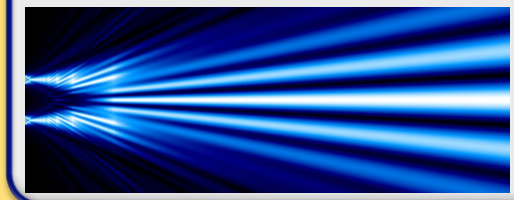
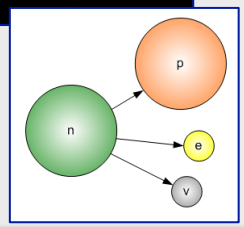
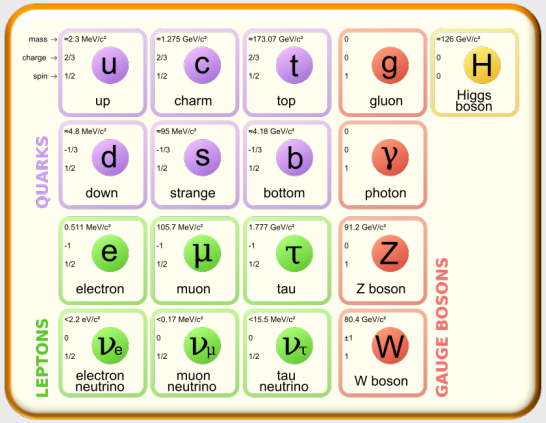
Particelle, Relatività e Meccanica Quantistica

Vittorio Lubicz

Dipartimento di Matematica e Fisica



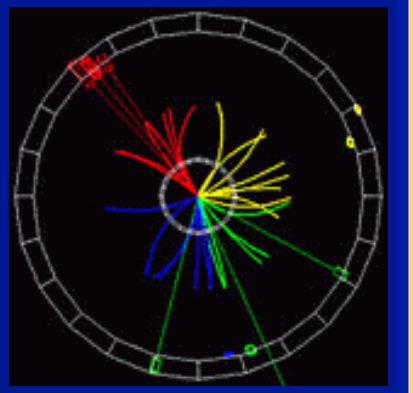




Masterclass 2015

Fisica delle Particelle Elementari

6 - 27 marzo 2015



MODELLO STANDARD

Simmetria di gauge

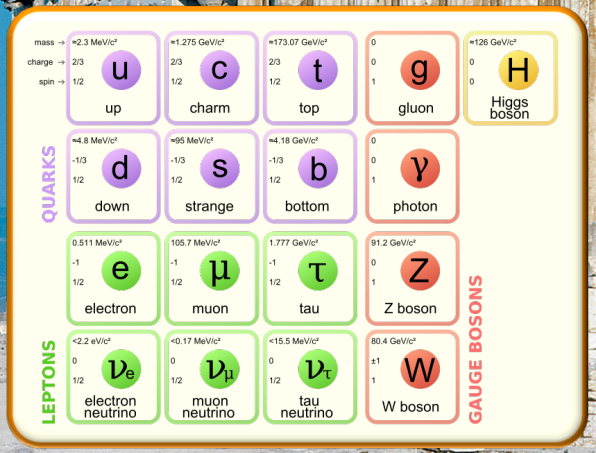
Interazioni elettromagnetiche, forti e deboli

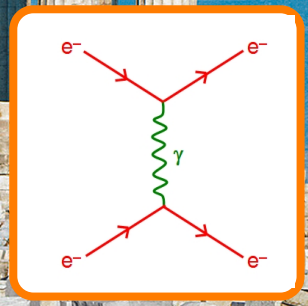
Quark

Bosone di Higgs

Leptoni

Mediatori delle forze





Meccanica quantistica

Relatività

PER I FISICI DELLE PARTICELLE

4 LEZIONI DA

RELATIVITA' E MECCANICA QUANTISTICA

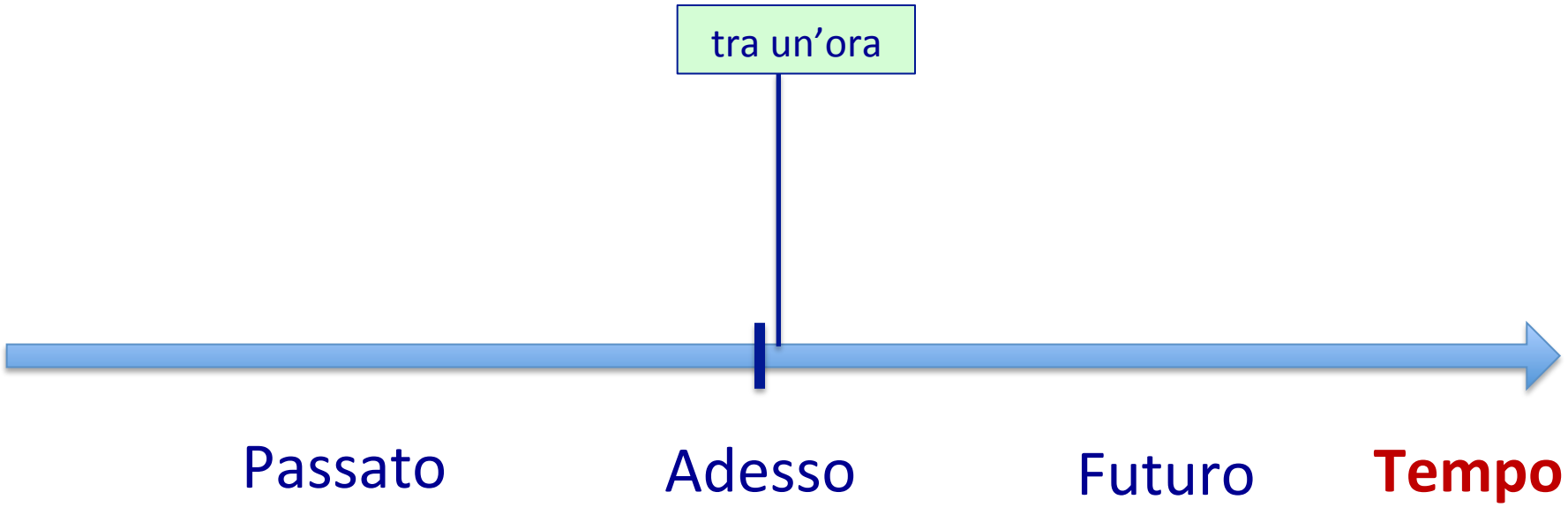
1. IL TEMPO
2. MASSA E ENERGIA
3. LE ONDE-PARTICELLE
4. LE PROBABILITA' QUANTISTICHE

