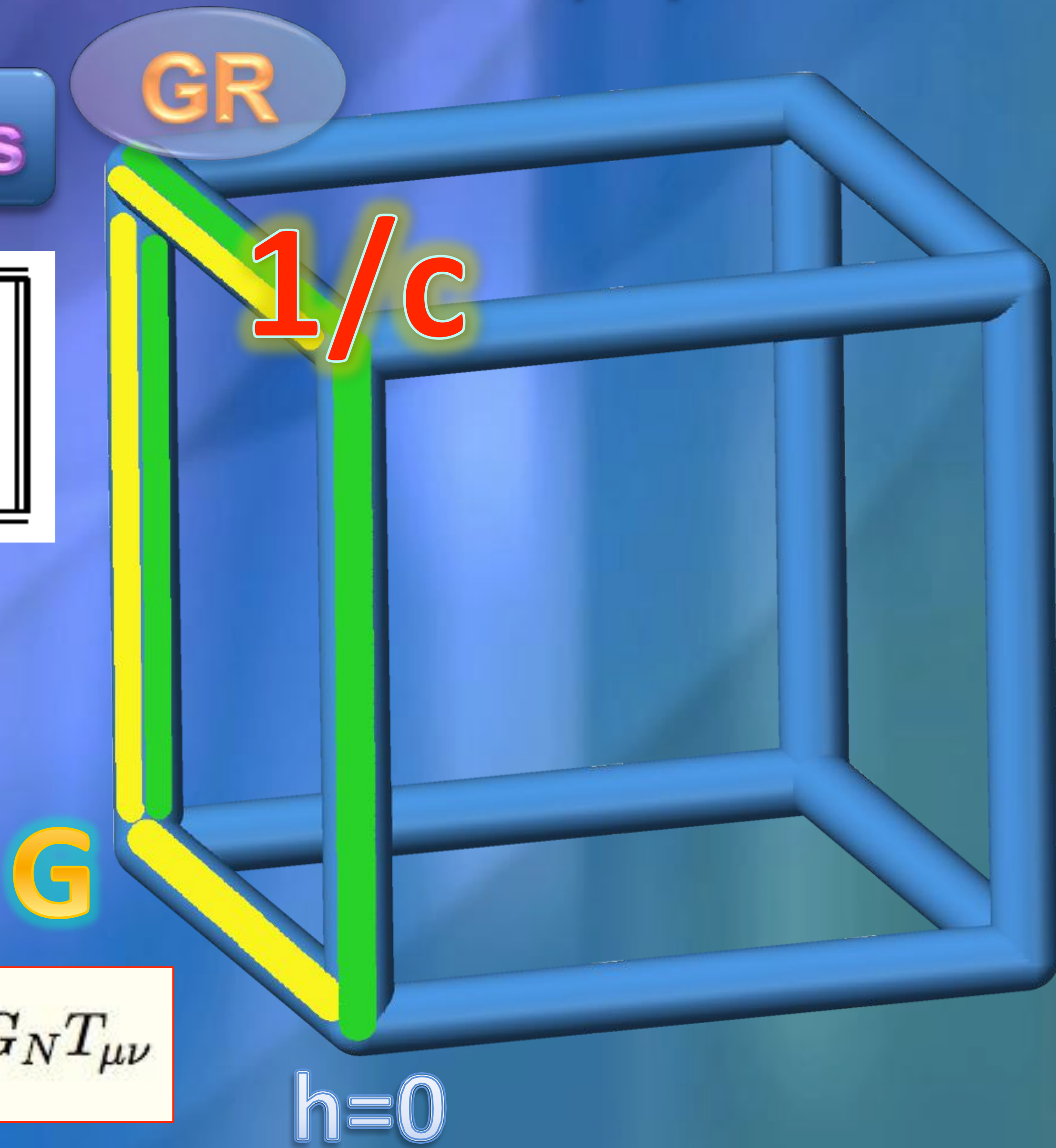
Relatività Generale: $G, 1/c \neq 0$

Einstein Equations

