

A photograph of a sunset over a dark ocean. The sun is a bright yellow-orange orb on the horizon, with its light reflecting on the water. The sky is filled with dark, textured clouds, some of which are illuminated by the low sun, creating a gradient of orange and red near the horizon.

Barbara Sciascia (LNF-INFN)

15 marzo 2017

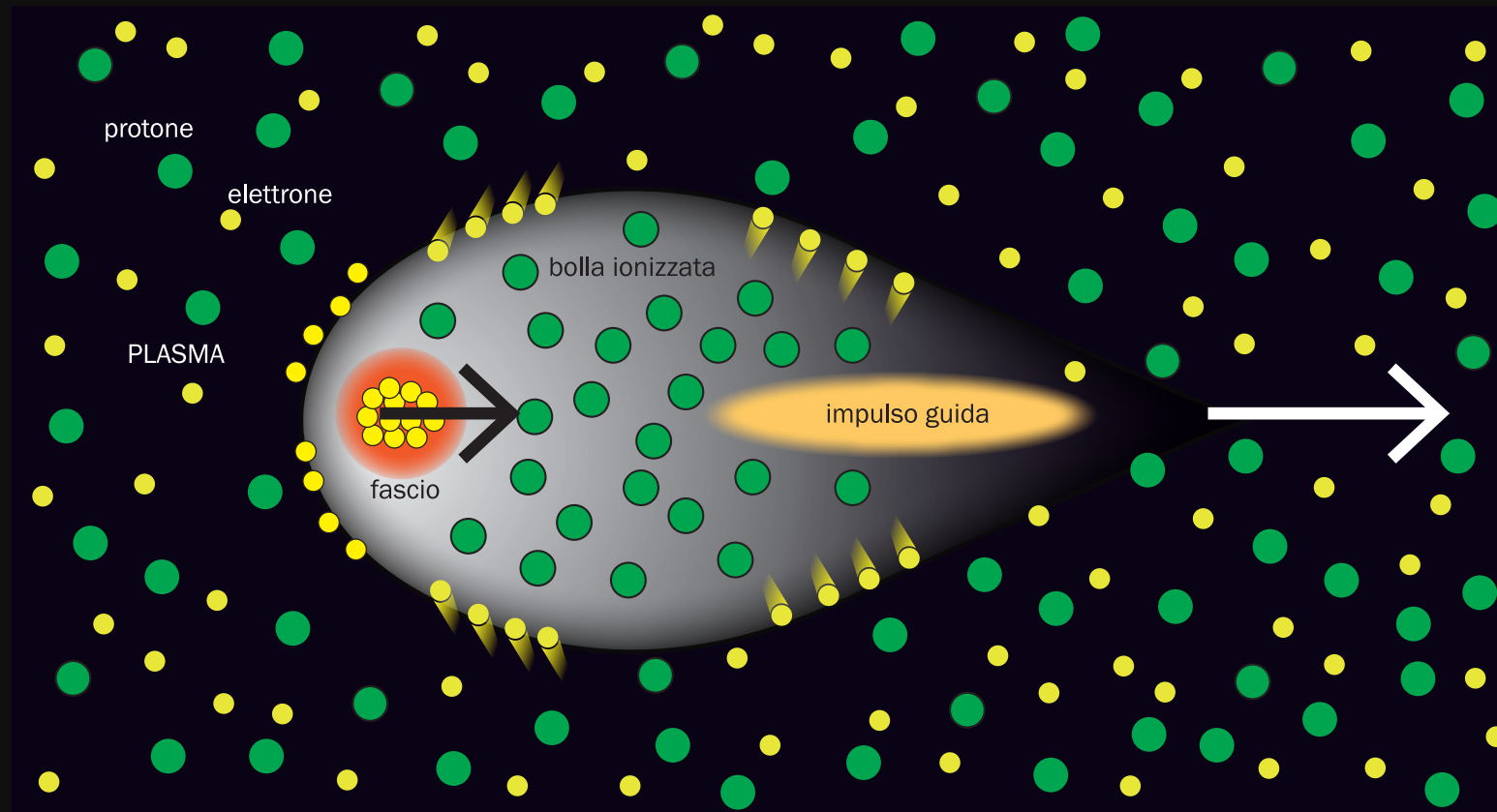
International Masterclass 2017

Laboratori Nazionali di Frascati - INFN

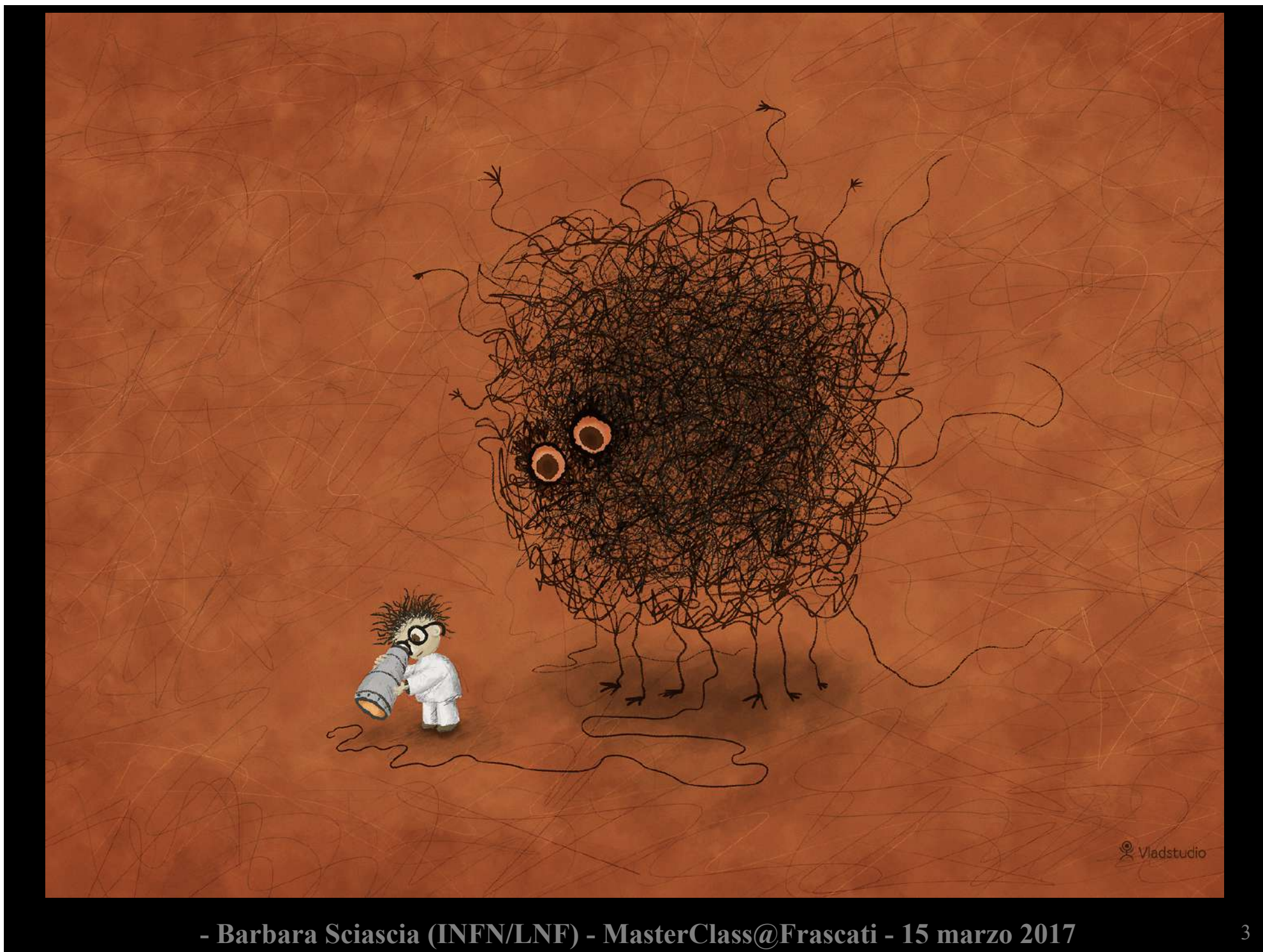
E quindi?

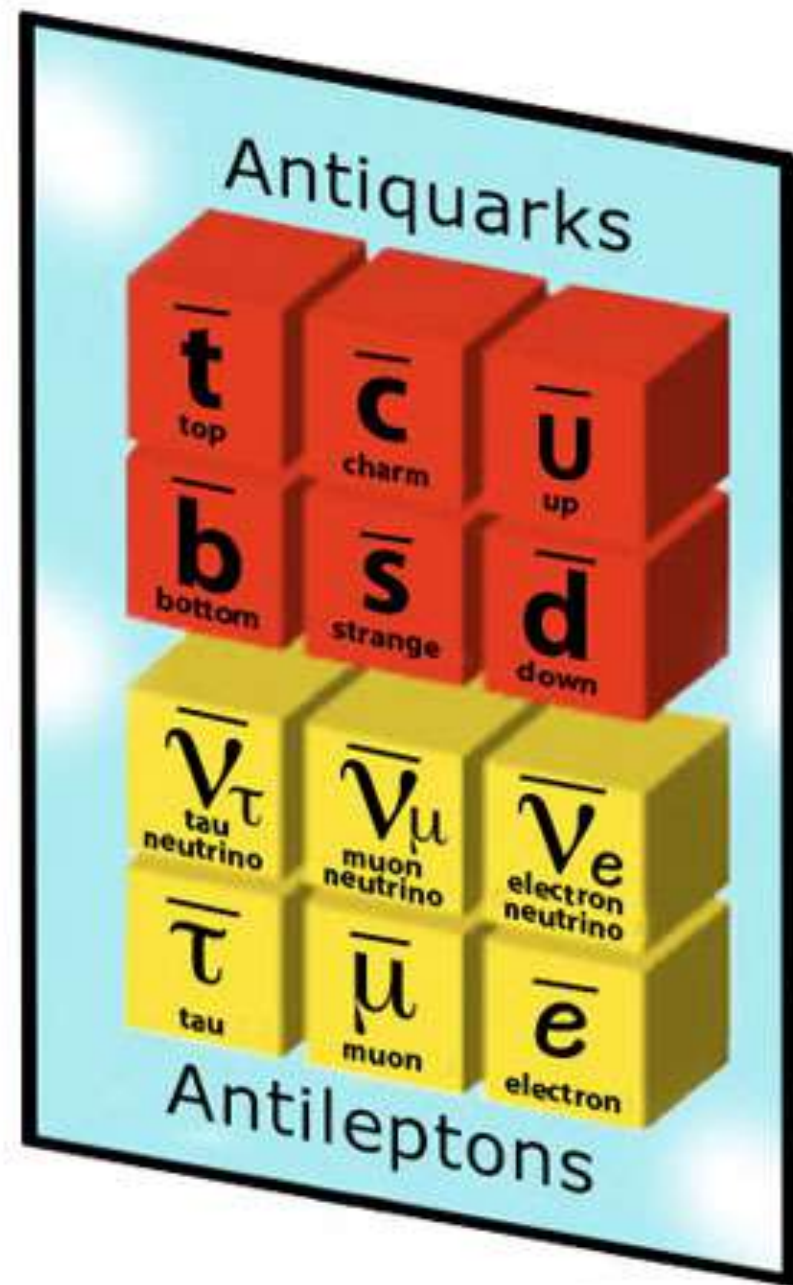
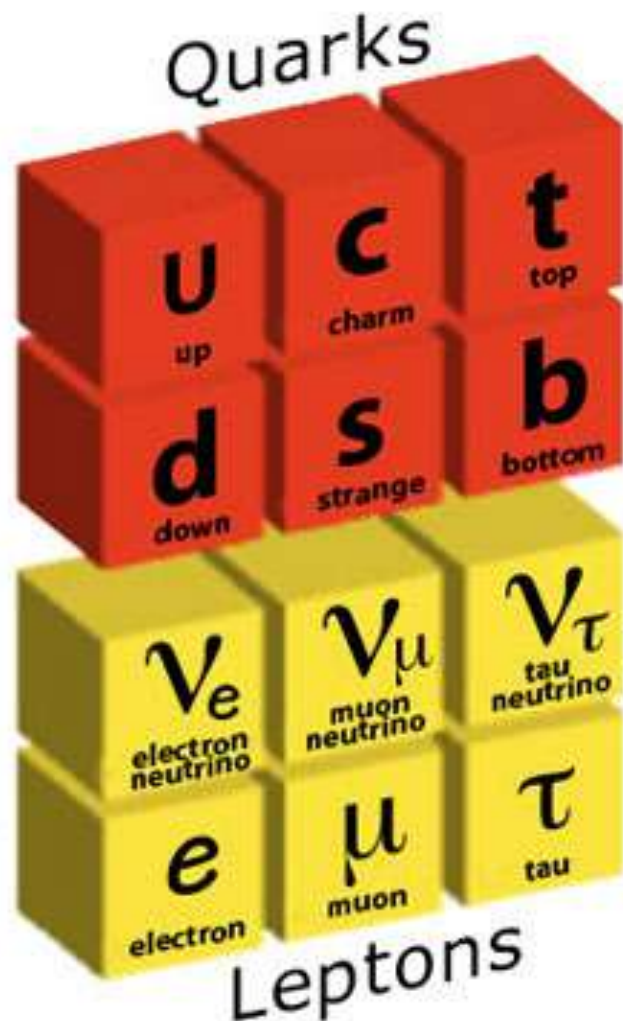
Quello che (ancora) non sappiamo dell'Universo

Acceleratori di particelle

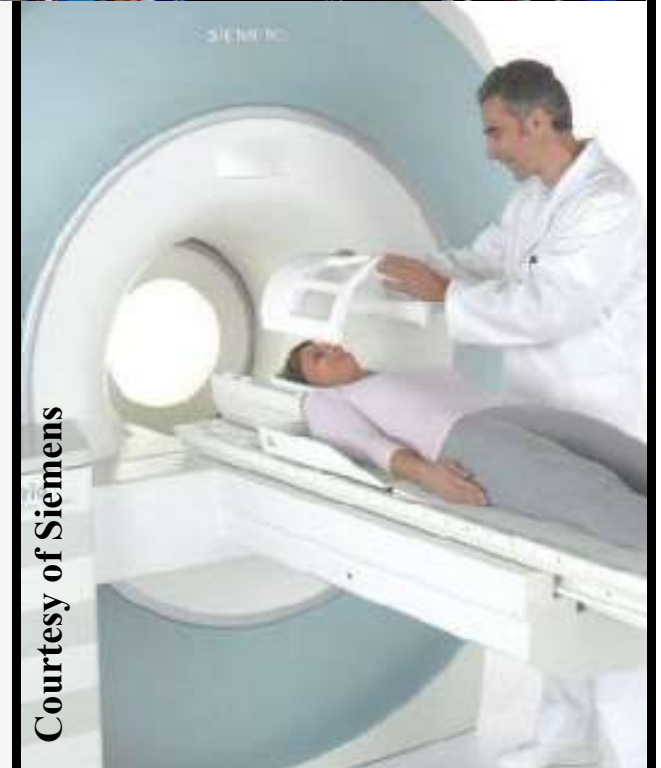
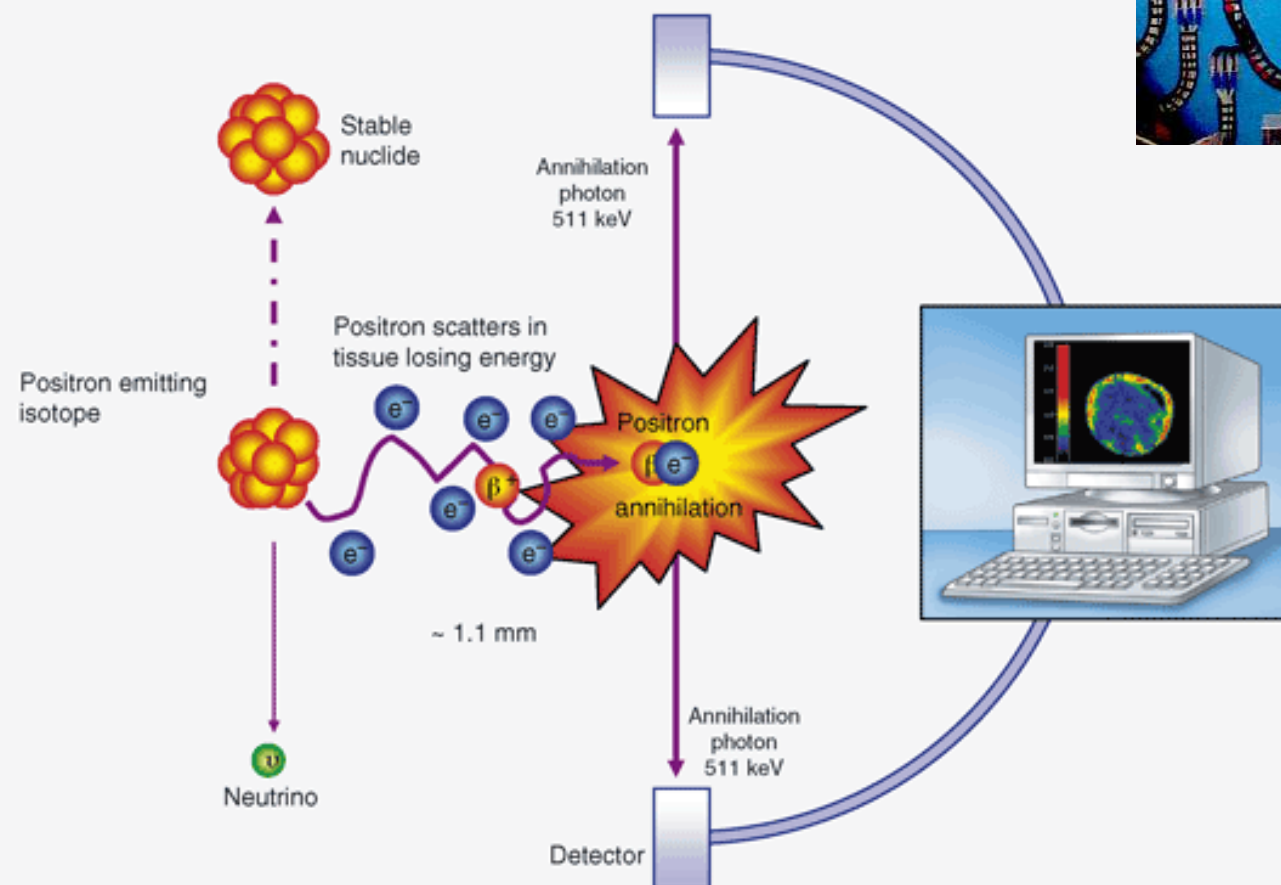
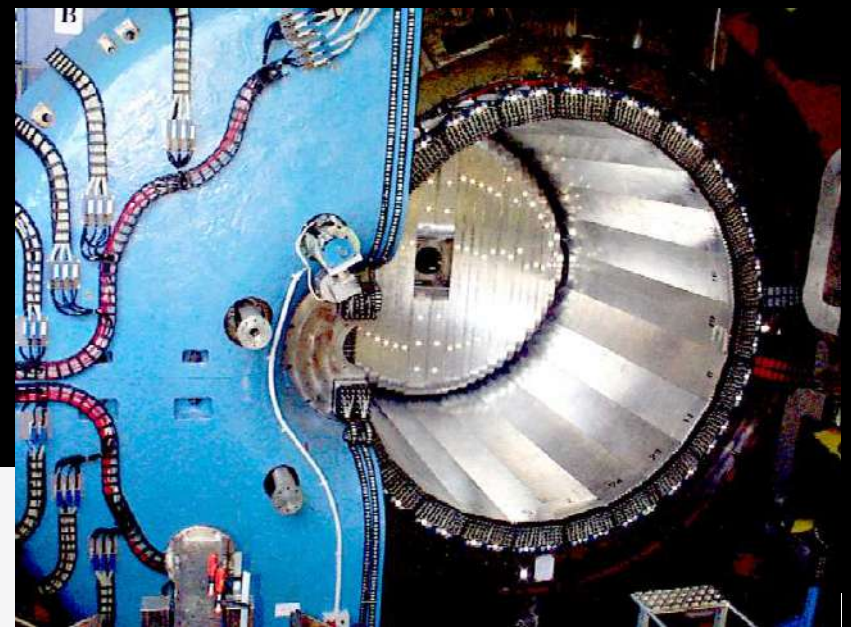


Accelerazione al plasma
[Molto altro è stato discusso ieri da D. Alesini]





Positron Emission Tomography (PET)



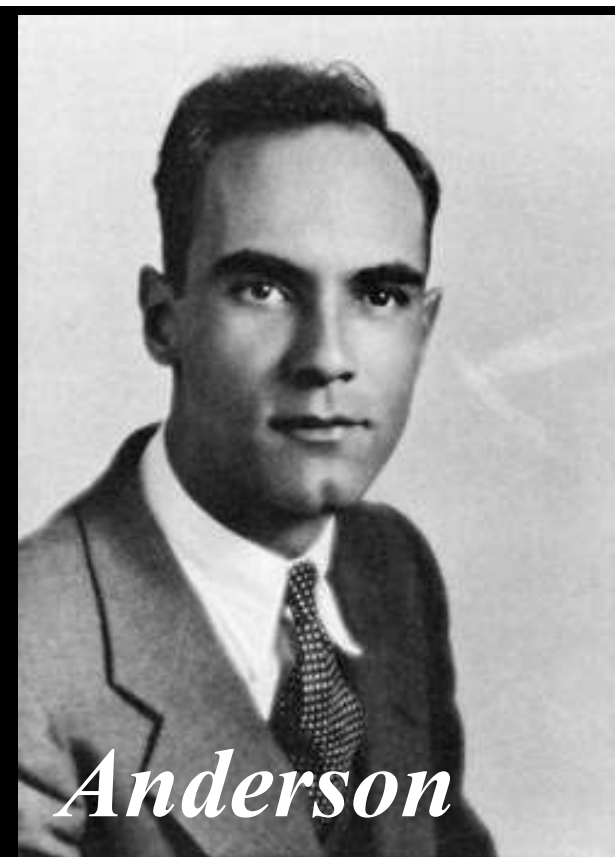
Courtesy of Siemens



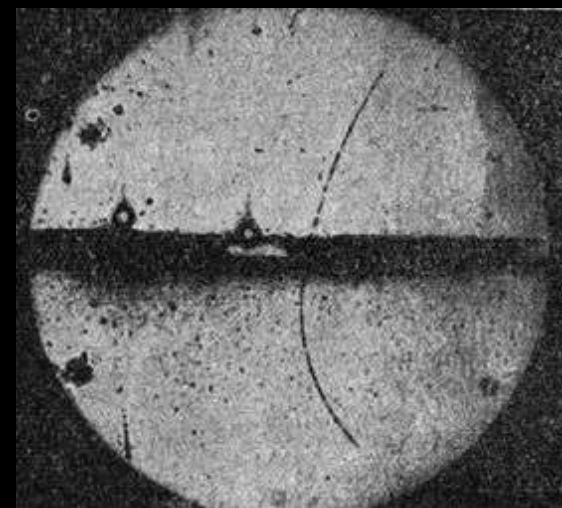
Dirac

$$(i\gamma^\mu \partial_\mu - m)\psi = 0$$

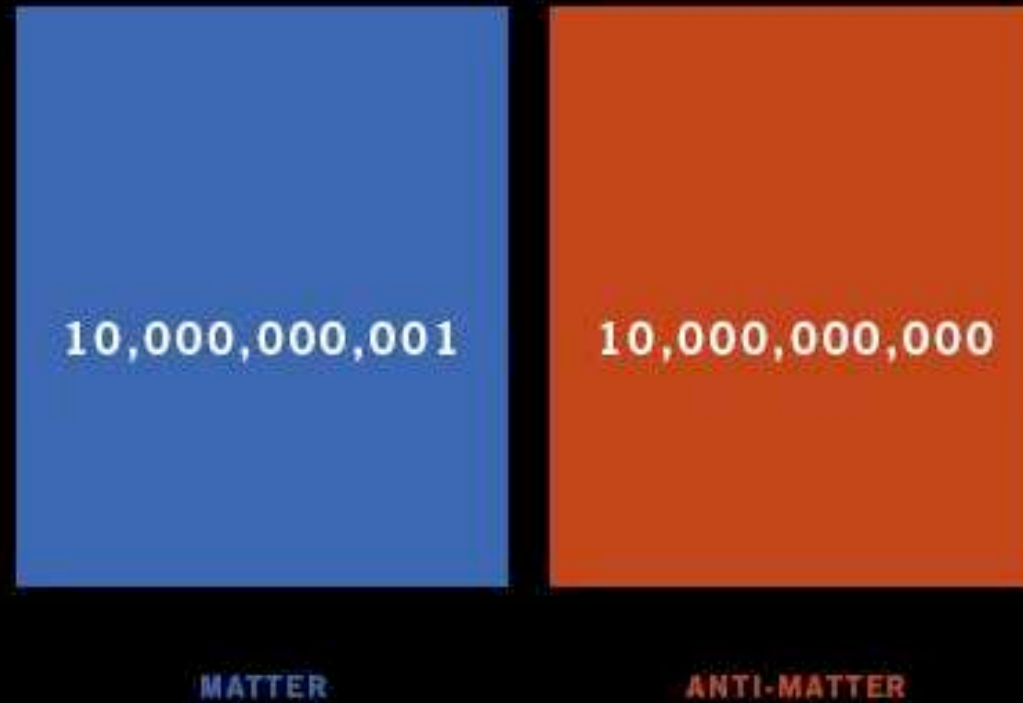
Materia e Antimateria



Anderson

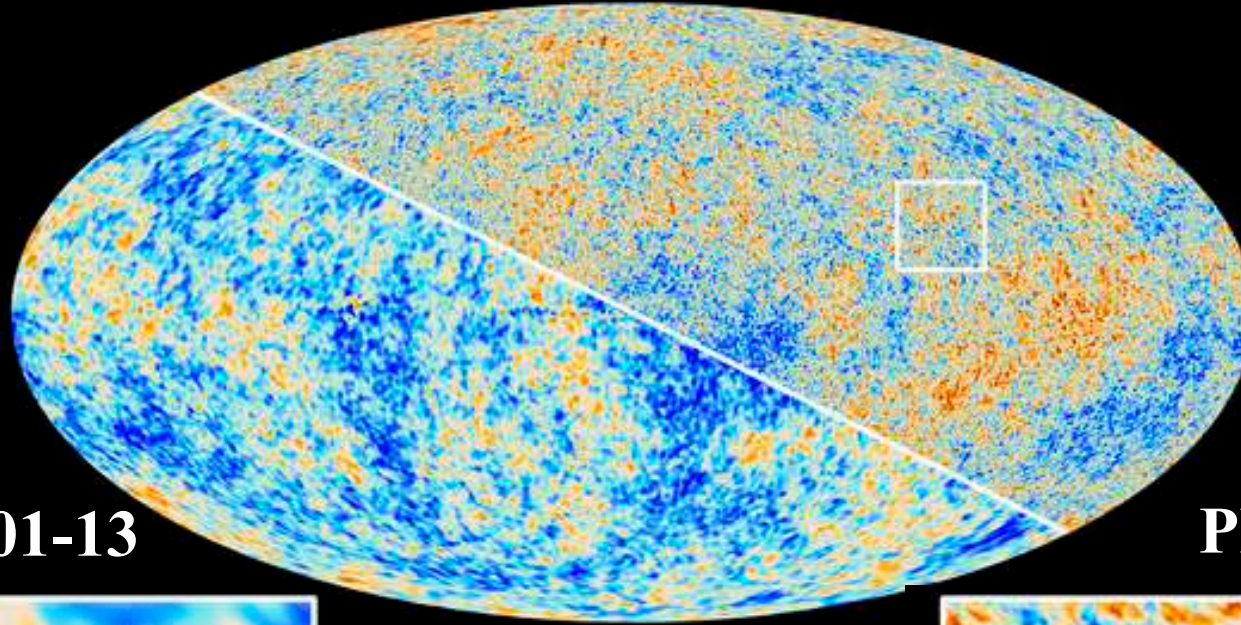


Materia e Antimateria



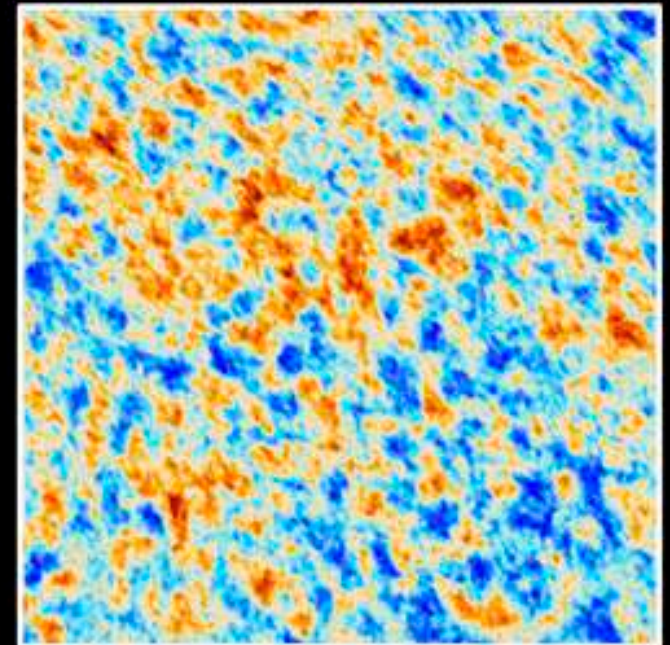
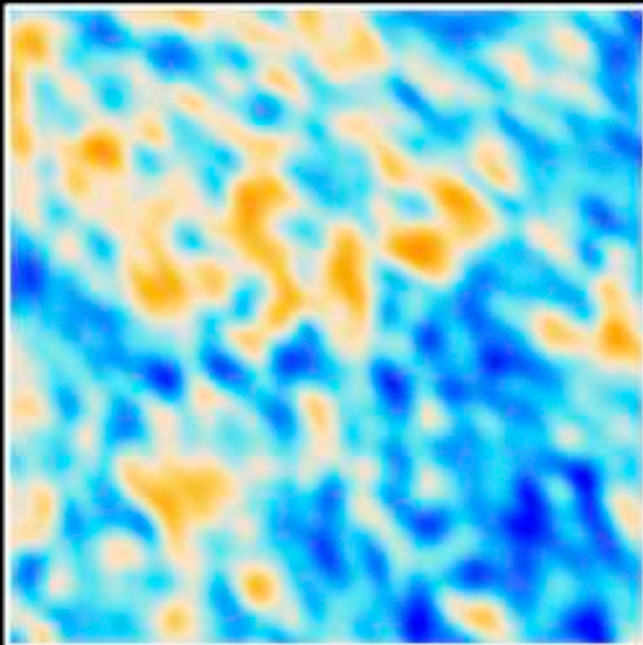
Credits: Hitoshi Murayama

Radiazione cosmica di fondo

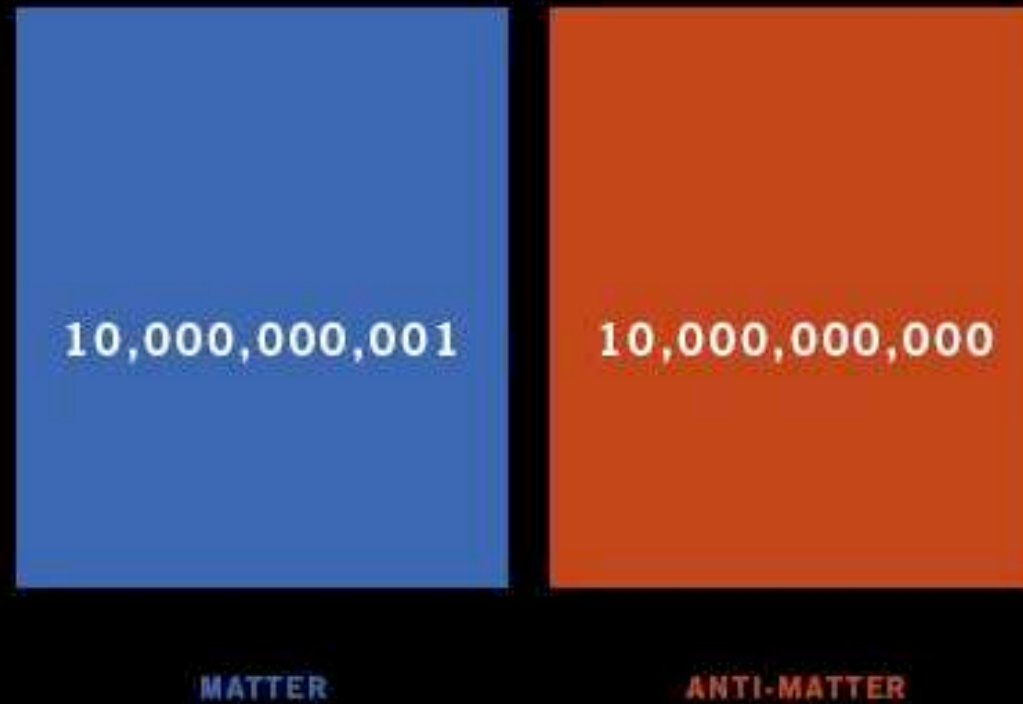


WMAP, 2001-13

Planck, 2013



Materia e Antimateria



Credits: Hitoshi Murayama

Materia e Antimateria

•
US

1

MATTER

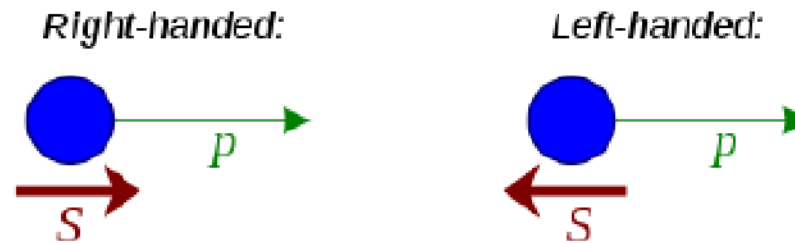
ANTI-MATTER

Credits: Hitoshi Murayama

Violazione di CP

[Dalla lezione di V. Barone]

L'interazione debole distingue tra **destra** e **sinistra** (violazione di P)



Non è possibile che la **destra per le particelle** sia equivalente alla **sinistra per le antiparticelle** (simmetria CP)?