PARTICELLE E RELATIVITÀ

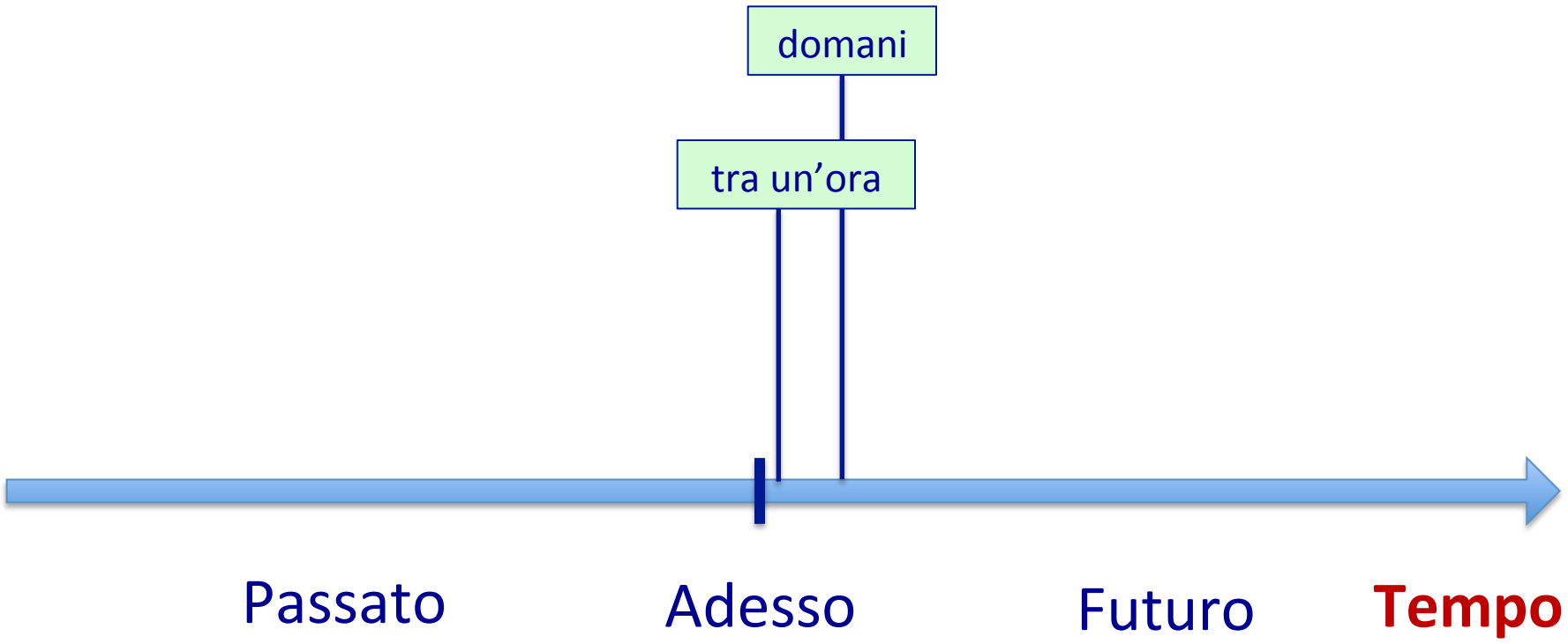
1 "IL TEMPO"

