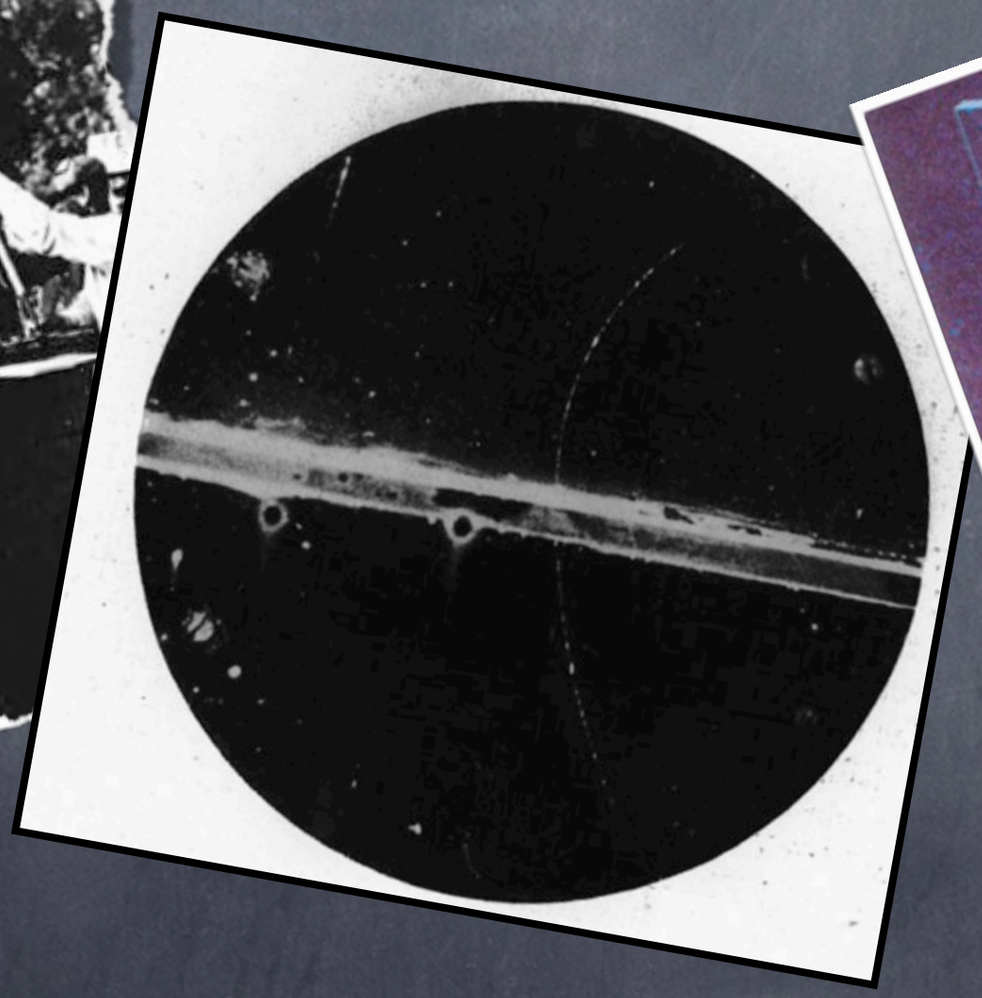
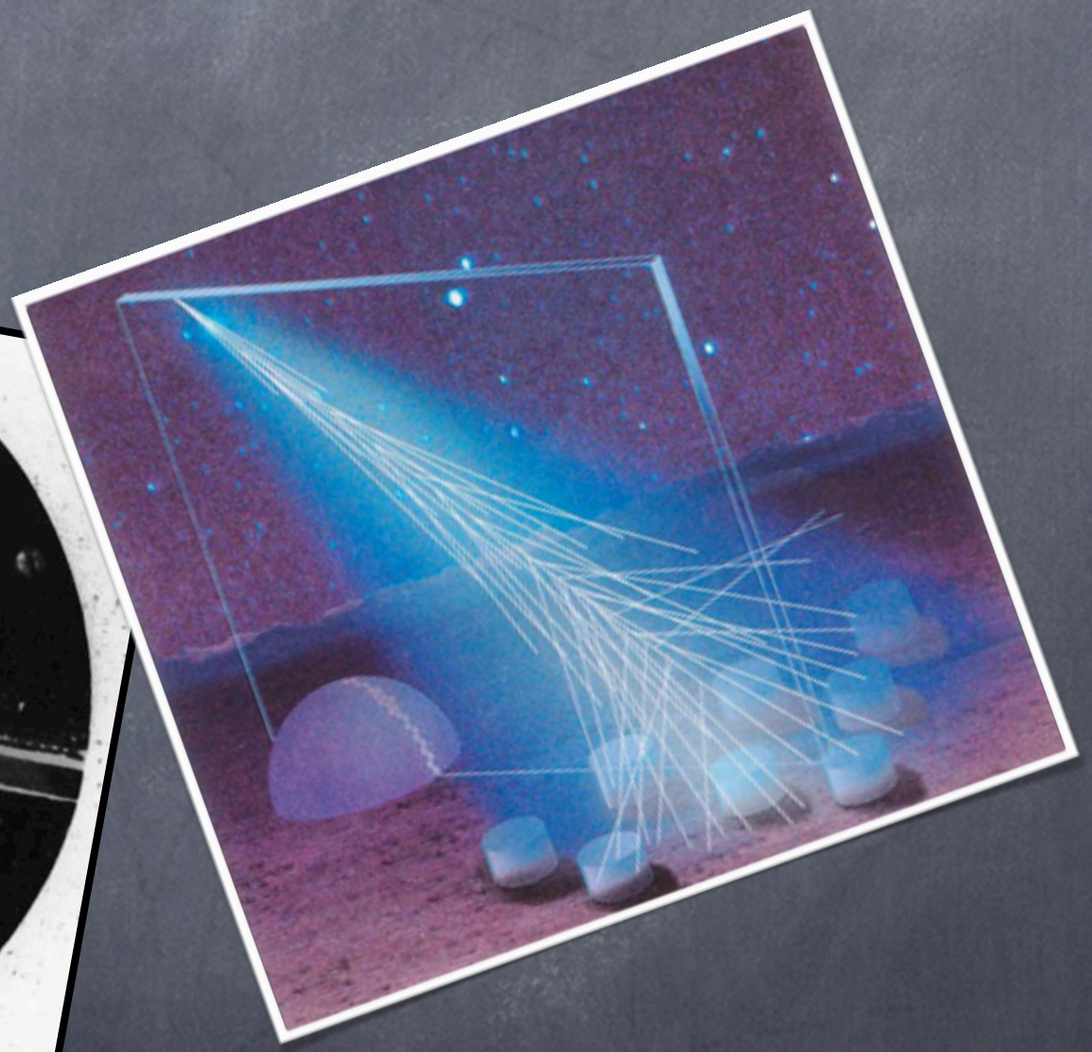
Raggi cosmici:

un secolo di sorprese



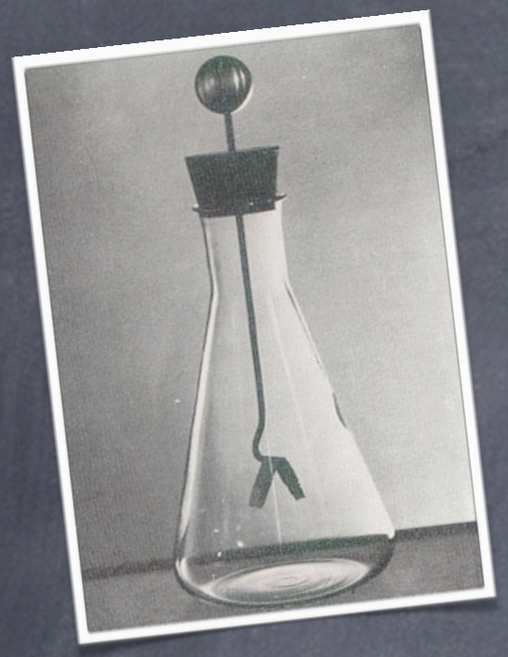


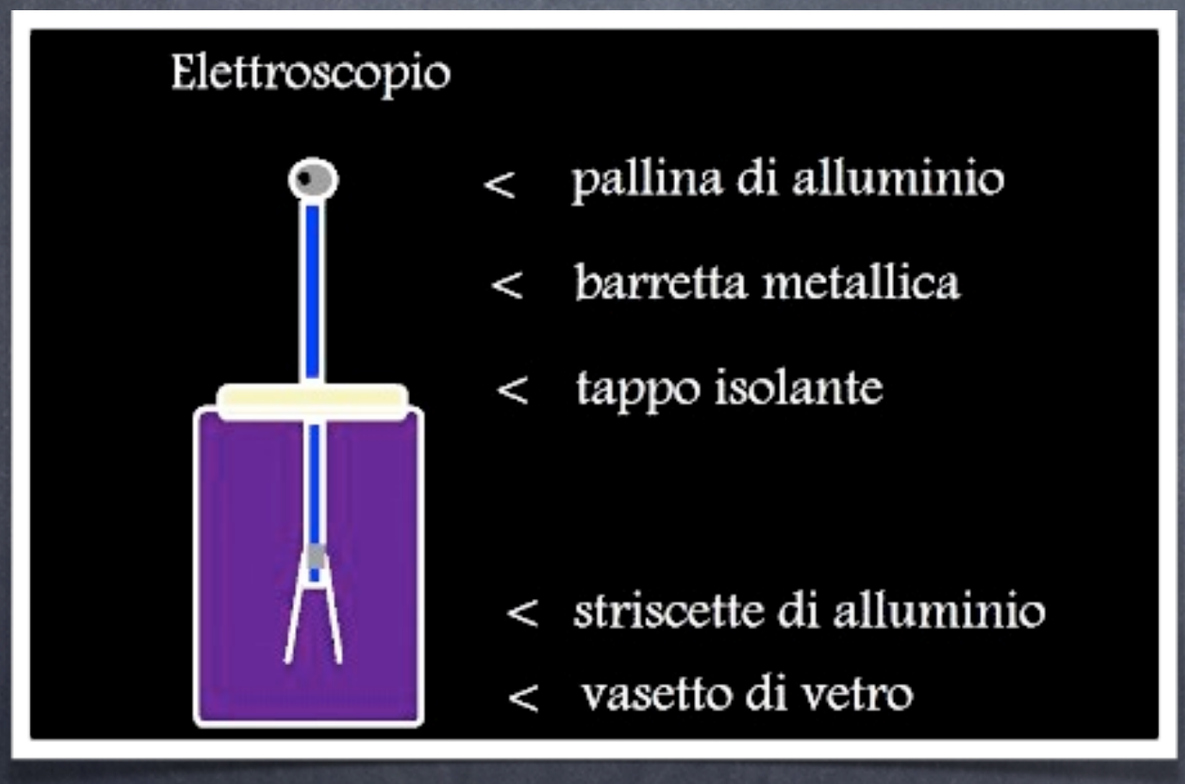
OAB

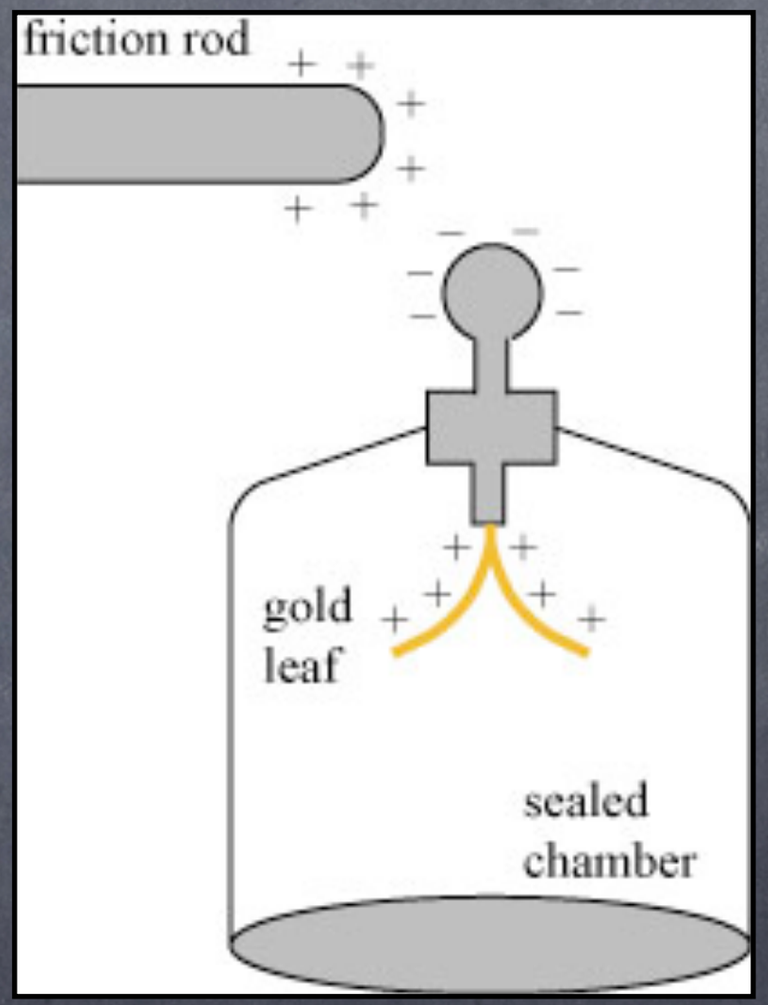
3 Dicembre 2014

Un po' di storia...