La risposta è **no**. Anche **la simmetria CP è violata**

Esperimenti di Fitch e Cronin sui kaoni neutri (1964)

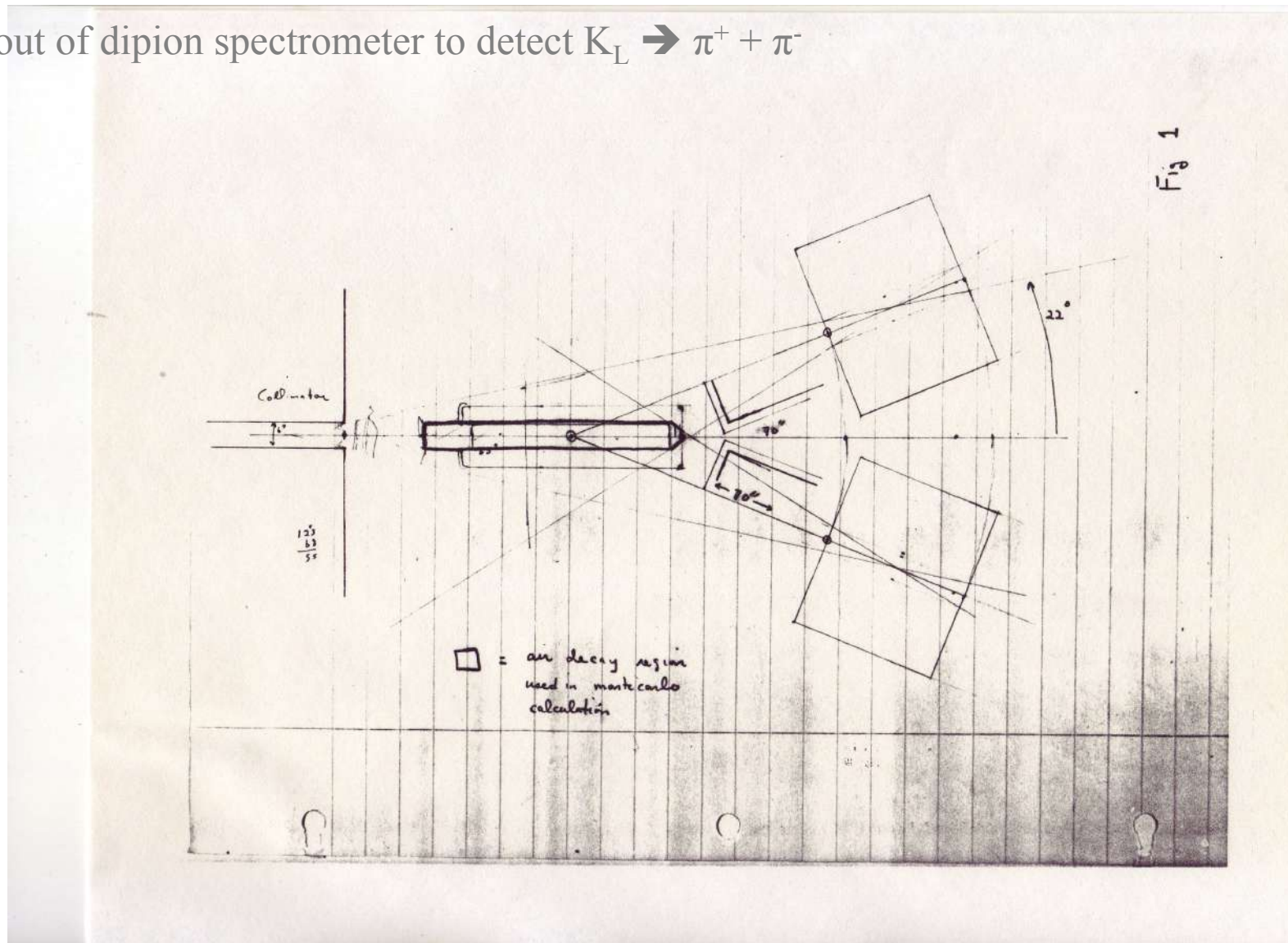
Se la simmetria CPT è esatta, e CP è violata, anche T è violata

I fenomeni deboli non sono invarianti rispetto all'inversione temporale

Esiste una **freccia microscopica del tempo** (non ha niente a che vedere con quella macroscopica, che è un fenomeno statistico)

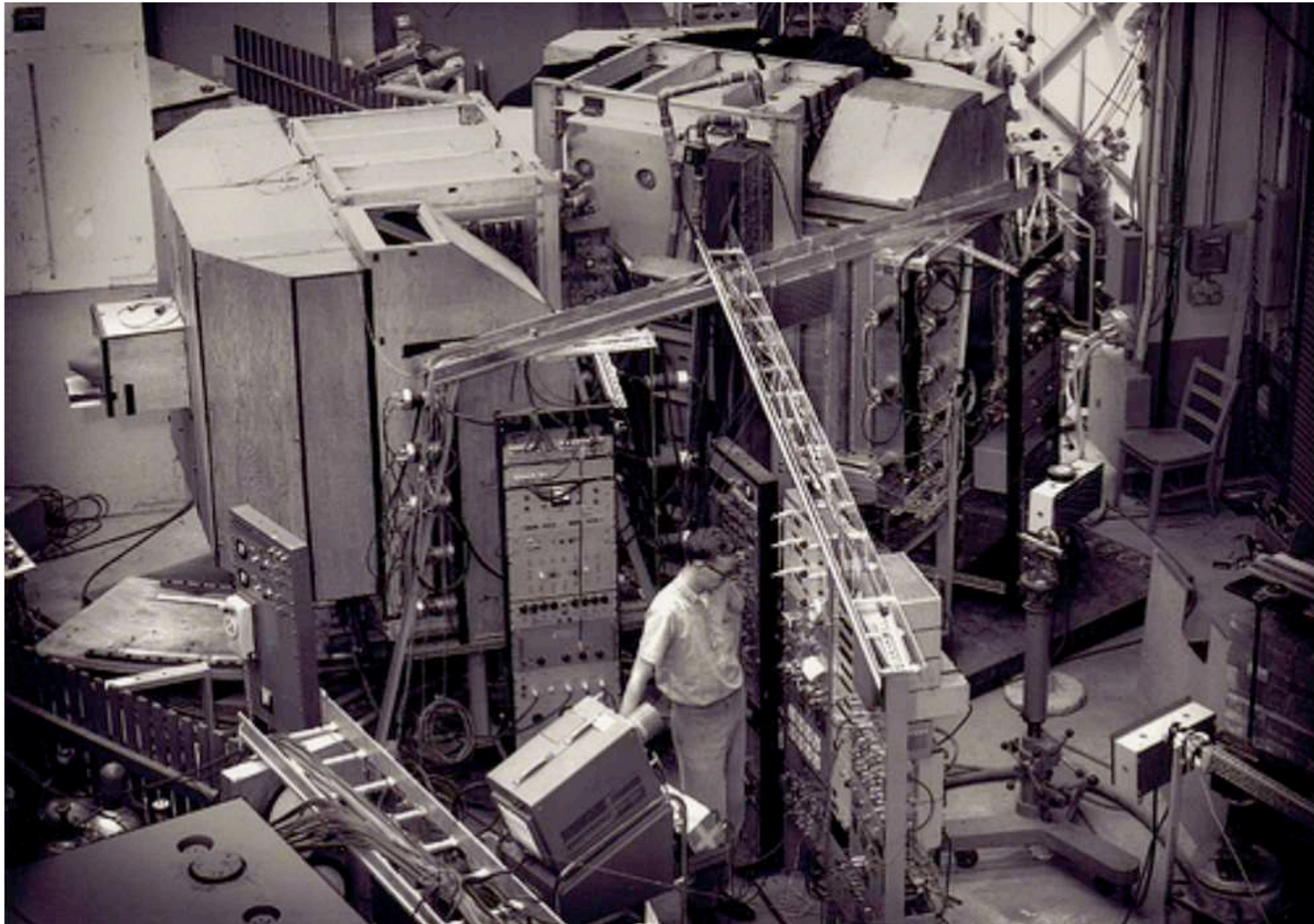
Violazione di CP

Layout of dipion spectrometer to detect $K_L \rightarrow \pi^+ + \pi^-$



[courtesy of Jim Cronin]

Violazione di CP



Violazione di CP

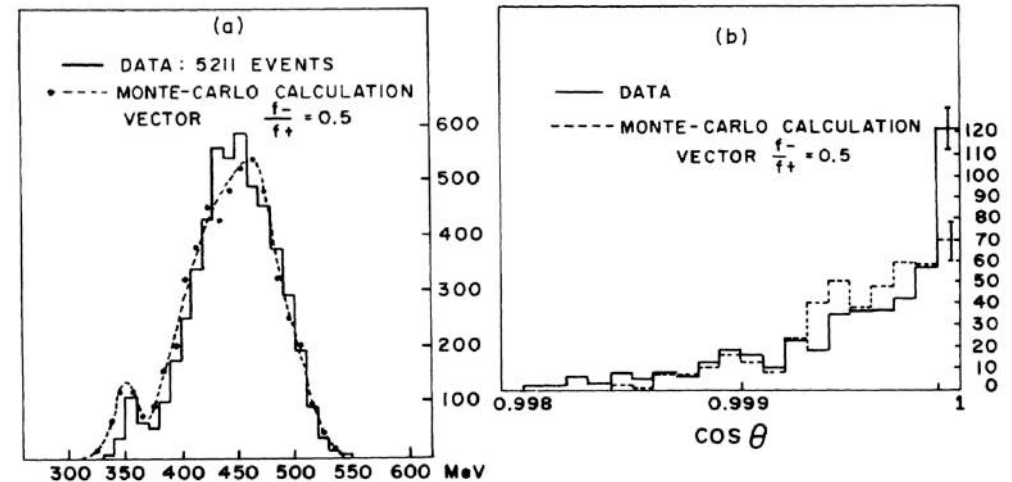
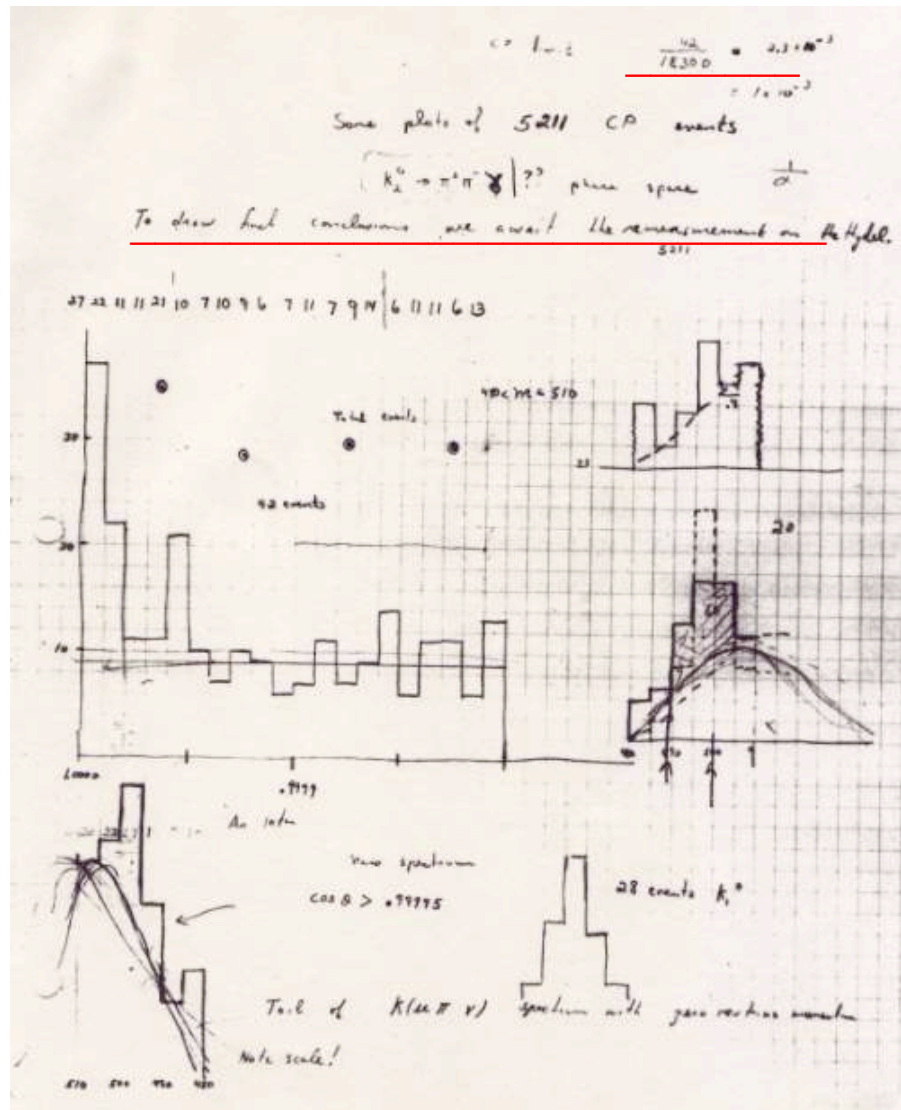
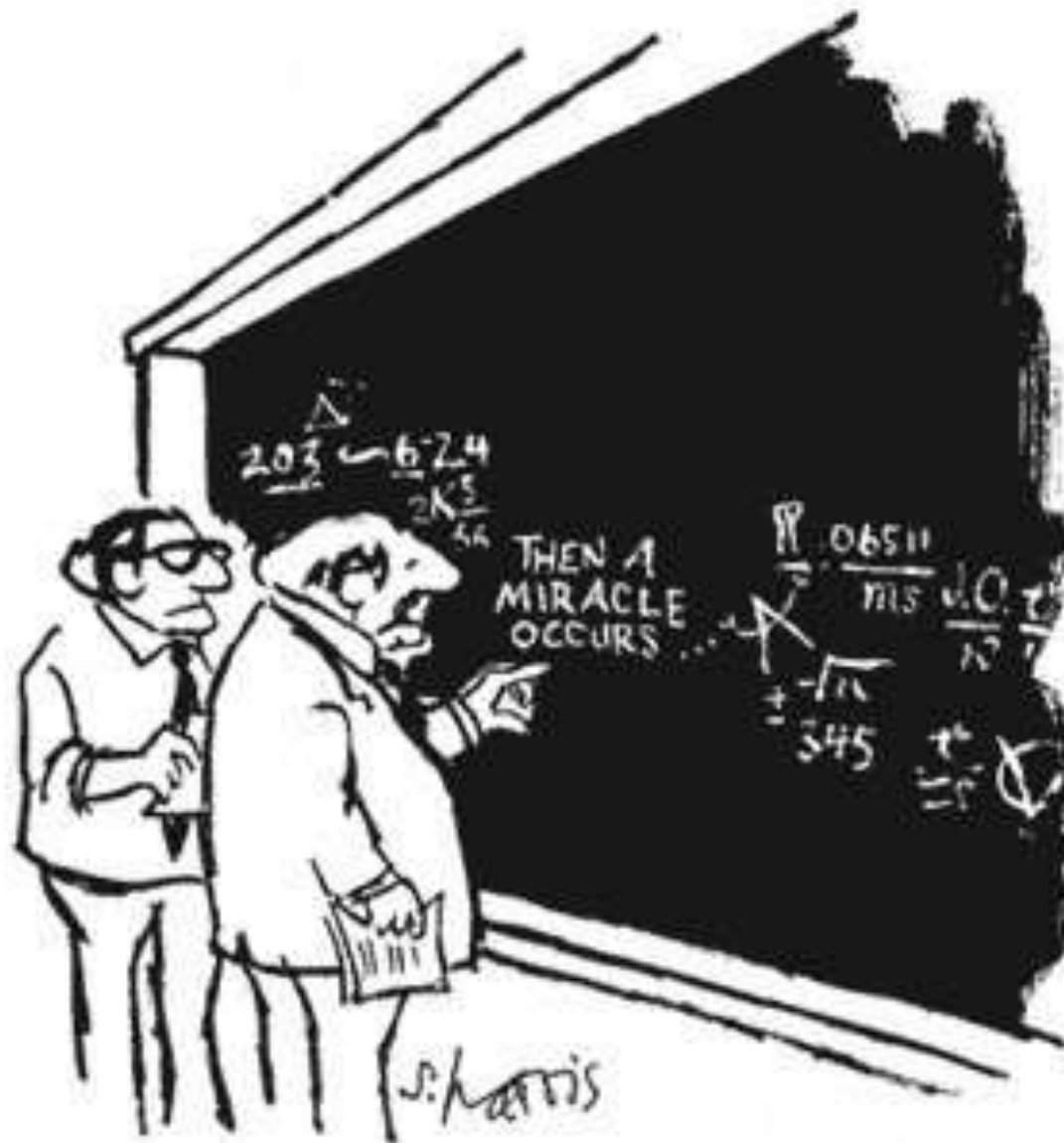


FIG. 2. (a) Experimental distribution in m^* compared with Monte Carlo calculation. The calculated distribution is normalized to the total number of observed events. (b) Angular distribution of those events in the range $490 < m^* < 510$ MeV. The calculated curve is normalized to the number of events in the complete sample.



"I THINK YOU SHOULD BE MORE EXPLICIT HERE IN STEP TWO."

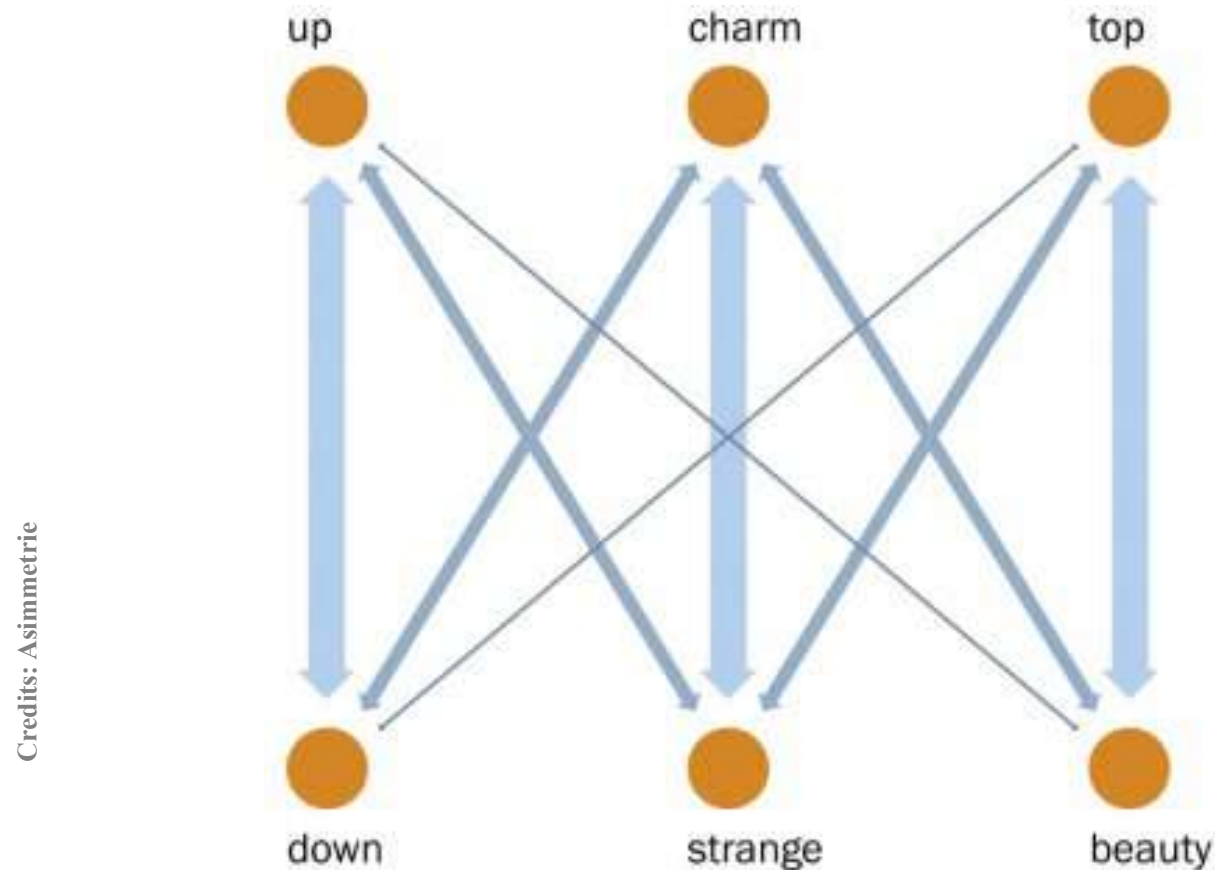
“Angeli e Demoni”

- **Creazione di atomi di anti-materia**: la prima volta 9 atomi in 3 settimane, oggi decine di migliaia al giorno. **10 milioni di miliardi di volte** per riempire un palloncino (cioè molti miliardi di anni)



- **Potere distruttivo**: con 0.5 g di anti-materia stesso effetto di una bomba nucleare da 20 kton, ma ci metteremmo miliardi di anni per produrla... è poco probabile che chiunque voglia aspettare così a lungo.
- **Costi**: l'anti-materia ha solo **1 decimiliardesimo dell'energia** usata per produrla. Tutta l'anti-materia finora prodotta al CERN potrebbe fornire energia per una lampadina per pochi minuti.

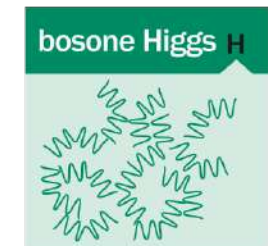
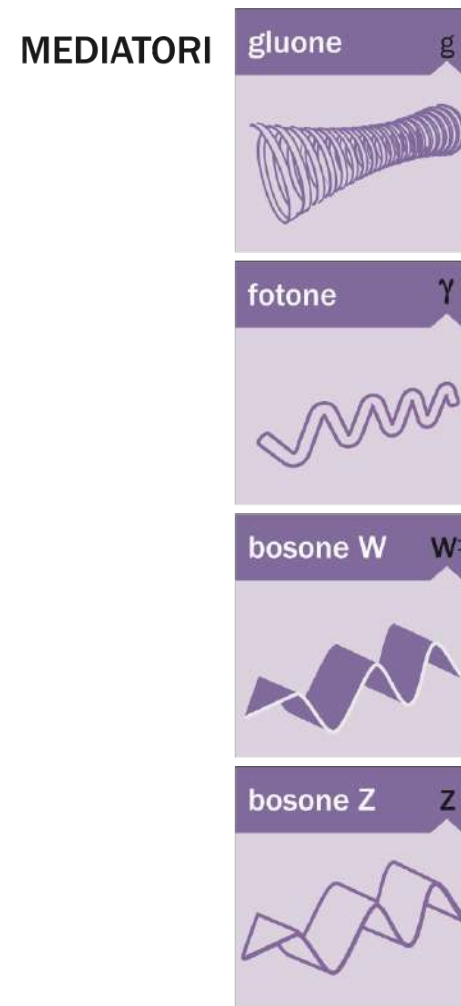
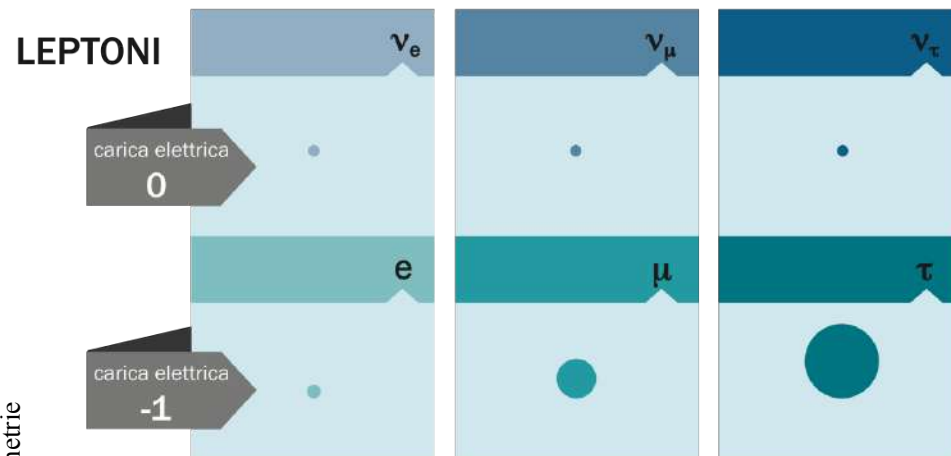
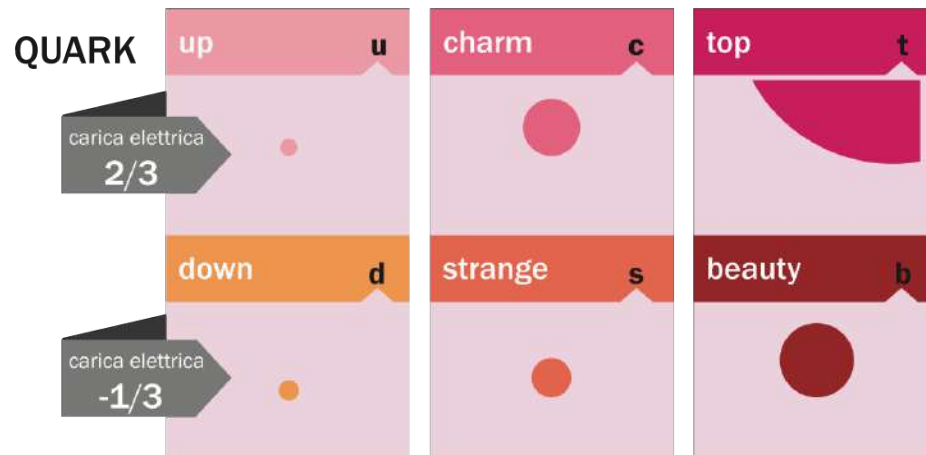
Un altro ingrediente del Modello Standard: **il mescolamento dei sapori**



I quark d, s, b si mescolano tra loro per accoppiarsi a u, c, t
(Meccanismo CKM, **Cabibbo – Kobayashi – Maskawa**)

Un parametro nella matrice CKM produce una **violazione di CP**

Modello Standard

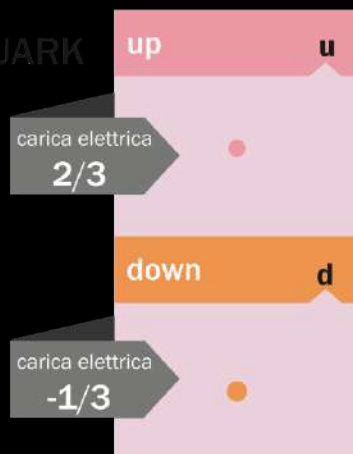


Credits: Asimmetrie

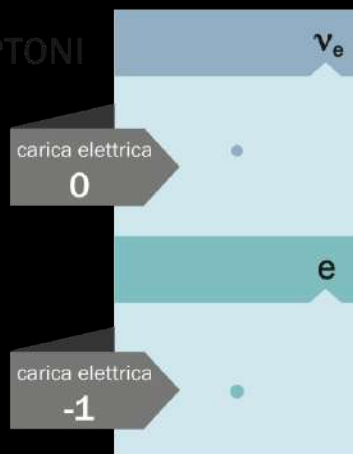
“Modello standard della chimica”



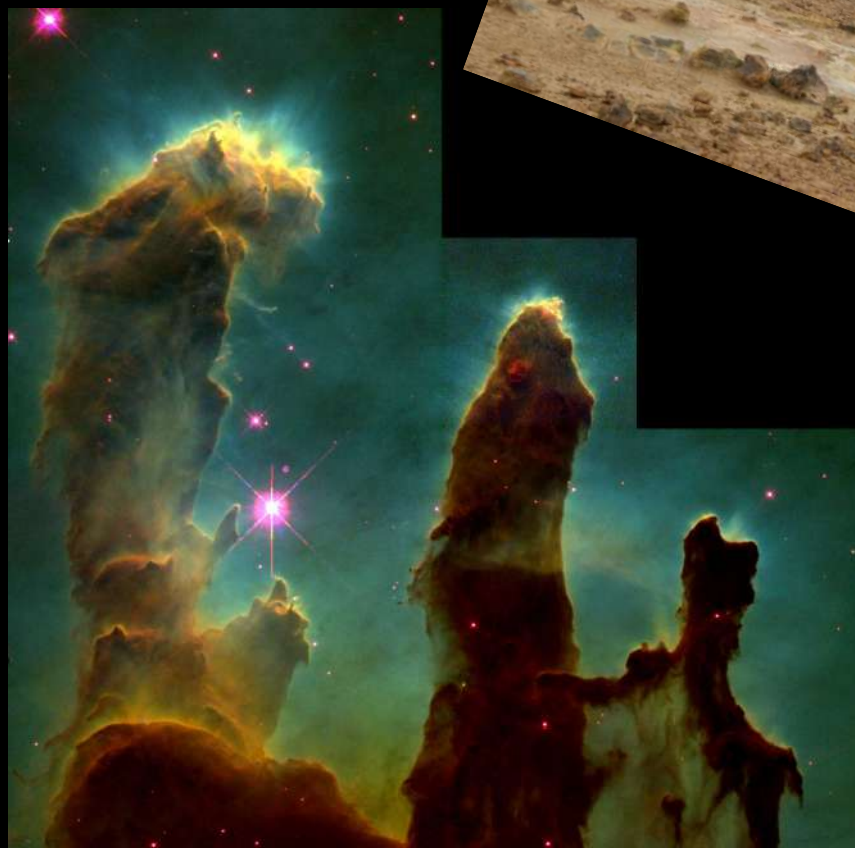
QUARK

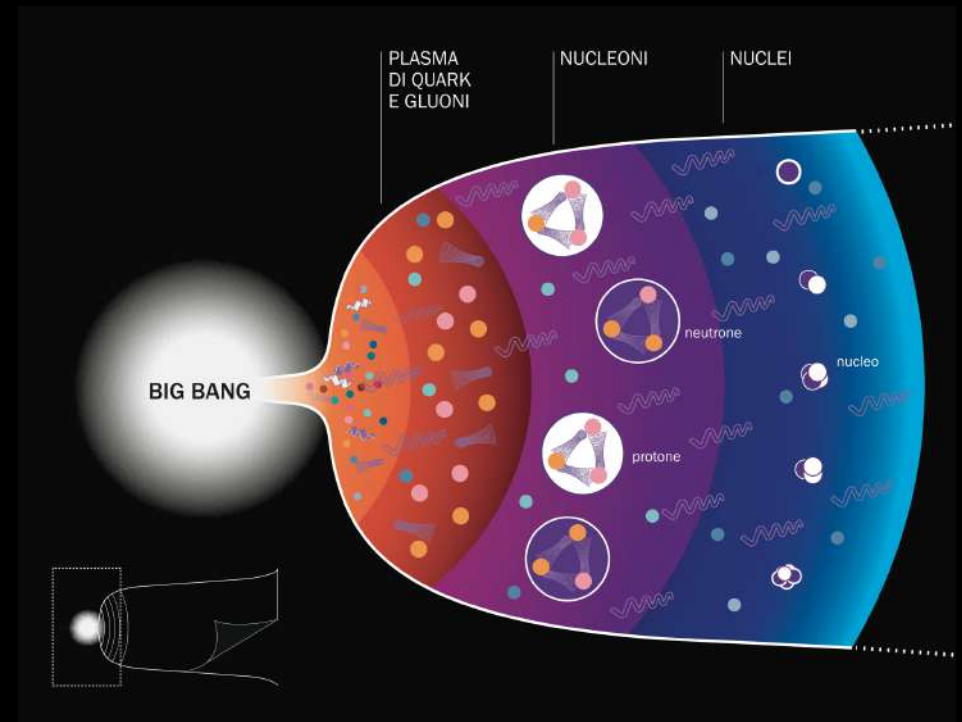
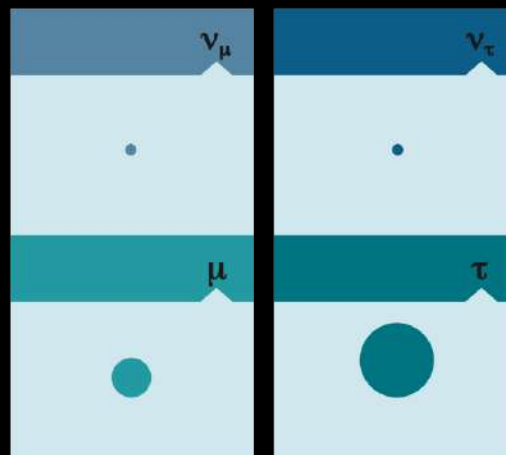
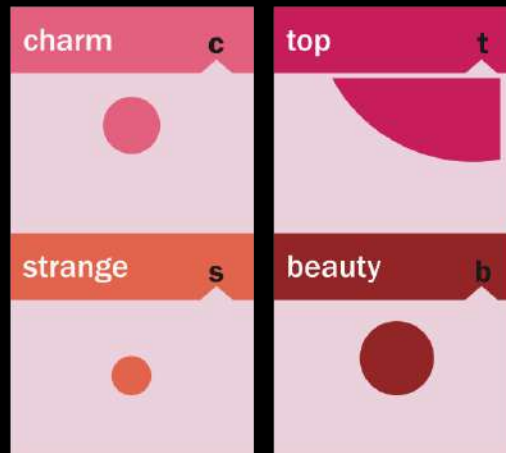