Il tempo

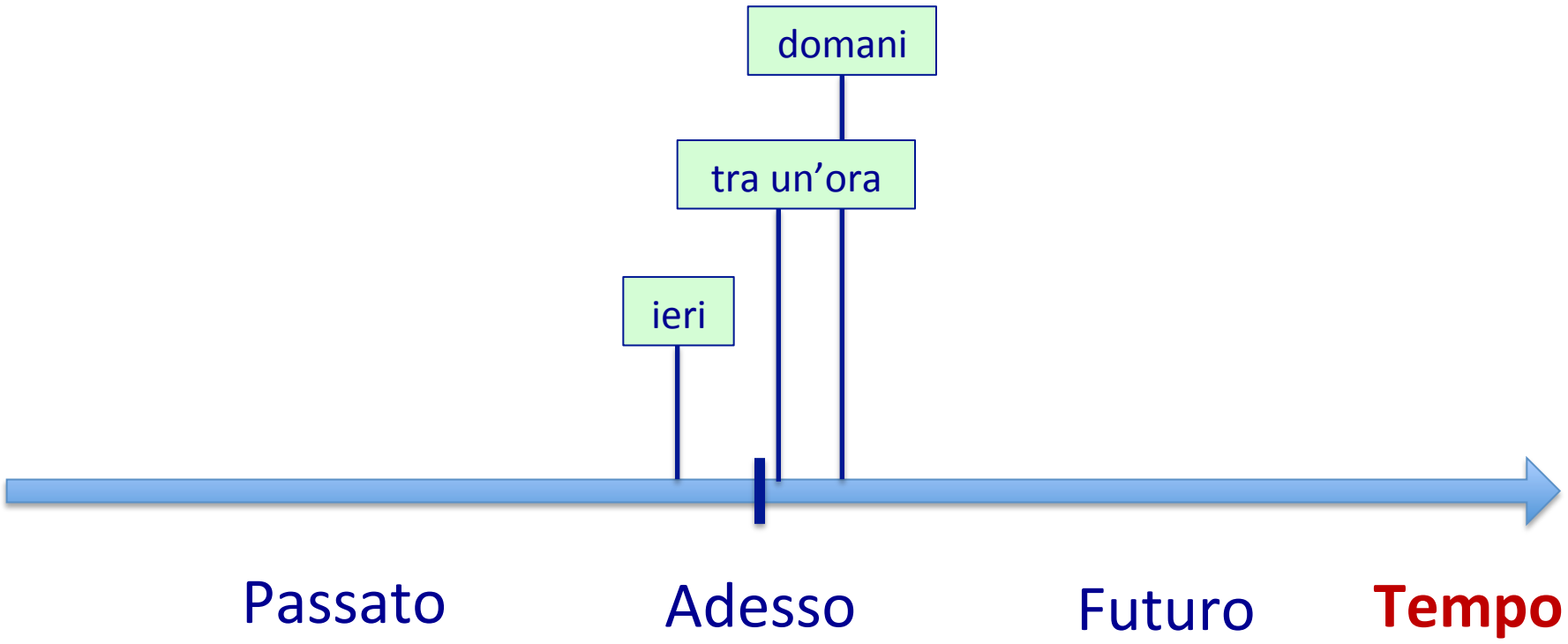
Il tempo



Il tempo



Il tempo



Il tempo

domani

tra un’ora

ieri

Passato Adesso Futuro **Tempo**

Il tempo

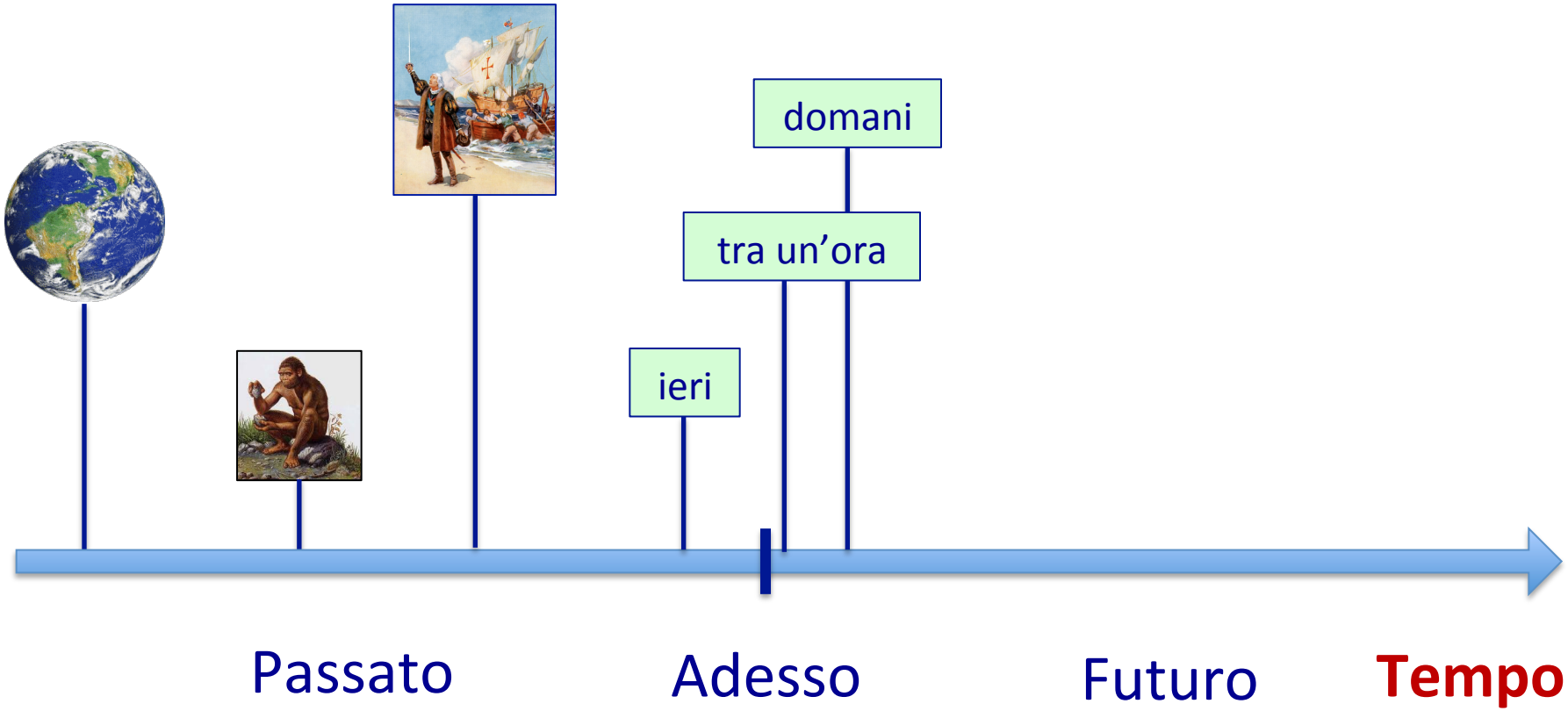
domani

tra un’ora

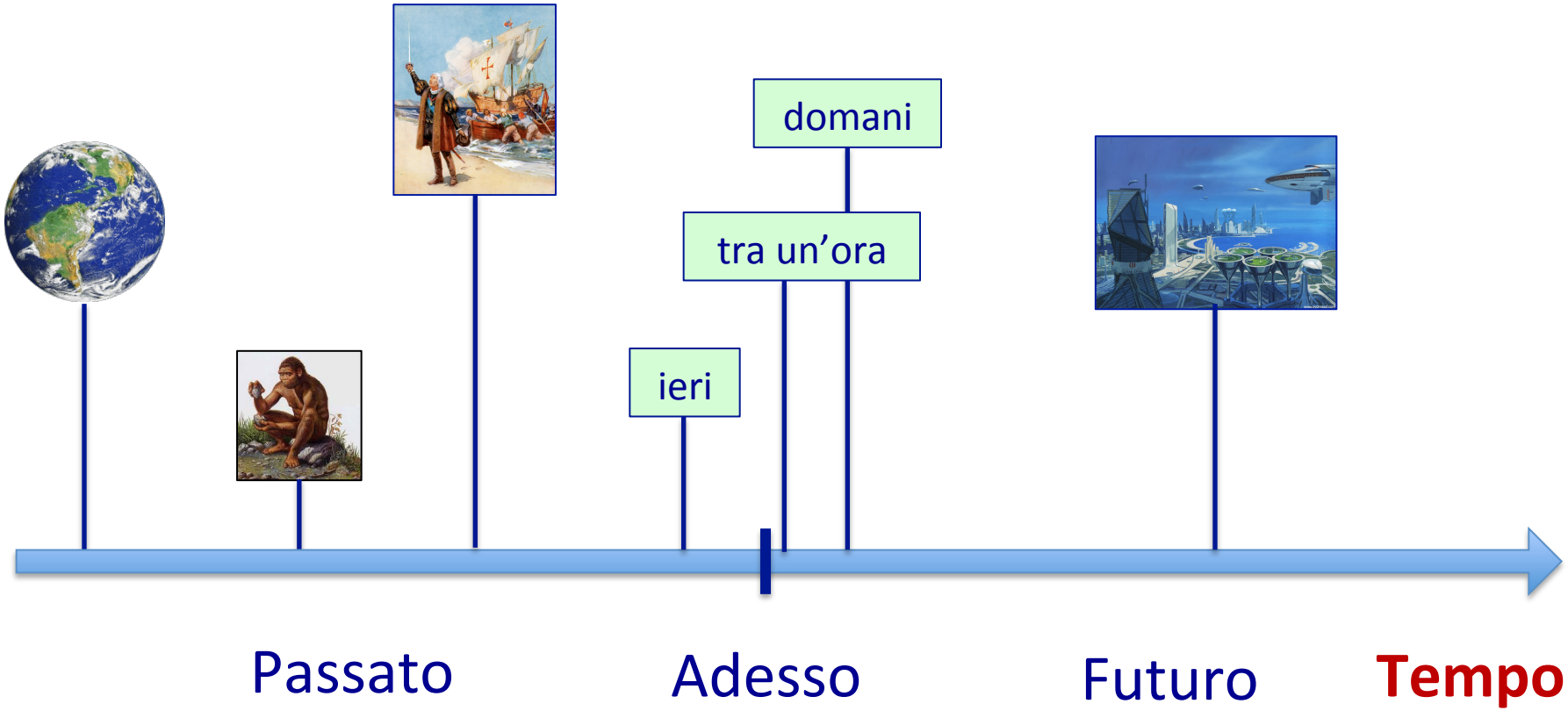
ieri

Passato Adesso Futuro **Tempo**

Il tempo



Il tempo



Il tempo

ieri

tra un'ora

domani

Passato

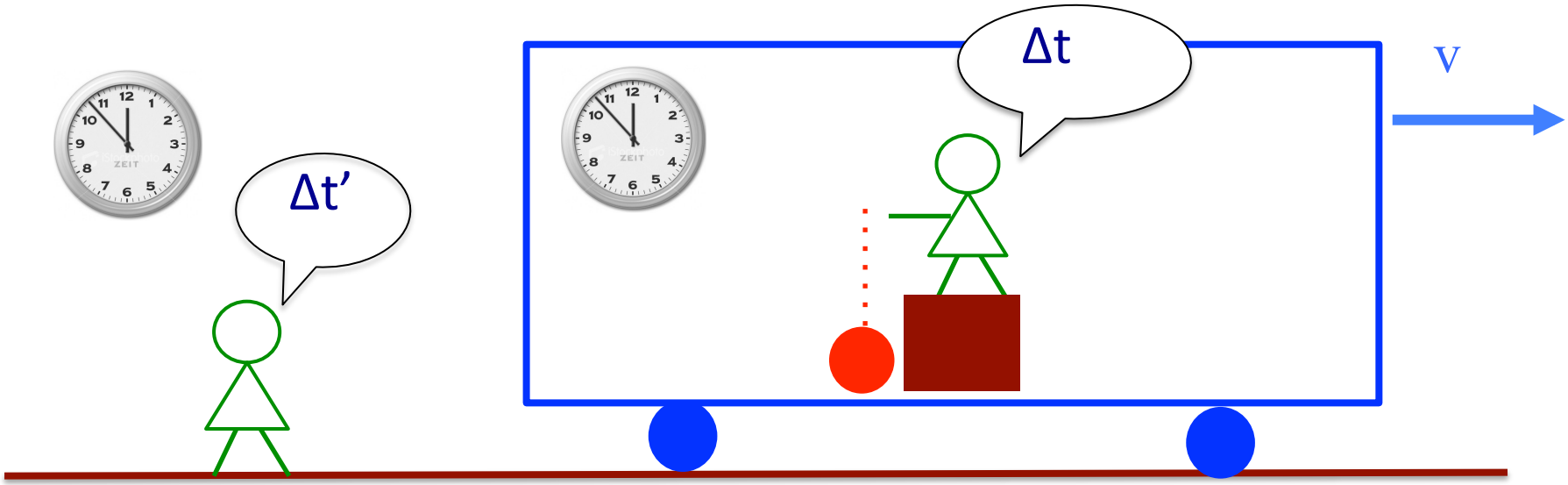
Adesso

Futuro

Tempo