Elettroscopio





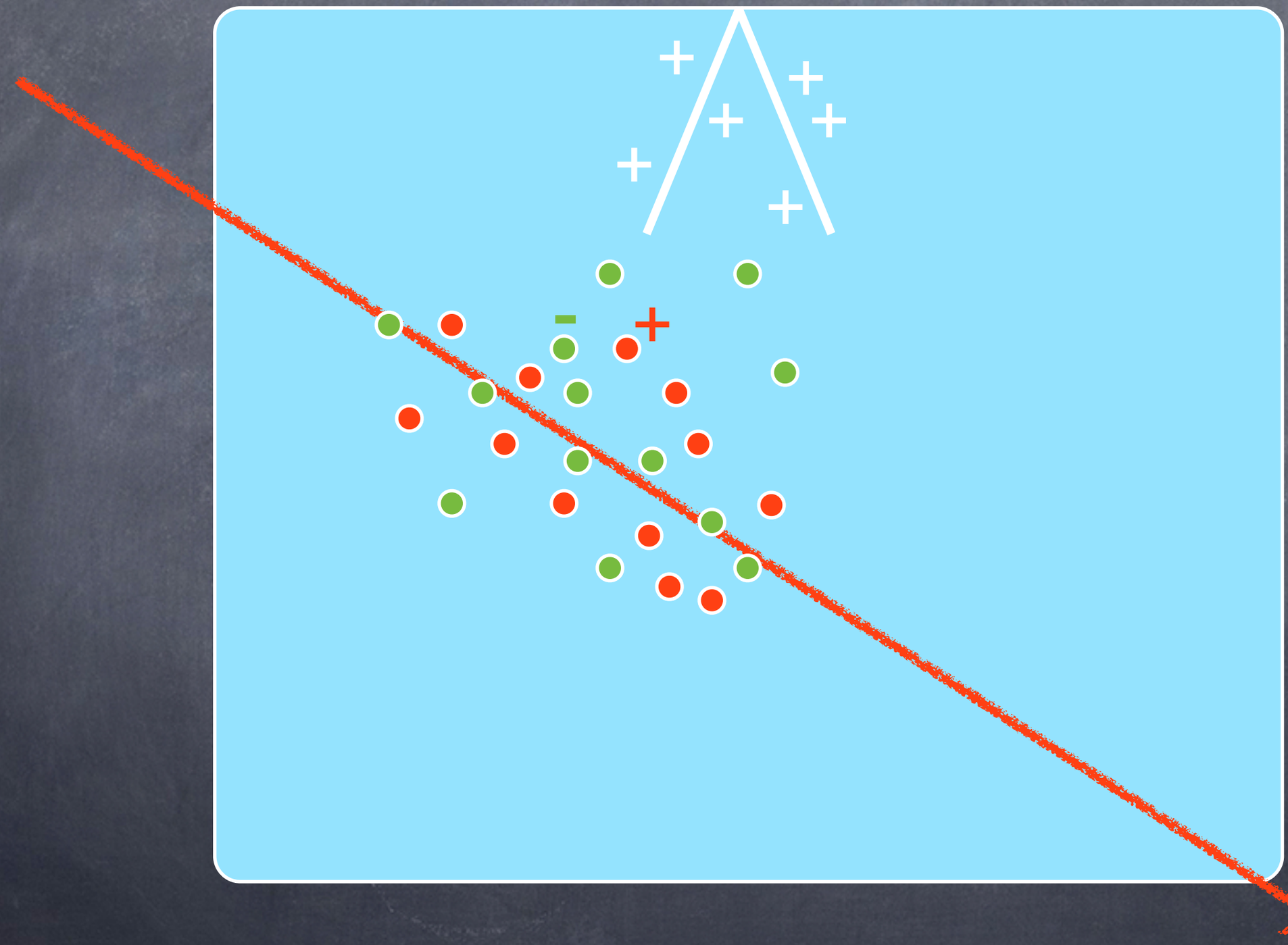


Becquerel: posto vicino a sostanze radioattive l'elettroscopio si scarica

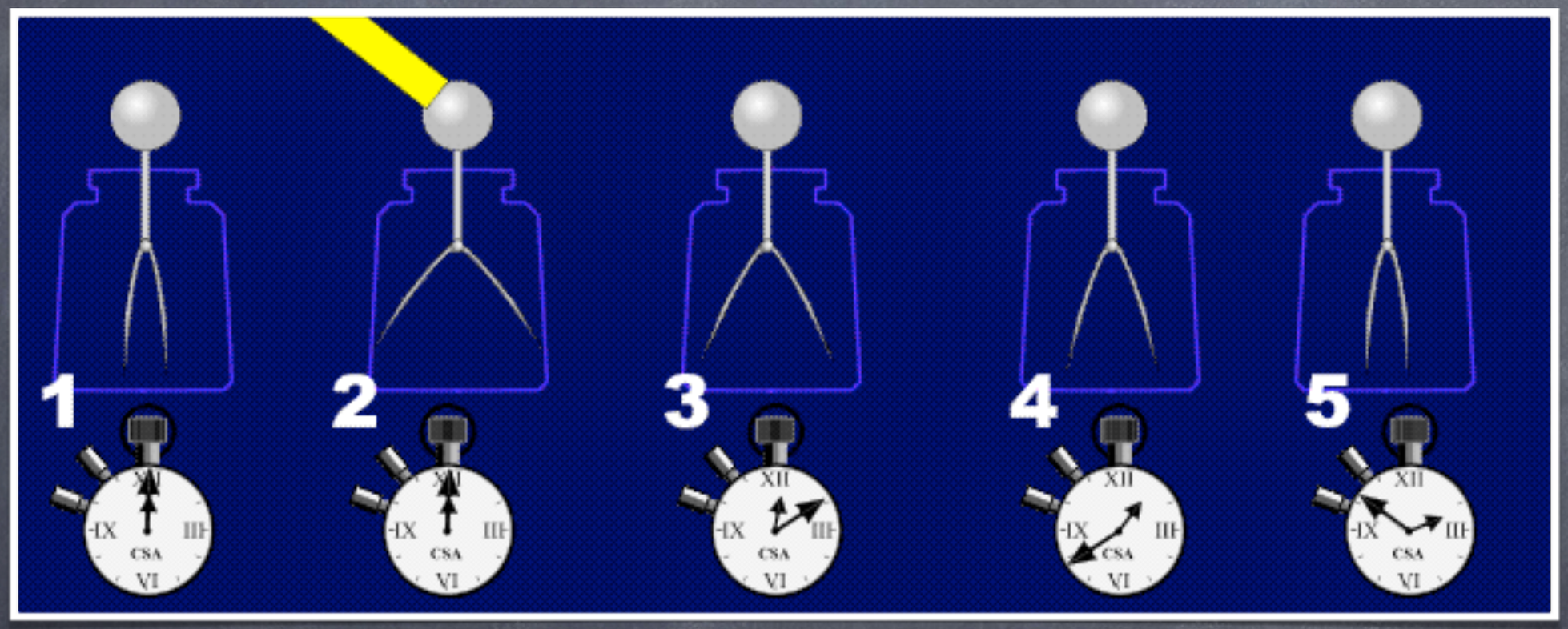
?

Nel gas all'interno (aria) si formano cariche elettriche attraverso la "*ionizzazione*" causata dal passaggio della radiazione carica elettricamente (particelle beta, alfa). Queste neutralizzano le cariche sulle striscette

Elettroscopio come rivelatore di radiazioni ionizzanti



Scarica spontanea!



Coulomb (1785)

Perche' l'elettroscopio si scarica?

Ipotesi 1: e' mal isolato, la carica si disperde

Ipotesi 2: esiste una radiazione che ionizza il gas nell'elettroscopio: le cariche cosi' create neutralizzano la carica delle striscette

2a: di origine terrestre (radioatt.)

2b: di origine extraterrestre

Perche' l'elettroscopio si scarica?

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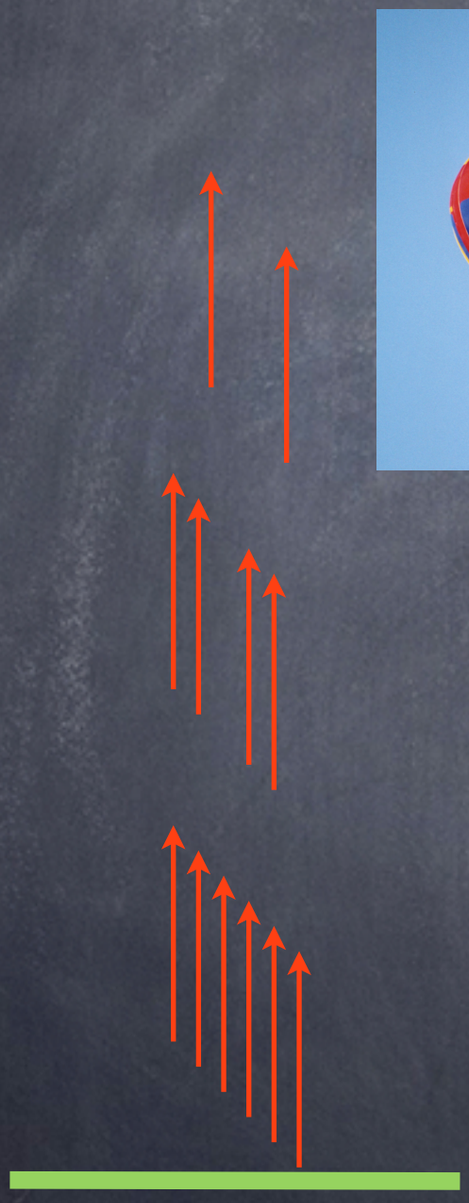
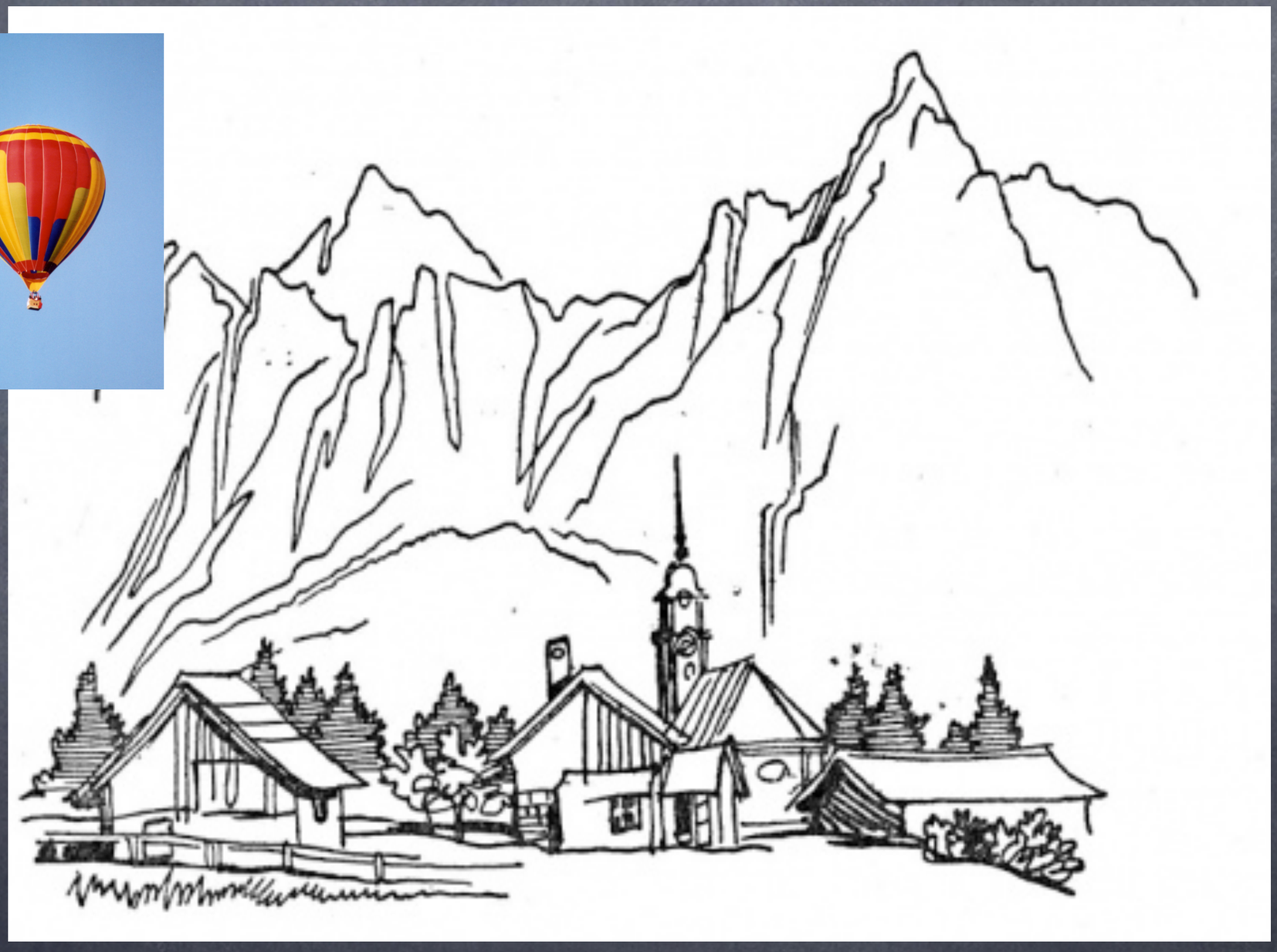
2b: di origine extraterrestre

La prova del nove!

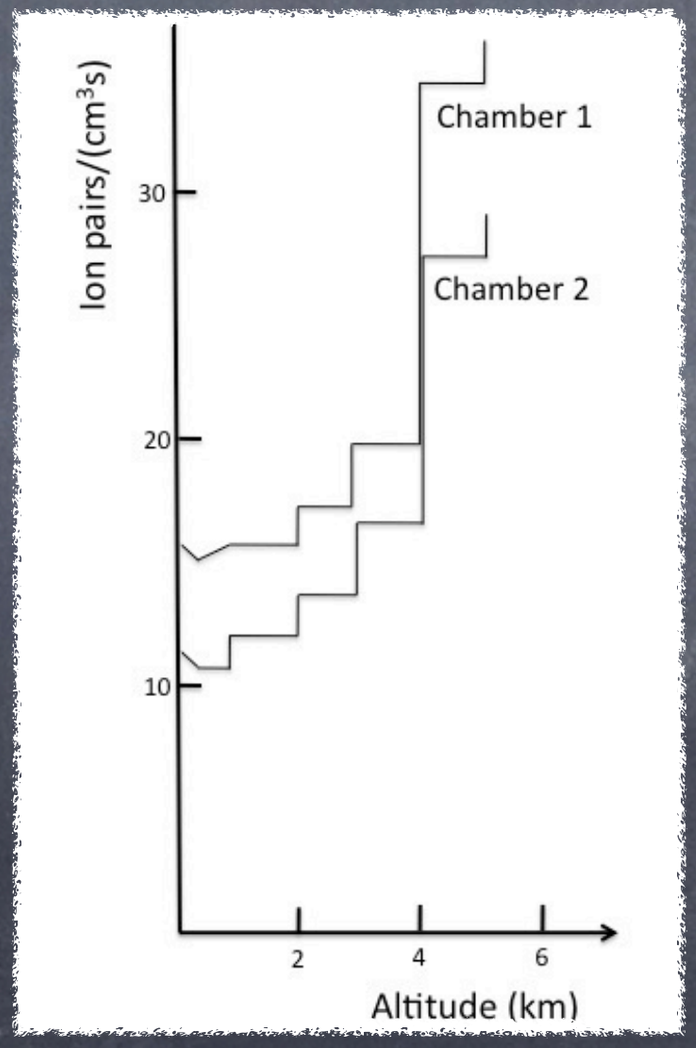




La prova del nove!

Victor Hess
(1883-1964)

1912:
La prima misura risolutiva



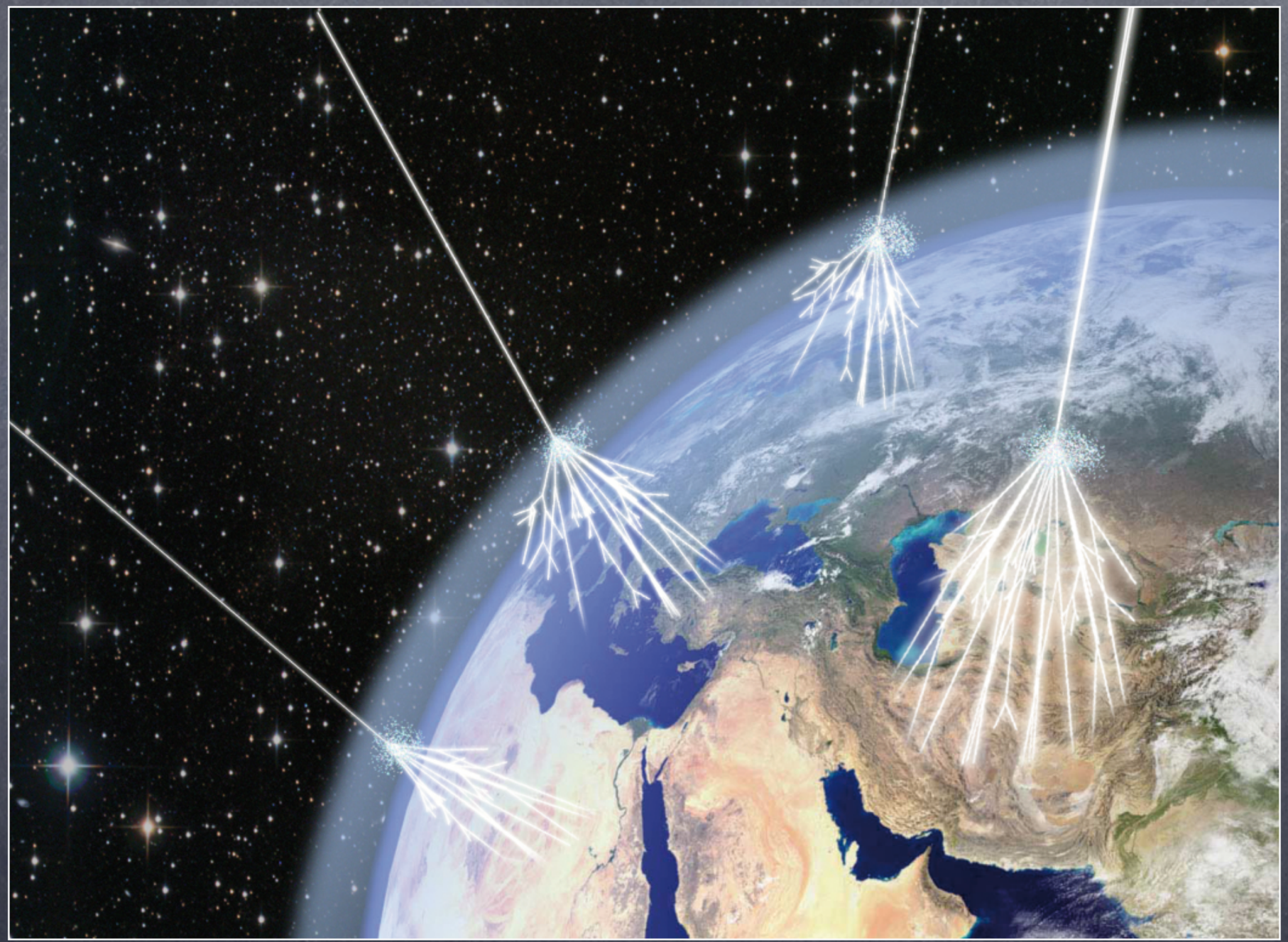
La ionizzazione aumenta con l'altezza!