LEPTONI



Credits: Asimmetrie



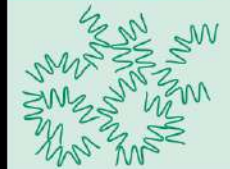


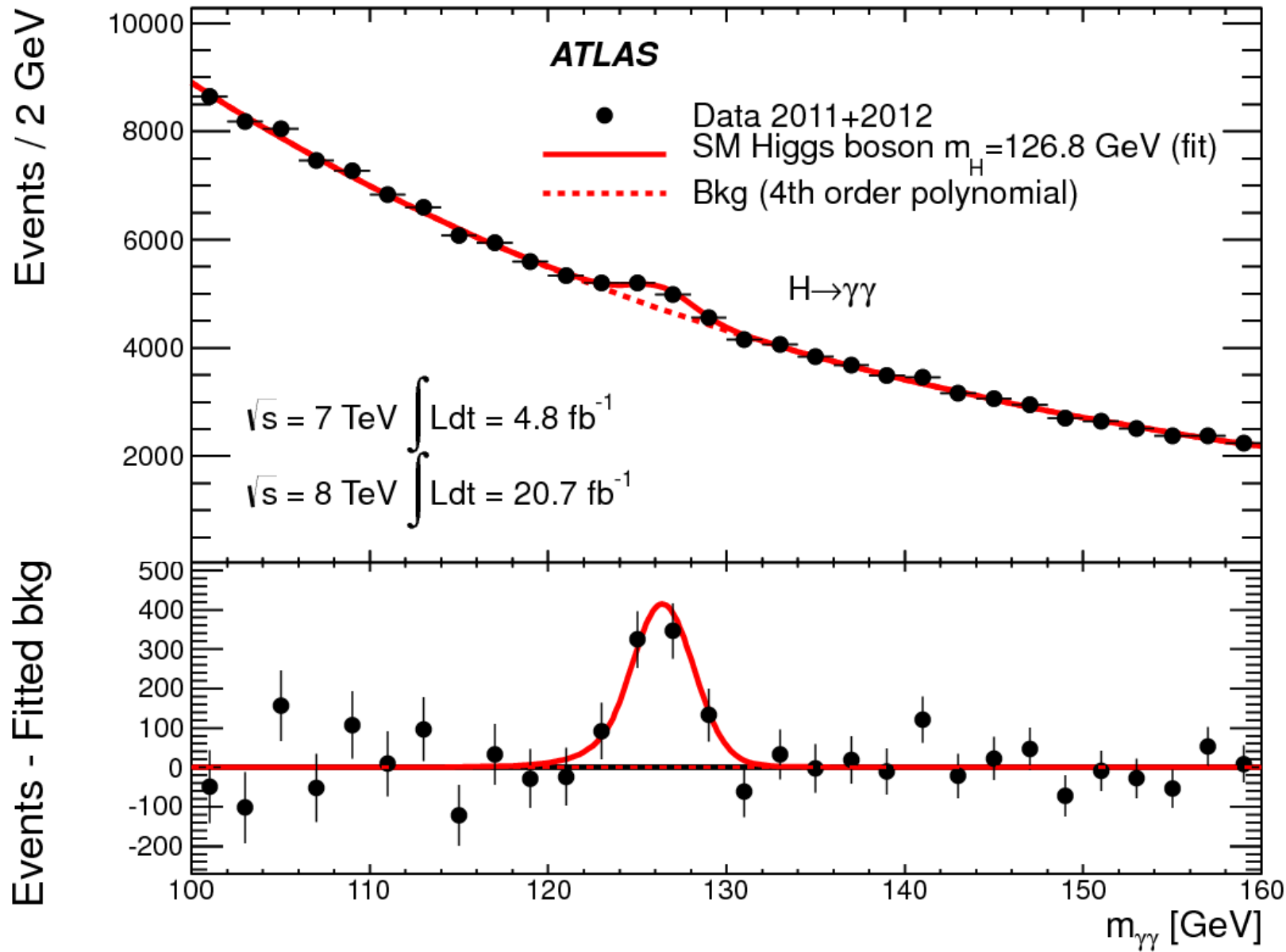
SAY GOD PARTICLE

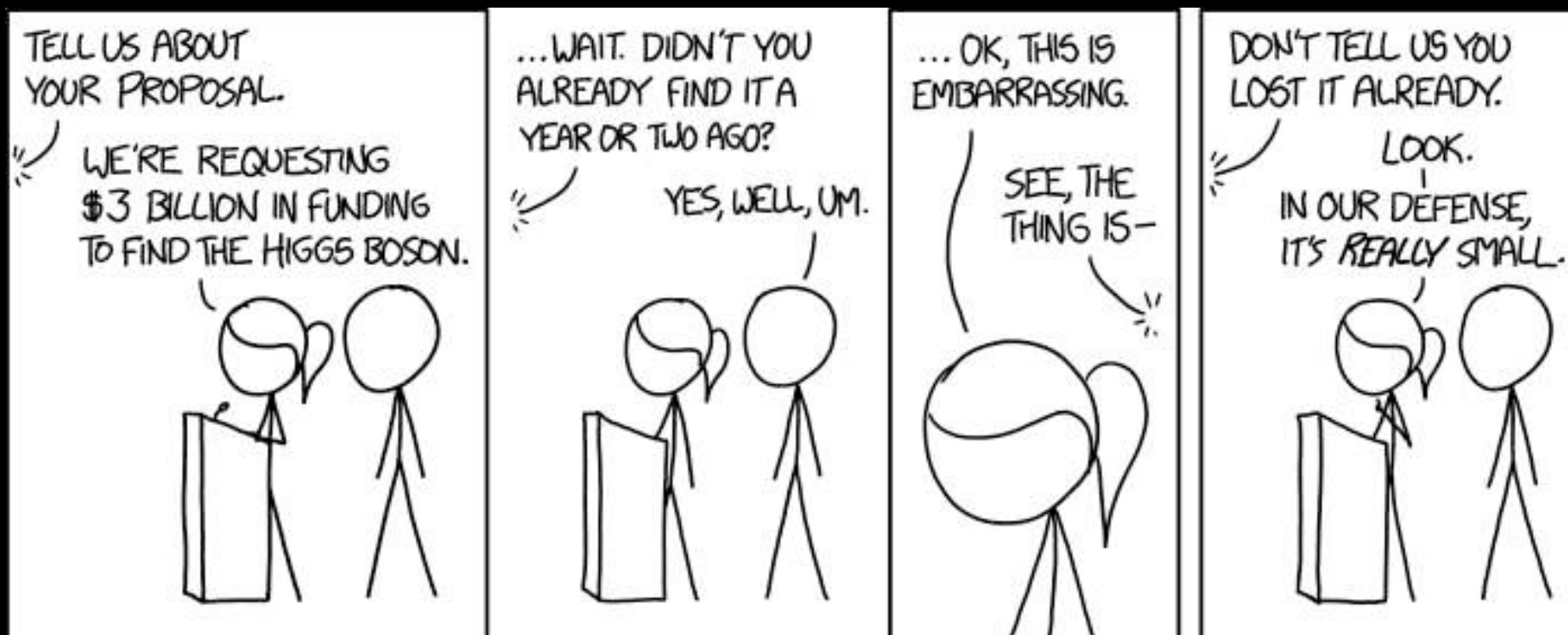


**ONE MORE
GODDAMN TIME**

bosone Higgs H



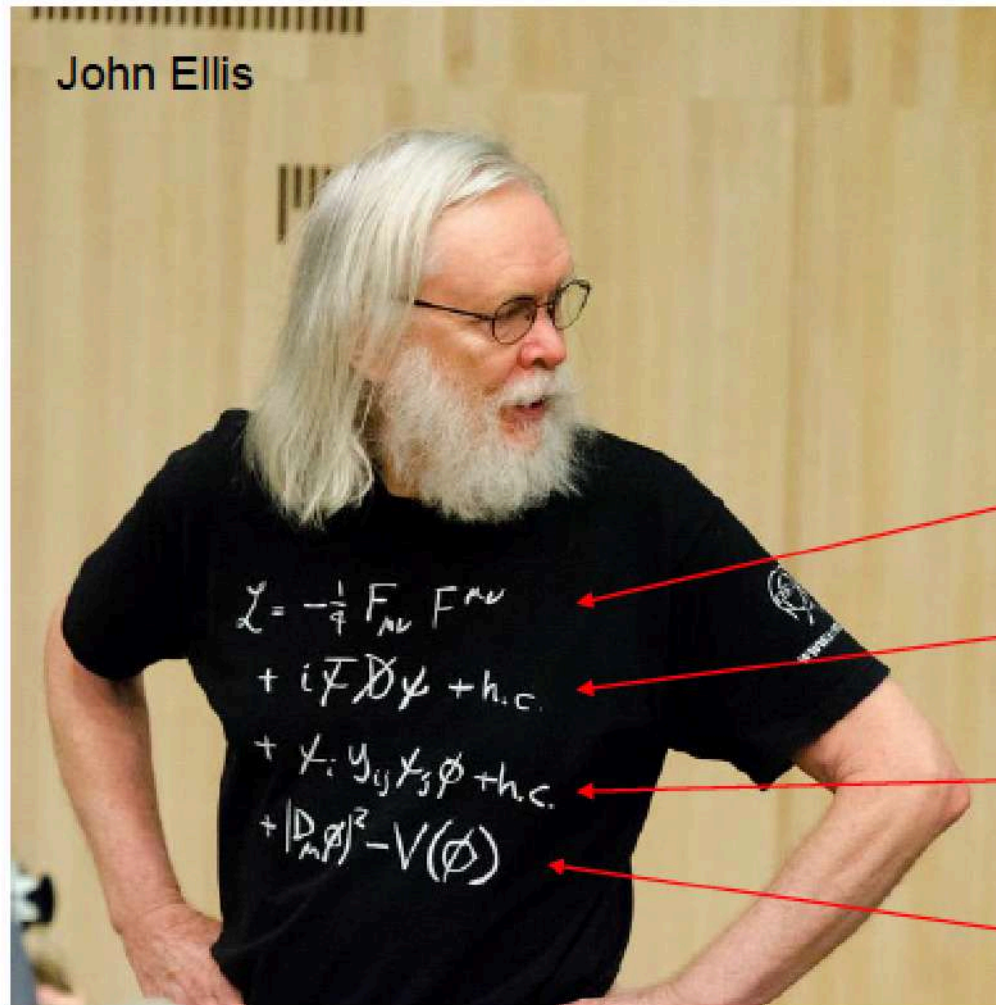




<https://xkcd.com/1437/>

Modello Standard

Il Modello Standard: una **teoria quantistica di campo** di **tre** delle quattro **interazioni fondamentali**, basata su **simmetrie**



Particelle di forza
(fotoni, W, Z, gluoni)

Particelle di materia
(quark e leptoni)

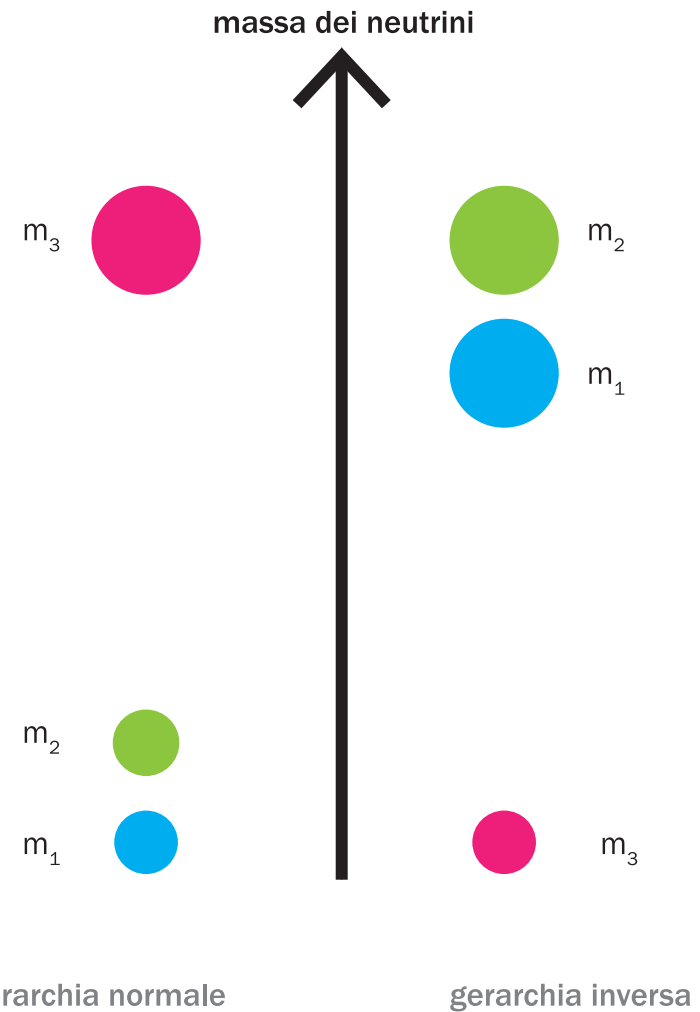
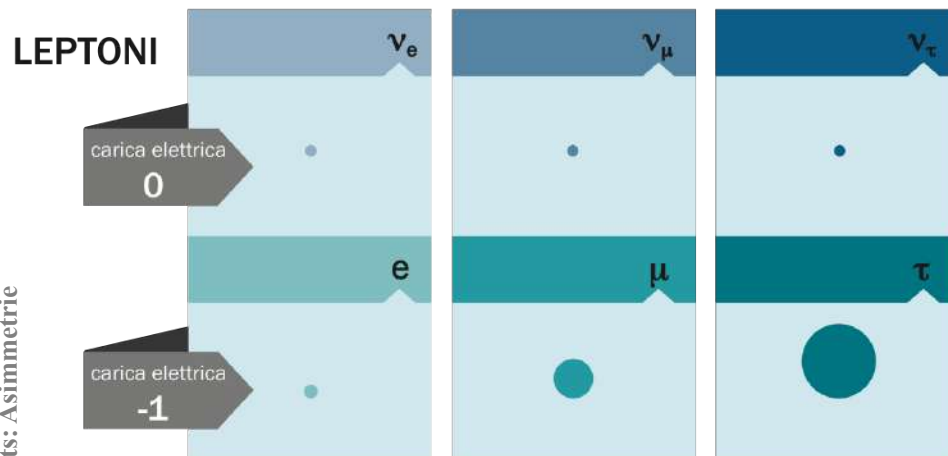
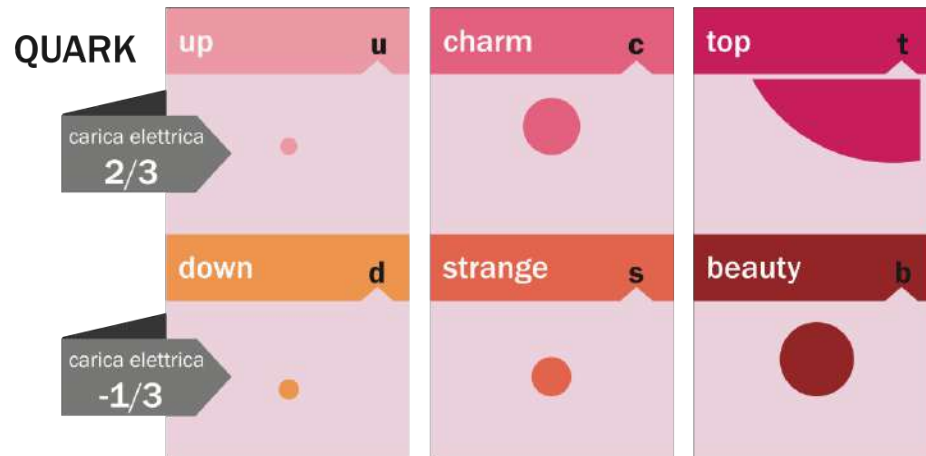
Termine di massa per
le particelle di materia

Termine di massa per
le particelle di forza
Rottura spontanea

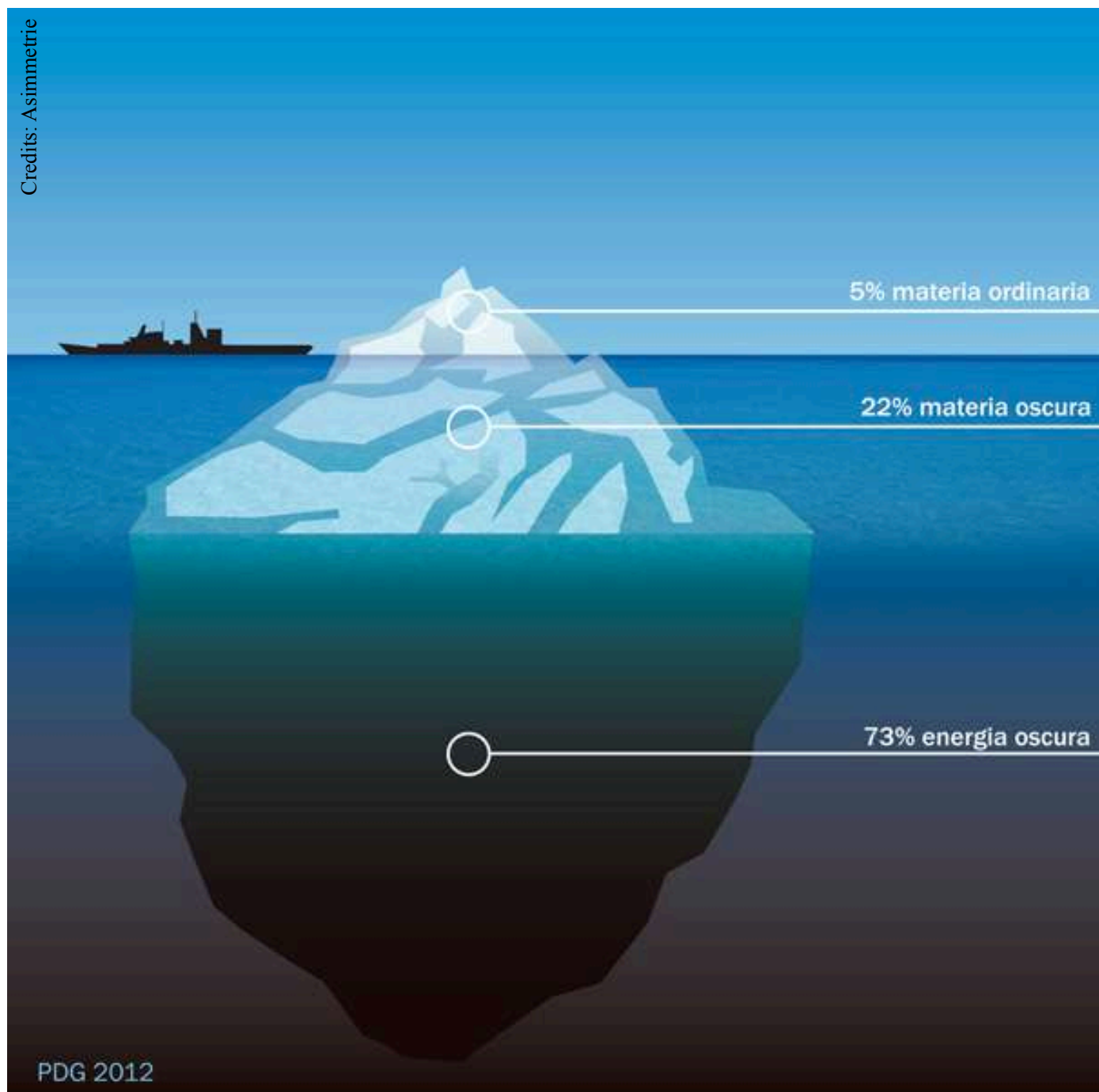
Modello Standard



Modello Standard?



Credits: Asimmetrie



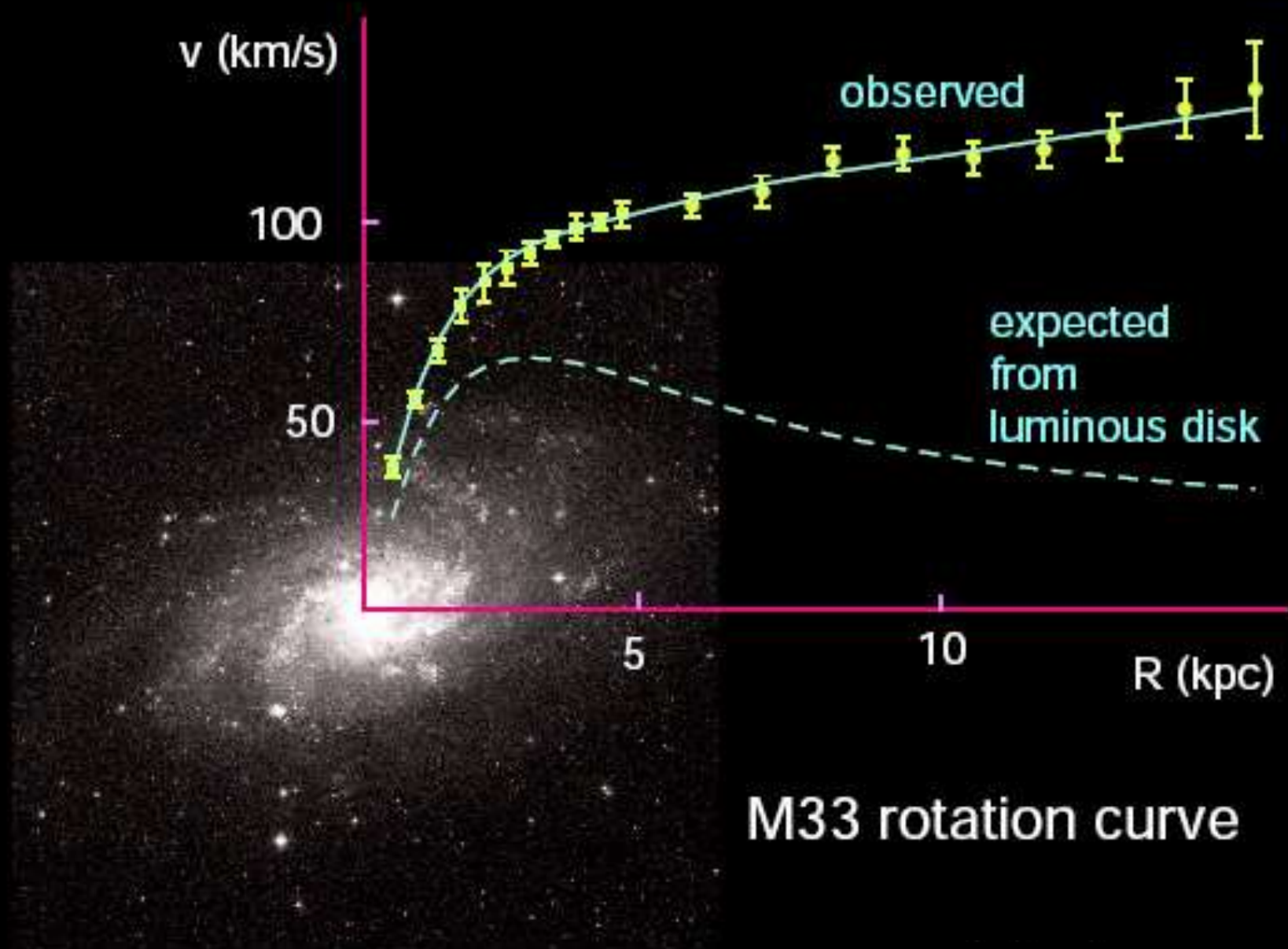
[PDG 2014:
Materia ordinaria 5%
Materia oscura 27%
Energia oscura 68%]

Materia e Materia Oscura

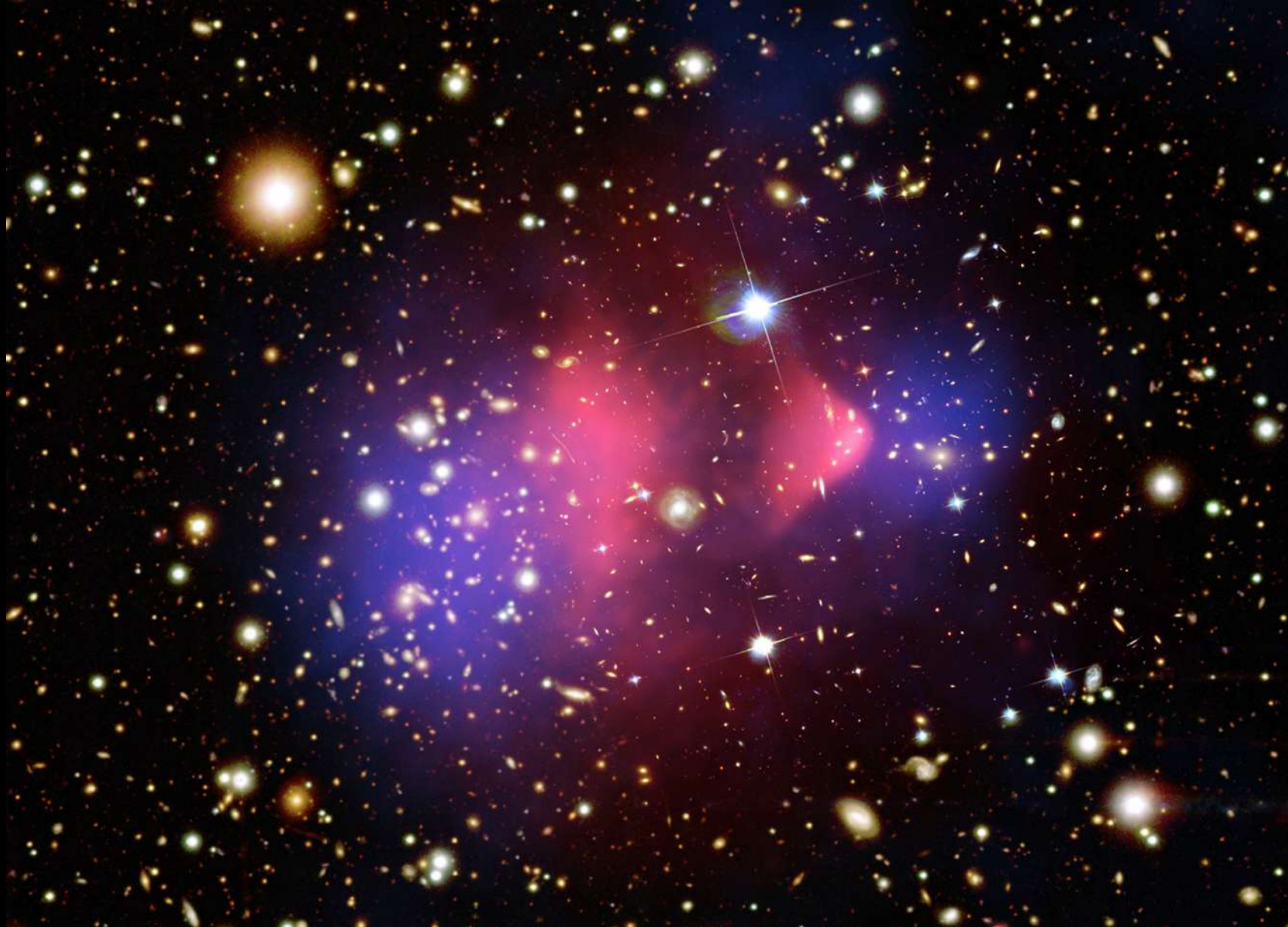


Fonte: CNPM/EMBRAPA, 2007.