Ma questa rappresentazione del tempo è sbagliata…

Il tempo relativistico

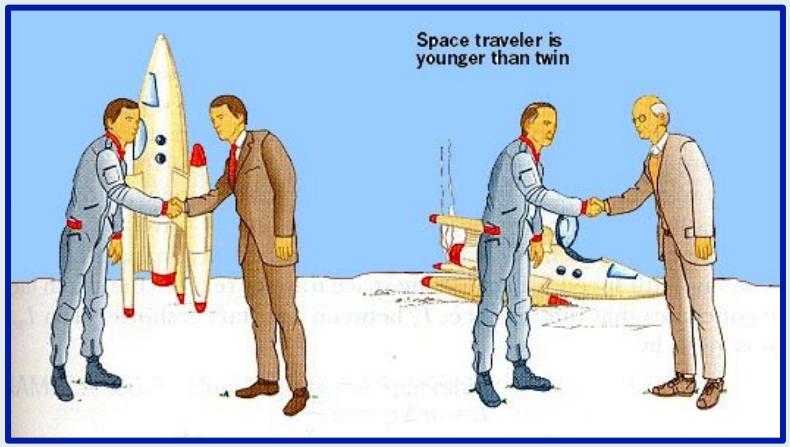


Il tempo scandito dall'orologio in moto scorre più lentamente del tempo scandito dall'orologio fermo

$$\Delta t' = \frac{\Delta t}{\sqrt{1 - v^2 / c^2}} = \gamma \Delta t$$

[Se v = 30 Km/sec, velocità della Terra intorno al Sole ($v/c = 10^{-4}$, $\gamma = 1 + 5\ 10^{-9}$)
1 ora si "allunga" di 18 microsecondi]