La prova del nove!

Raggi cosmici

Primari e cascate

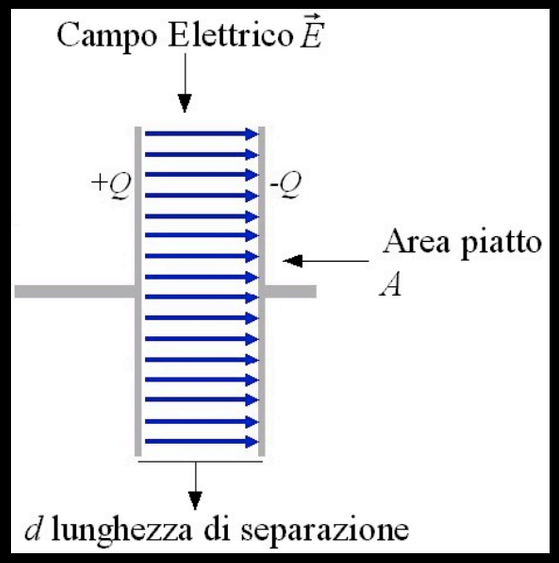
Radiazione primaria e secondaria



Digressione: scale di energia

I fisici usano l'elettronvolt (e i suoi multipli)

$1\ eV = 1.6 \times 10^{-19}$ Joule



eV
reazioni chimiche

keV
raggi-X

10^3

MeV
reazioni nucleari

10^6

GeV

10^9

TeV-PeV

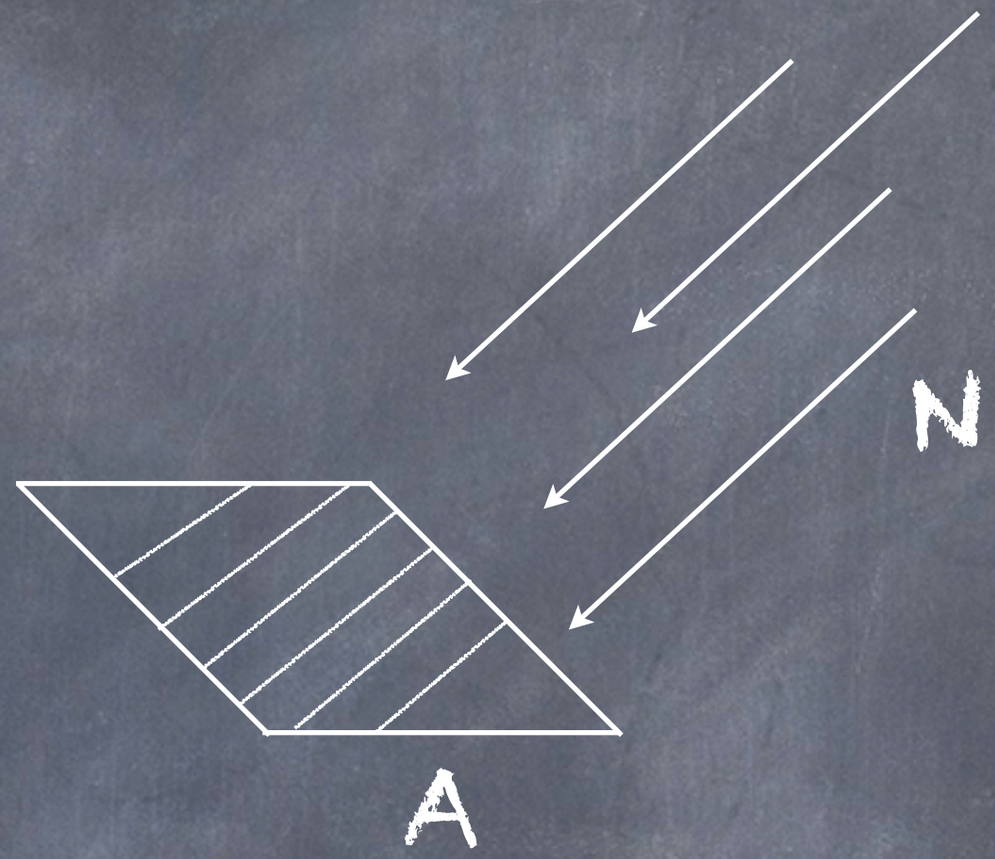
$10^{12\text{-}15}$

1TeV=1.6 erg

LHC 4 TeV

Digressione: il **flusso**

T



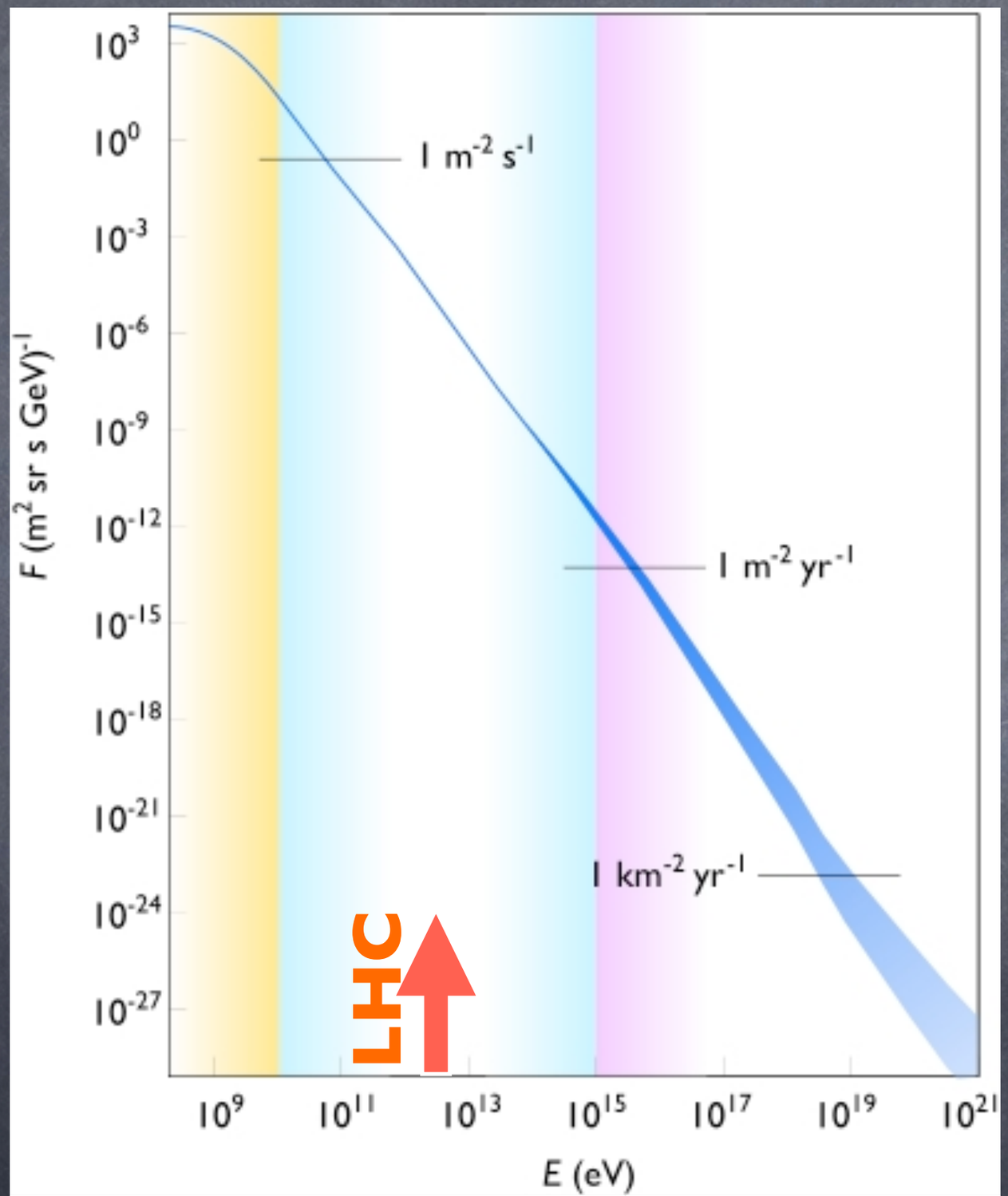
N

A

$$F = N/AT$$

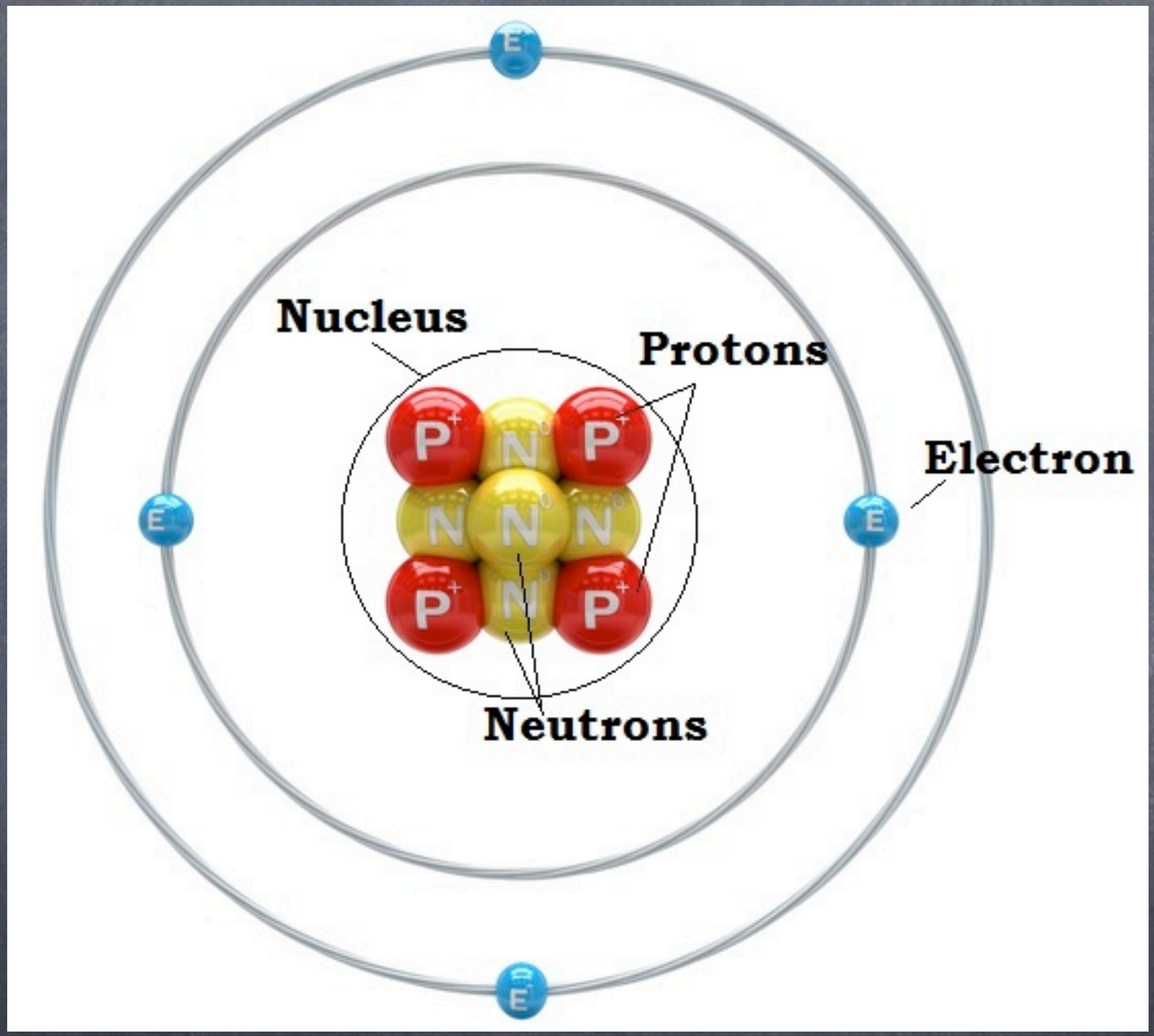
Spettro energetico dei RC primari

Flusso

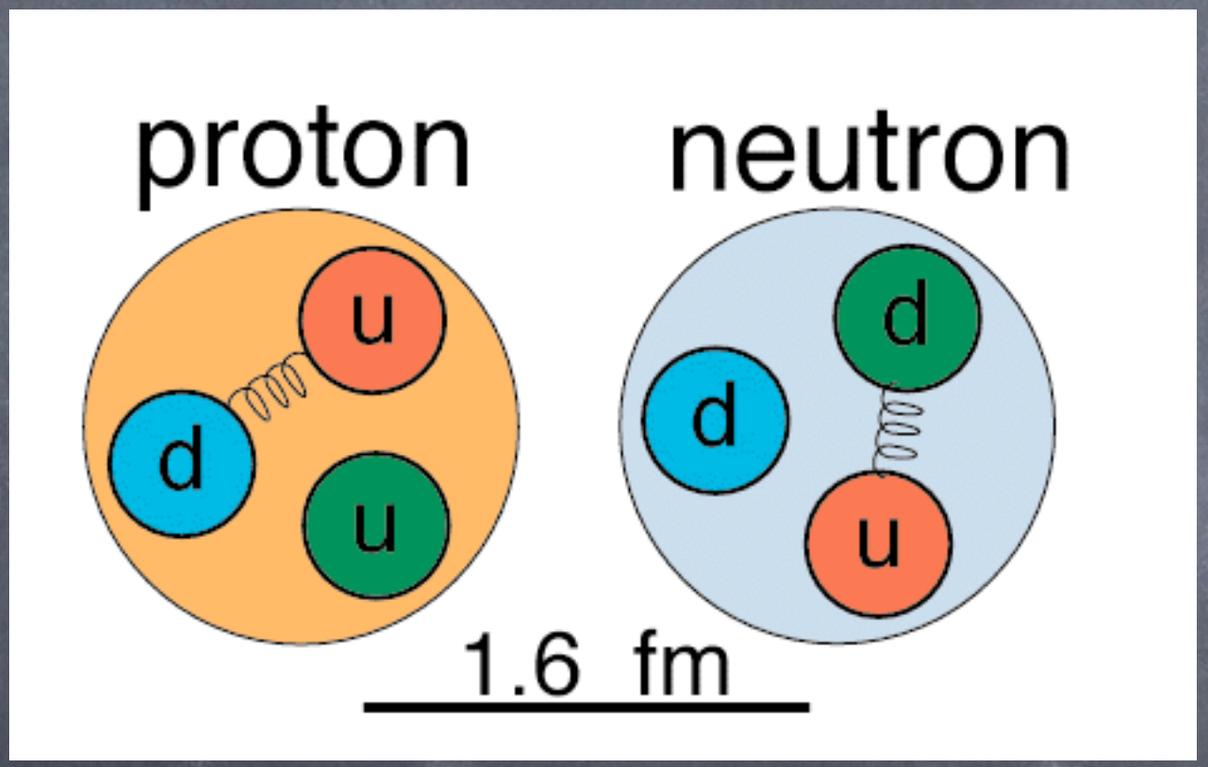


Energia

Parentesi: il modello standard delle particelle



quarks



Parentesi: il modello standard delle particelle

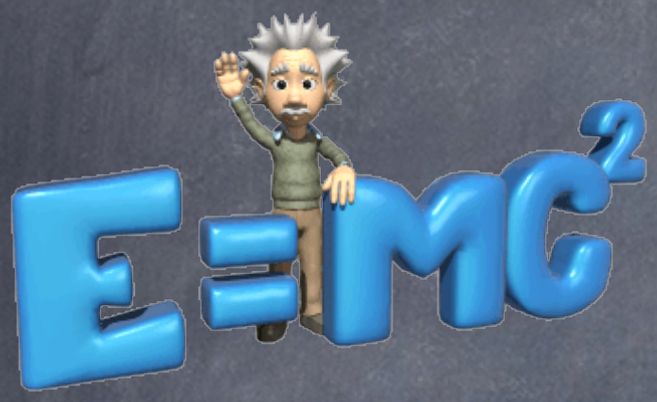
p, n

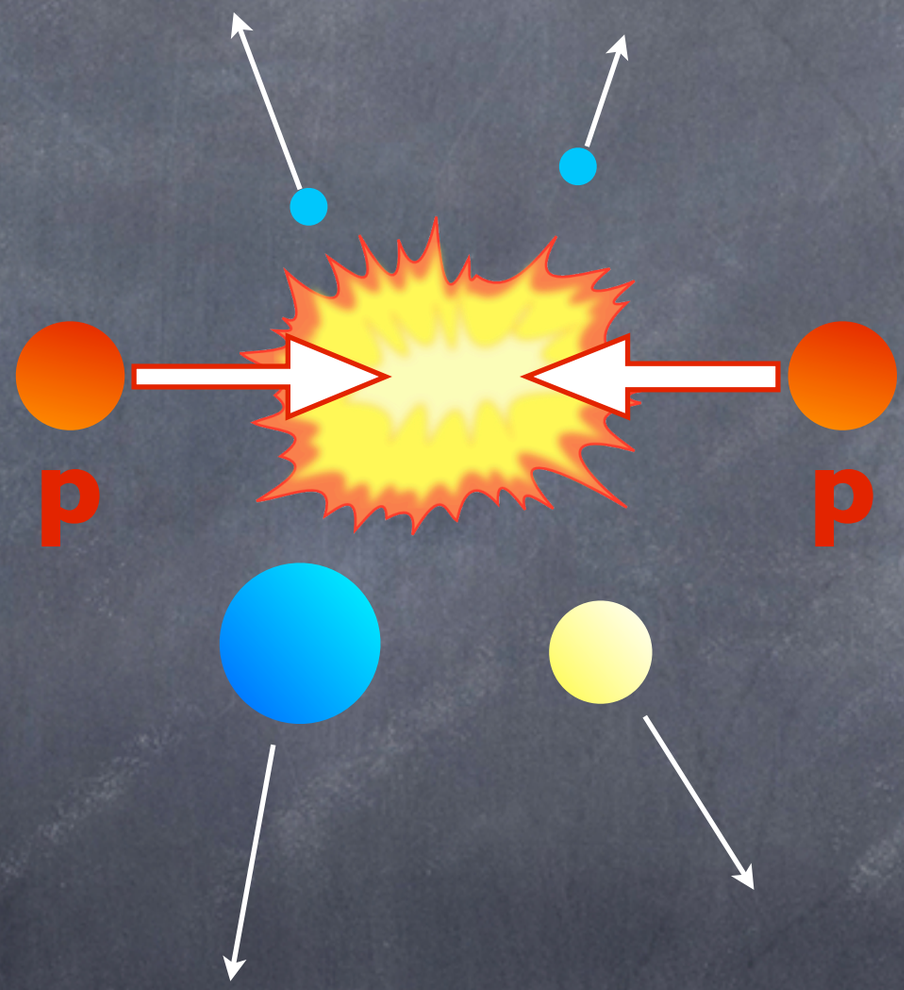
p,n

Muone: elettrone "pesante"
(circa ~200 volte)