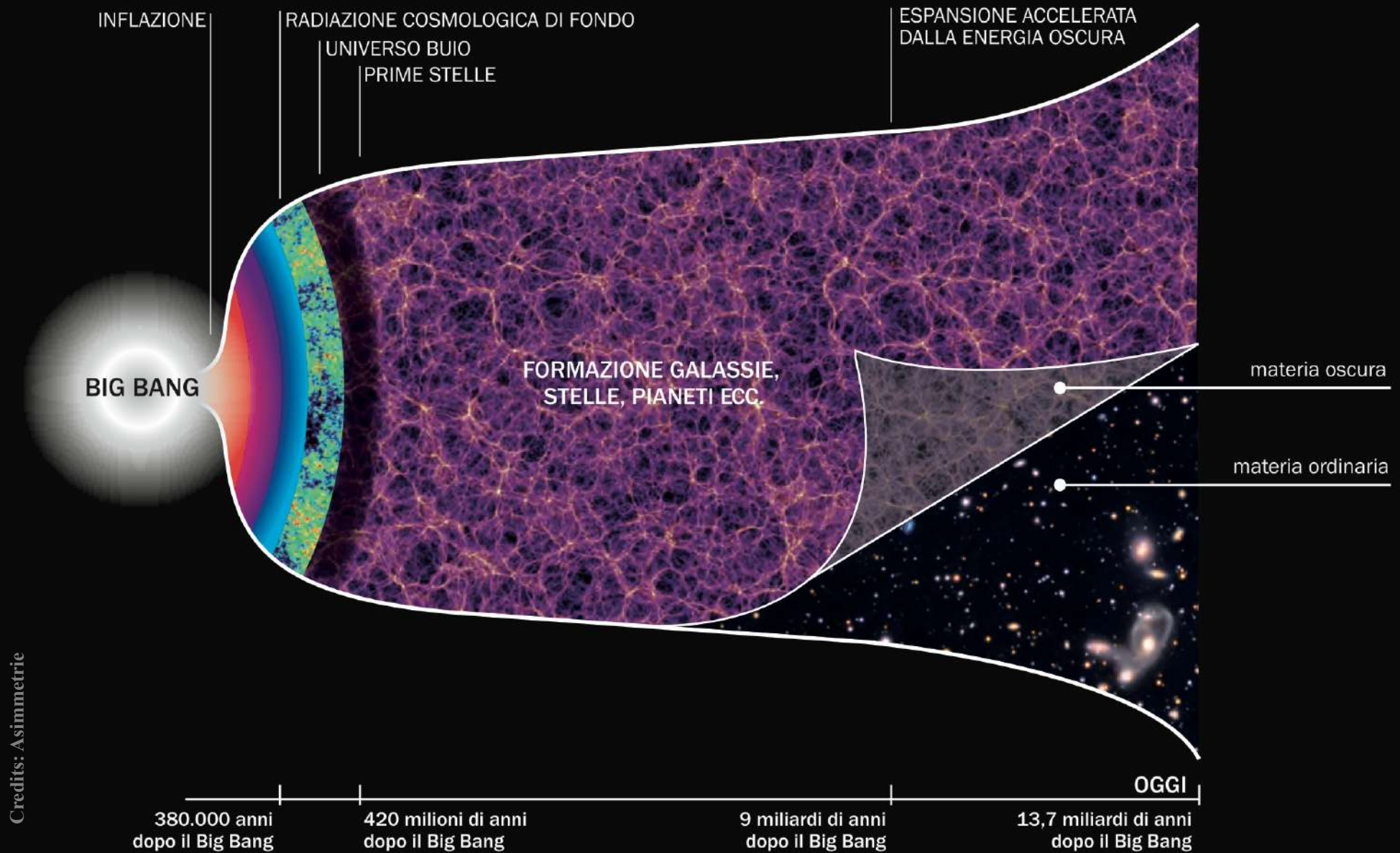
Materia e Materia Oscura



Materia e Materia Oscura

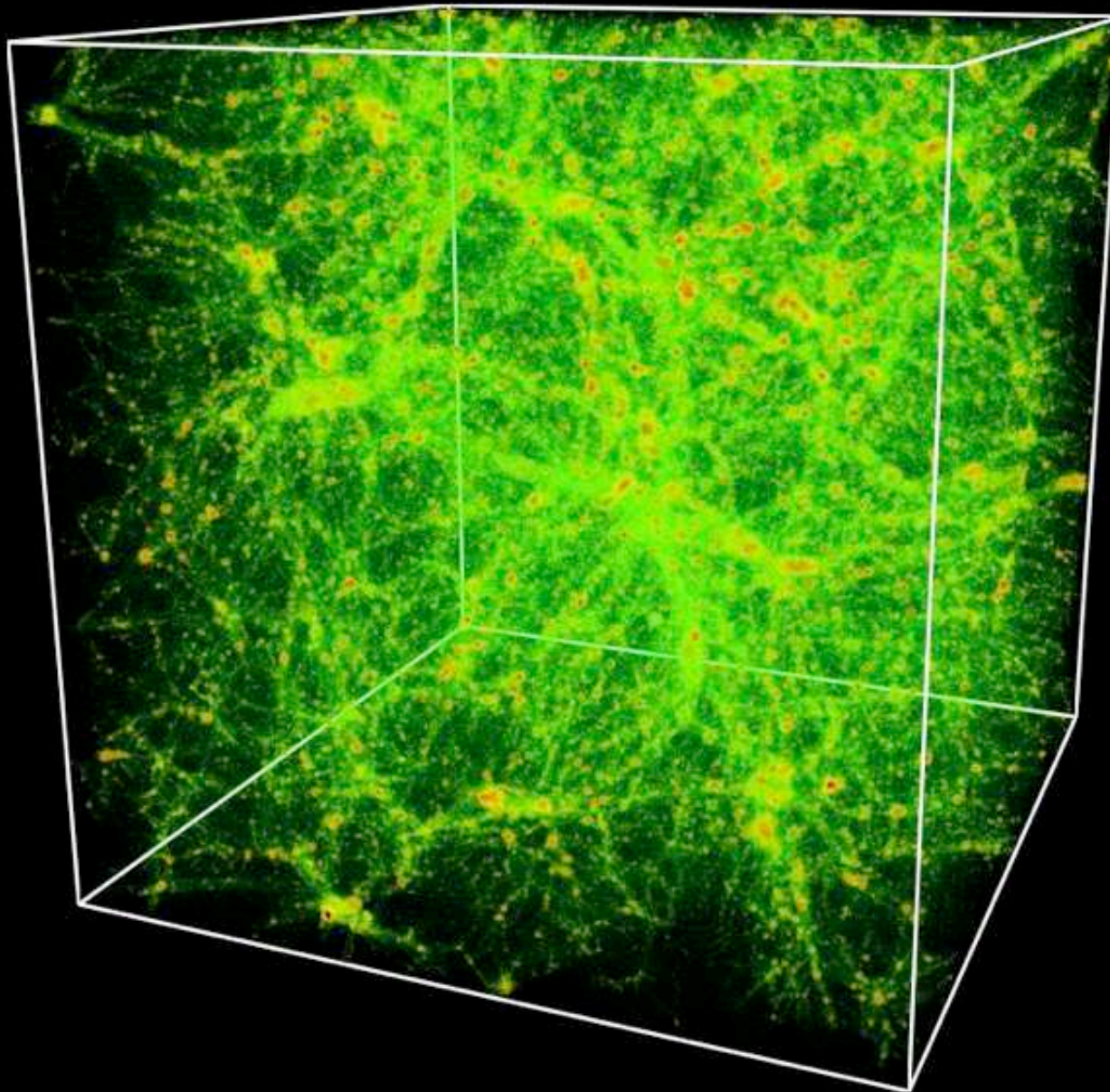


Modello Standard Cosmologico



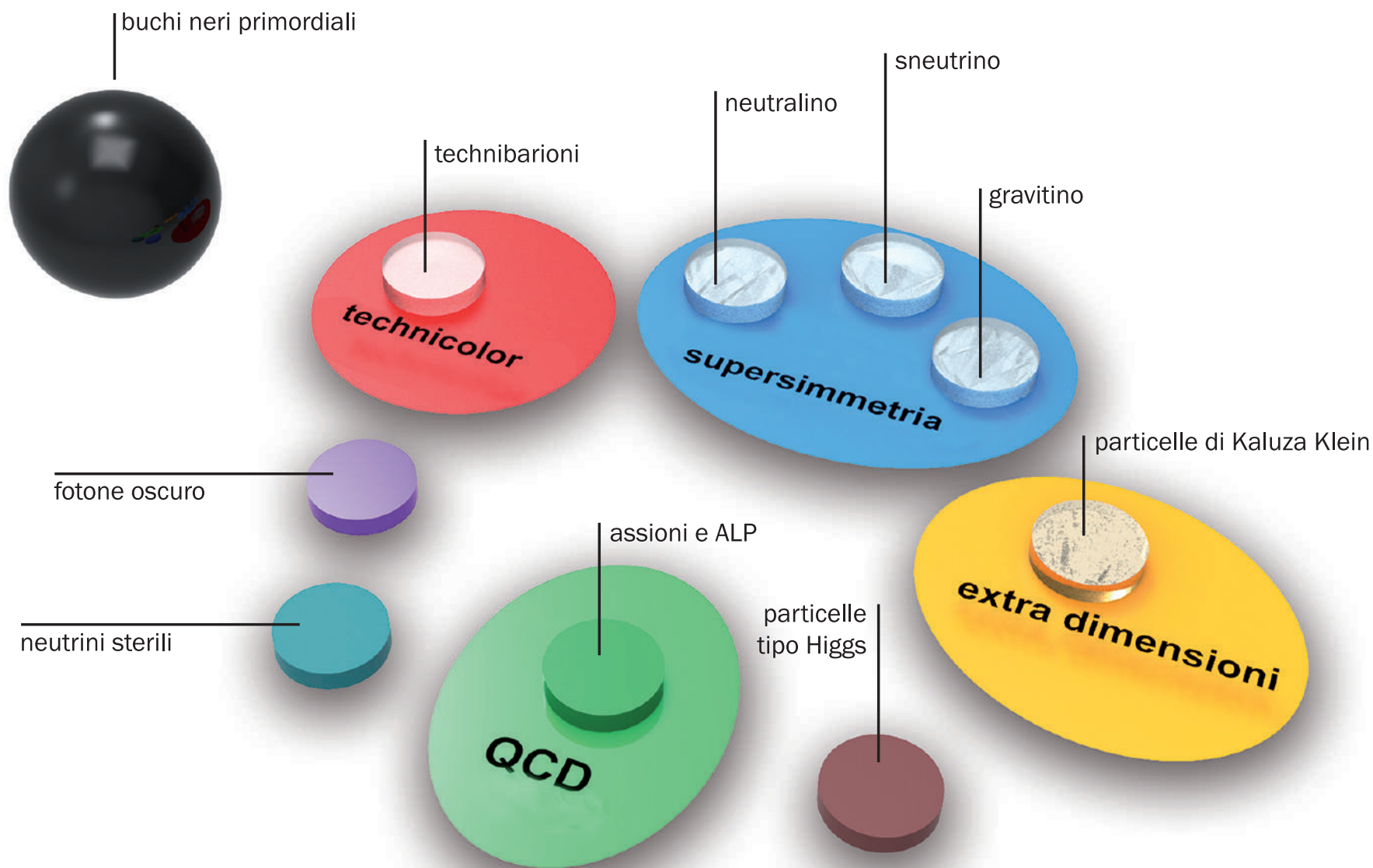
Credits: Asimmetrie

Materia e Materia Oscura



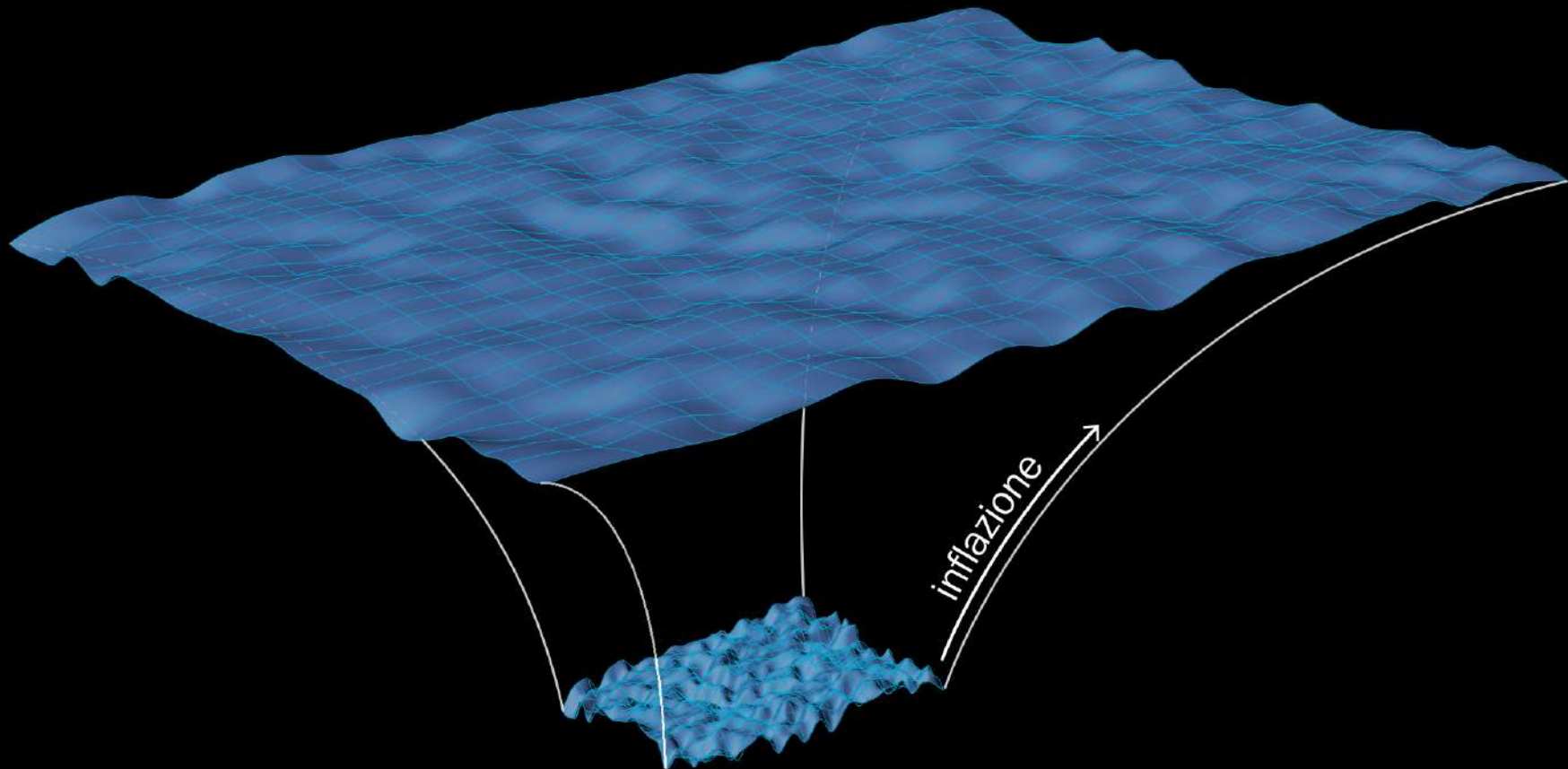
Credits: Asimmetrie

Lo zoo oscuro



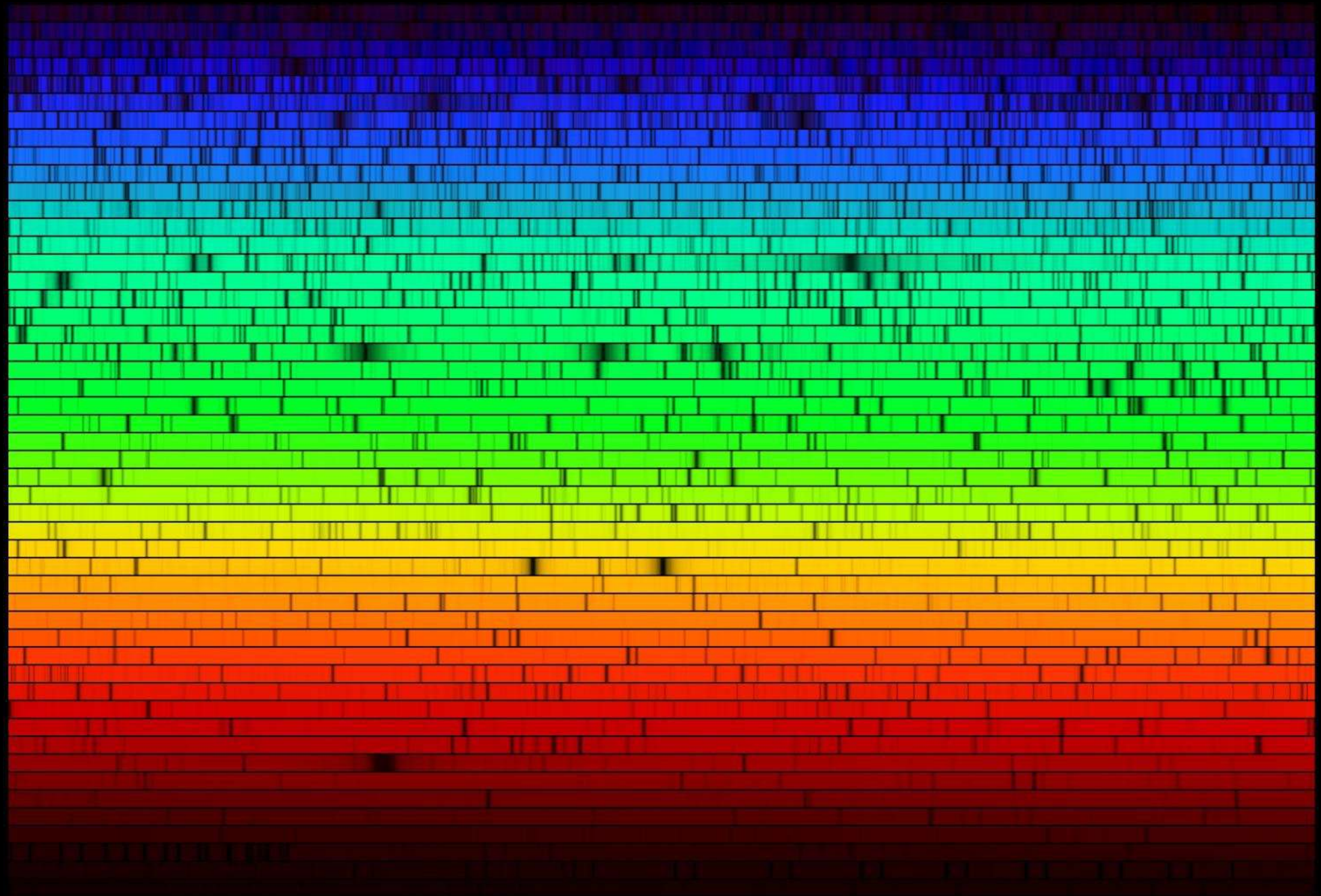
Credits: Asimmetrie

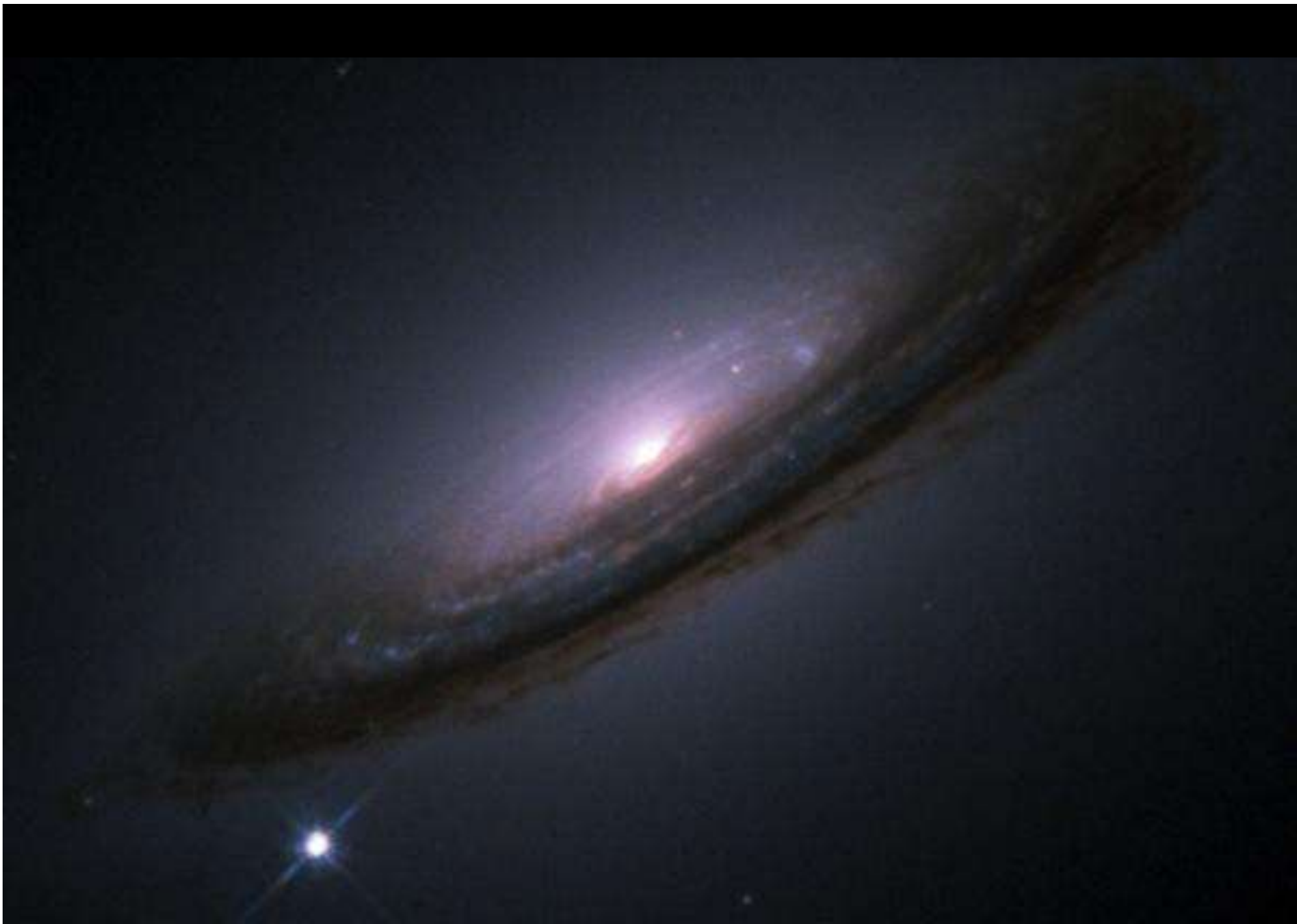
Inflazione



Credits: Asimmetrie







supernova

stella di neutroni

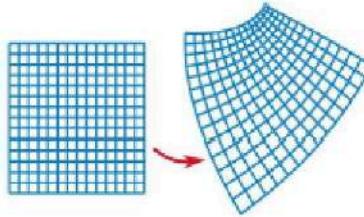
buco nero

Credits: Asimmetrie

Relatività generale

Simmetrie come principi delle teorie:
Relatività generale

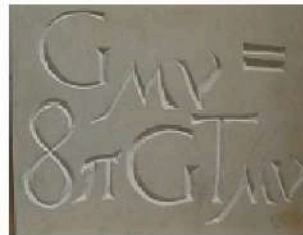
Simmetria generale
delle coordinate



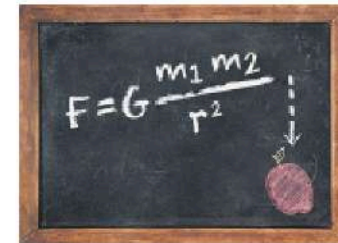
(Invarianza rispetto a una generica
trasformazione delle coordinate)



Equazione di Einstein
(Relatività generale)

The Einstein field equation is shown carved into a stone tablet, similar to the Rosetta Stone. The equation is $G_{\mu\nu} = 8\pi G T_{\mu\nu}$.

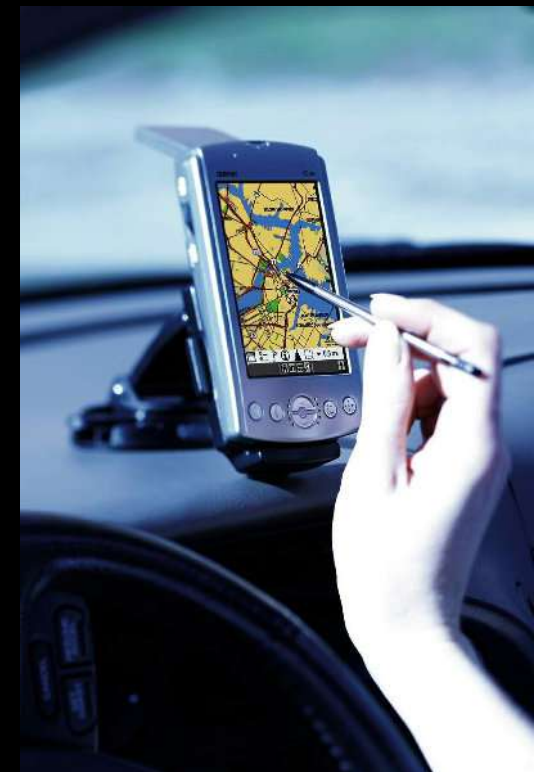
caso
particolare

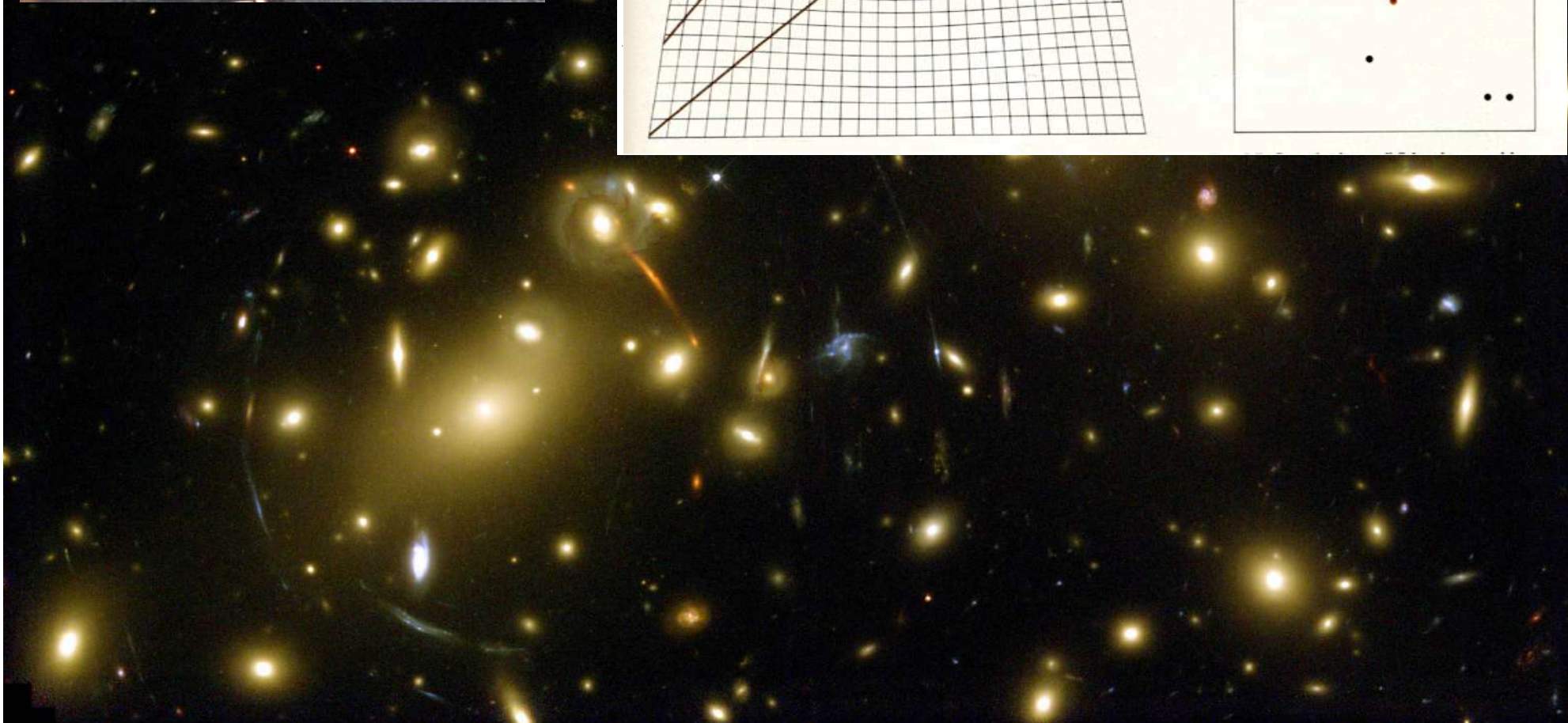
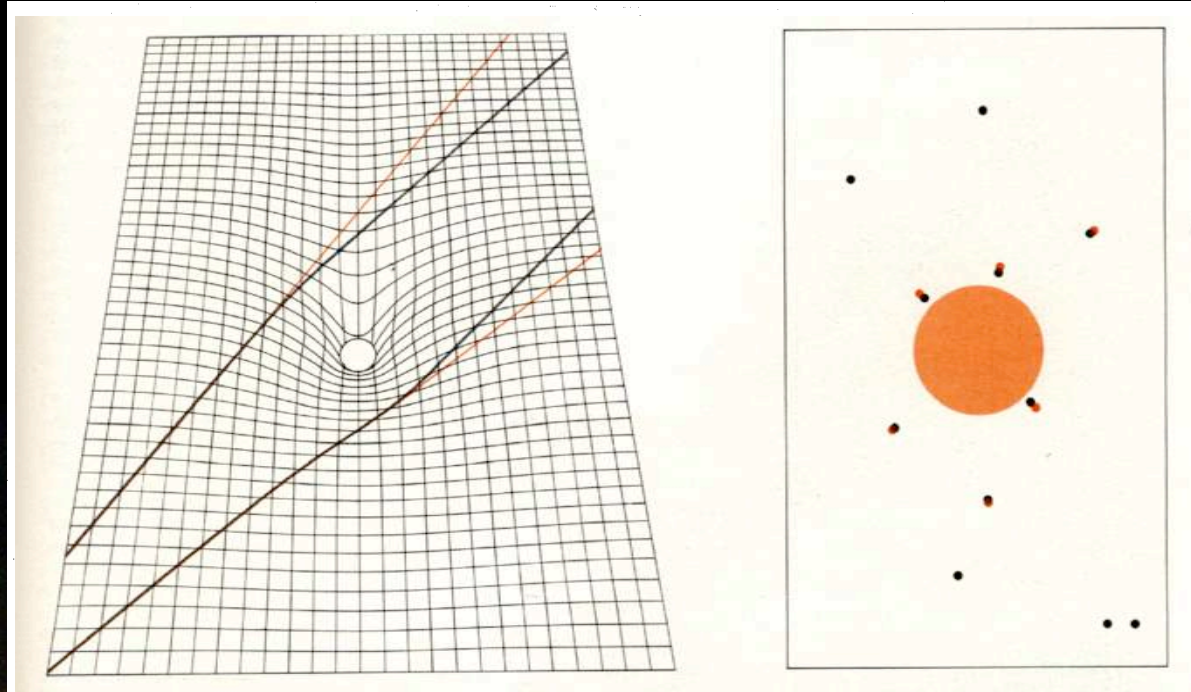
The equation for Newton's law of universal gravitation is written on a chalkboard. The equation is $F = G \frac{m_1 m_2}{r^2}$. A small red apple is shown falling from the top right corner of the chalkboard.