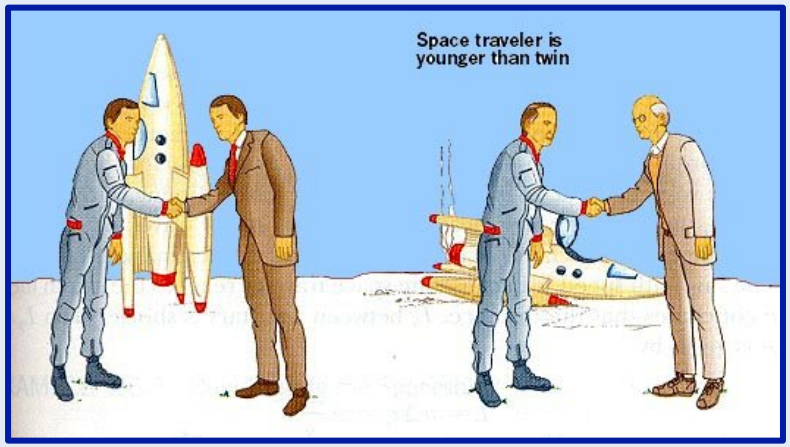
Il tempo relativistico



Il “paradosso” dei gemelli

L’esperimento di Hafele e Keating, 1971

Il tempo relativistico

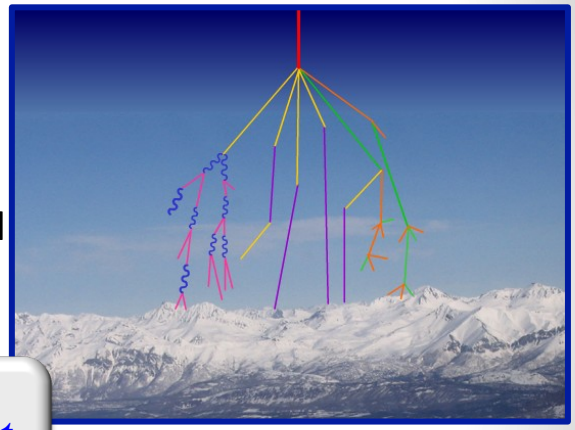


Il "paradosso" dei gemelli

L'esperimento di Hafele e Keating, 1971

La "vita media" dei muoni

I muoni si disintegrano spontaneamente dopo una vita media di 2.2×10^{-6} s. Alcuni muoni giungono sulla Terra nei raggi cosmici, prodotti nell'atmosfera a circa 10 km di altezza. Seppur viaggiando ad una velocità prossima a quella della luce, i muoni non potrebbero percorrere più di circa 660 metri. Eppure molti muoni vengono rivelati al suolo, in perfetto accordo con le previsioni sulla dilatazione del tempo.



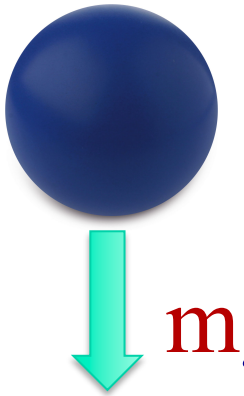
$$\Delta t' = \frac{\Delta t}{\sqrt{1 - v^2 / c^2}} = \gamma \Delta t$$

PARTICELLE E RELATIVITÀ

② "MASSA E ENERGIA"

Massa e Energia

Massa



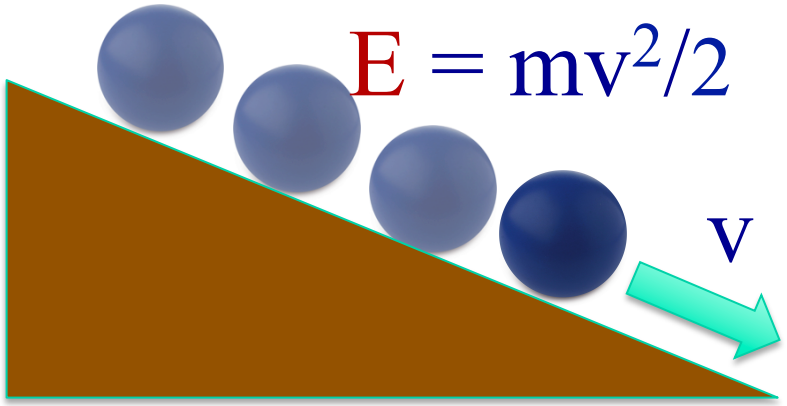
$F = ma$

Inerziale

mg Gravitazionale

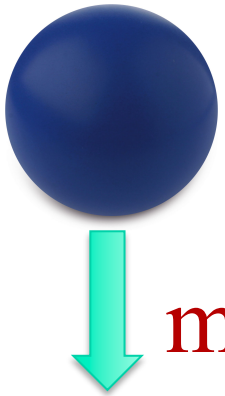
Energia

$E = mv^2/2$



Massa e Energia

Massa



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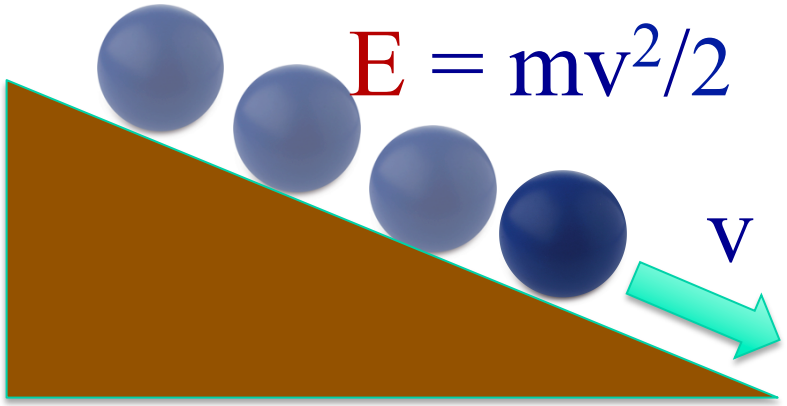
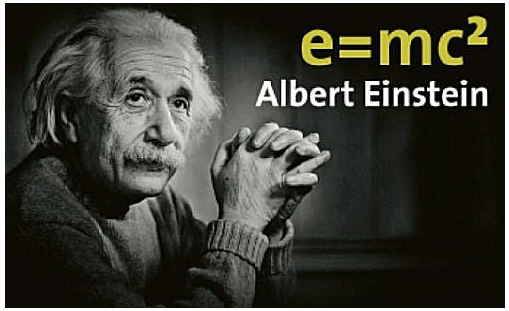
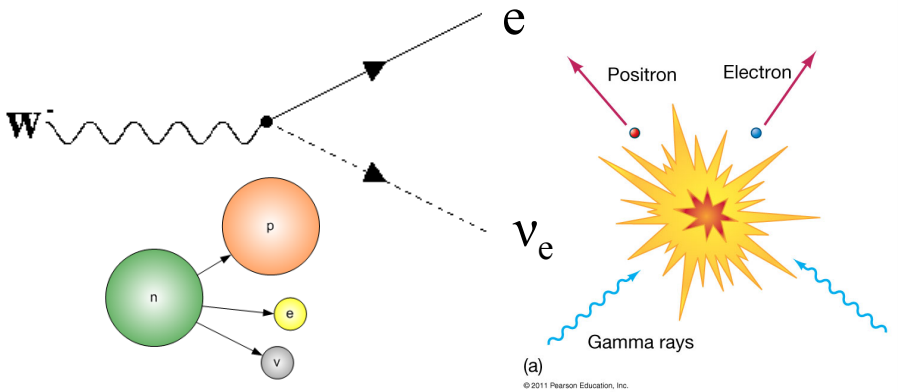