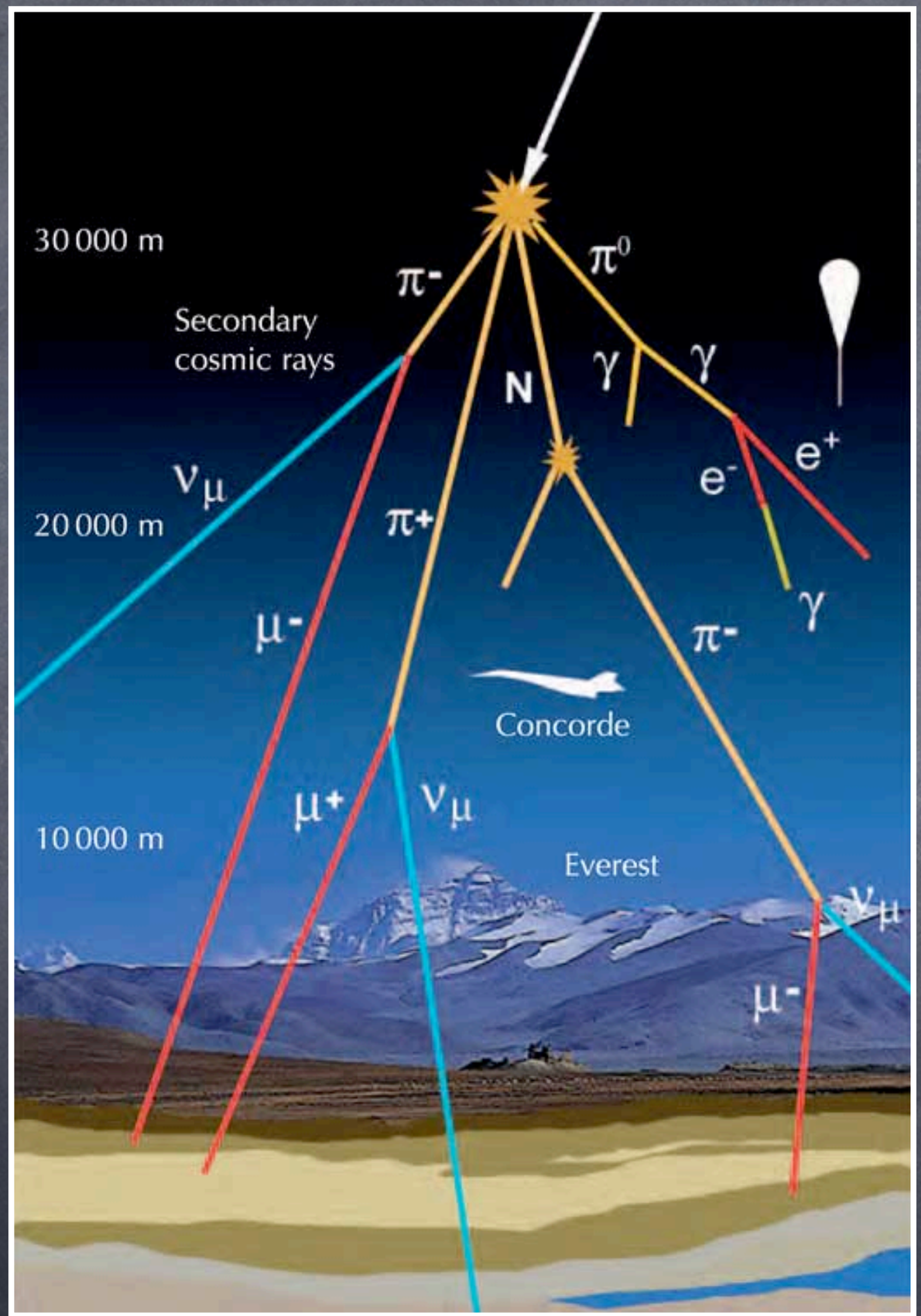
Pioni: due quarks

Parentesi: produzione/distruzione di particelle





Cascate

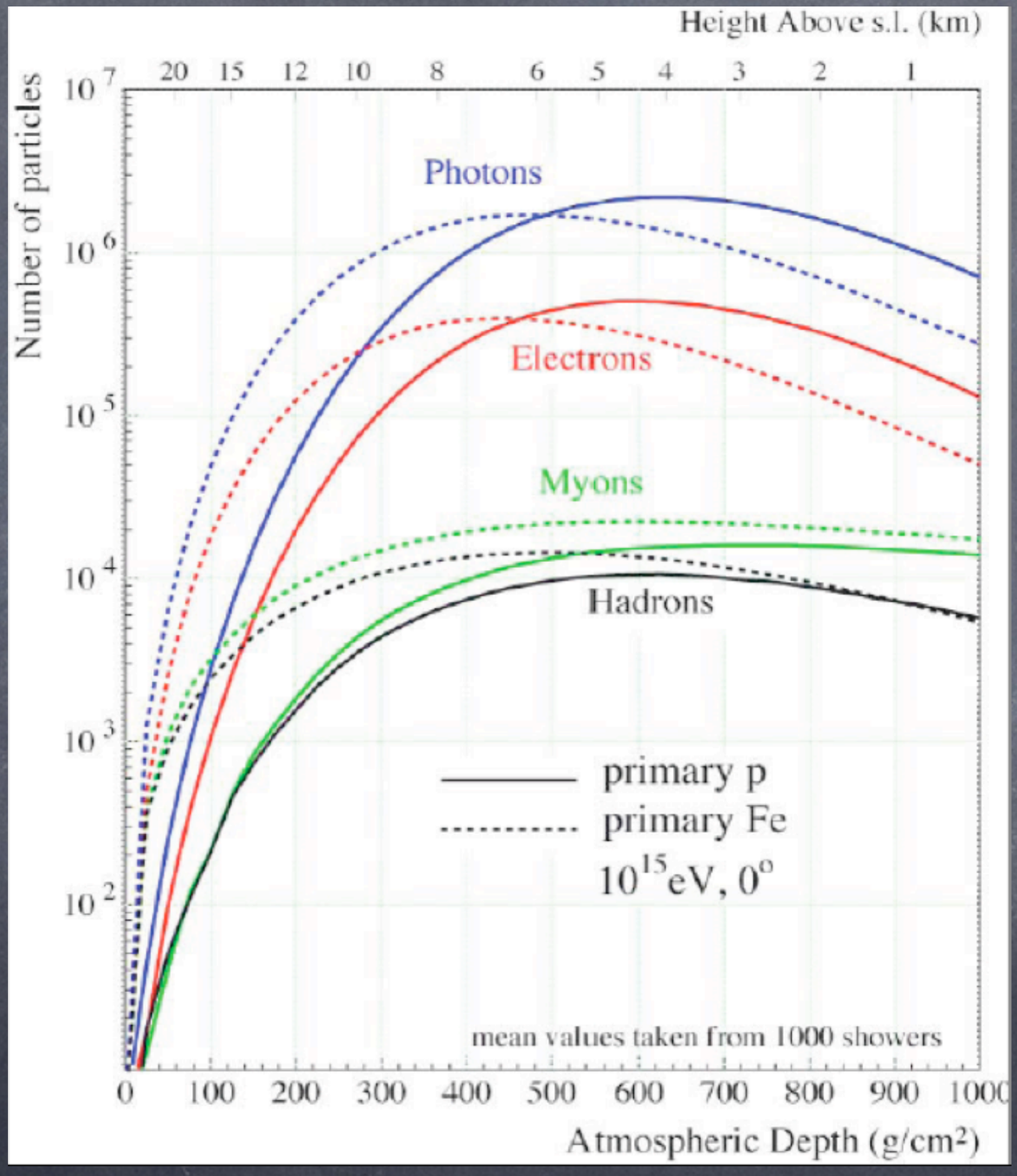


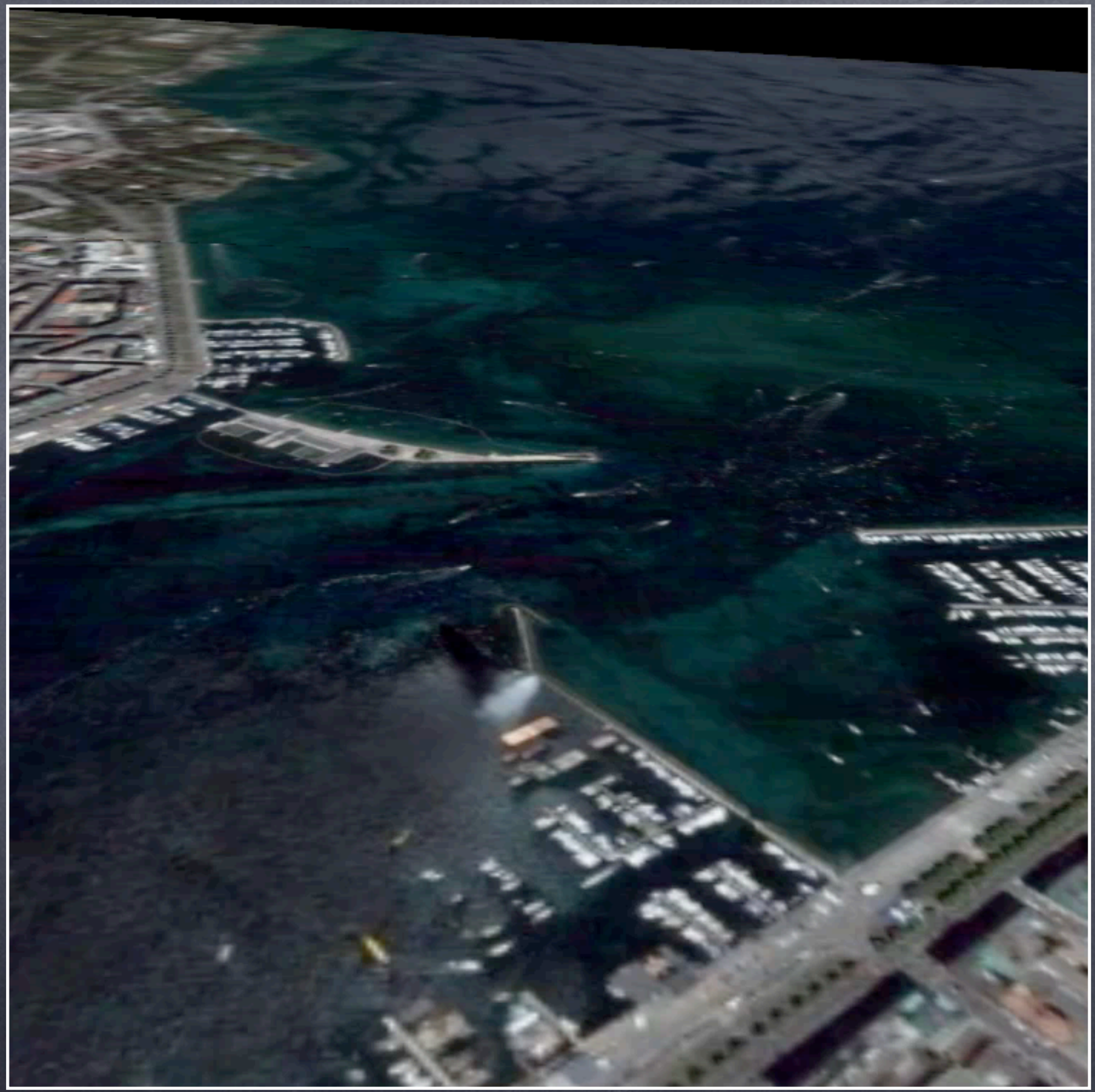
Primario

Secondari

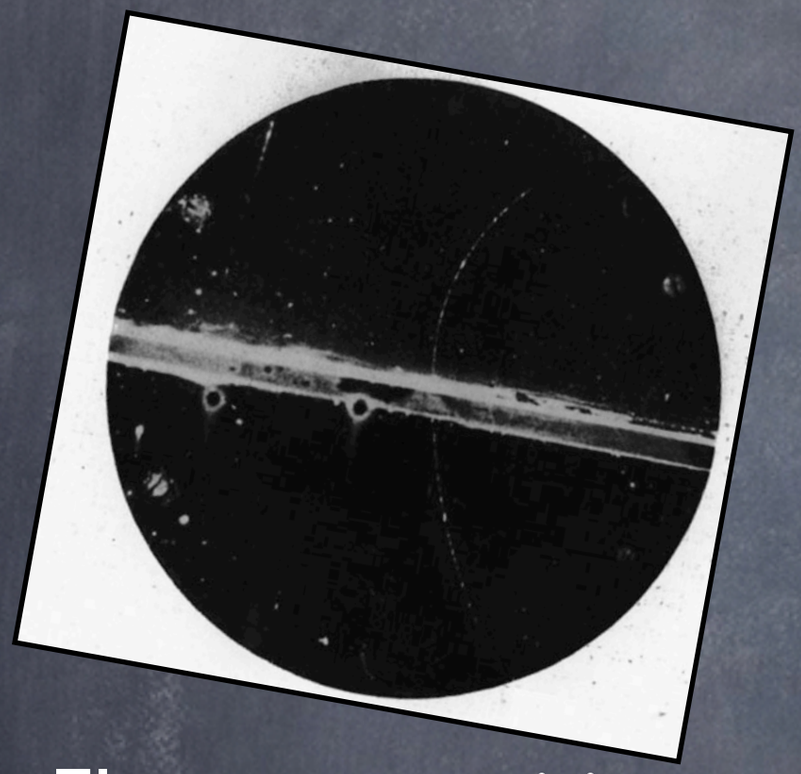
Altezza

Numero di particelle





Raggi cosmici secondari: la nascita della fisica delle particelle



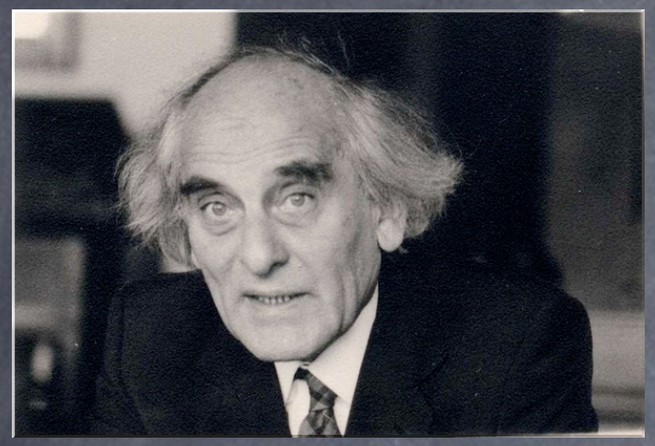
Elettrone positivo
(positrone)
1932

Pione
1947

Muone
1937

“Materializzazione”
di un fotone in
elettrone e positrone

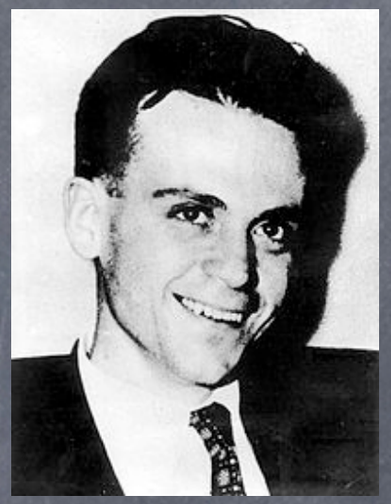
Alcuni protagonisti



G. Occhialini

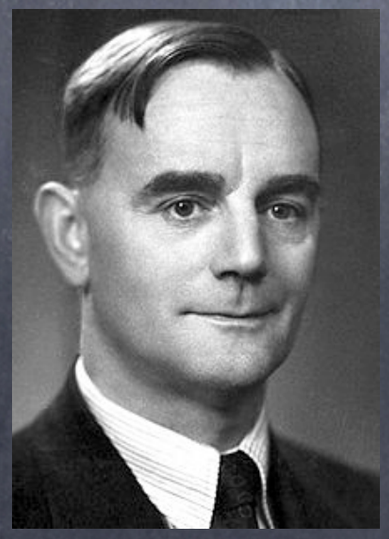
B. Rossi

C. Lattes

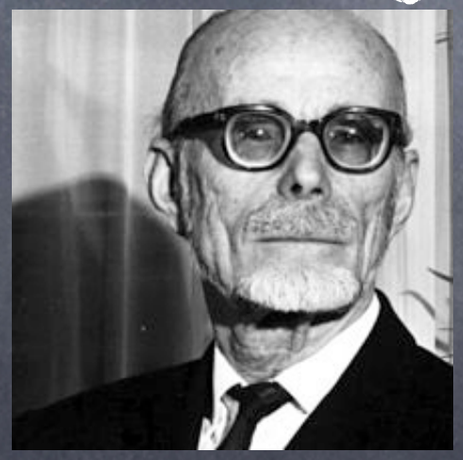


P. Blackett

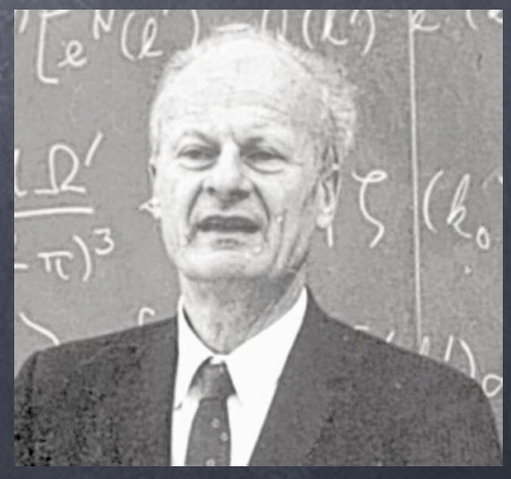
C. Powell



P. Auger

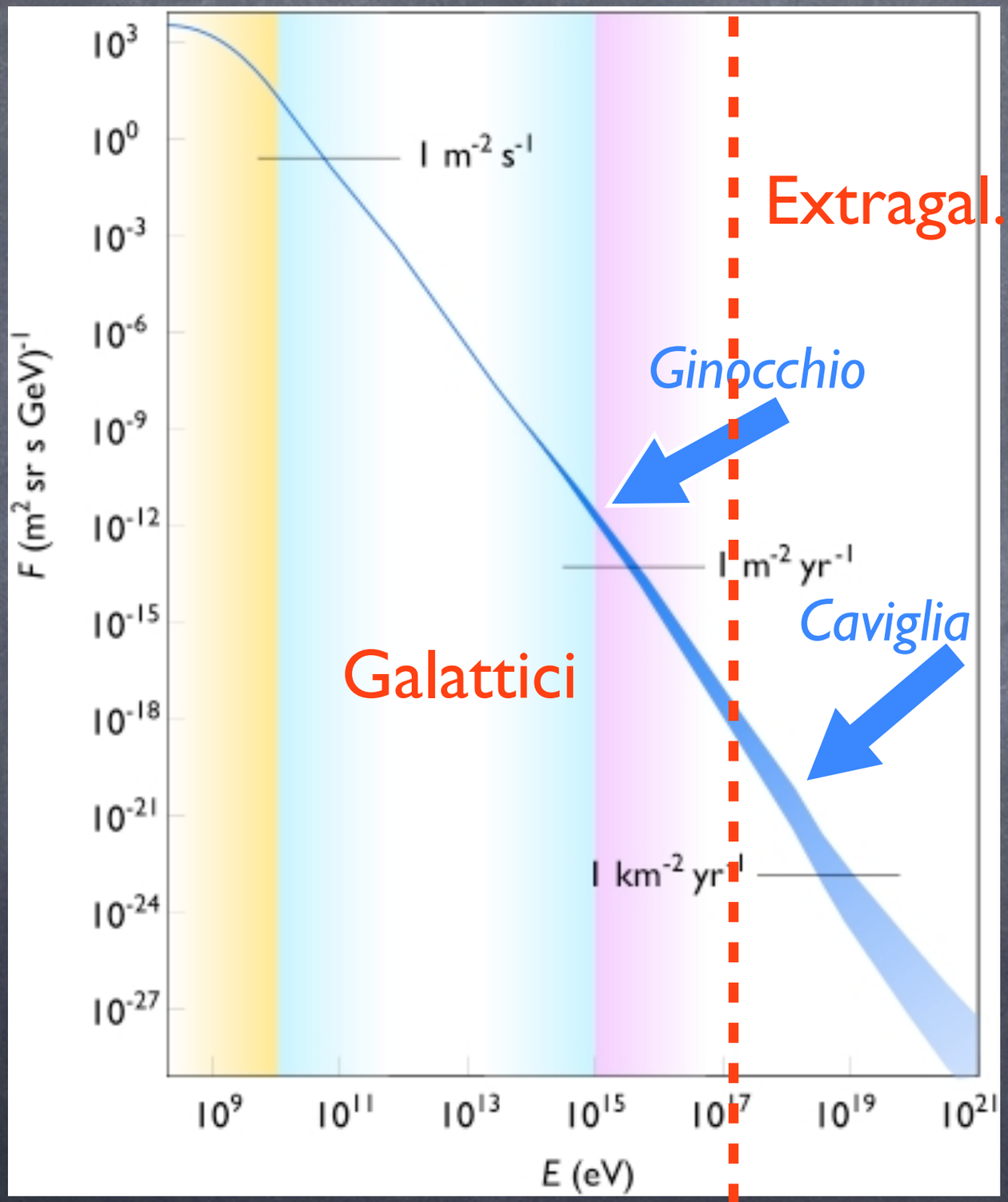


H. Bethe



Da dove provengono?