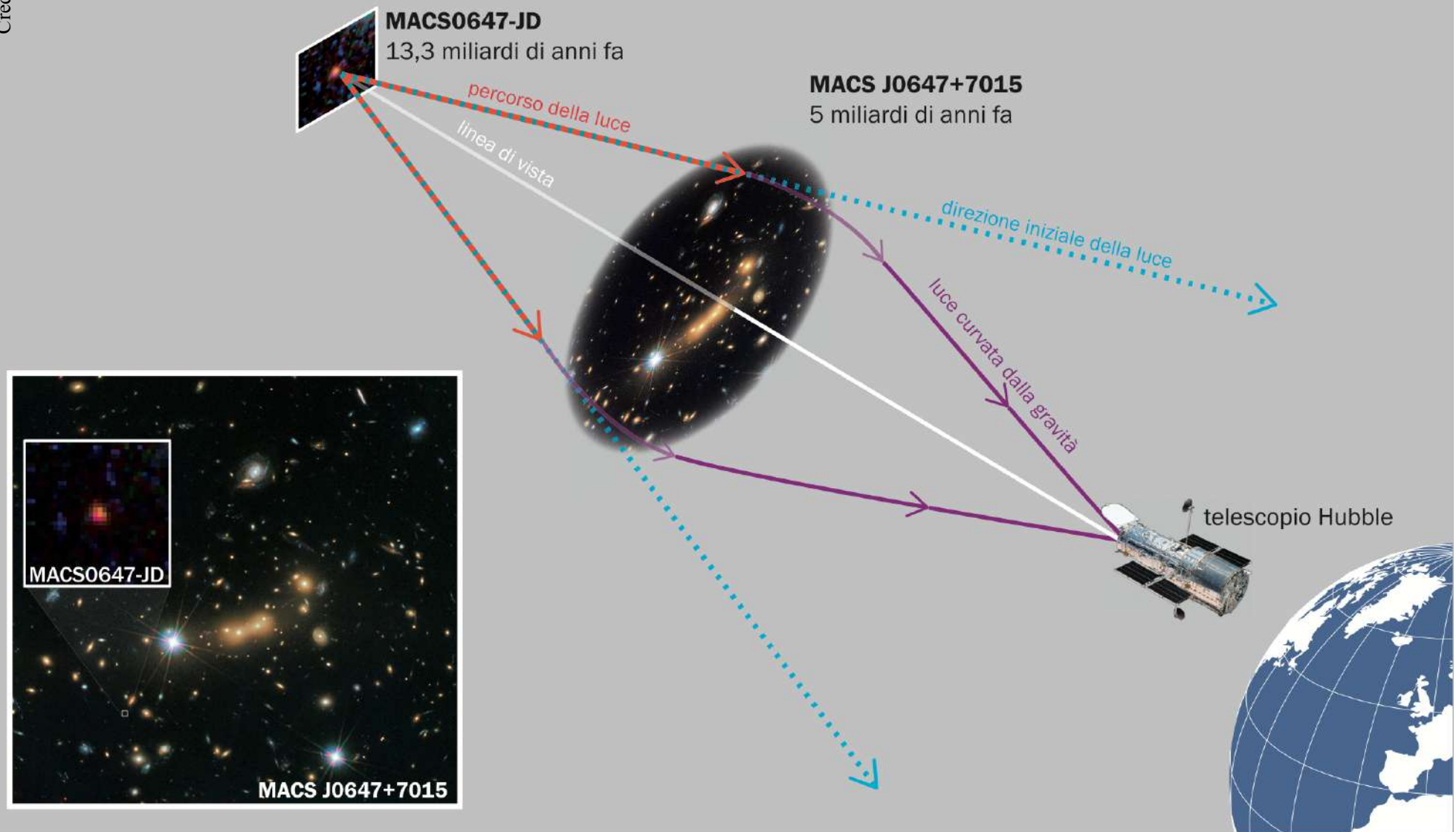
Relatività generale





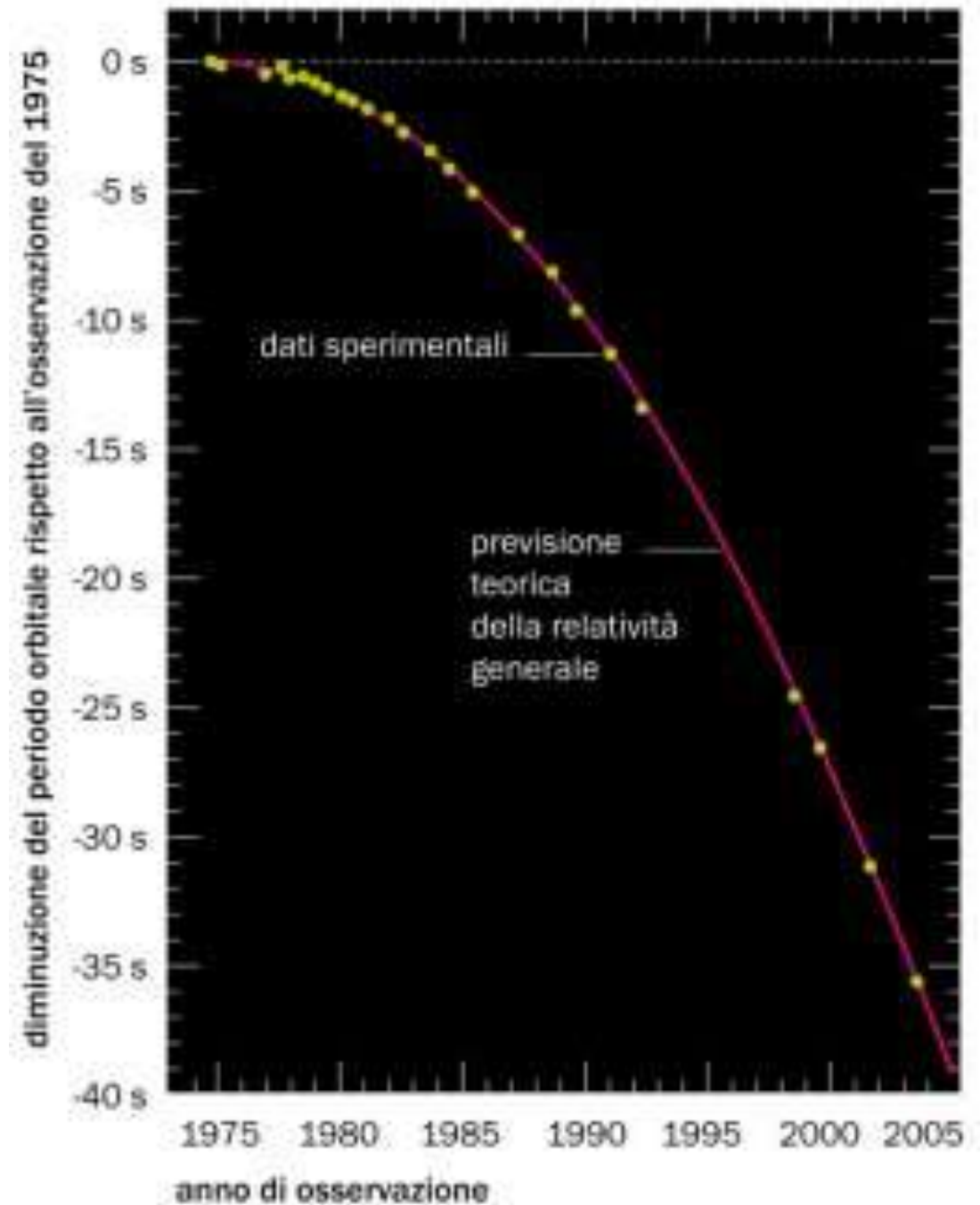


Gravitational lensing



Pulsar PSR1913+16

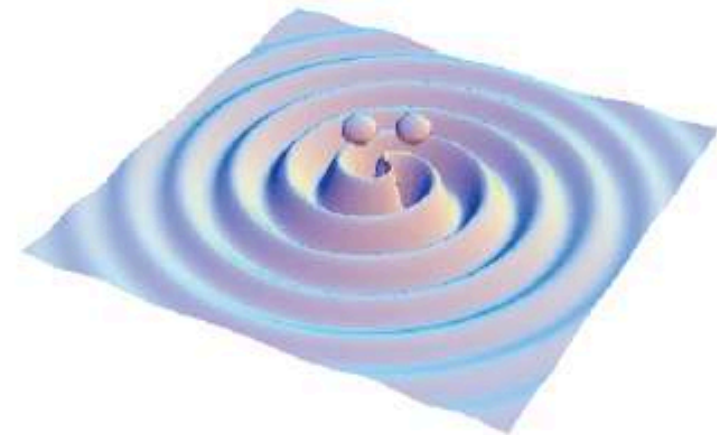
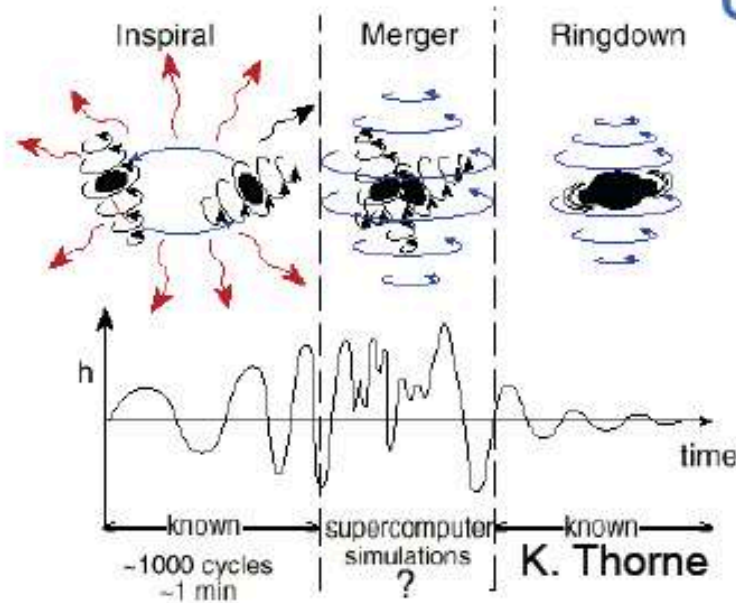
[Hulse e Taylor]



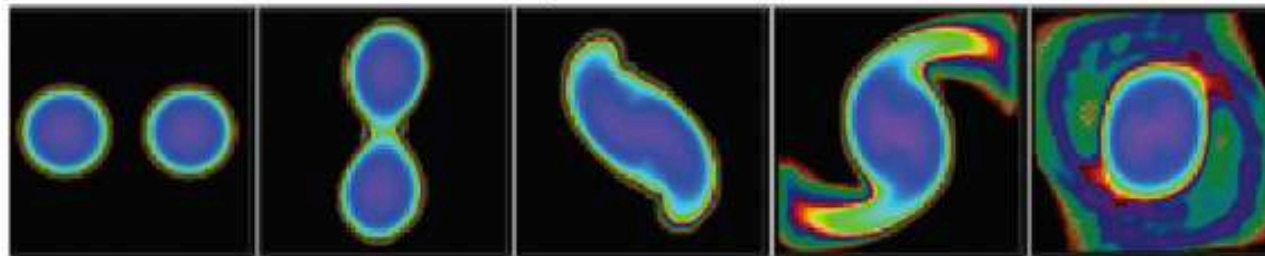
Credits: Asimmetrie

GWs from coalescing compact binaries (NS/NS, BH/BH, NS/BH)

Compact binary mergers



- Neutron star – neutron star (Centrella et al.)



*Da un seminario
del 2009*



LIGO: Laser Interferometer Gravitational-wave Observatory



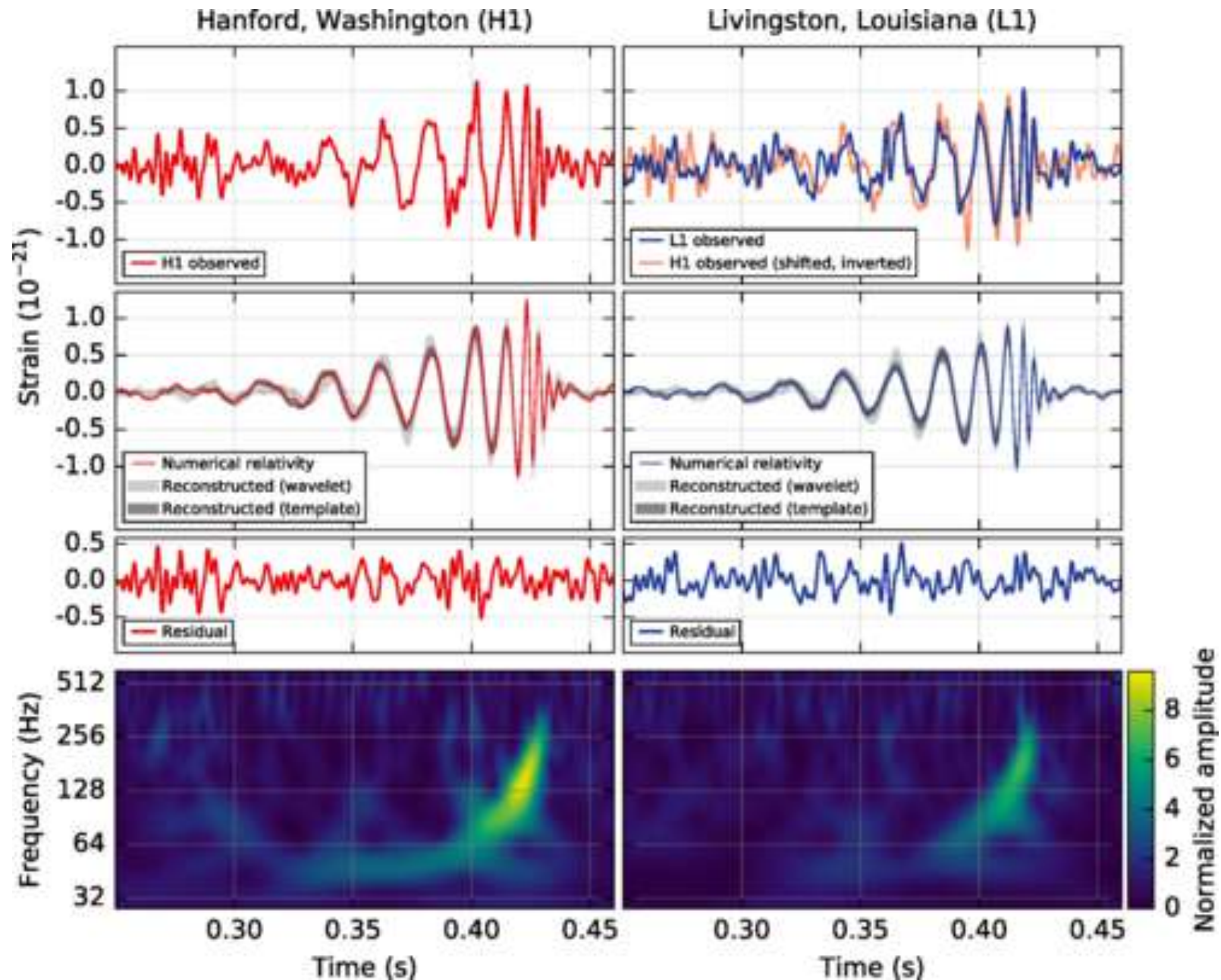
LHO

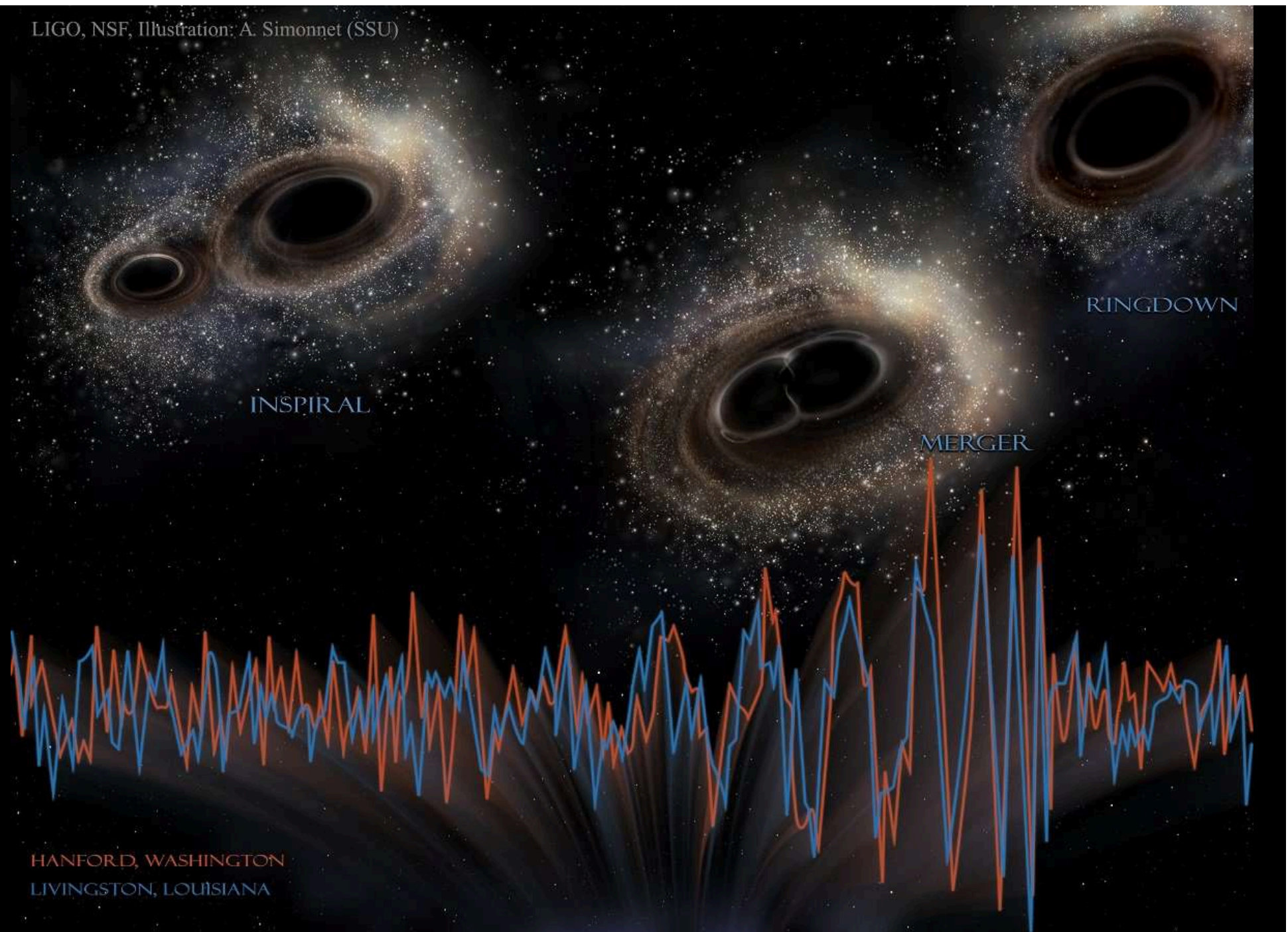


LLO



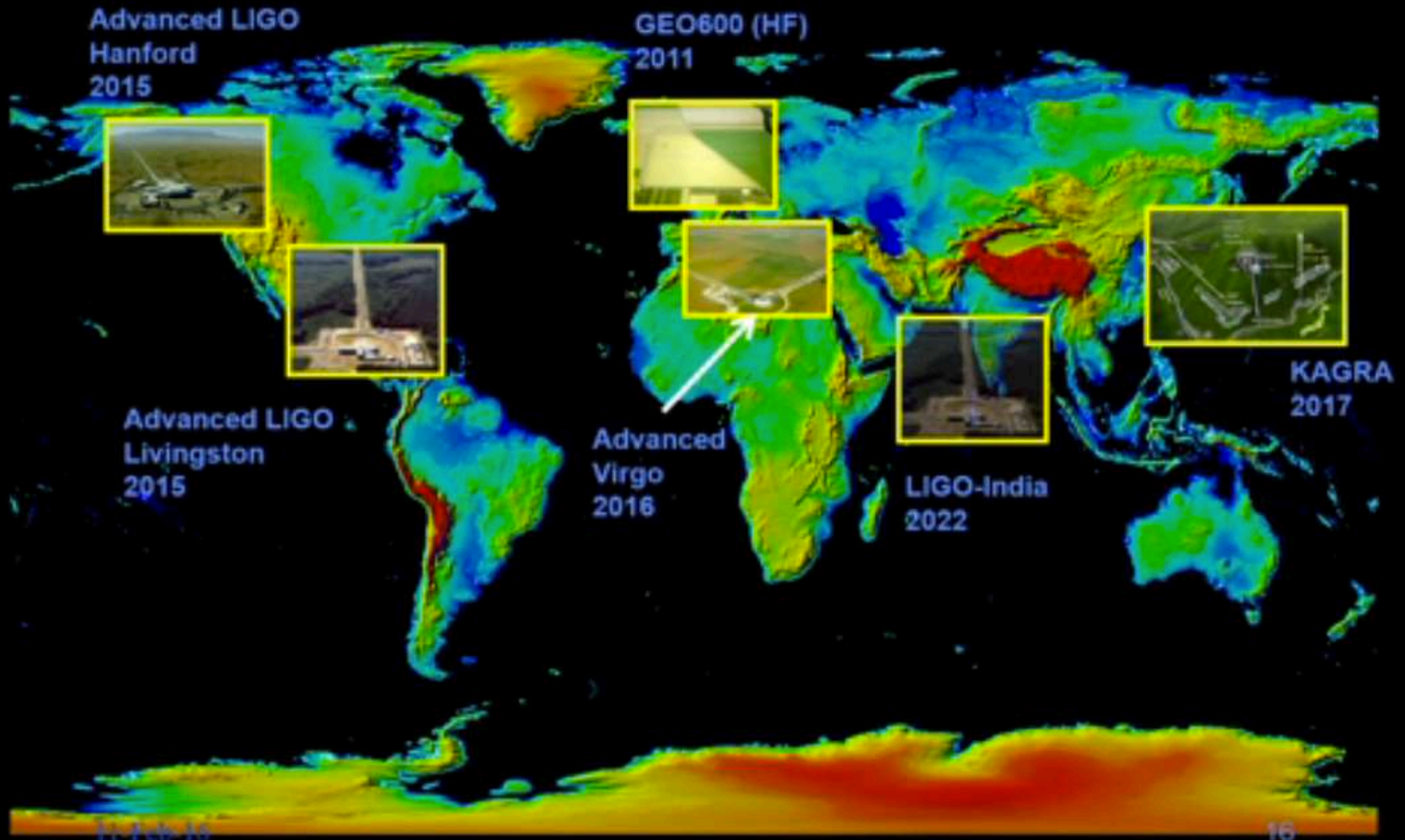
GW150914

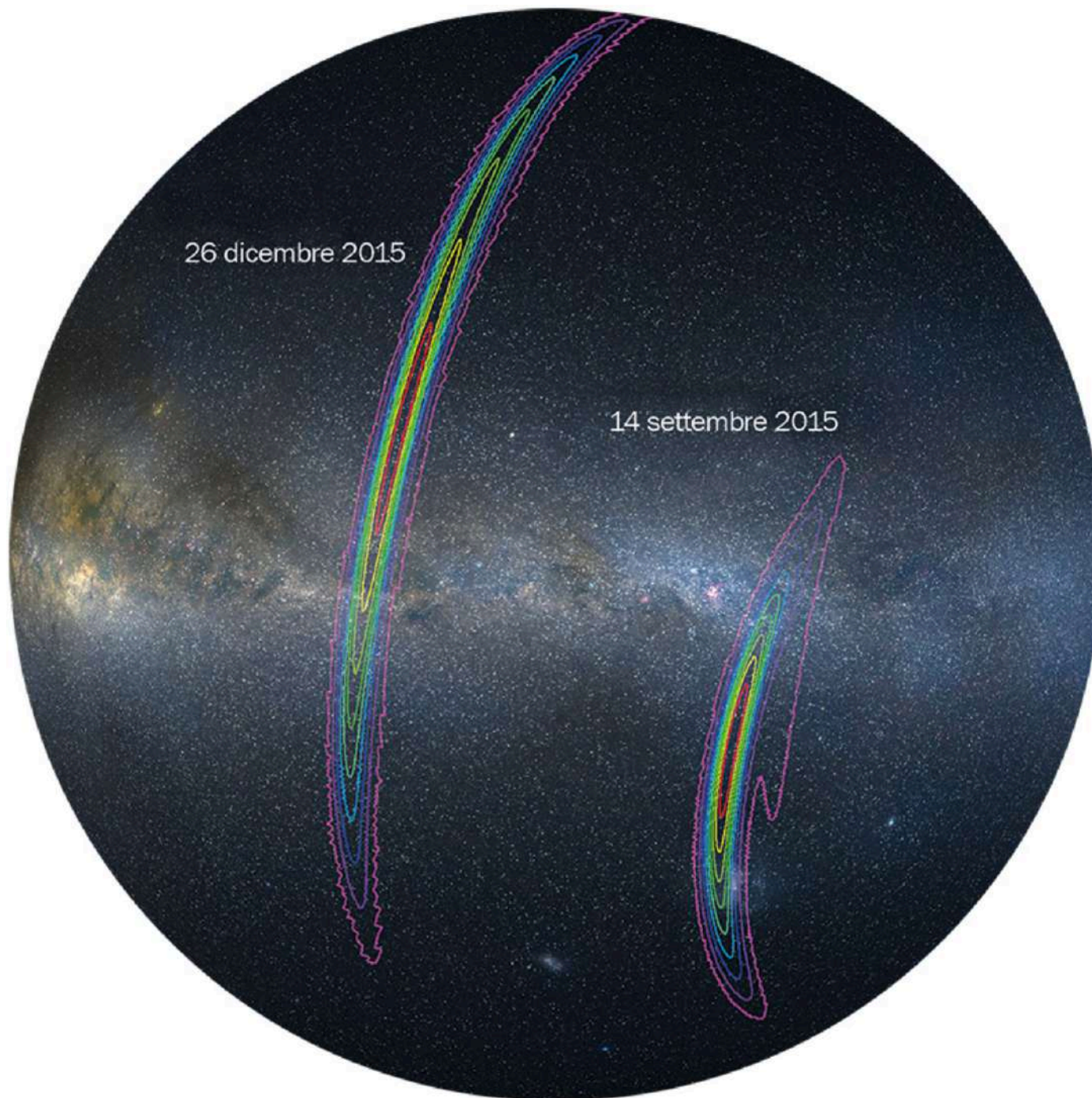


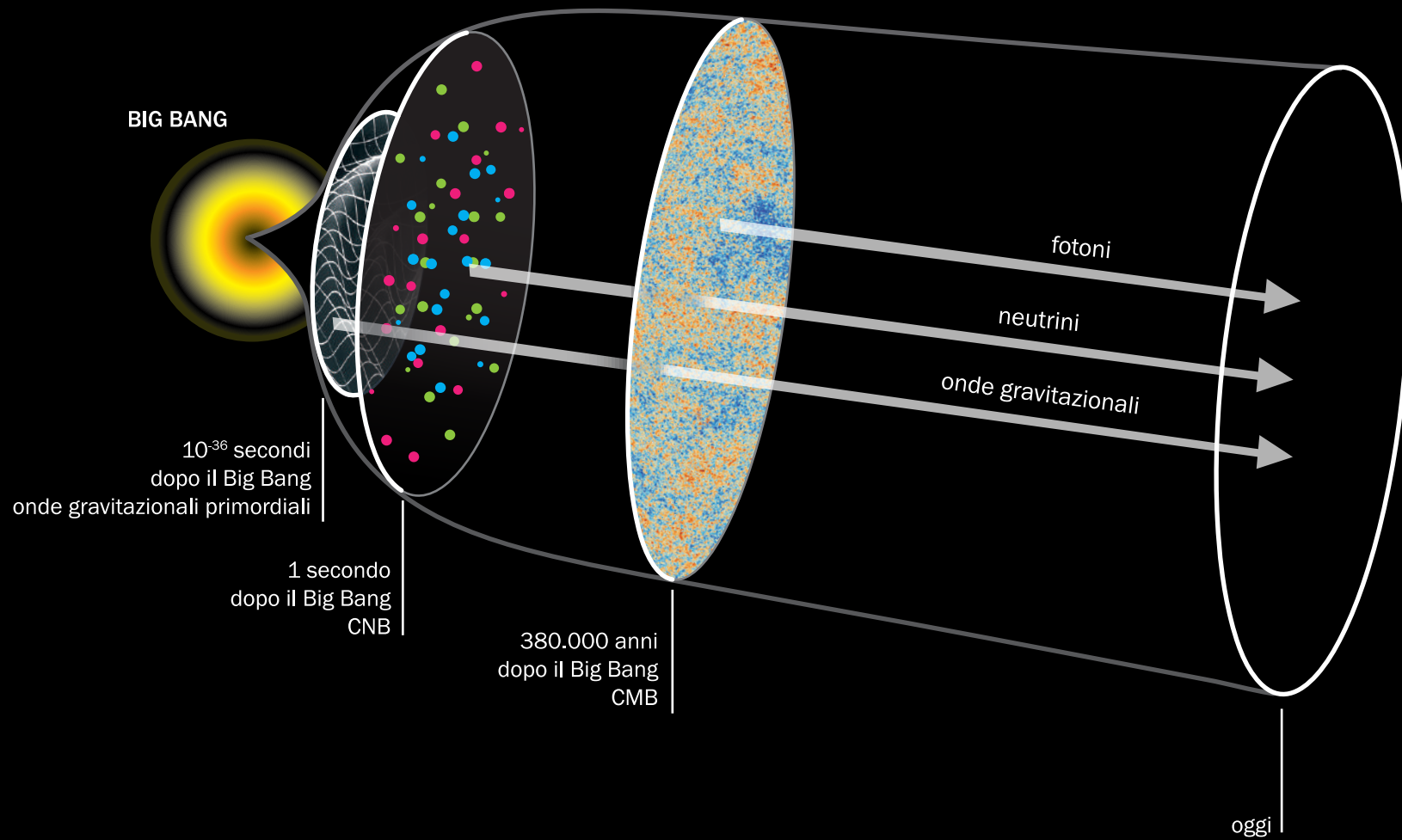




The advanced GW detector network: 2015-2025

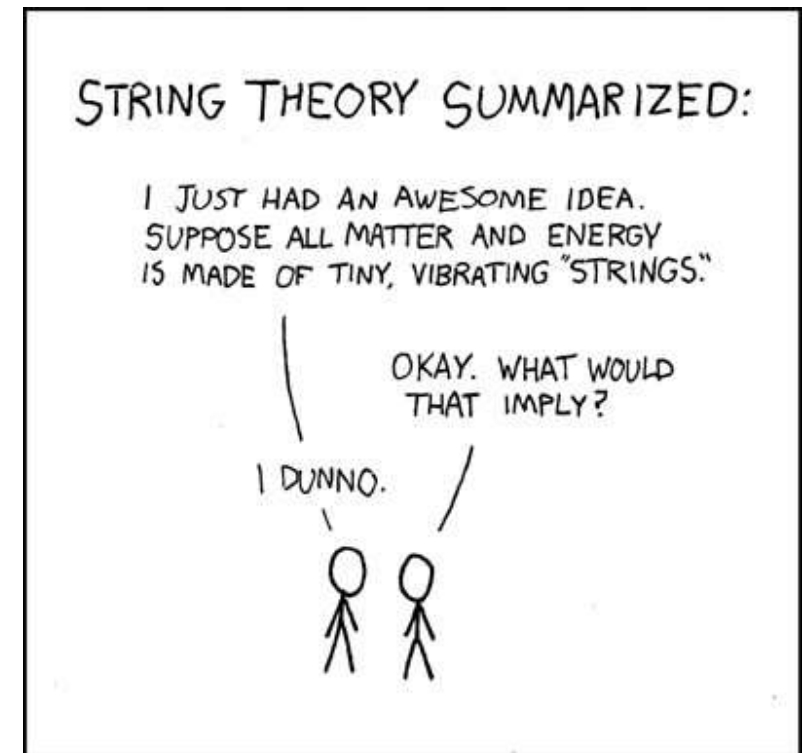
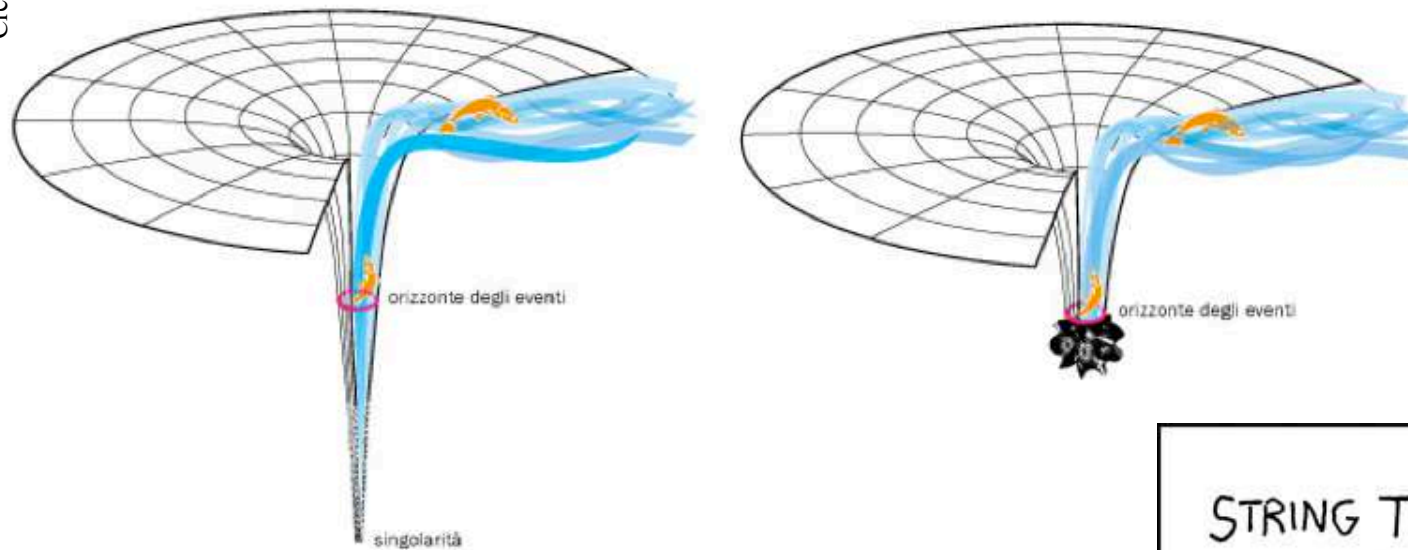






Credits: Asimmetrie

Teoria delle stringhe (?)



Buco nero a LHC?

Accusa: <http://www.lhcdefense.org/>
Difesa: <http://public.web.cern.ch/Public/en/LHC/Safety-en.html>



Bush: Svizzera stato canaglia nascondeva armi di distruzione di massa

Il presidente degli Stati Uniti accusa Al Qaeda di essersi infiltrata al CERN tramite i tecnici pachistani. E ammette: "colpevole leggerezza concentrarsi sulla ricerca nucleare iraniana invece che su quella europea". Il Pentagono spinge per usare l'atomica: "ne abbiamo una scorta sufficiente a distruggere quel che resta del pianeta". Obama: "Un nero alla casa bianca sarebbe stato la fine del mondo". McCain: "Sono stato prigioniero in Vietnam, sopravviverò anche a questo".