Massa = Energia

$$E = \sqrt{(mc^2)^2 + (mc\gamma v)^2}$$

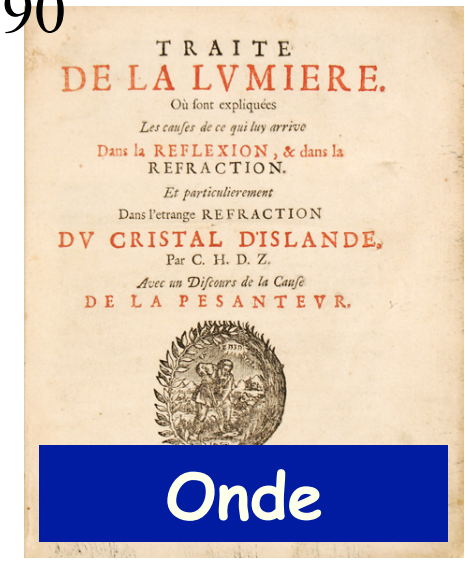


PARTICELLE E MECCANICA QUANTISTICA

3 LE ONDE-PARTICELLE

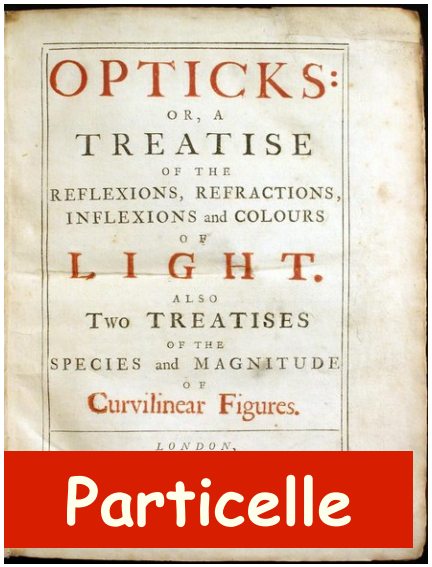
LA LUCE: ONDE O PARTICELLE ?

Christiaan Huygens, 1690


TRAITE
DE LA LVMIERE.
Où sont expliquées
Les causes de ce qui luy arrive
Dans la REFLEXION, & dans la REFRACTION.
Et particulierement
Dans l'etrange REFRACTION
DV CRISTAL D'ISLANDE.
Par C. H. D. Z.
Avec un Discours de la Cause
DE LA PESANTEVR.

Onde

Isaac Newton, 1704


OPTICKS:
OR, A
TREATISE
OF THE
REFLEXIONS, REFRACTIONS,
INFLEXIONS and COLOURS
OF
LIGHT.
ALSO
Two TREATISES
OF THE
SPECIES and MAGNITUDE
OF
Curvilinear Figures.
LONDON,

Particelle

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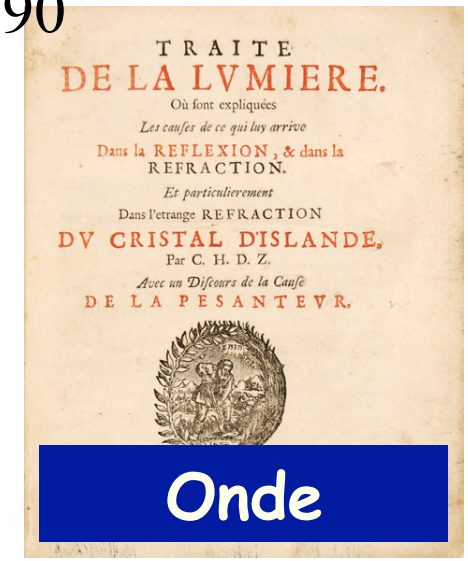
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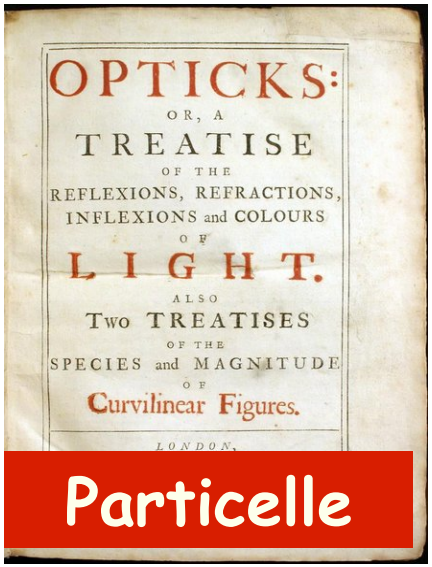
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LONDON,

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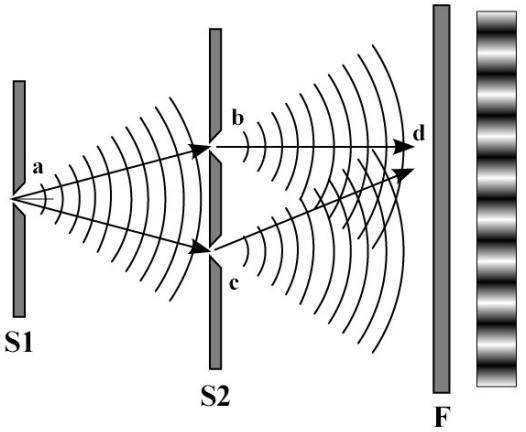
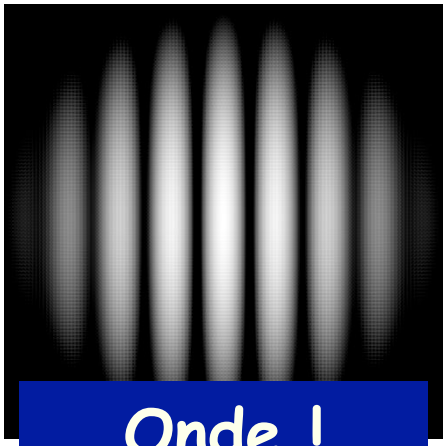
Thomas Young 1804





Onde !