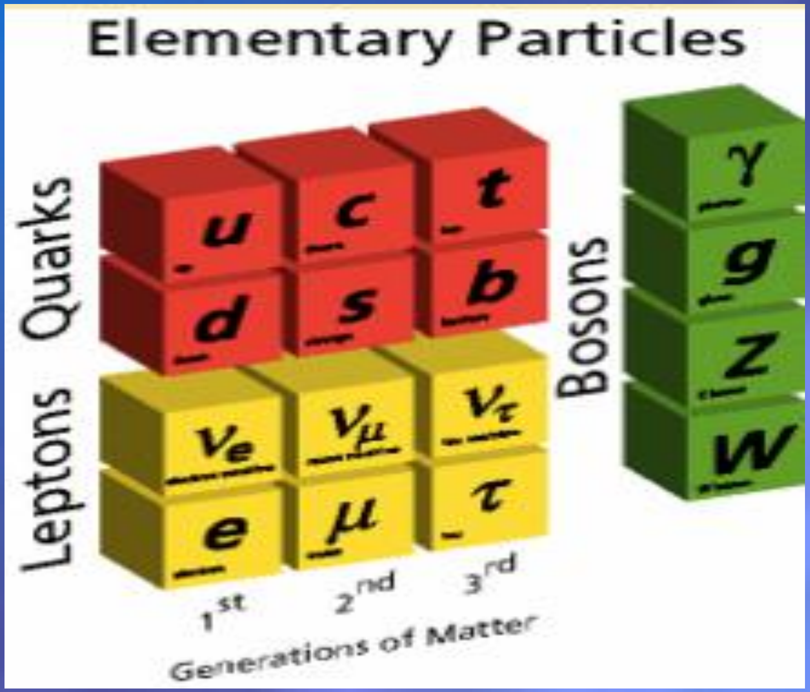
$$R_{\mu\nu} - \frac{1}{2} g_{\mu\nu} R = 8\pi G_N \, T_{\mu\nu}$$