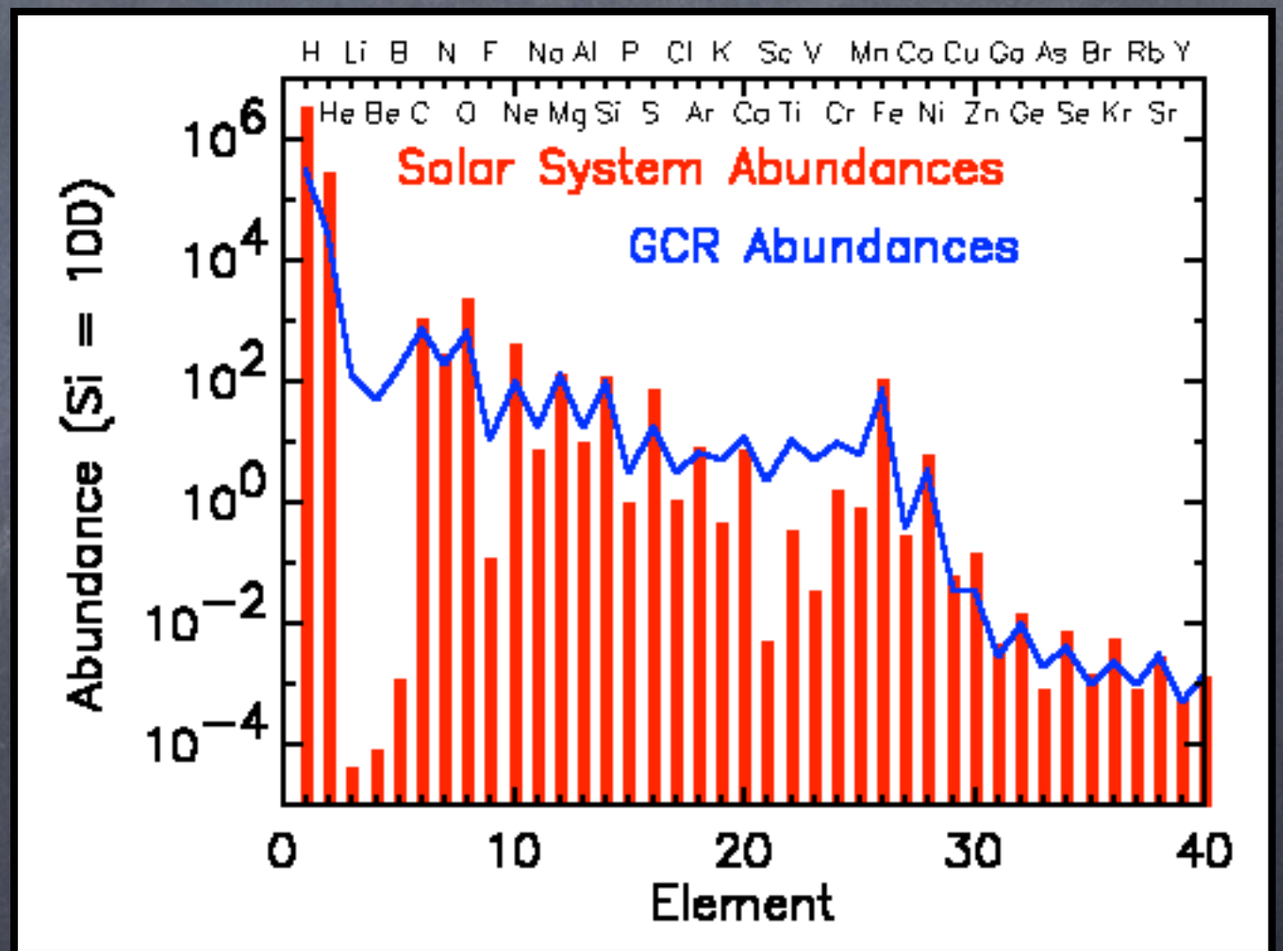
Spettro energetico dei RC primari



Composizione

2% elettroni
98% nuclei

87% H
12% He
1% nuclei pesanti



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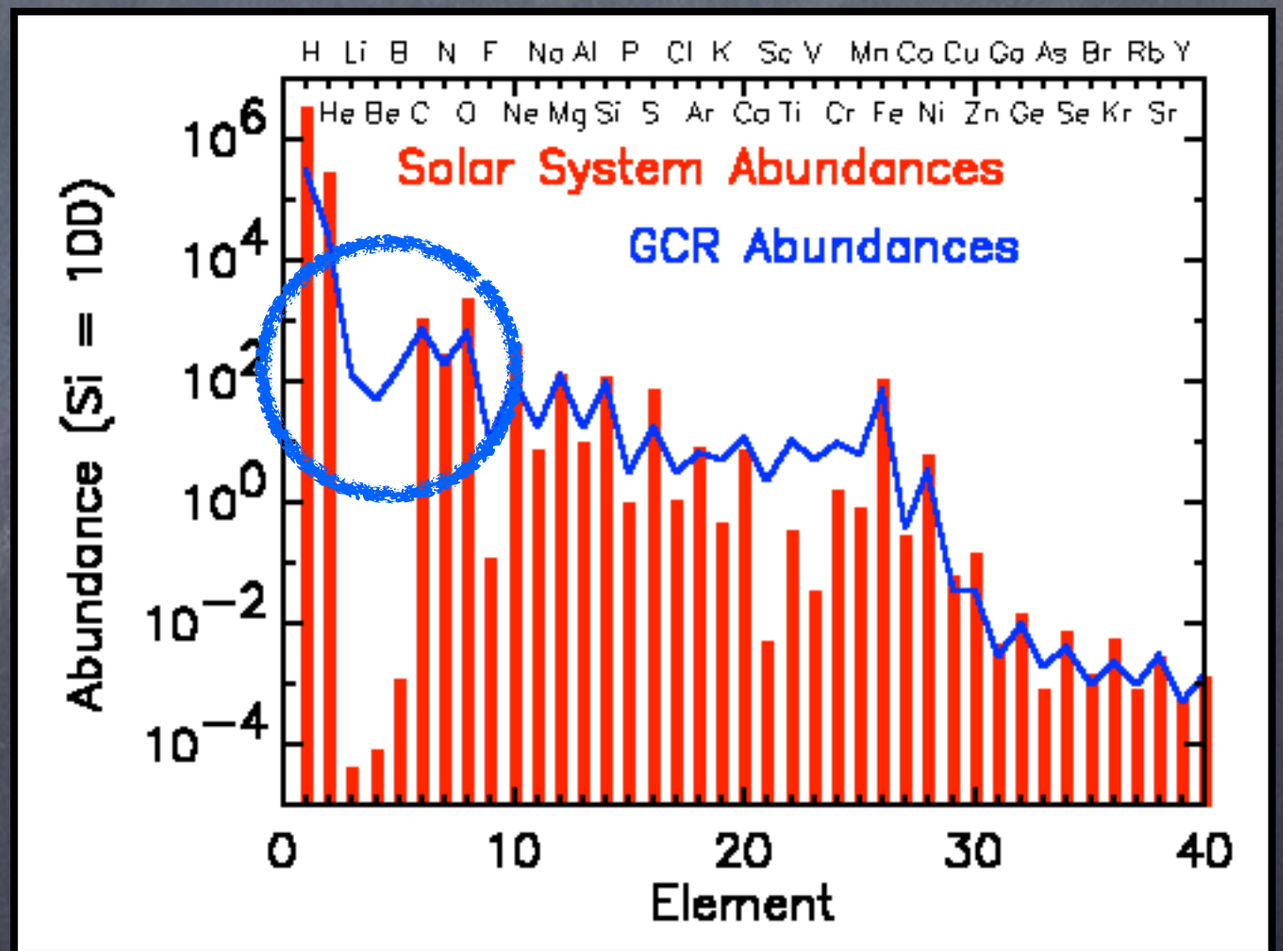
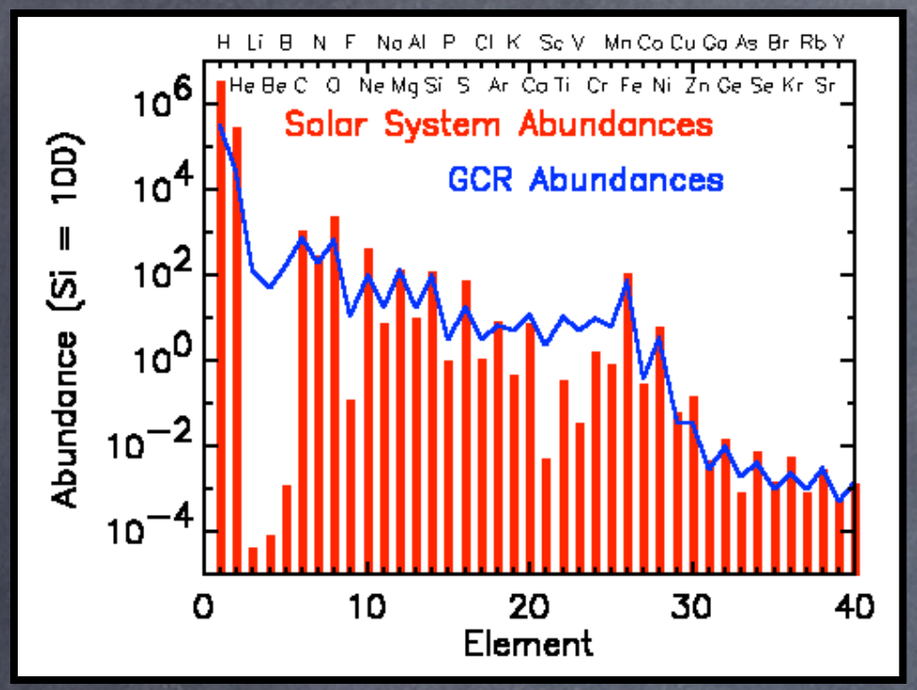
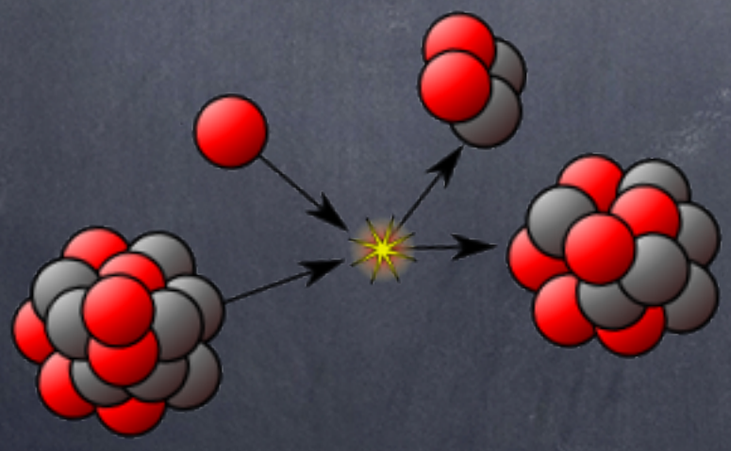


Composizione





Frammentazione di nuclei pesanti durante la propagazione nella Galassia

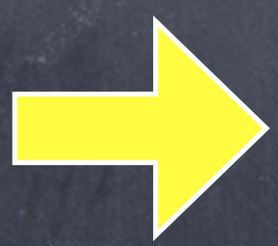
"spallazione"