Benedetto XVI: "Una scienza senza Dio ci ha portati alla catastrofe"

Se si perde il riferimento a Dio, "le grandi e meravigliose conoscenze della scienza diventano ambigue: possono aprire prospettive importanti per il bene, per la salvezza dell'uomo, ma anche - e lo vediamo oggi - diventare una terribile minaccia, la distruzione dell'uomo e del mondo". Ci occupa il dipartimento di fisica de "La Sapienza" per l'ultima veglia di preghiera.

Berlusconi convoca il consiglio dei ministri a Lampedusa.

Il premier rifugiato nel lembo d'Italia più lontano da Ginevra: "È un complotto comunista contro i successi del governo". Tremonti: "Il buco nero eredità della sinistra". Carlucci: "La colpa è di Maliani". Franceschini (Pd): "Teniamo la vicenda Buco Nero fuori dalla polemica politica". Vendola: "Linea comune della sinistra, almeno di fronte alla fine dell'universo". Ma Diliberto prende le distanze. Di Pietro: "Se fosse per me il direttore del CERN starebbe in galera". L'OPINIONE Moriremo berlusconiani di EZIO MAURO



"Pregate, ma non garantisco niente"
Lo scetticismo di Papa Benedetto

"Il buco nero è il risultato ultimo di ricerca scientifica dissennata che ha voluto porre l'uomo davanti a Dio. Non resta che la preghiera, forse". Dal suo ritiro in Alto Adige, il Papa gela i pellegrini venuti ad ascoltare un messaggio di speranza. IL VIDEO / LE IMMAGINI / "SANTITÀ, IL BUCO NERO È L'INFERNO?"

Net Monitor: "Proprio adesso che andavo in ferie" di V. ZAMBARDINO

Hawking deluso: "mi sono sbagliato"

"La mia radiazione avrebbe dovuto eliminare il buco nero, ma evidentemente ho sbagliato qualcosa". Lo scienziato non esclude la possibilità che un nuovo universo possa riformarsi dal caos. "Ci vorranno milioni di anni, ma la prossima volta saremo più prudenti".



Buco nero a LHC?

Buchi neri: non necessari né previsti da nessuna teoria; in alcune teorie esotiche solo un **limite superiore alla possibilità che si formino**.

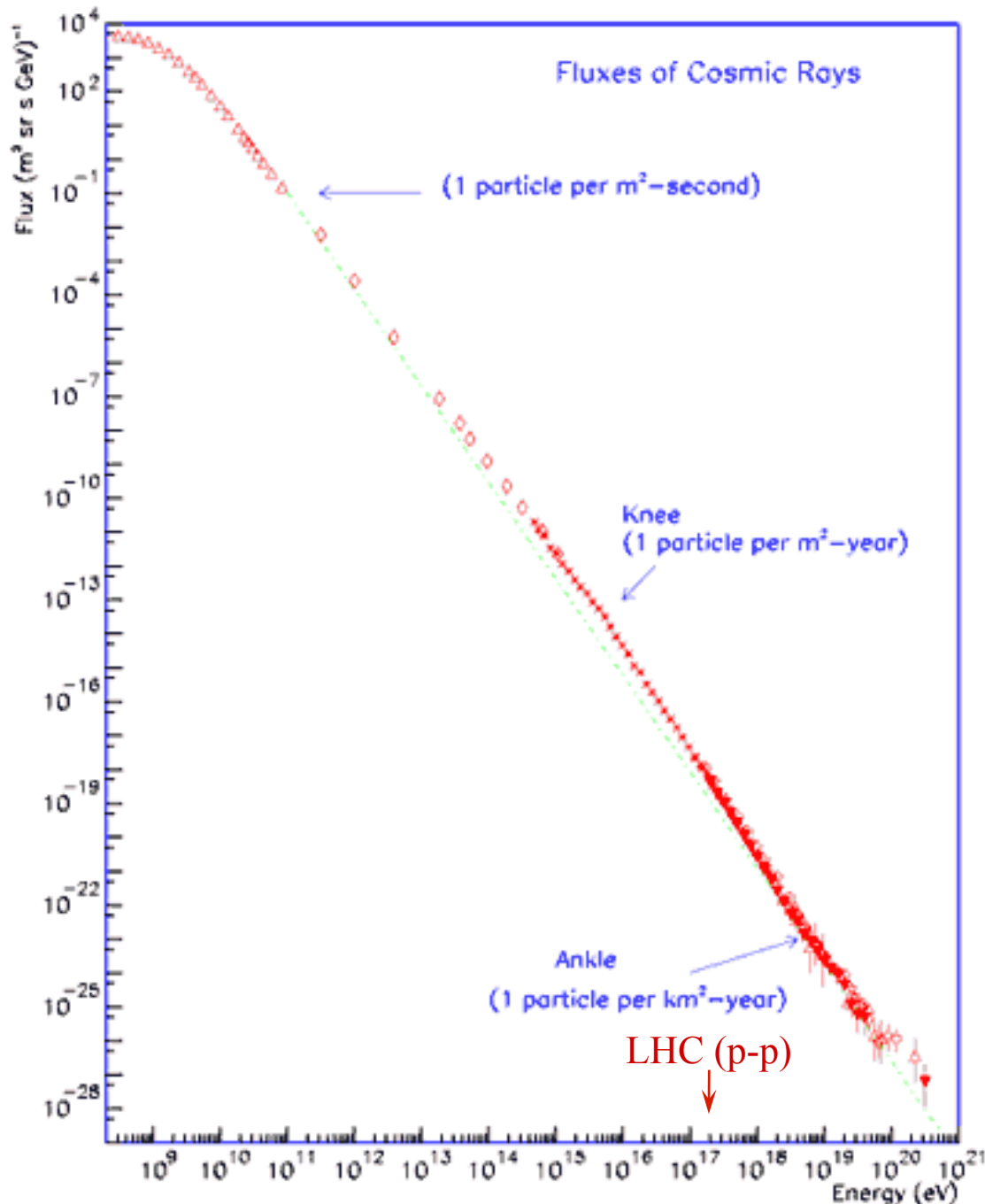
In ogni caso, come **ESCLUDERE** la possibilità di un disastro ambientale?

Evidenza empirica dai Raggi Cosmici

- In 5 miliardi di anni 10^{22} urti/A sulla Terra con energia superiore a LHC
- In 10 anni di operazione per LHC: 10^{17} .

Solo la Terra $10^{22}/10^{17} = 10^5$, ma aggiungendo le stelle della Galassia simili al Sole: $10^{36}/10^{17} = 10^{19}$.

Aggiungendo le altre galassie...



Approfondimenti

Libri:

“L’universo elegante” di B. Greene, Einaudi

“La legge fisica” di R.P.Feynman, Adelphi

“I primi tre minuti” di S. Weinberg, Mondadori.

“La particella di Dio” di L.Lederman, Mondadori

“Particelle familiari” di M. Delmastro, Laterza

Asimmetrie, rivista semestrale dell’INFN

(www.asimmetrie.it) in particolare AS6 [acceleratori],

AS7 [antimateria], AS8 [bosone di Higgs],

AS11 [simmetrie], AS14 [massa], AS16 [1964],

AS18 [#NuovaFisica], AS21 [next]

TED talks (<https://www.ted.com>)

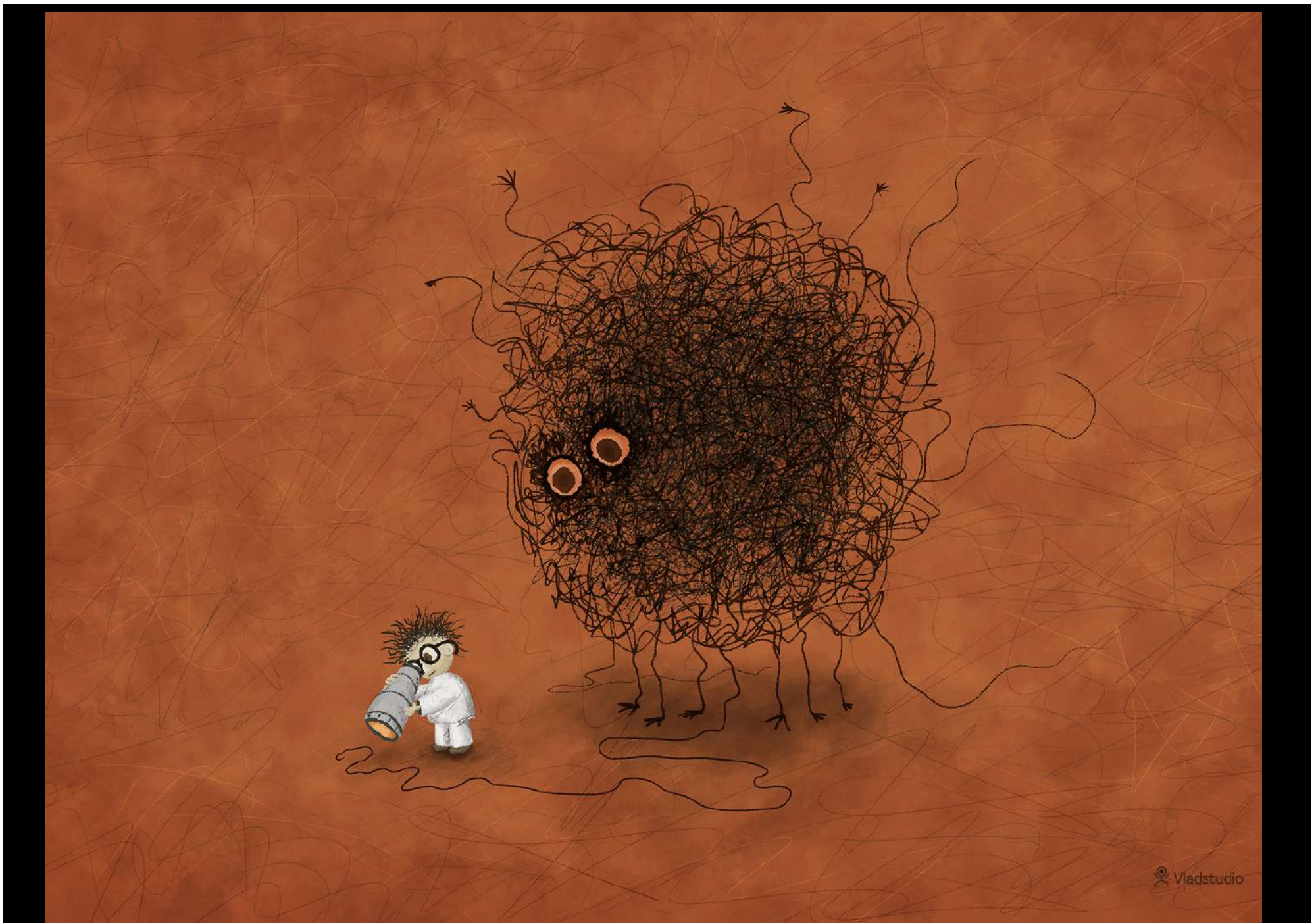
cercate B. Cox, B. Greene.

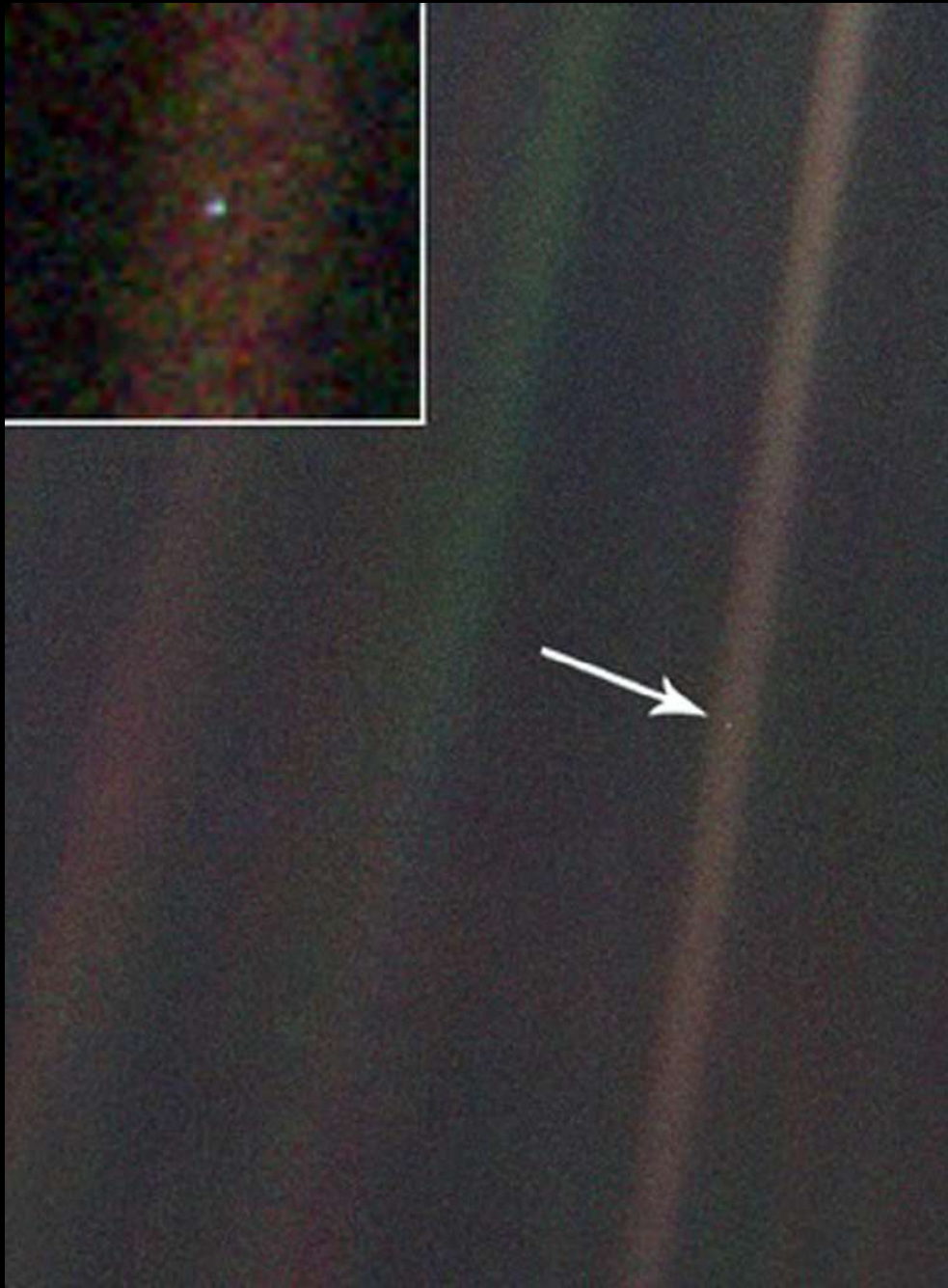
Corsi universitari online:

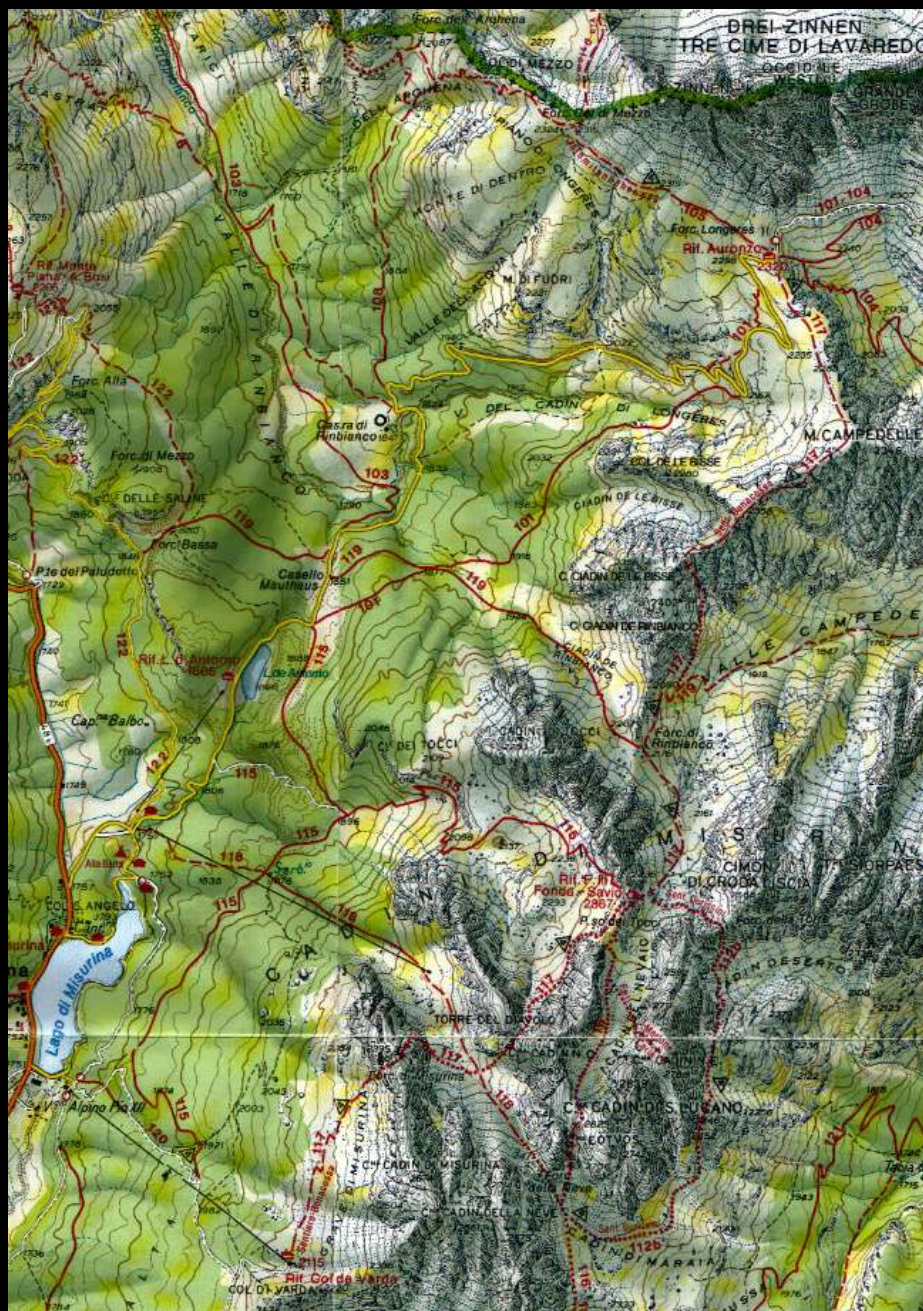
<https://www.youtube.com/user/StanfordUniversity>

<https://www.youtube.com/user/caltech>





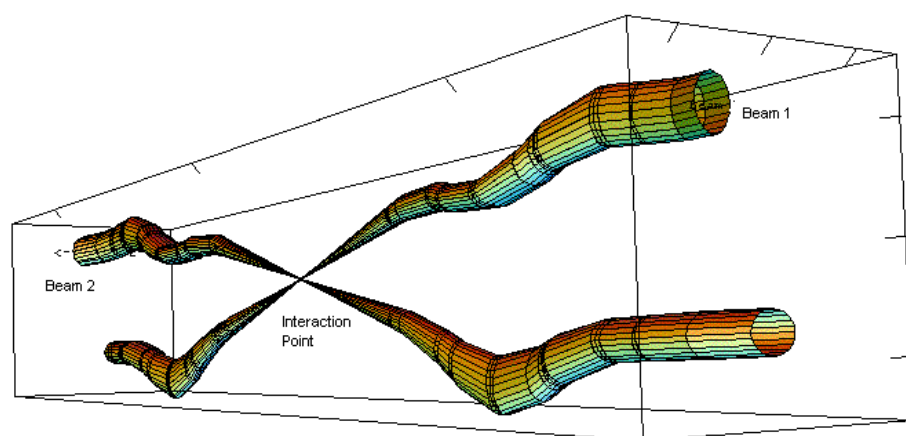
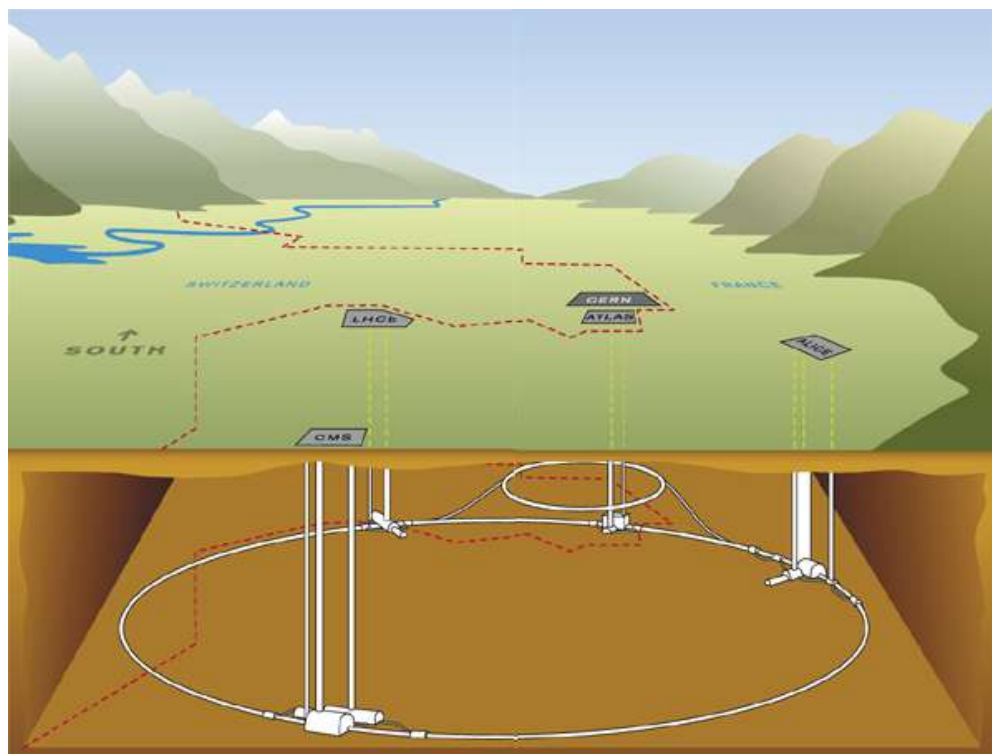




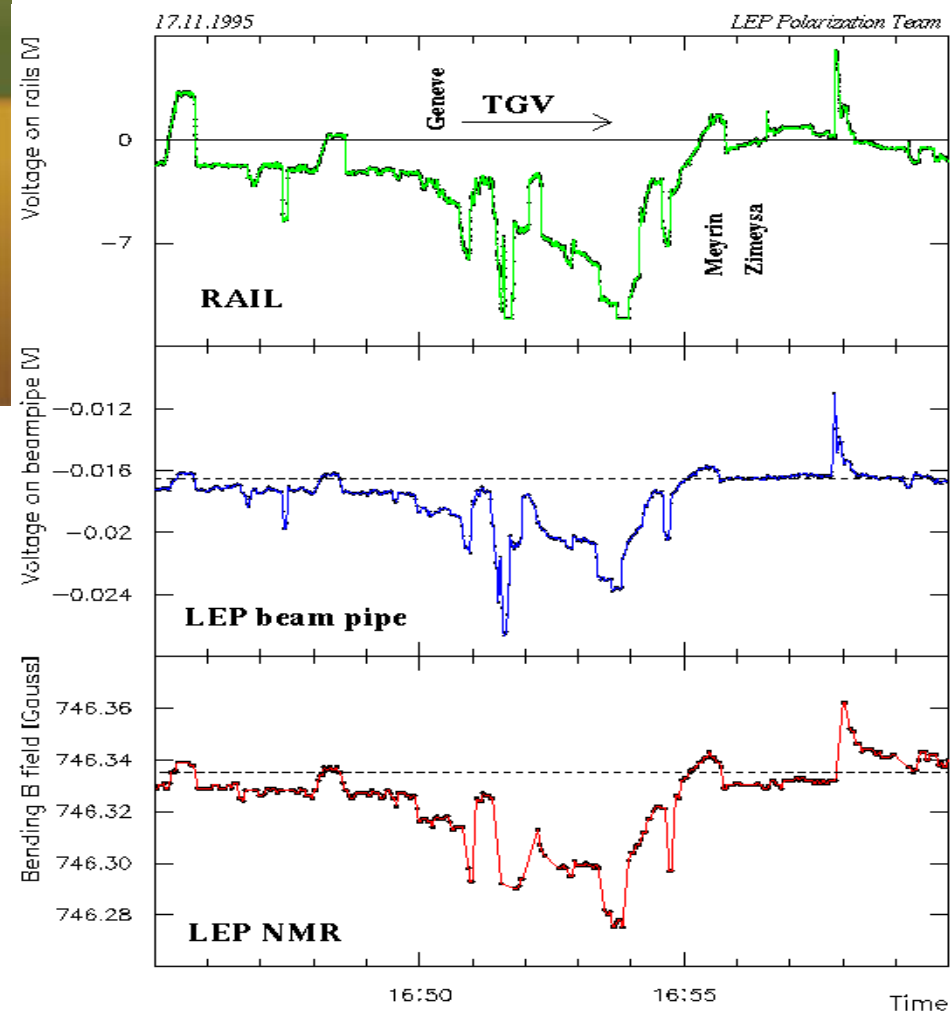
Mediatori delle forze



gluone	g
fotone	γ
bosone W	$W^{\pm}$
bosone Z	Z



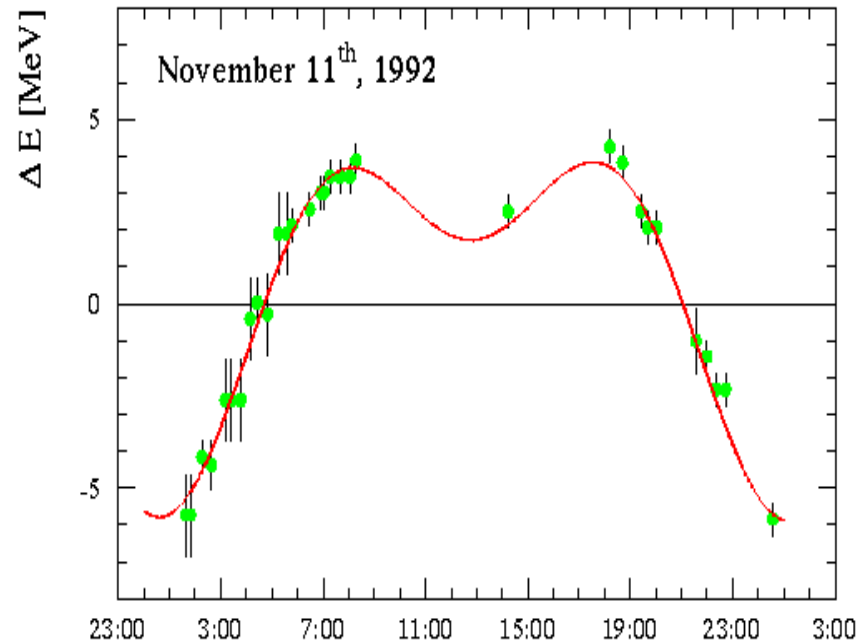
Relative beam sizes around IP1 (Atlas) in collision



Energia a LEP

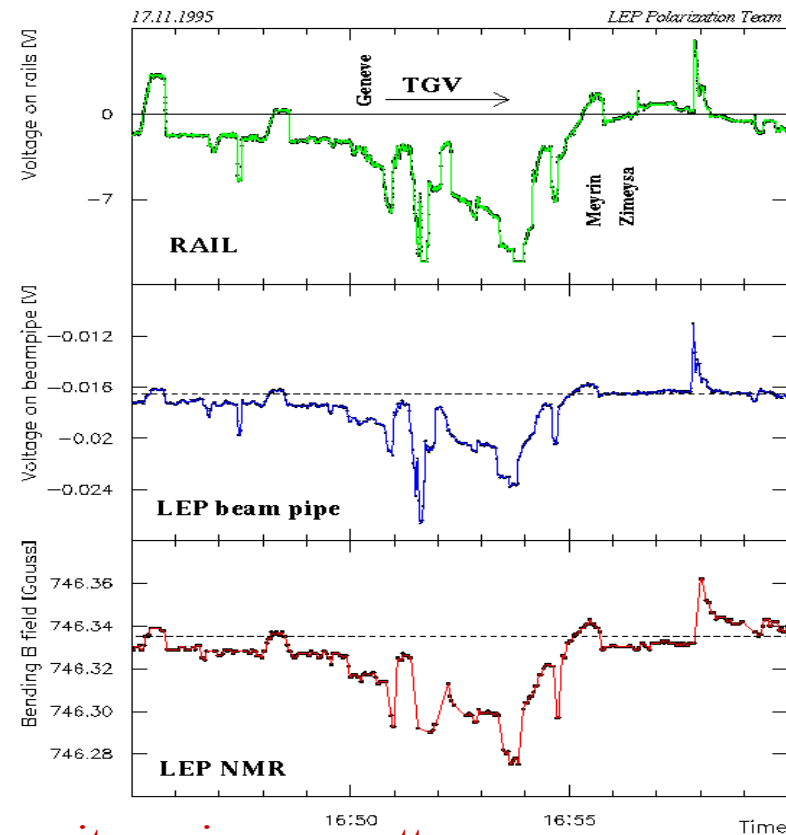
LA LUNA

LEP a mezzanotte e' circa $\sim 300 \mu\text{m}$ piu' lungo che a mezzogiorno $\rightarrow e^\pm$ vedono meno campo magnetico $\rightarrow E$ e' piu' piccola



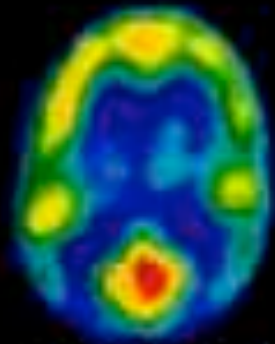
Il TGV

Le correnti indotte dal passaggio del treno sulla beam pipe di LEP cambiano il campo magnetico.