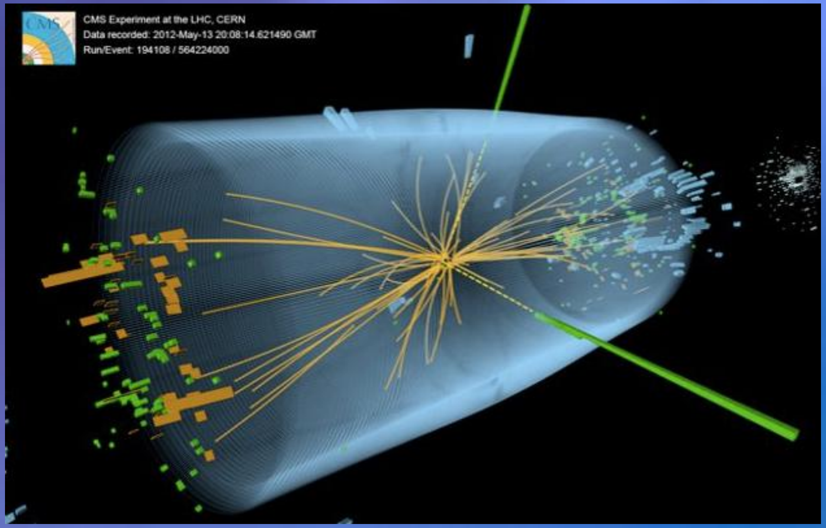
Cosmological constant

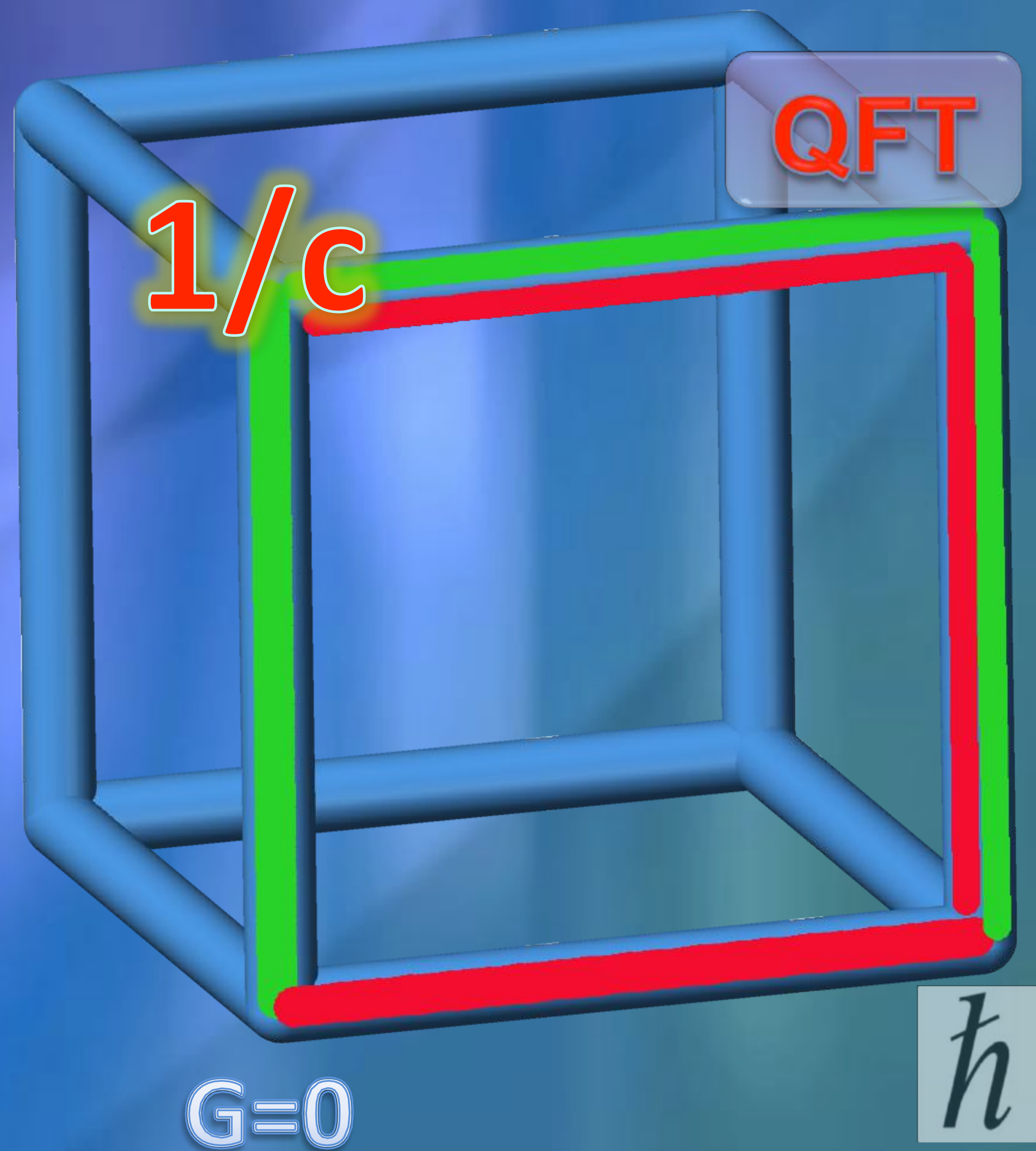
$$R_{\mu\nu} - \frac{1}{2} g_{\mu\nu} R + \Lambda g_{\mu\nu} = 8\pi G_N T_{\mu\nu}$$