Composizione

Conoscendo
1) la densita' del gas (bersagli)
2) la probabilita' di interazione

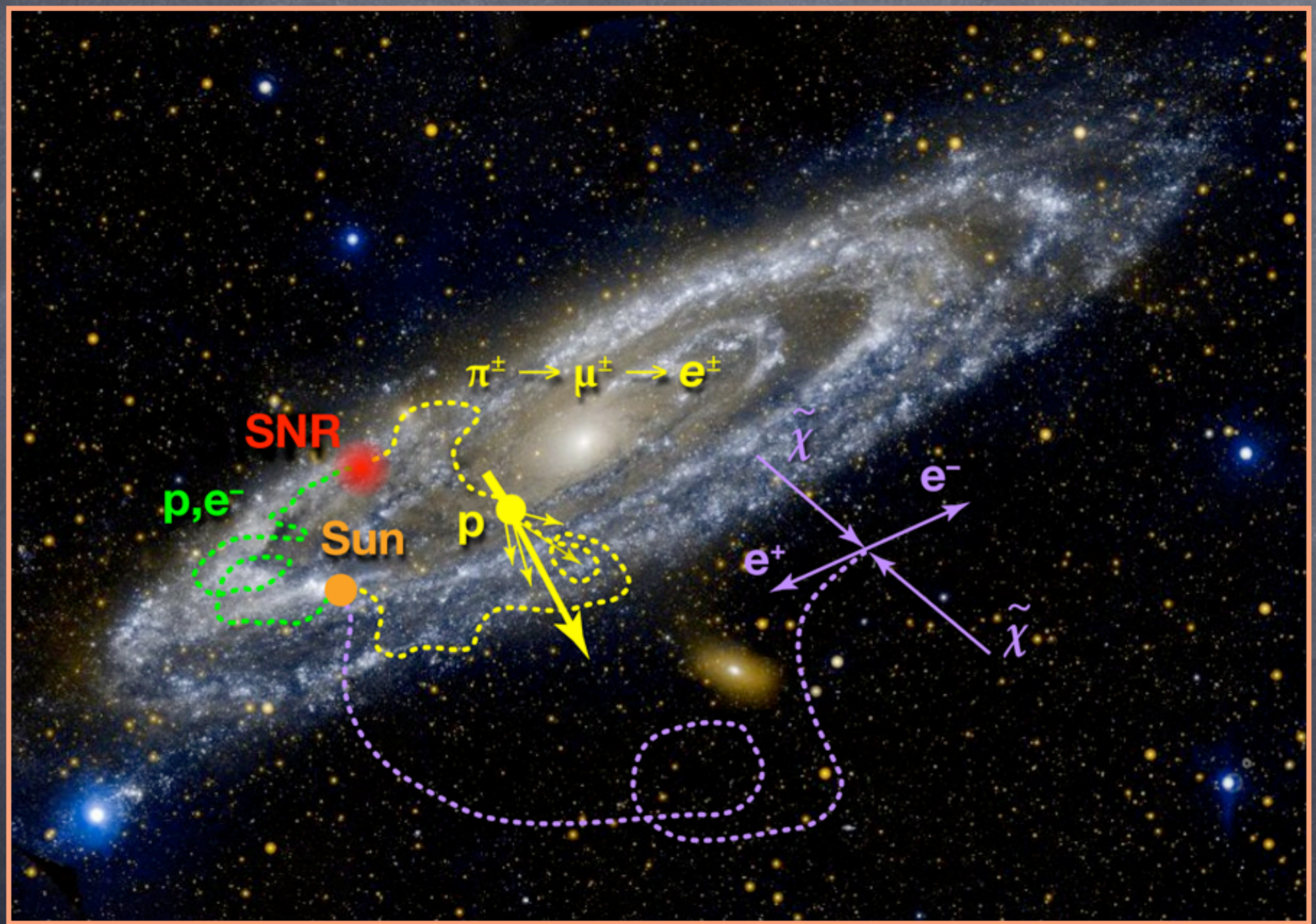
si stima il percorso totale

d~1 Mpc

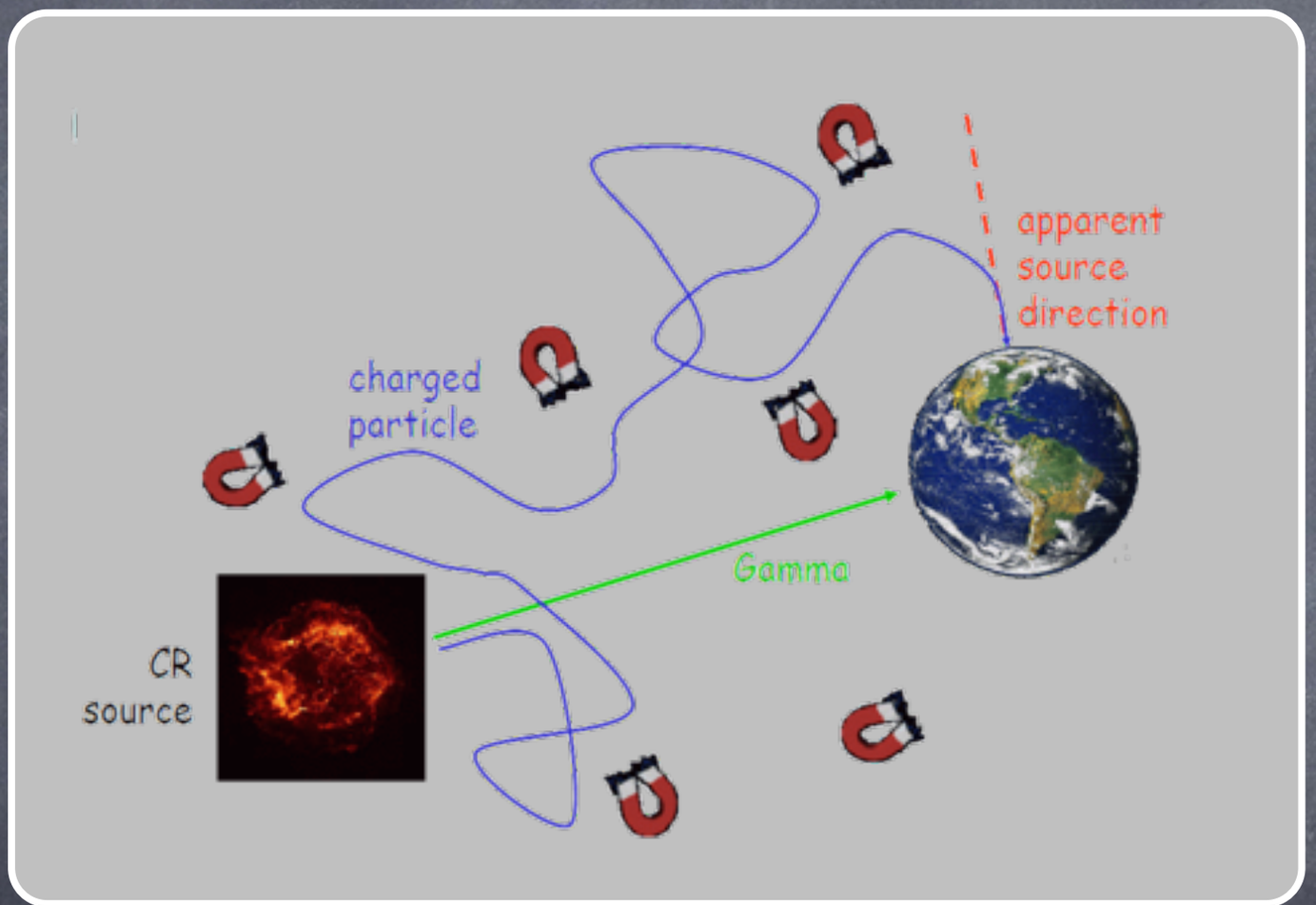


Diffusione

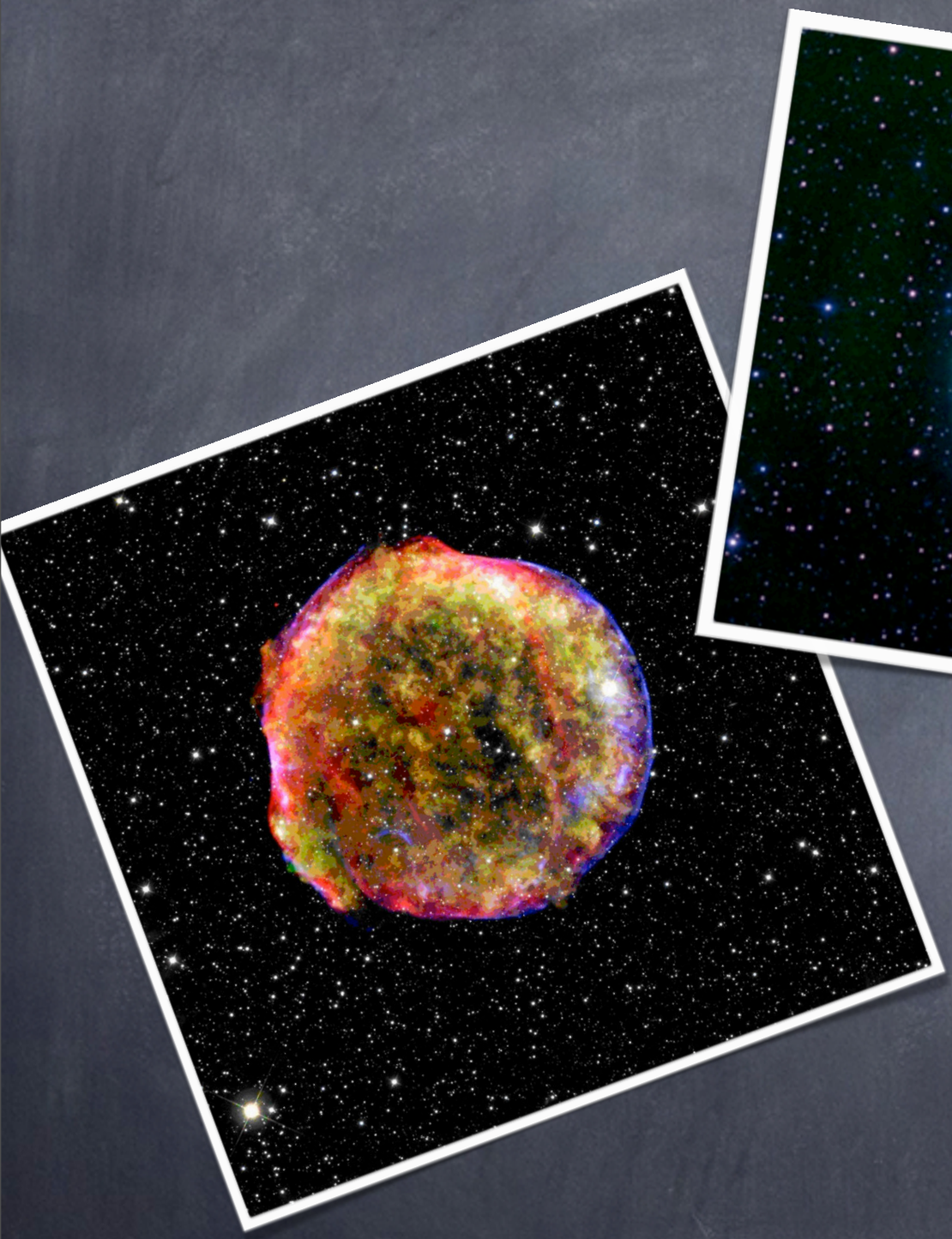
Raggi cosmici galattici