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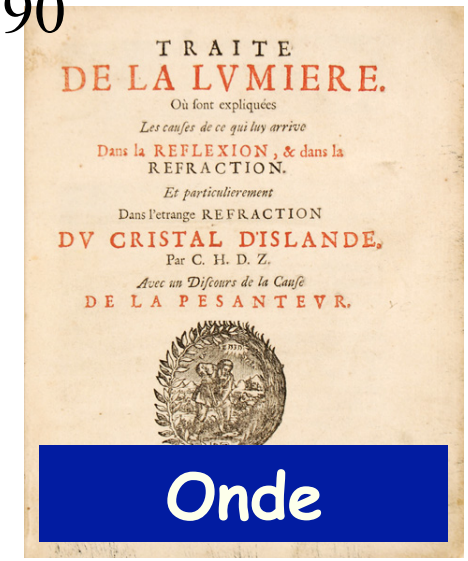
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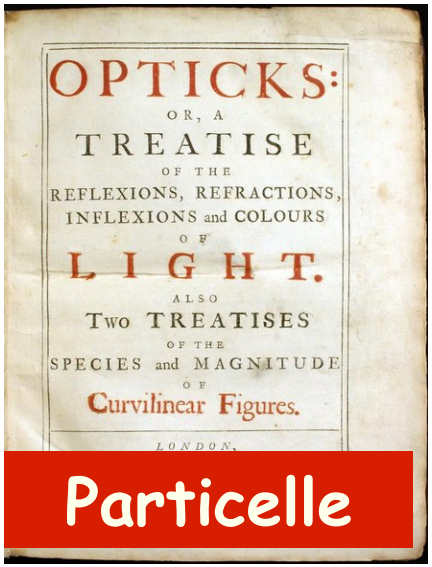
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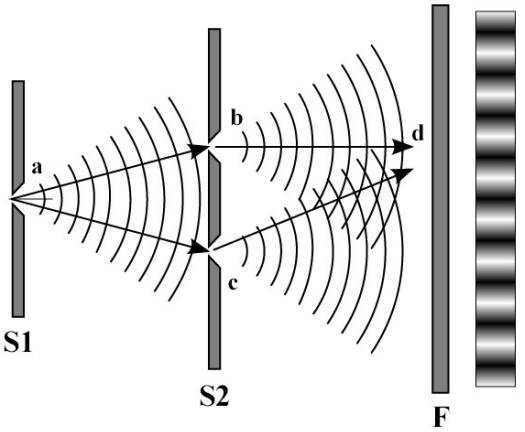
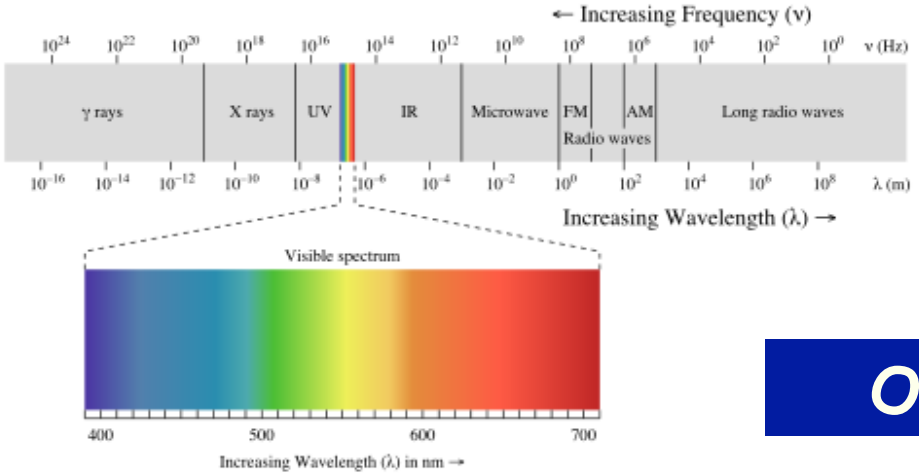
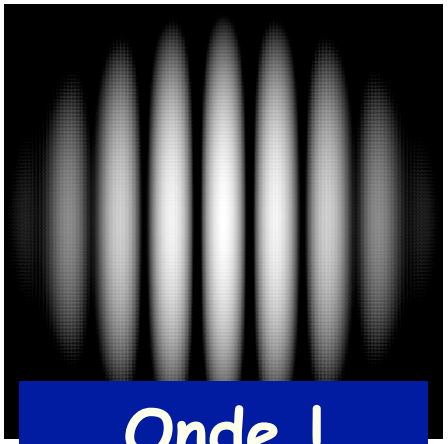




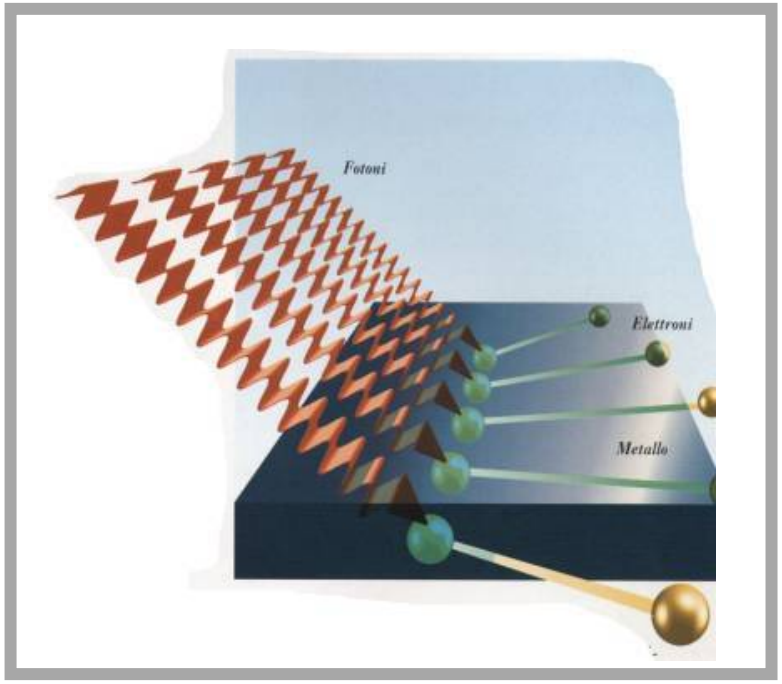
James Clerk Maxwell 1865

Onde !

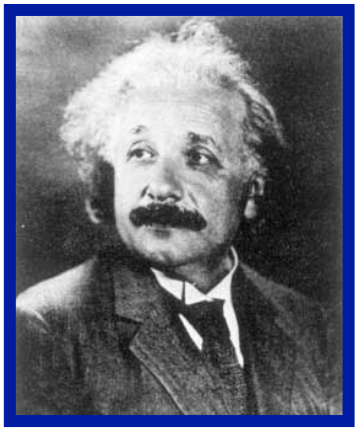


Onde !

EINSTEIN E L'EFFETTO FOTOELETTRICO



Scoperta:
Hertz 1887



Teoria:
Einstein 1905

FOTONI

$$E_{\text{fotone}} = \hbar\omega$$

ONDE O PARTICELLE ?