Teoria Quantistica dei Campi: h,1/c ≠ 0







Quantum Field Theory: Unità naturali

$c \neq \infty$

$\hbar \neq 0$

Proviamo a porre per definizione c = h =1

$[C] = [L]\,[T]^{-1} = [1] = 0 \rightarrow [L] = [T]$

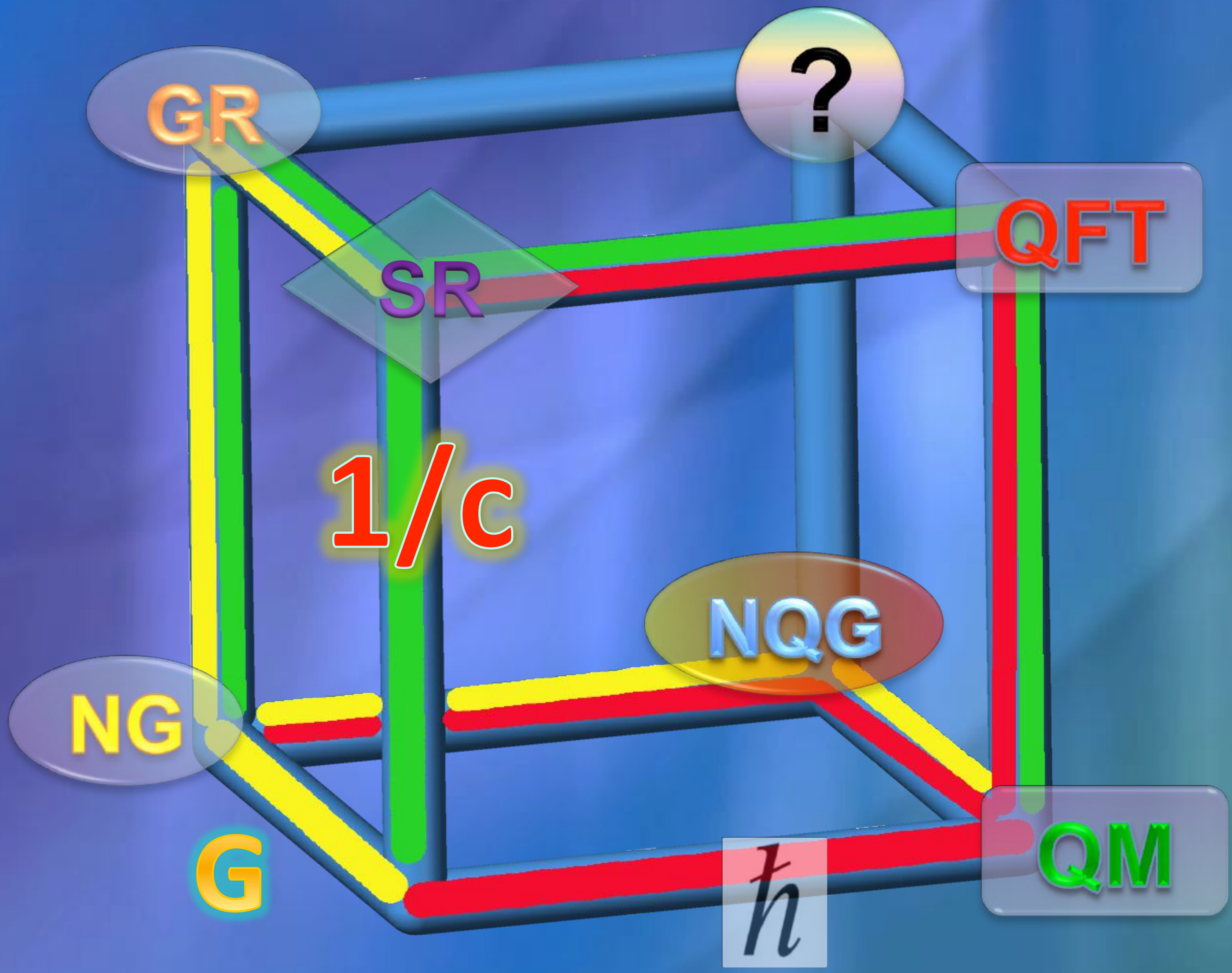
$[\hbar] = [E]\,[T] = [1] = 0 \rightarrow [L] = [T] = [E]^{-1}$

Tutto si può quindi misurare, e senza ambiguità, in unità di energia: eV = electronvolt, keV,MeV,GeV

$\hbar c = 197.326$ MeV fm = 1

$\hbar = 6.582 \times 10^{-22}$ MeV s = 1

Lo stato attuale della fisica moderna



Lo stato della fisica nel futuro (prossimo) ?