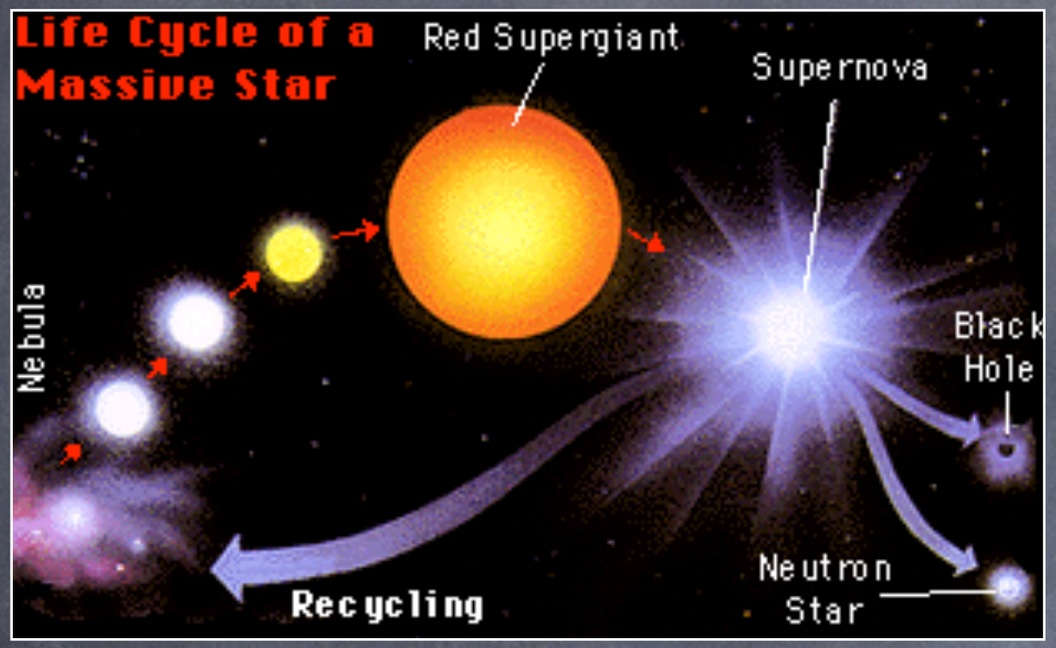
Raggi cosmici galattici: il ruolo del campo magnetico



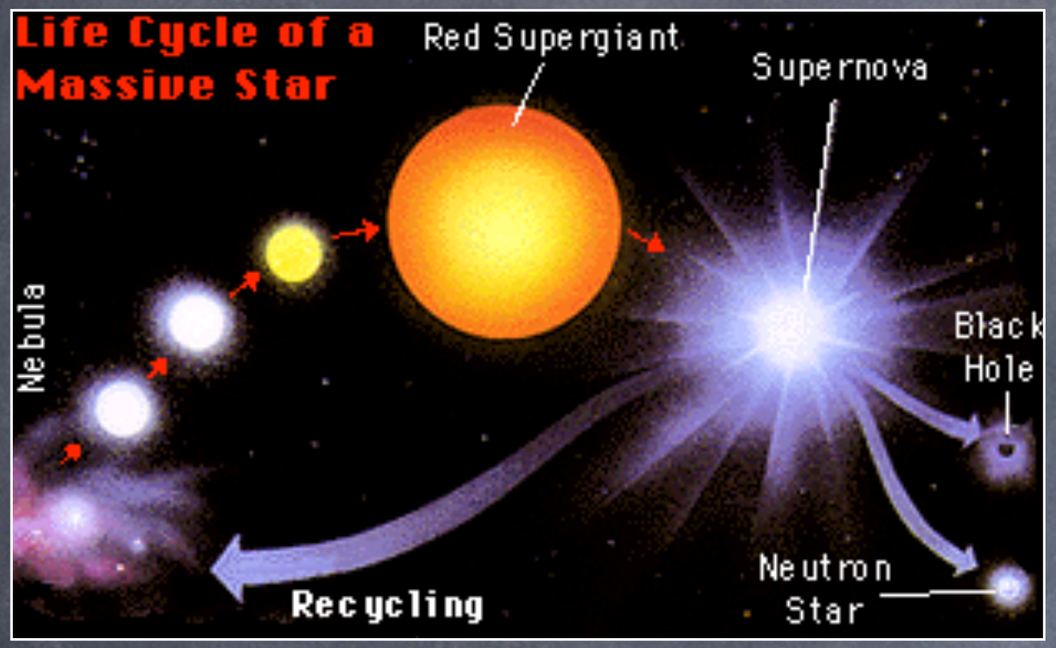
Sospetti: resti di supernovae

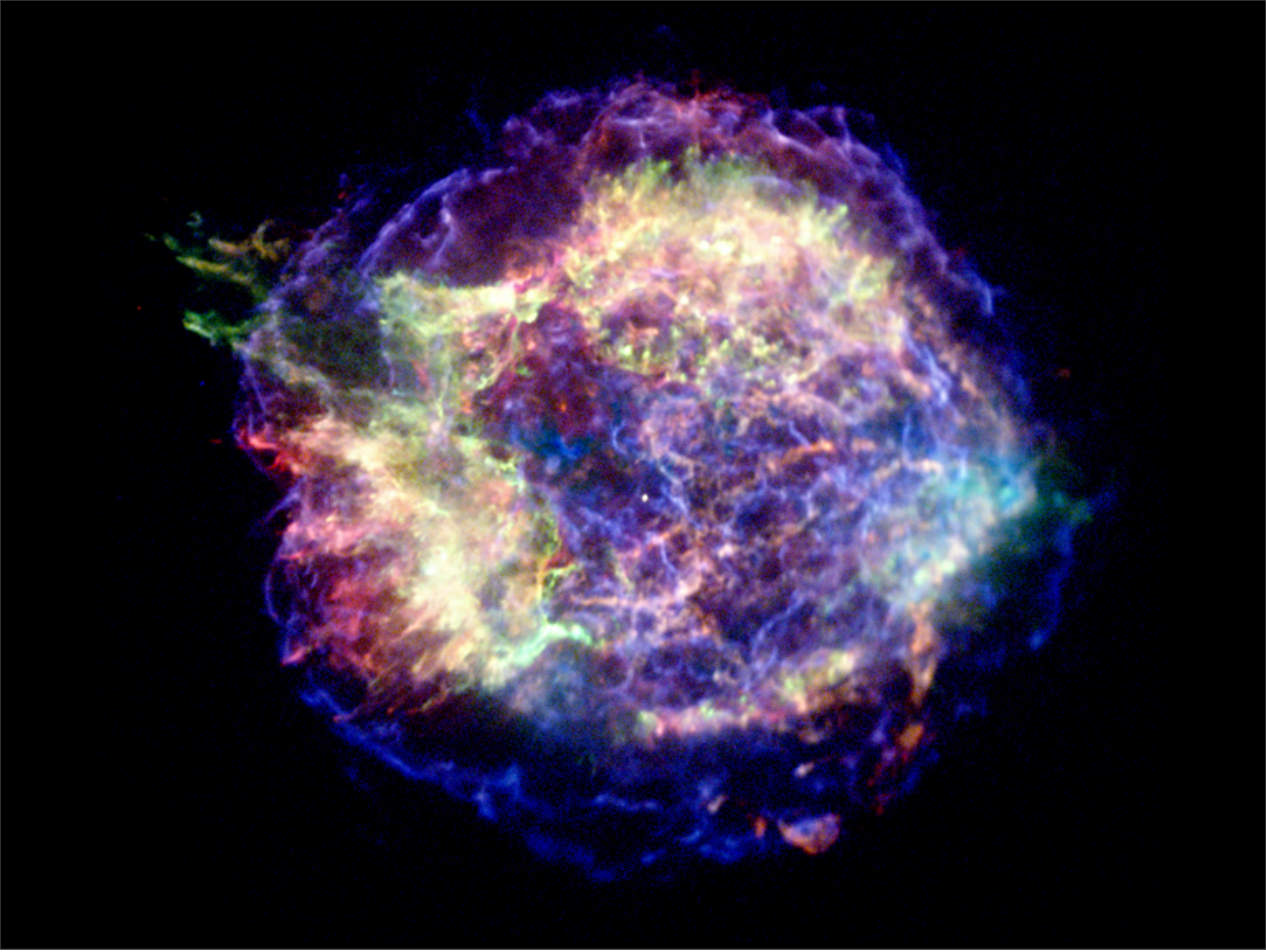


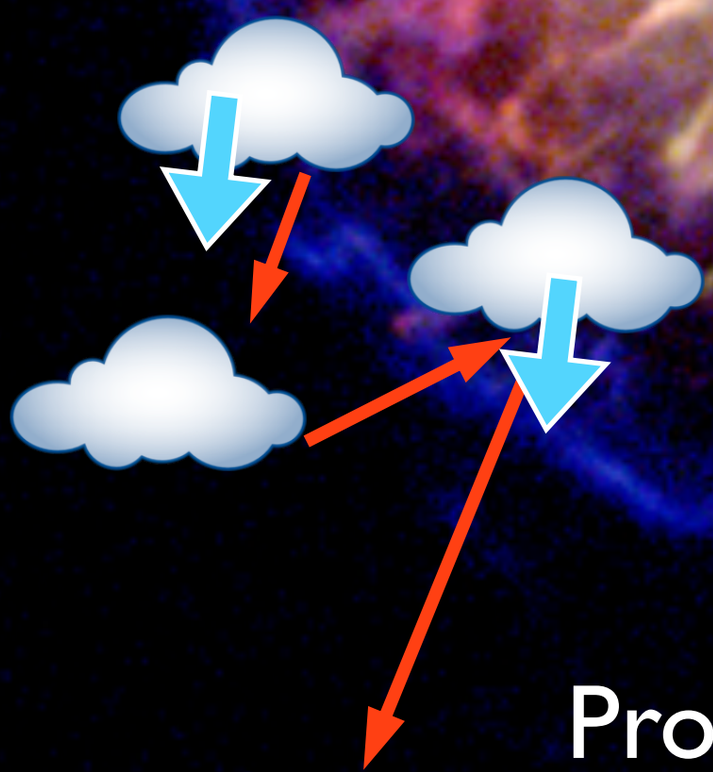
Prodotte nelle fasi finali dell'evoluzione stellare