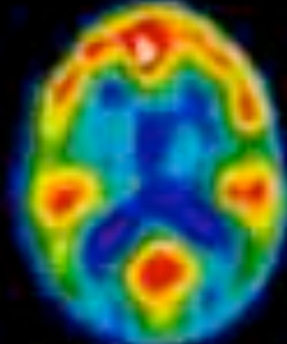


Variazioni fino a ~ 20 MeV ma l'effetto e' ben capito e viene corretto

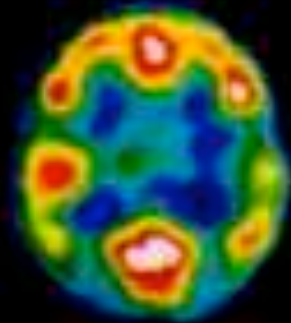
PET



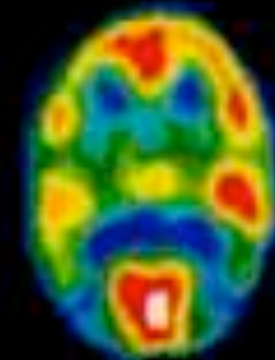
RESTING STATE



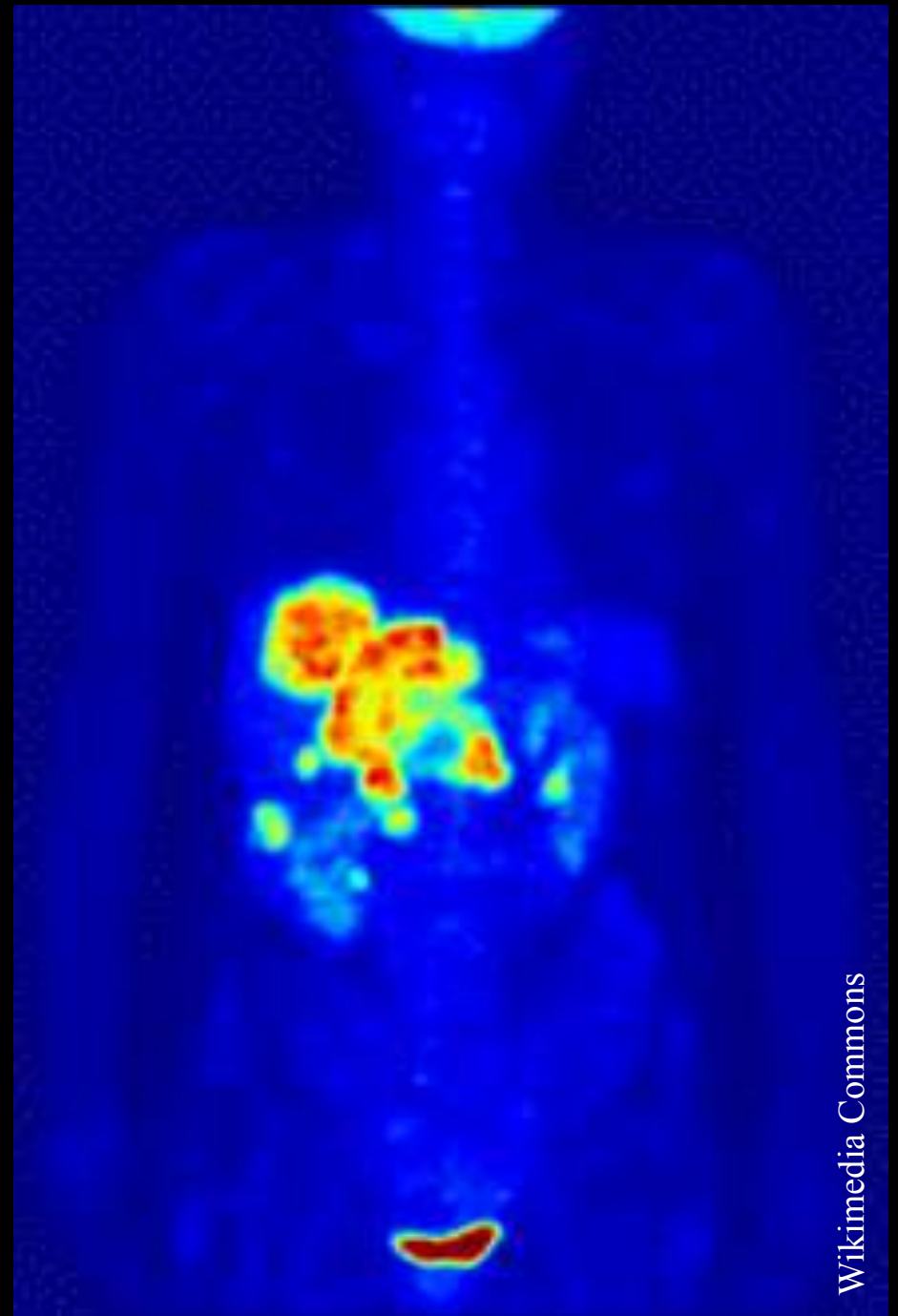
LANGUAGE AND MUSIC



LANGUAGE

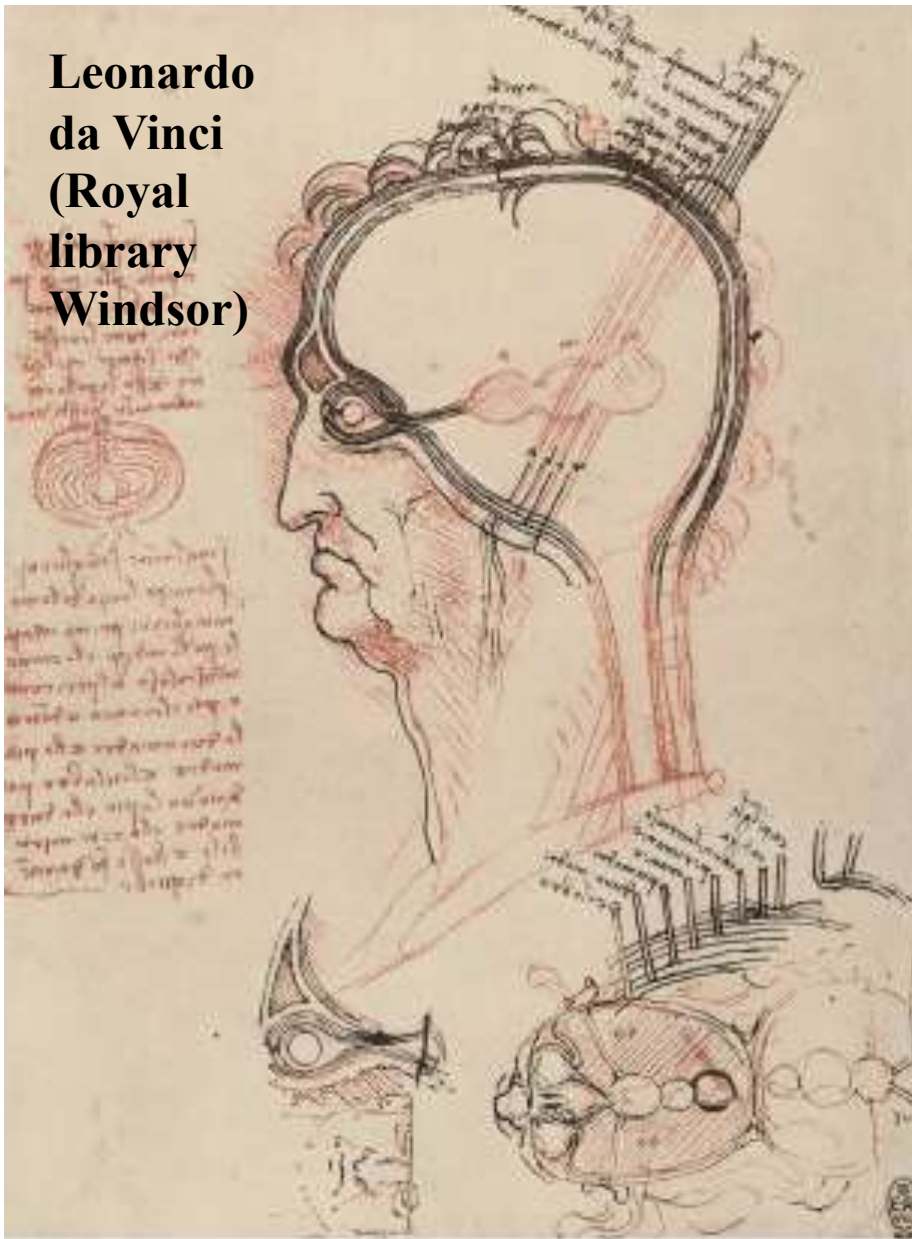


MUSIC



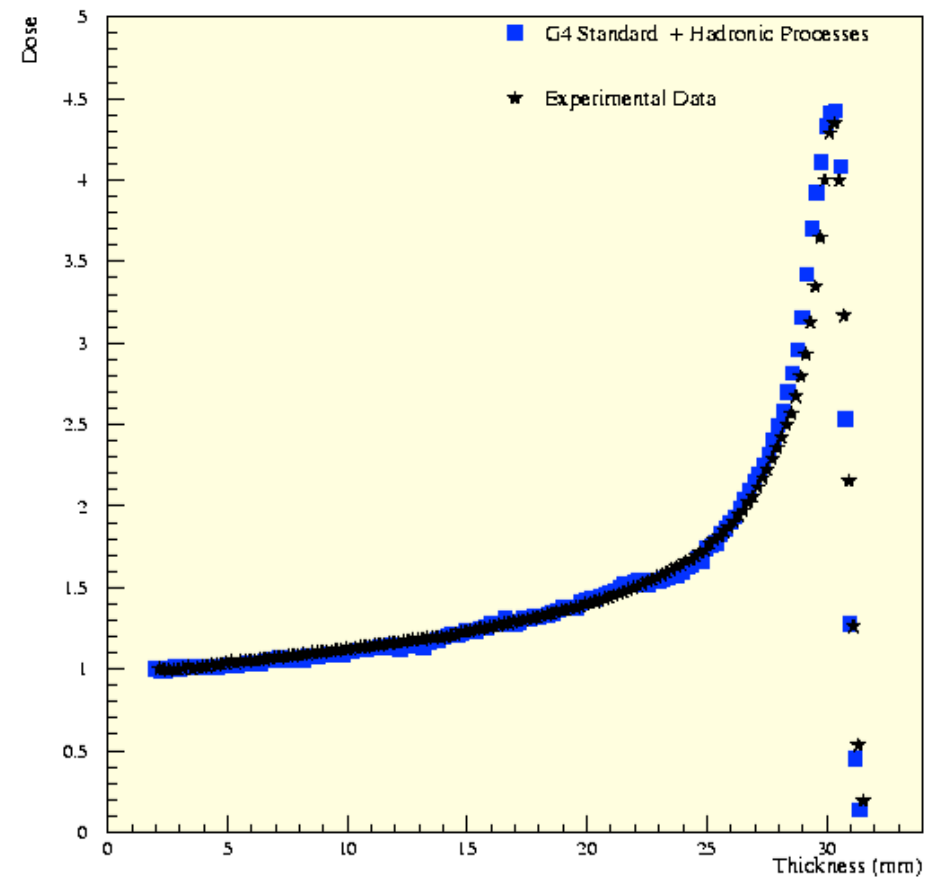
Wikimedia Commons

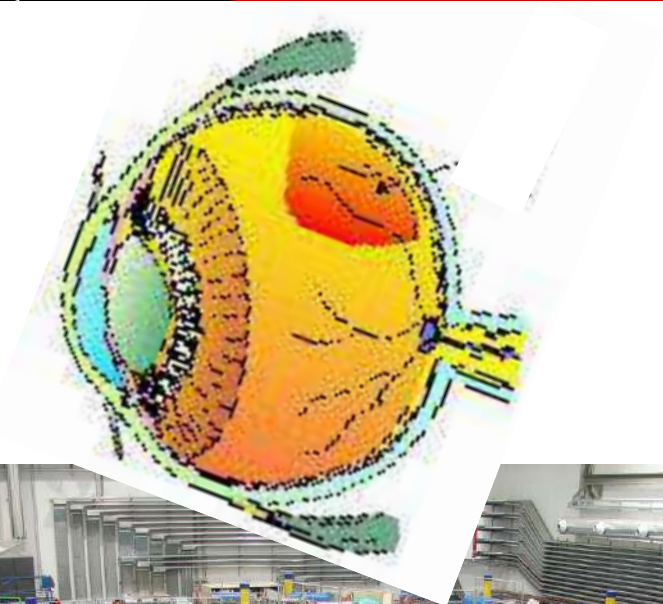
Leonardo
da Vinci
(Royal
library
Windsor)



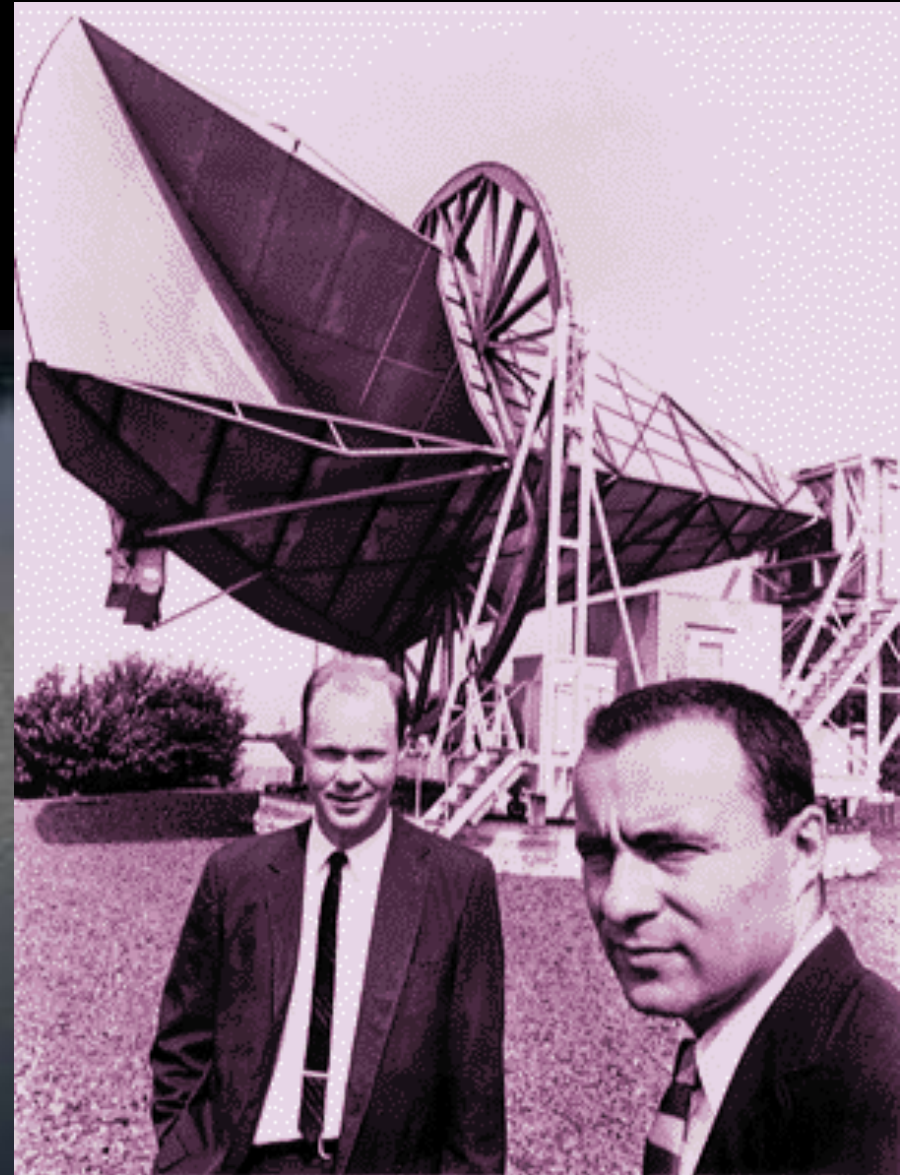
*Ostinatamente
curiosi...*

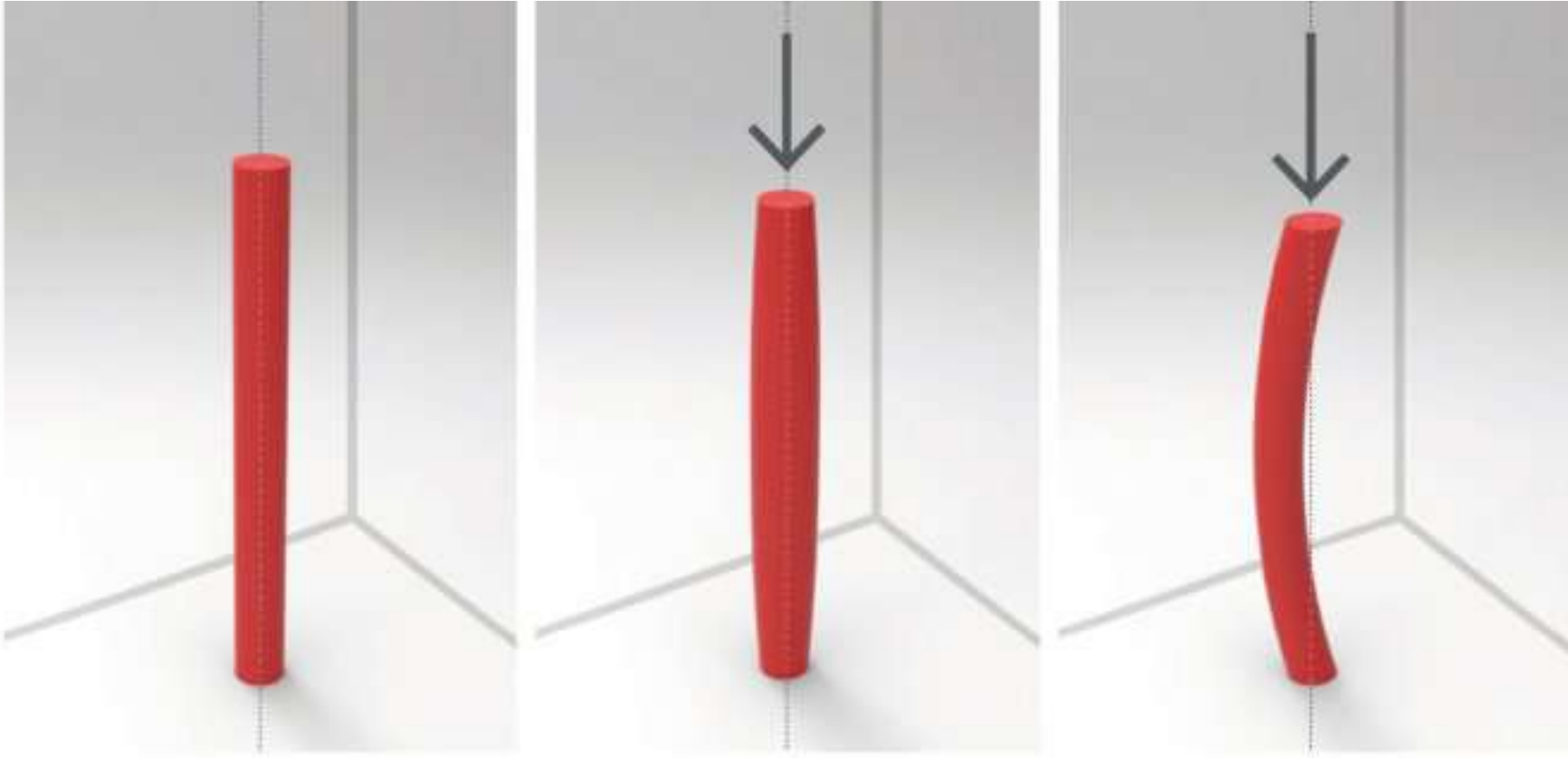
Protons - Bragg Peak - Water



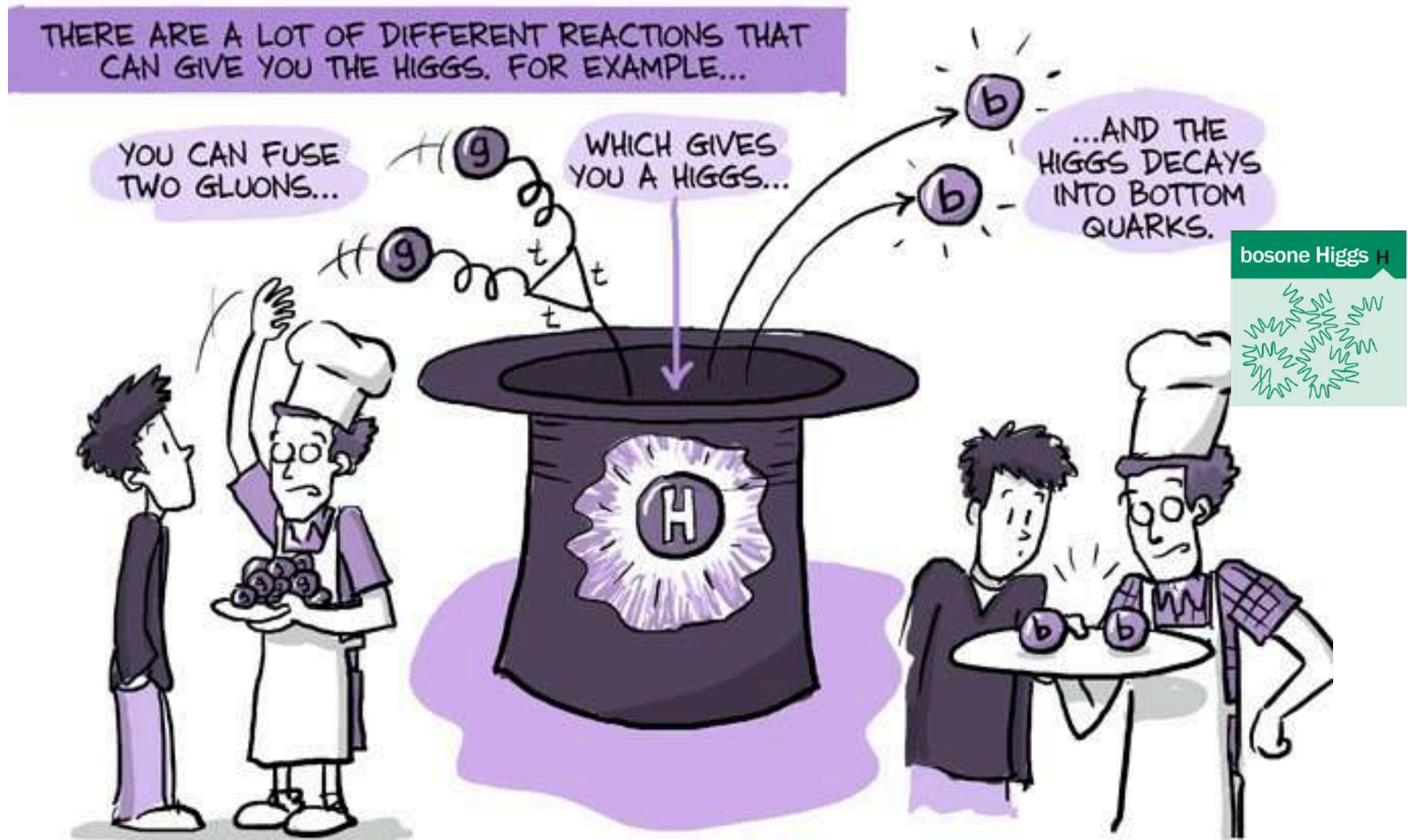


Arno Penzias e Robert Wilson





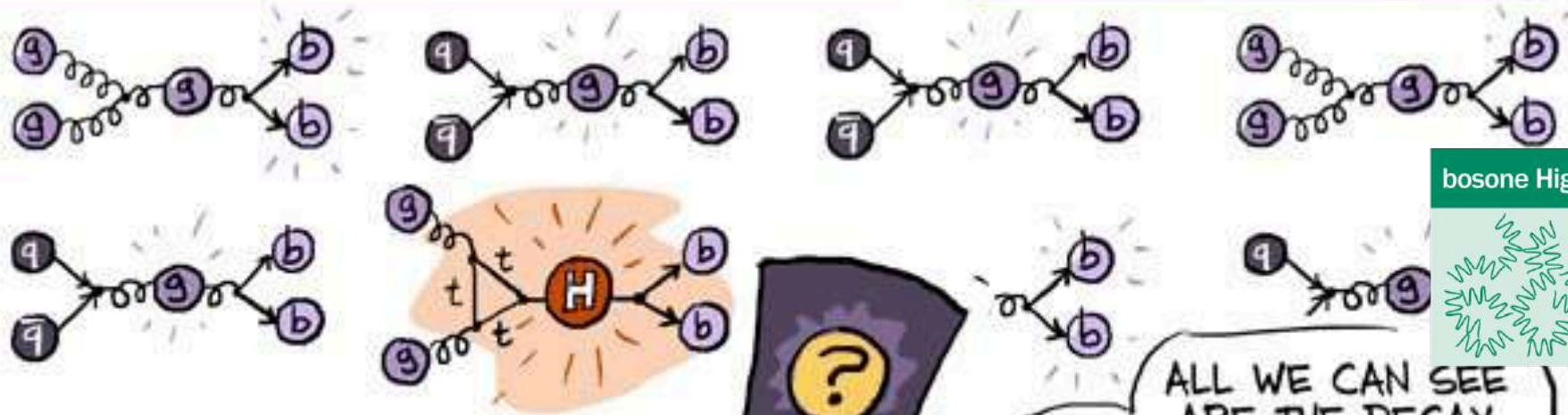
Il bosone di Higgs



Il bosone di Higgs

THE PROBLEM IS, THERE'S LOTS OF OTHER WAYS YOU CAN MAKE TWO BOTTOM QUARKS:

IT'S ONE OF THE MOST COMMON THINGS TO MAKE.



bosone Higgs H

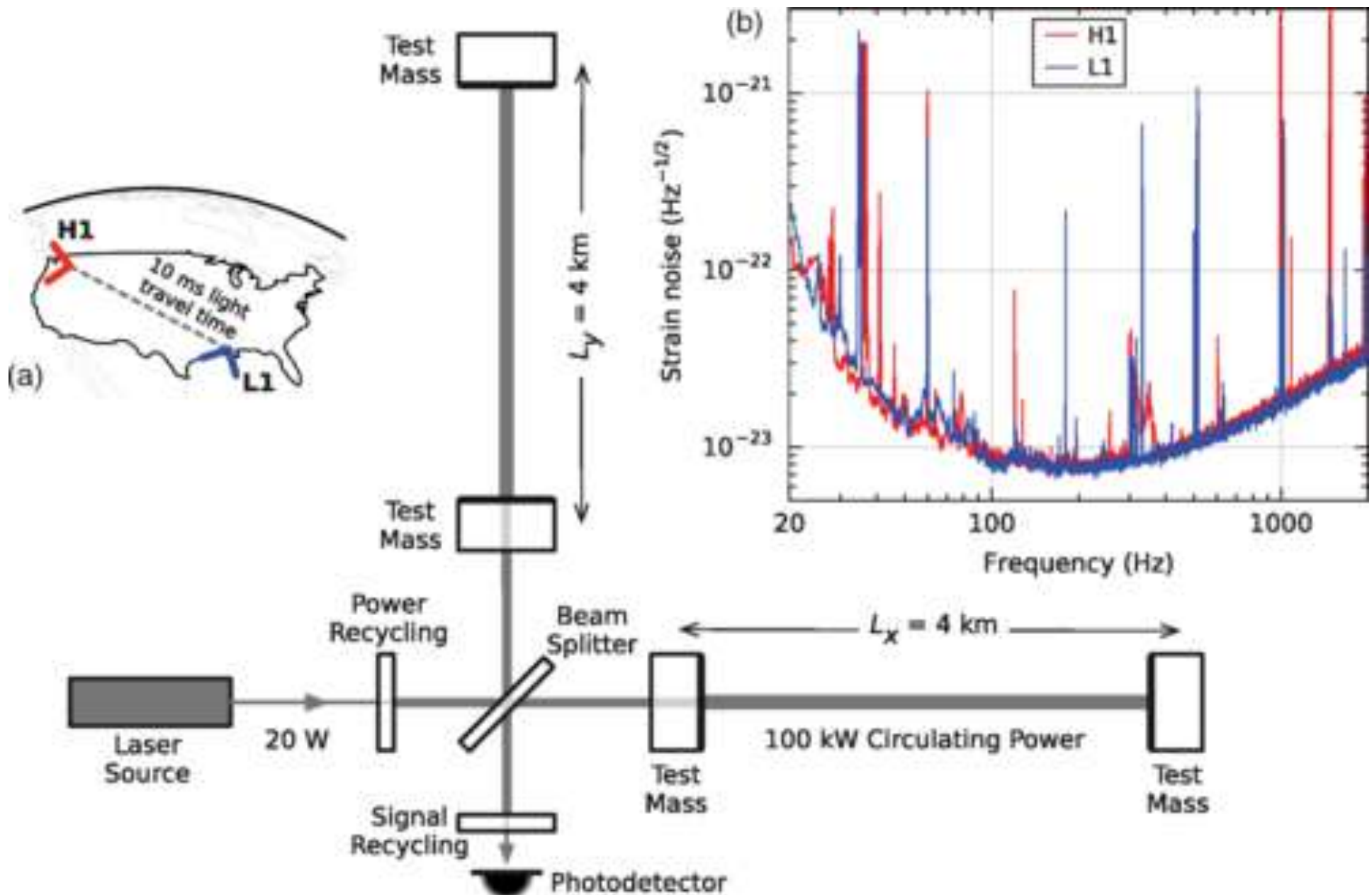
ALL WE CAN SEE
ARE THE DECAY
PRODUCTS.

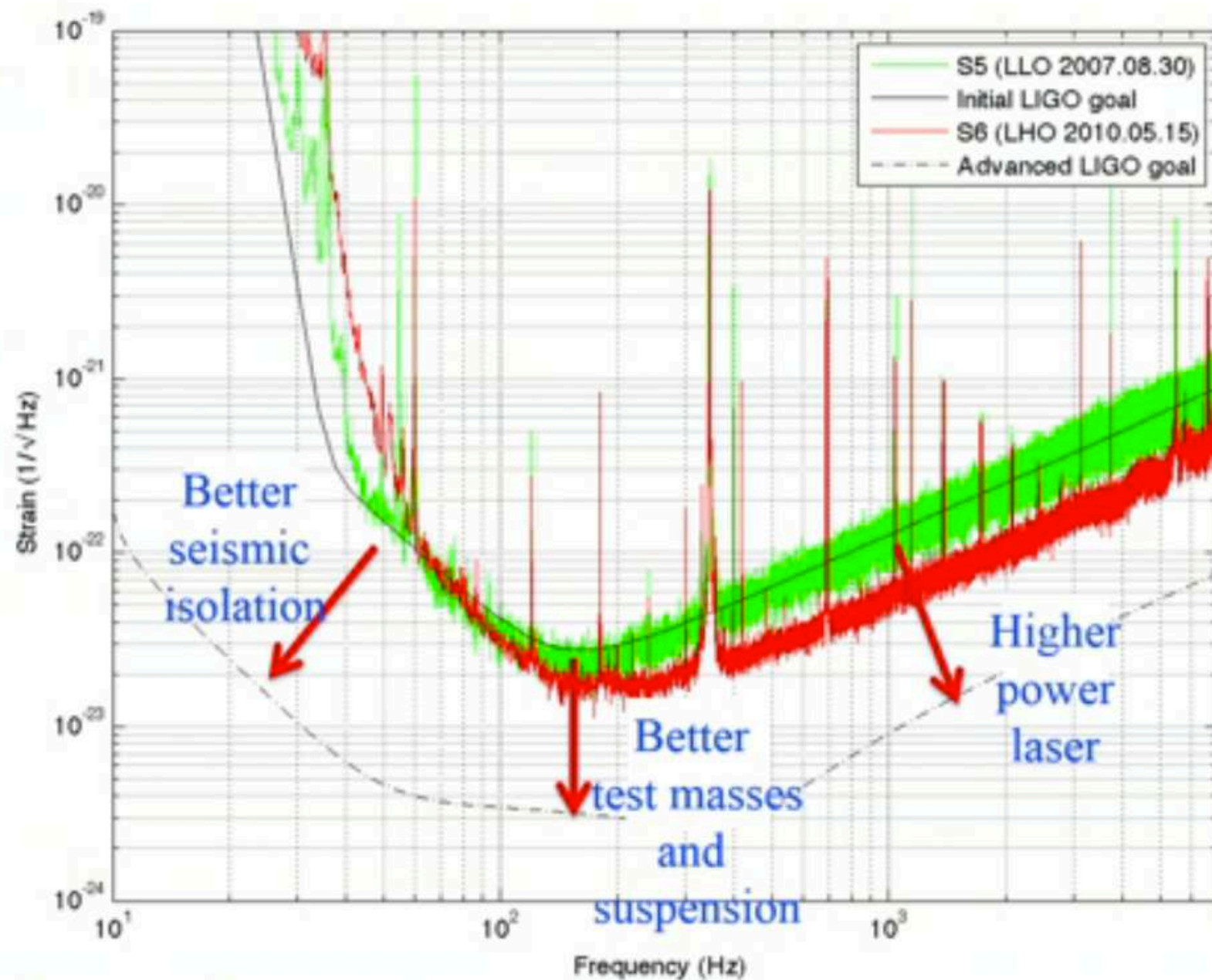
AND WHAT YOU
WANT TO KNOW IS...

DID THE HIGGS EXIST?

THE THING IS, WE CAN'T SEE INSIDE THESE REACTIONS...