$c \neq \infty$

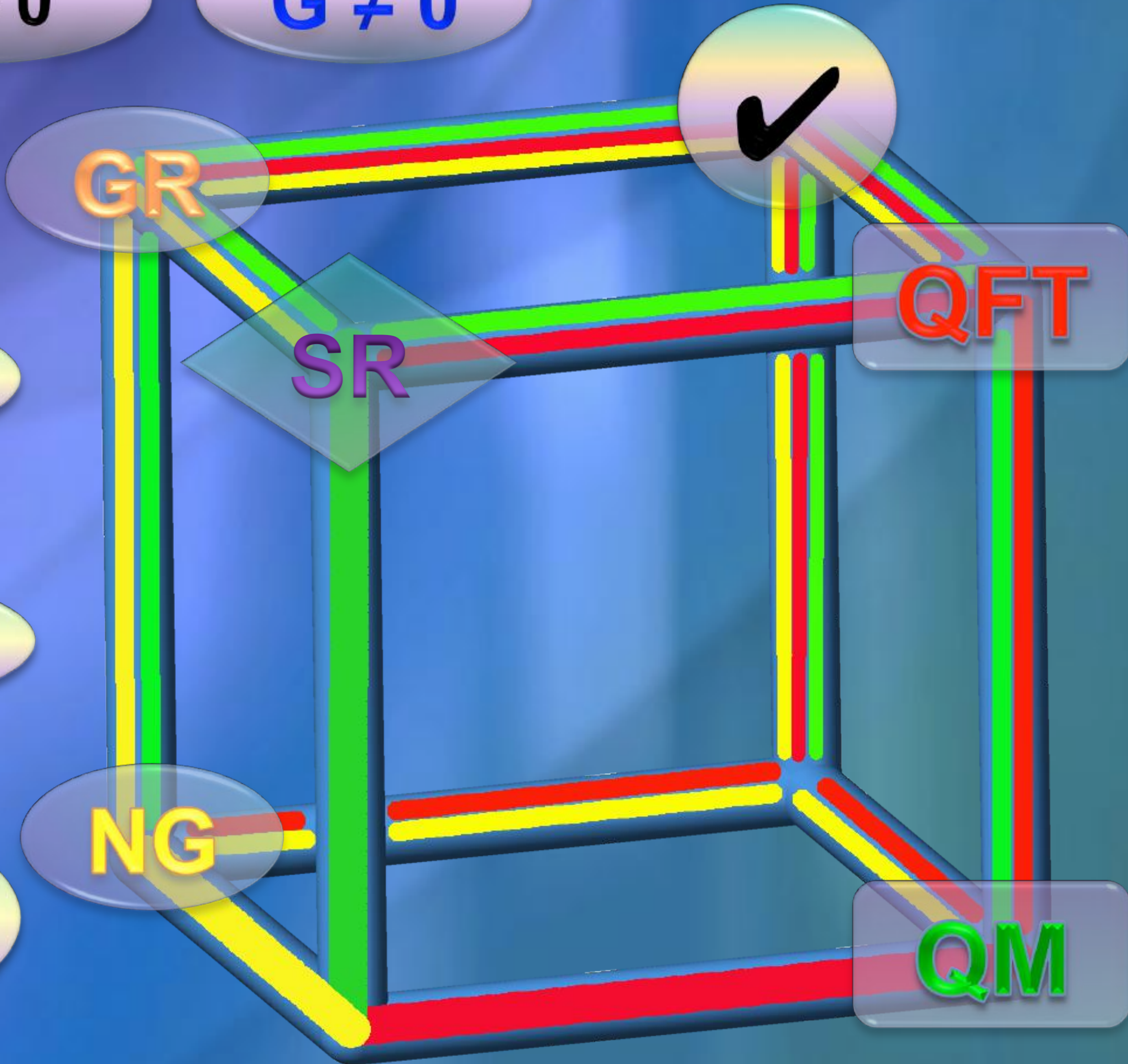
$\hbar \neq 0$

$G \neq 0$

Superstrings?

M-Theory?

Loop Quantum Gravity?



L’ ultimo vertice del cubo delle teorie:

The elimination of logical inconsistencies requires modifying the ordinary concepts of space and time, replacing them by some deeper and non evident concepts.

(Matvei Petrovich Bronstein - 1934)

L'eliminazione di incoerenze logiche richiede di modificare i concetti ordinari di spazio e tempo, sostituendoli con concetti più profondi e non evidenti

Due referenze:

Per chi volesse approfondire, rimando alle seguenti due referenze , anche se di lettura non facile (ed in inglese):

"World Constants and Limiting Transition"
G. Gamow, D. Ivanenko, and L. Landau
http://gnsardan.appfarm.ru/GIL.pdf

Questa referenza del 1928 ha dato lo spunto a M. P. Bronstein per sviluppare la sua idea di connessione fra le costanti c,h,G e le teorie fondamentali.

"Trialogue on the number of fundamental constants"
M. J. Duff, L. B. Okun, G. Veneziano
http://arxiv.org/abs/physics/0110060

Un lucido resoconto di alcune conversazioni fra tre grandi fisici contemporanei riguardo all'effettivo numero di costanti fondamentali.

Nota sulle costanti adimensionali

$$F = \frac{Q_1 Q_2}{R^2} \longrightarrow [Q^2] = [L]^3 [M] [T]^{-2}$$

$$[\hbar c] = [M] [L]^2 [T]^{-1} [L][T]^{-1} = [Q^2]$$

$$Q_{Planck} = (\hbar c)^{1/2} = 5.3 \times 10^{-19} \text{ C}$$

$$Q(e^-) = e = 1.6 \times 10^{-19} \text{ C}$$

$$\alpha = \frac{e^2}{4 \pi \hbar c} = \frac{1}{137.036}$$

$$[\alpha] = 0$$