Louis-Victor Pierre Raymond De Broglie

1923

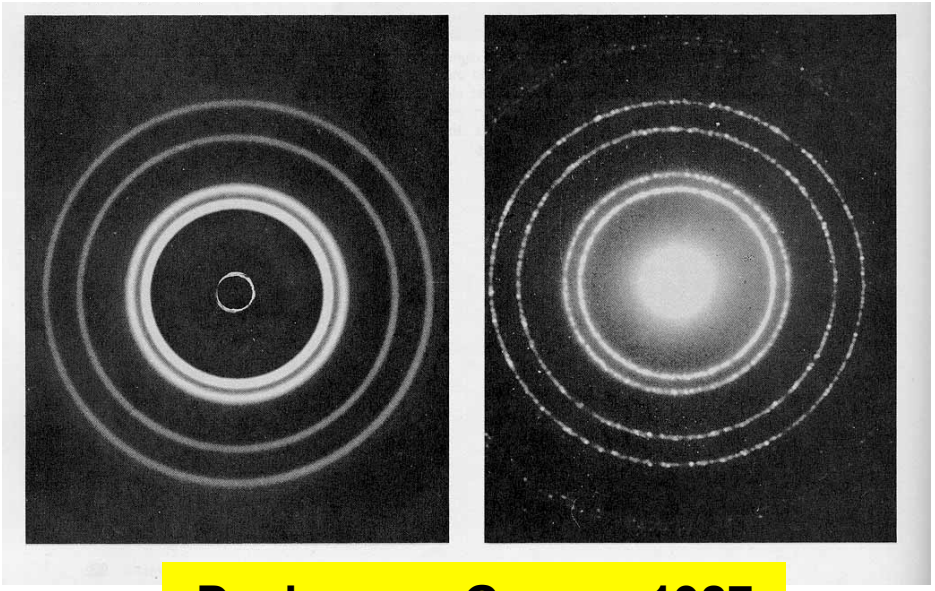
Anche le "particelle" sono "onde"

Fotoni: $p=h/\lambda$

Elettroni: $\lambda=h/p$

Raggi X

Elettroni



Davisson e Germer 1927

ONDE O PARTICELLE?

La meccanica quantistica risponde a questa domanda.

Il comportamento quantistico degli oggetti microscopici è lo stesso per tutti: elettroni, fotoni, W…

Sono tutti onde-particelle

(o qualunque altro nome gli si voglia dare)

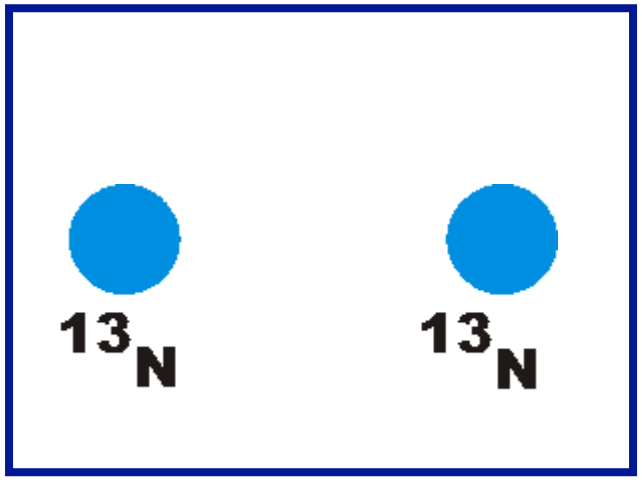
PARTICELLE E MECCANICA QUANTISTICA

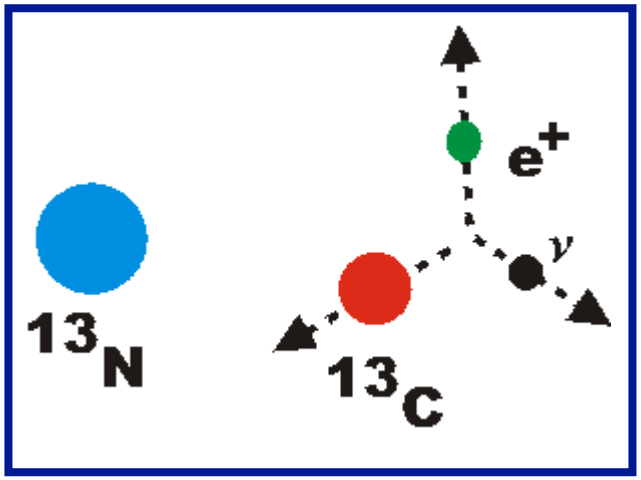
4 LE PROBABILITA' QUANTISTICHE

Il comportamento degli oggetti microscopici è non deterministico. Non possiamo prevedere "cosa avverrà" ma solo con che probabilità un evento avverrà.

Per es.: i decadimenti radioattivi

$$^{13}N \rightarrow {}^{13}C + e^{+} + n$$





Tempo di dimezzamento: 10 minuti

La probabilità non dipende da ciò che non sappiamo del mondo ma esprime il fatto che il mondo in sé ha caratteristiche indefinite.

A. Einstein: "Dio non gioca a dadi con l'universo"

A. Einstein: "Dio non gioca a dadi con l'universo"

N. Bohr: "Smettila di dire a Dio cosa deve fare"

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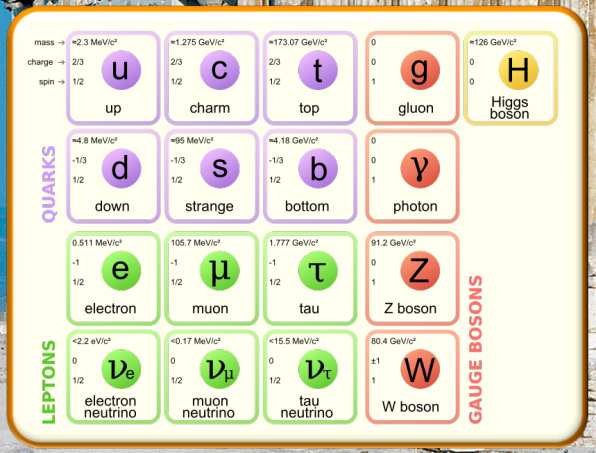

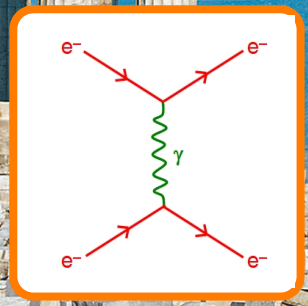

Meccanica quantistica

Relatività