JORGE CHAM © 2012





La forza della tradizione

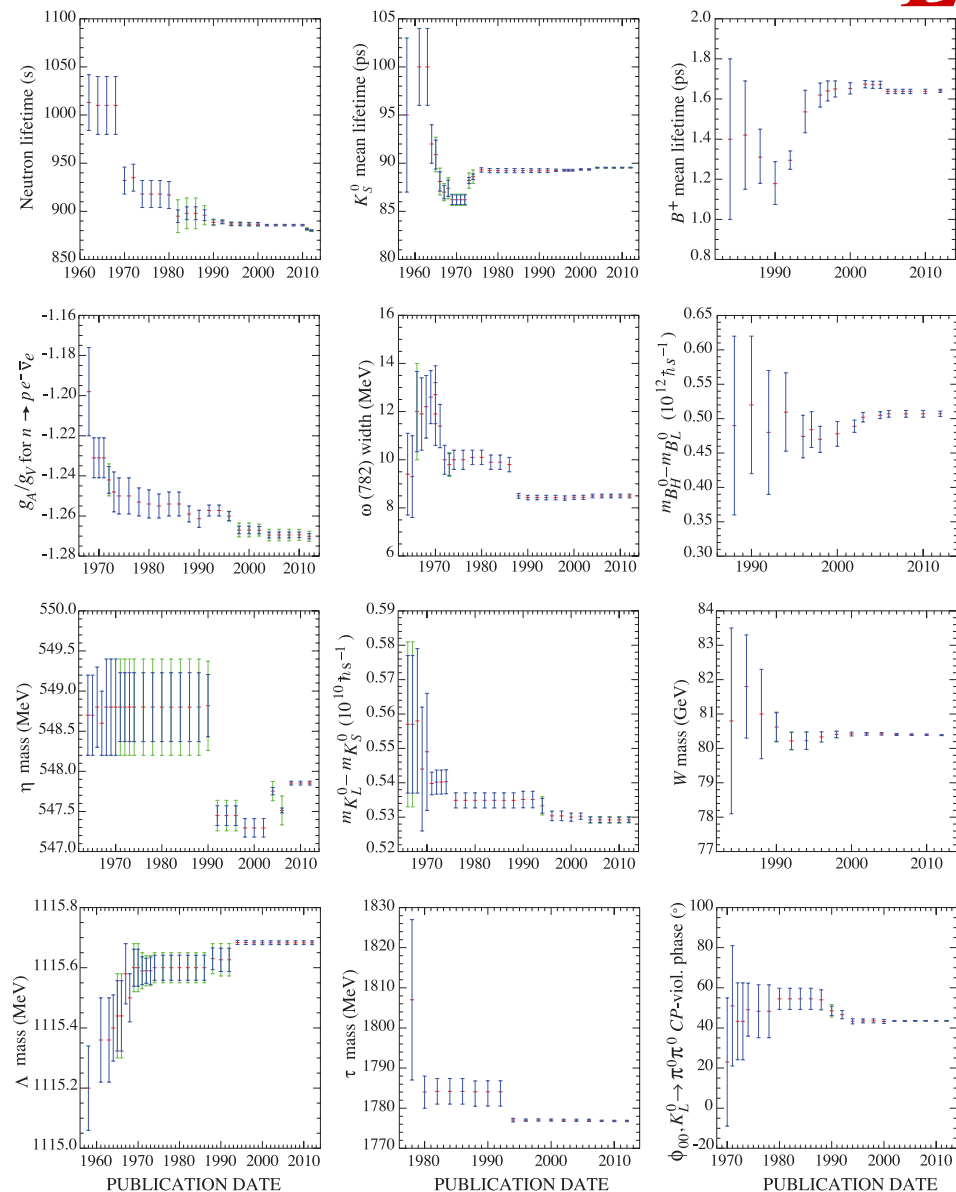


Figure 2: A historical perspective of values of a few particle properties tabulated in this *Review* as a function of date of publication of the *Review*. A full error bar indicates the quoted error; a thick-lined portion indicates the same but without the “scale factor.”

HOW MUCH DOES IT COST TO LAND ON A COMET?

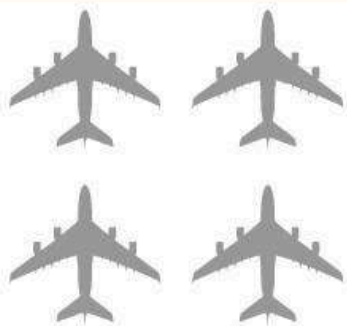
€1.4bn

Rosetta mission

Land on a comet for the first time in human history



...ABOUT THE SAME PRICE AS...



4.2

Airbus A380 aircraft

Cool engineering, but they won't get you into space...

WHO PAID FOR IT?

€3.50

cost per European citizen

(from 1996–2015, so

€0.20/person/year)

Cost of Rosetta
per person

■ **€3.50**

Cost of a cinema ticket
to see *Interstellar*

■ **€8.50**



scienceogram.org

Rosetta/Comet images: ESA; data from ESA, Airbus, UK average cinema ticket price
For full data and sources visit scienceogram.org

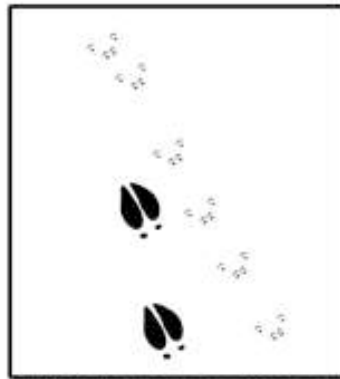


BACKYARD SNOW TRACKING GUIDE

*Vedere le
particelle?*



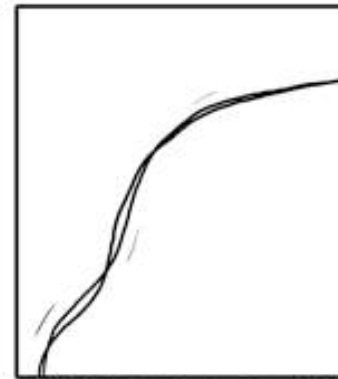
CAT



MOOSE AND SQUIRREL



LONGCAT



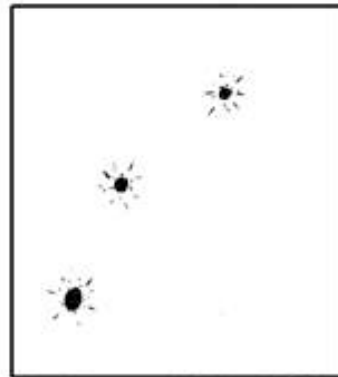
MOUSE RIDING BICYCLE



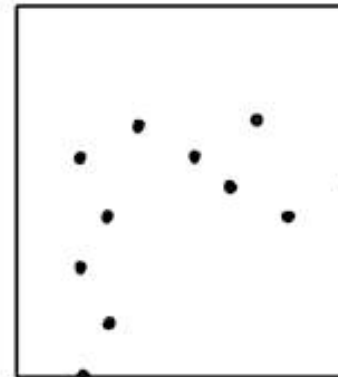
RABBIT STOPPING
TO USE HAIR DRYER



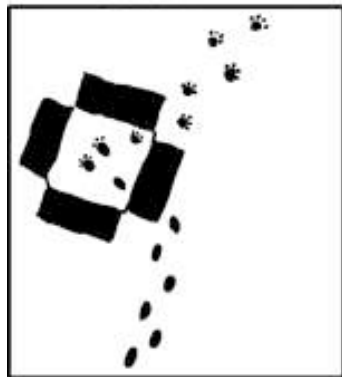
LEGOLAS



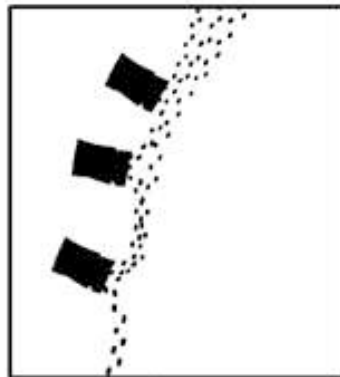
BOBCAT ON POGO STICK



KNIGHT



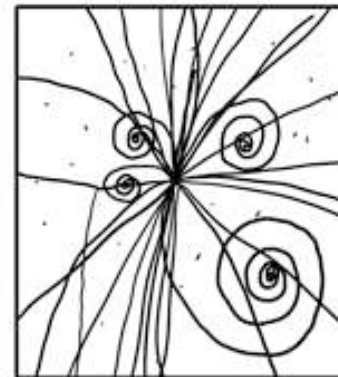
KID WITH
TRANSMOGRIFIER



KID WITH DUPLICATOR



PRIUS



HIGGS BOSON

[<https://xkcd.com/702/>]

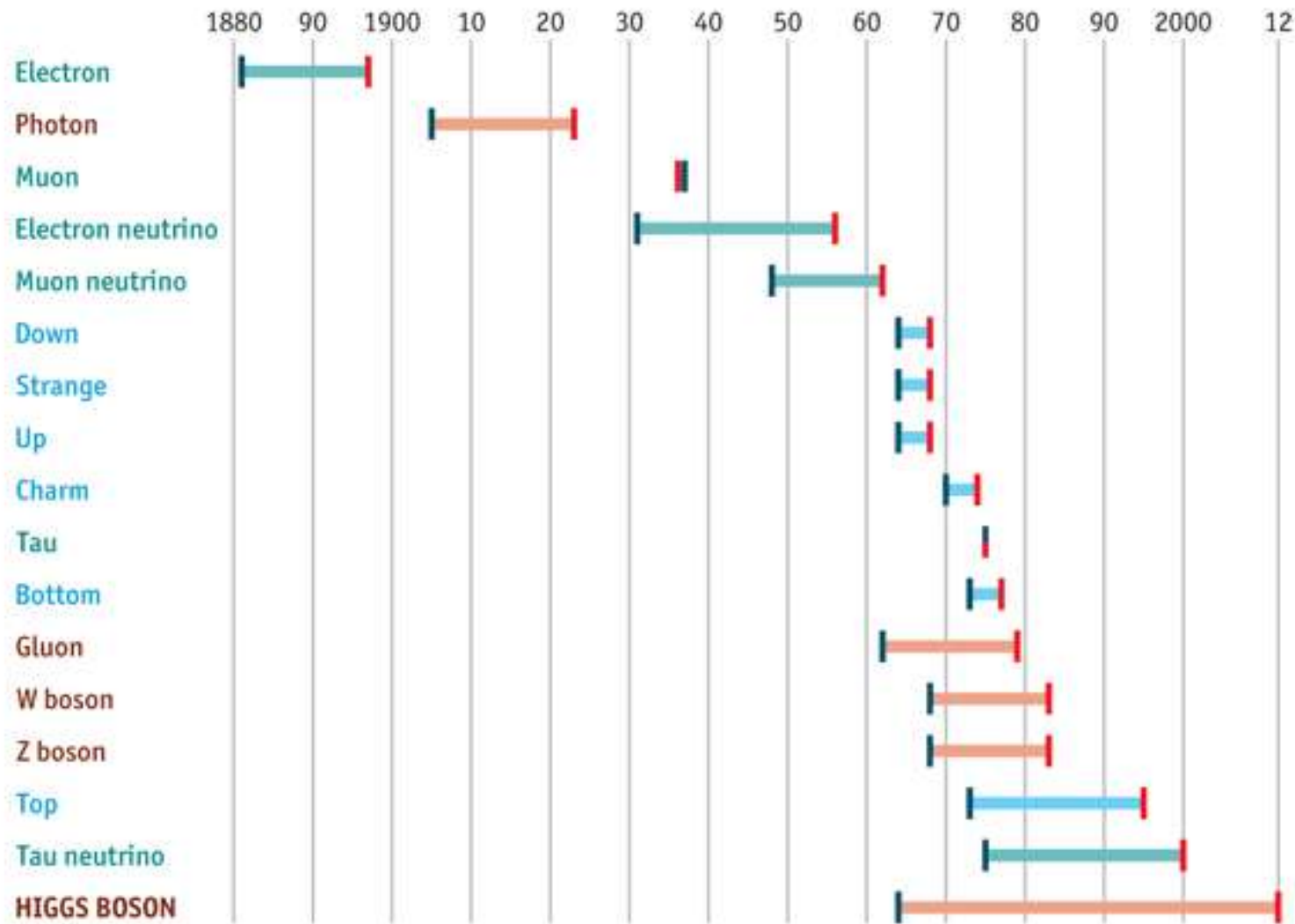
Modello Standard: 130 anni di scoperte

The Standard Model of particle physics

Years from concept to discovery

Leptons
Bosons
Quarks

Theorised/explained
Discovered

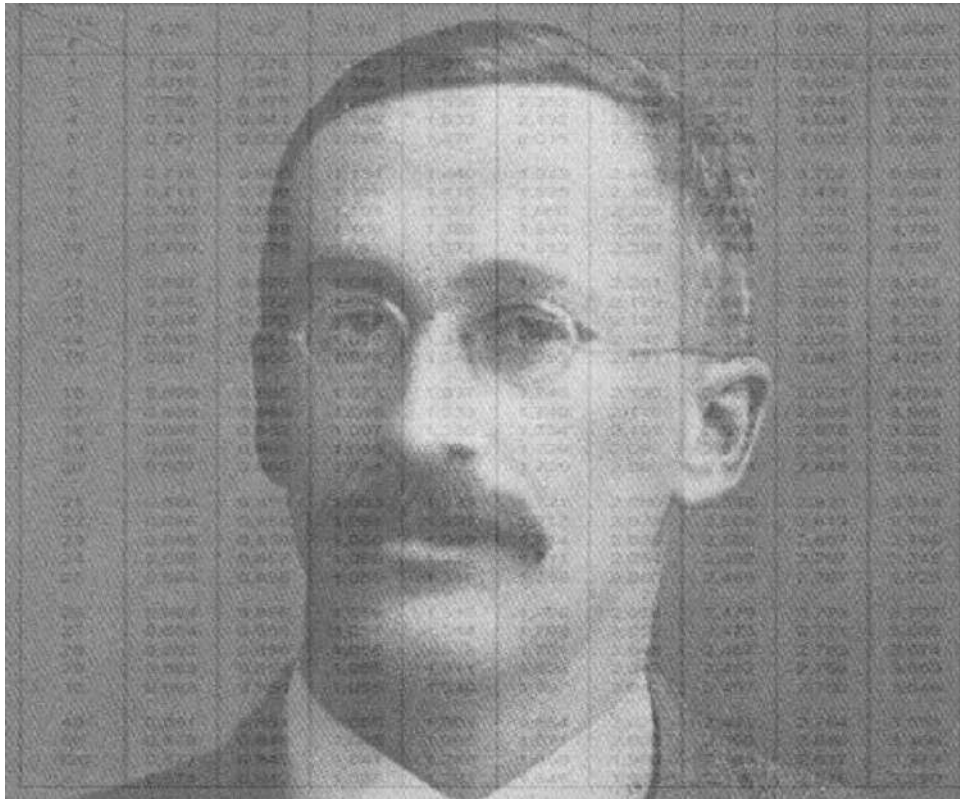


Source: The Economist

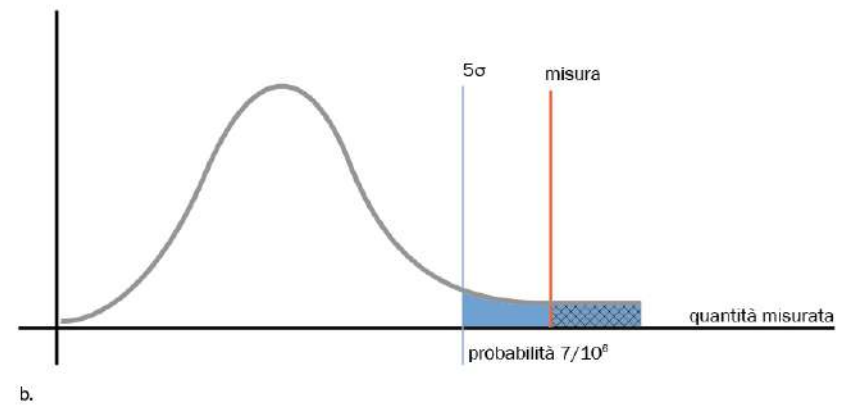
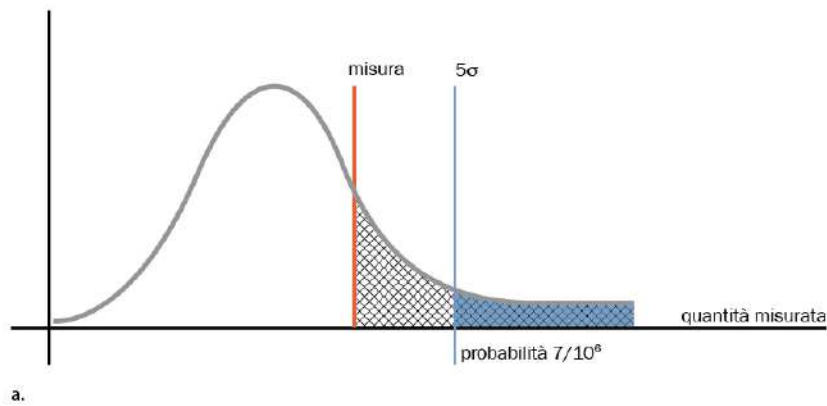
Emmy Noether

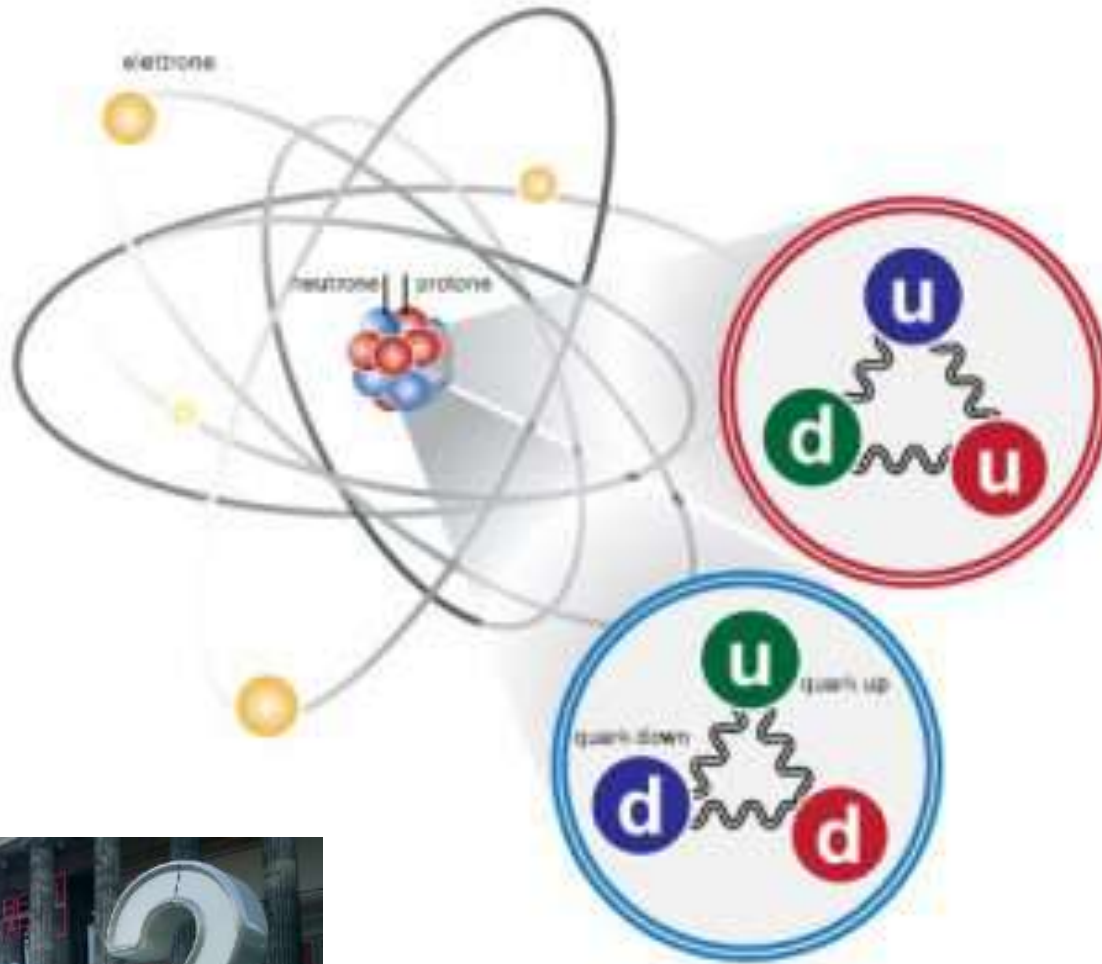


William Gosset

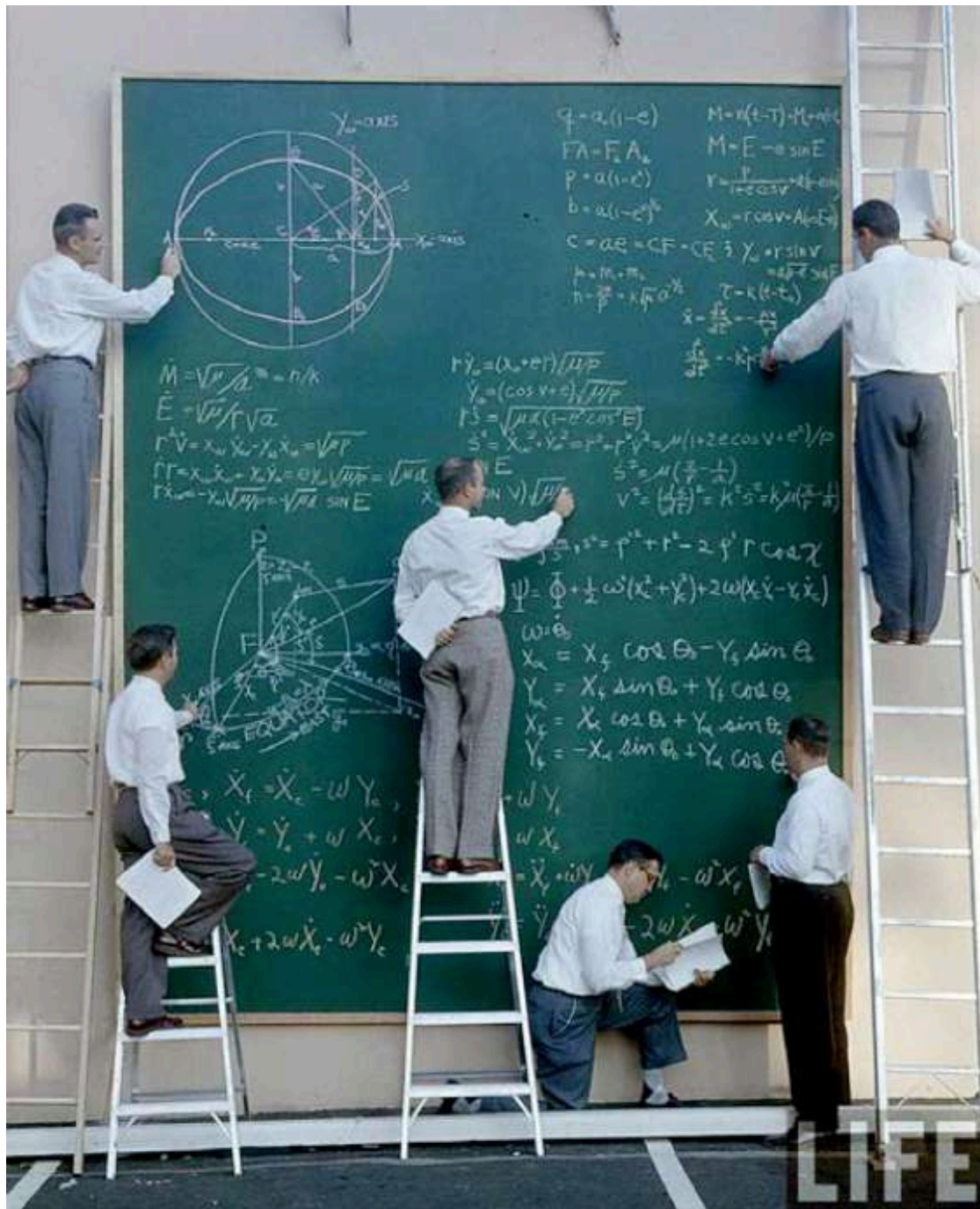


Credits: Asimmetrie

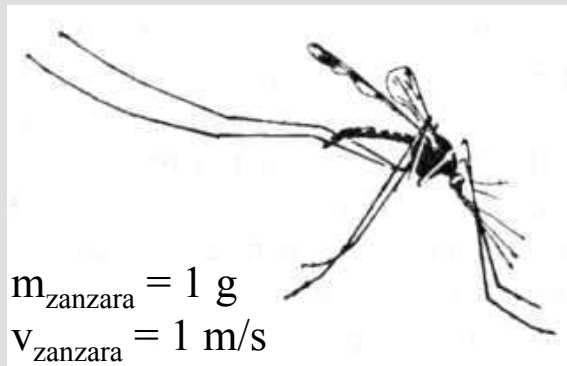
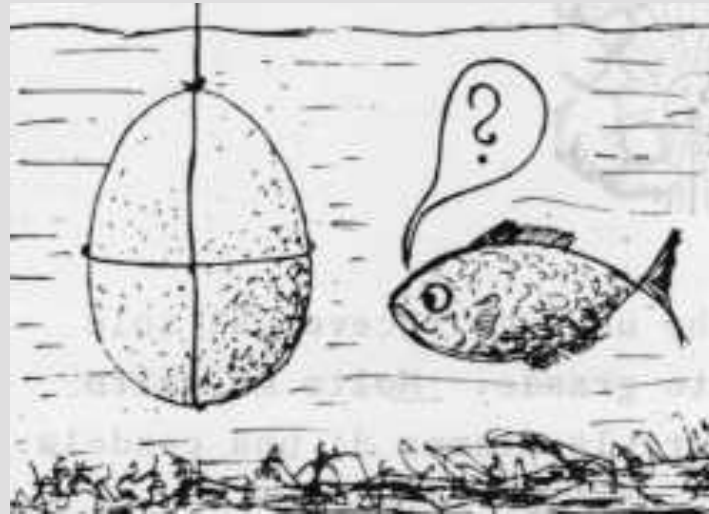
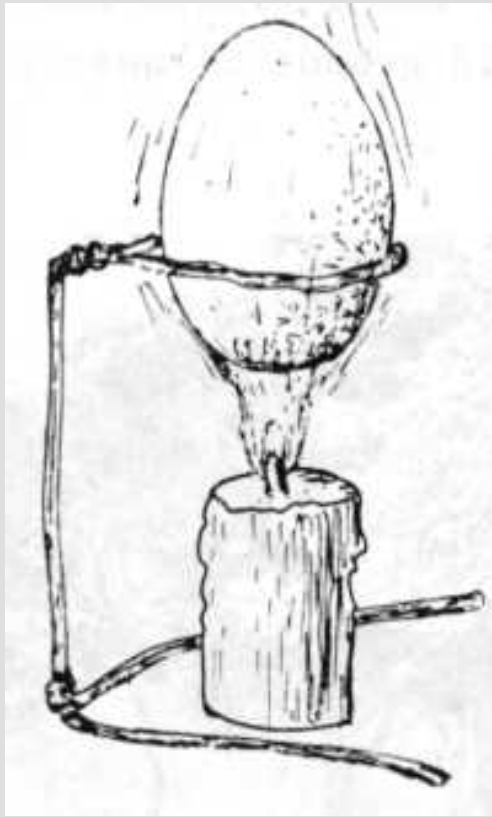




Teorie efficaci e scale di energia



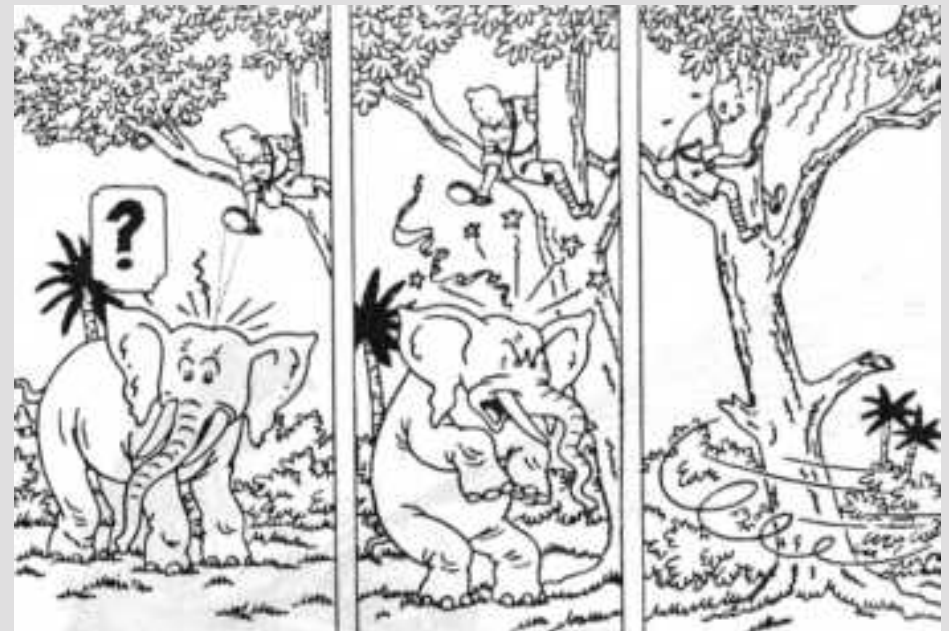
Fisica delle “alte” energie



$$m_{\text{zanzara}} = 1 \text{ g}$$
$$v_{\text{zanzara}} = 1 \text{ m/s}$$

$$E_{\text{zanzara}} = 10^{-3} \text{ J} = 6.25 \times 10^{15} \text{ eV} = \mathbf{6.25 \times 10^3 \text{ TeV}}$$

**LHC(2015):
13 TeV**

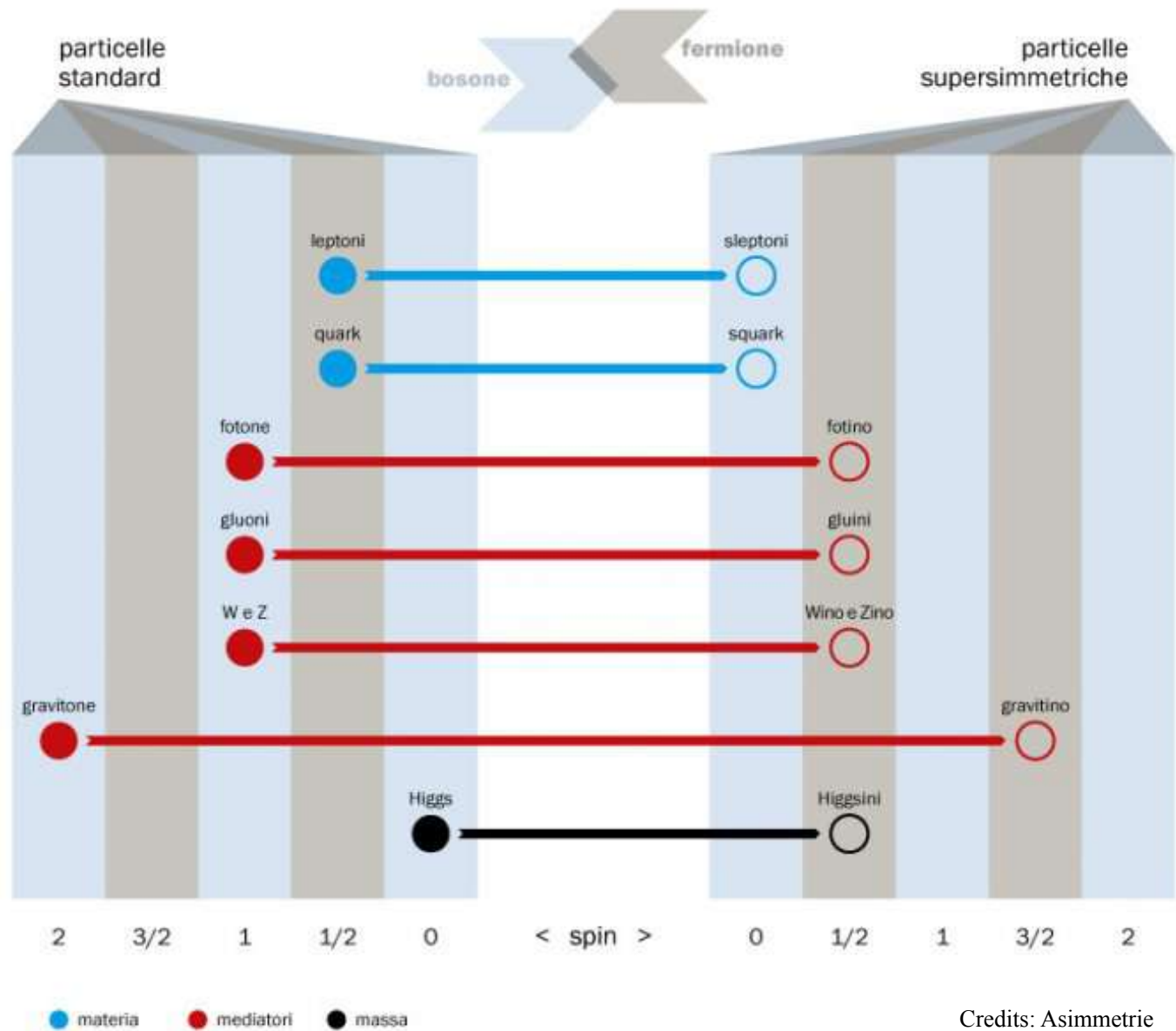


CON LA SCOPERTA
DELL'HIGGS CI HANNO
TAGLIATO DEL DIECI
PER CENTO

SE PER CASO SCOPRIAMO
LA SUPERSIMMETRIA CI
CHIUDONO PER SEMPRE
PER CENTO



Supersimmetria



Credits: Asimmetrie