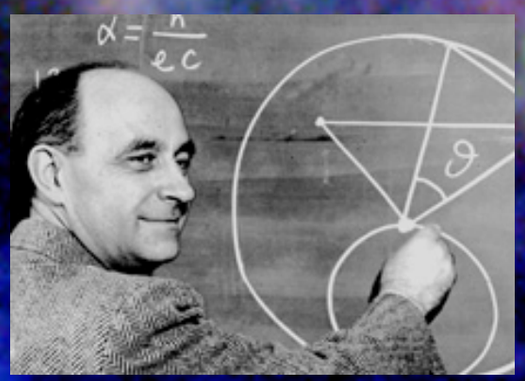


Prodotte nelle fasi finali dell'evoluzione stellare



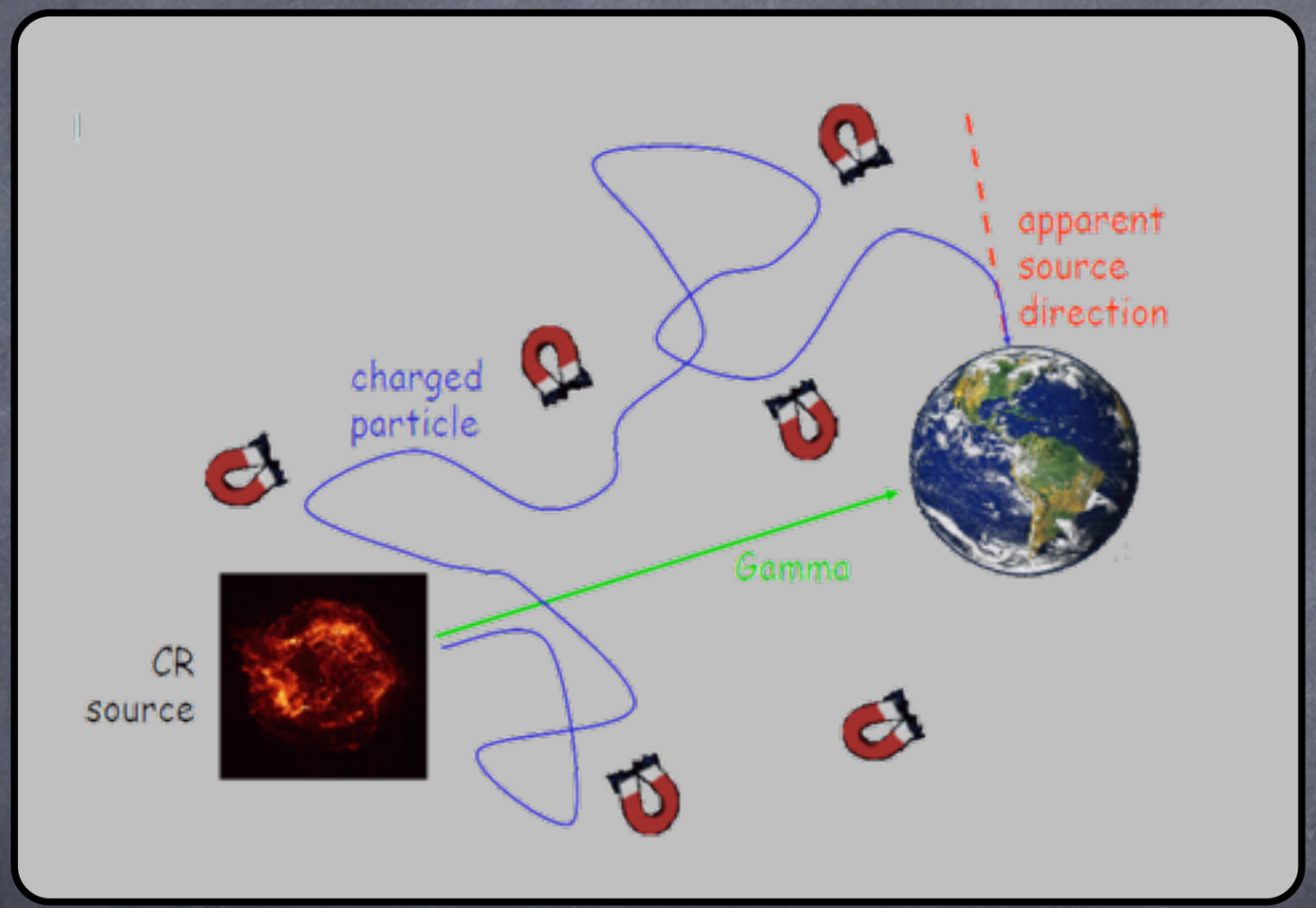


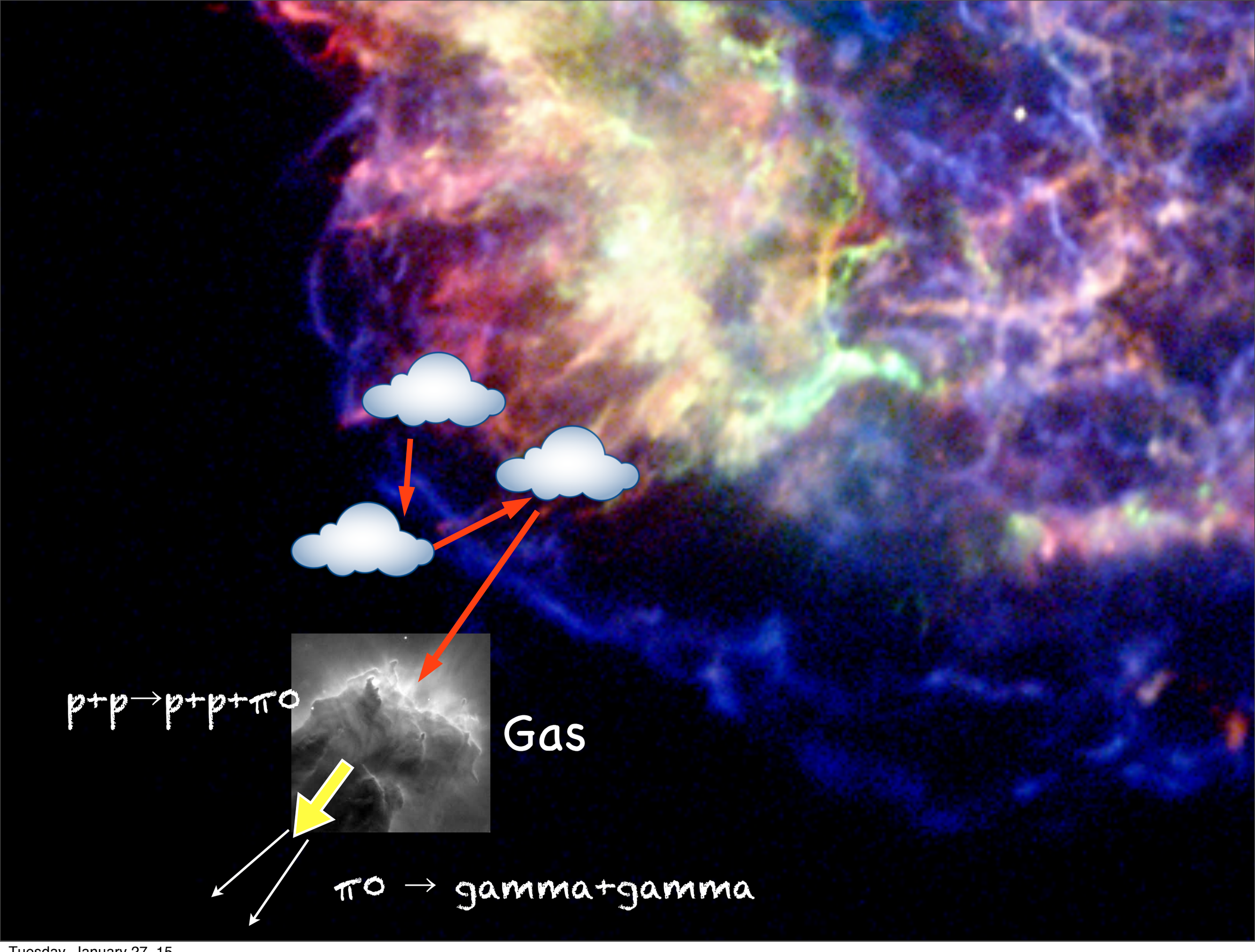




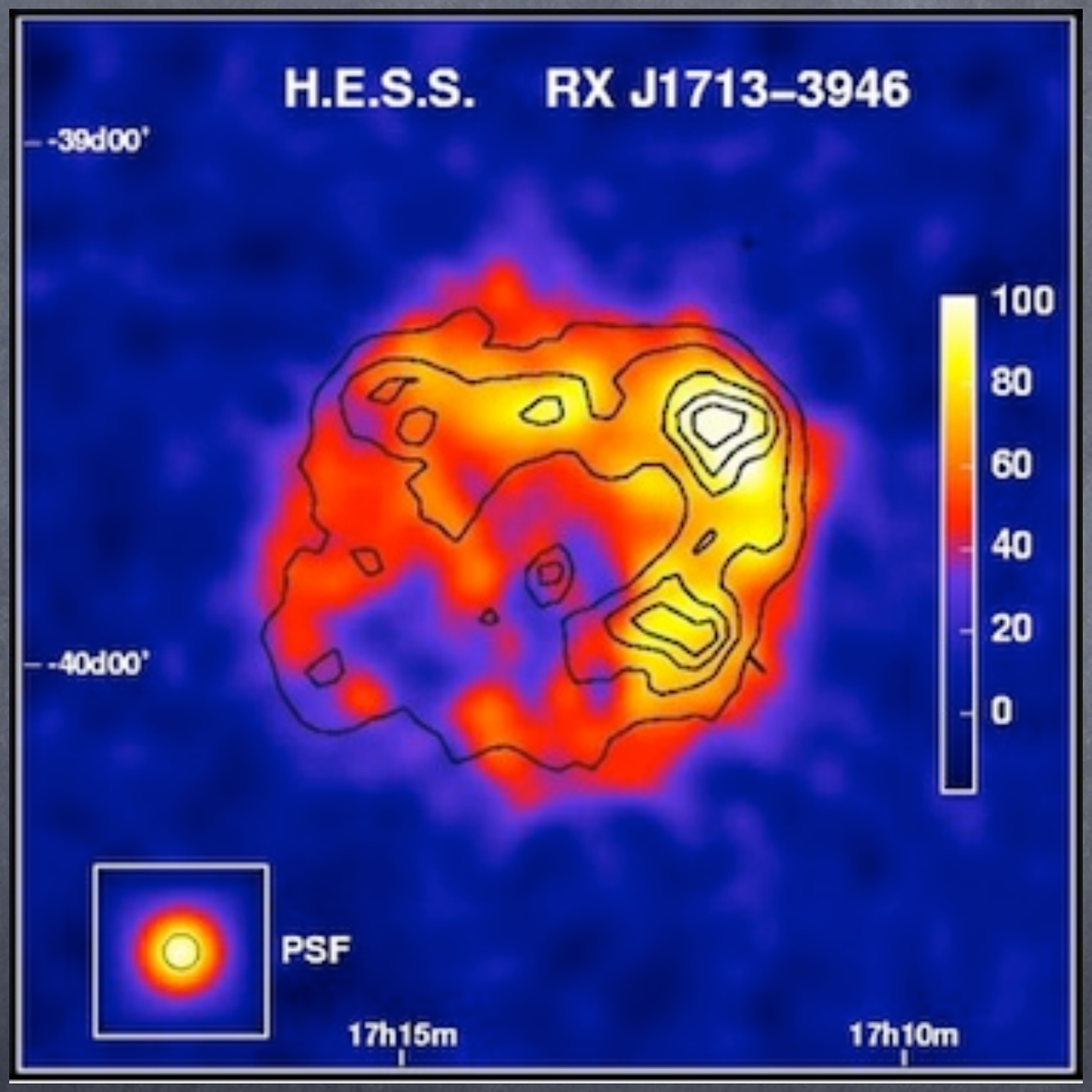
"Palla da flipper"

Processo di Fermi (1949)


apparent
source
direction
charged
particle
Gamma
CR
source


p+p→p+p+πo
Gas
πo → gamma+gamma

Resto di SN nei raggi gamma



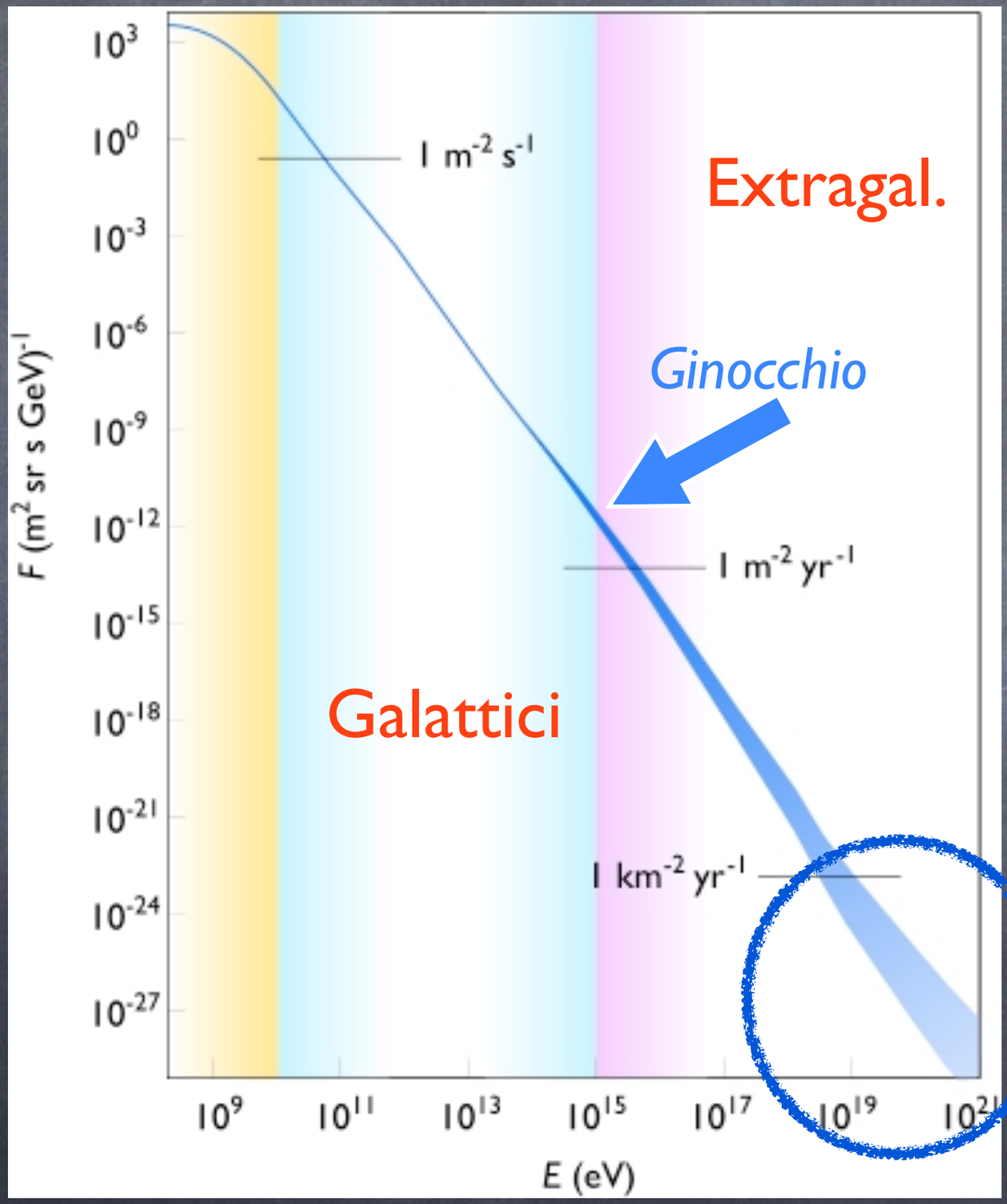
Mistero svelato?

Non ancora la prova sicura al 100%

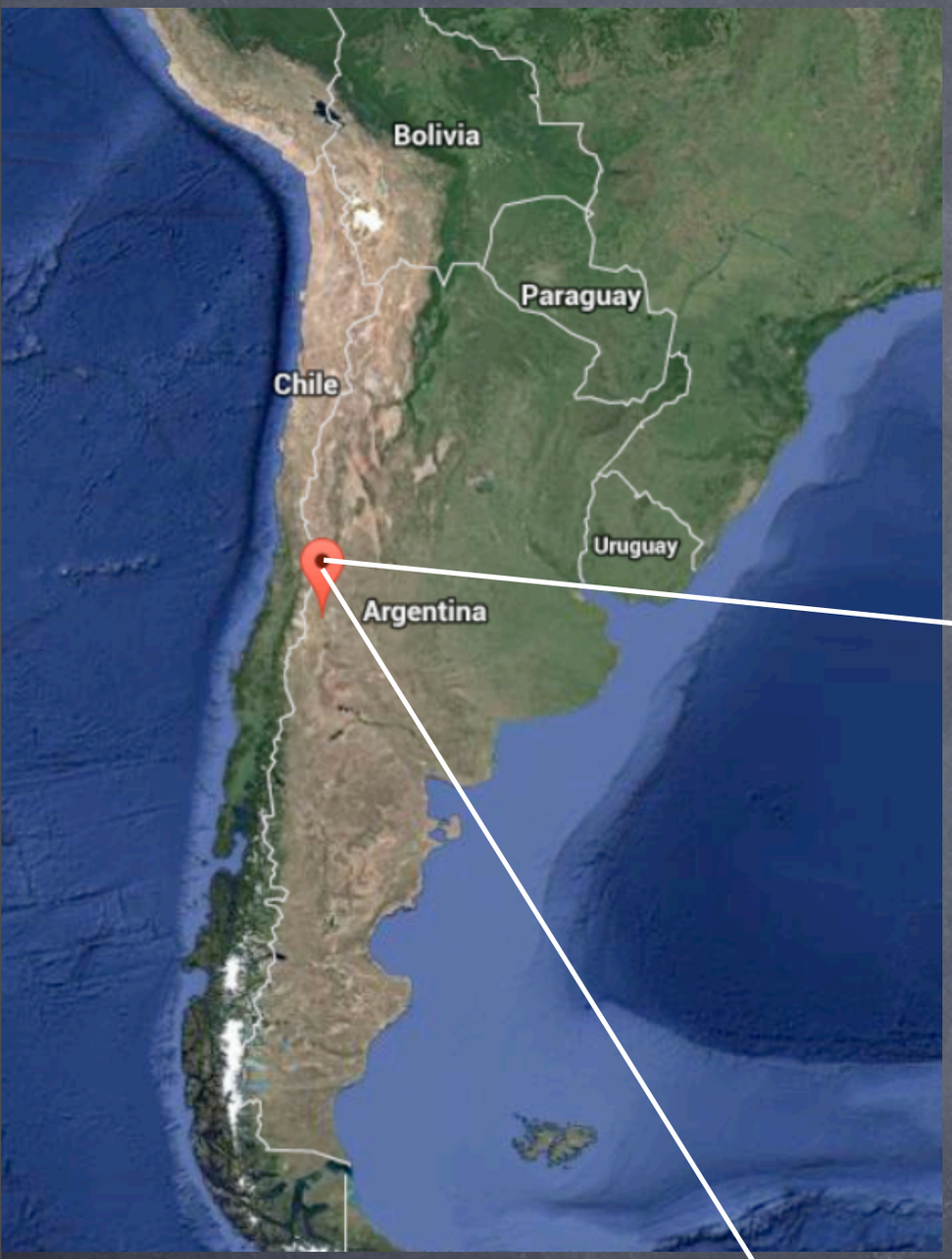
Altri processi fisici concomitanti possono contribuire

UHECR: ancora un mistero

Spettro energetico dei RC primari



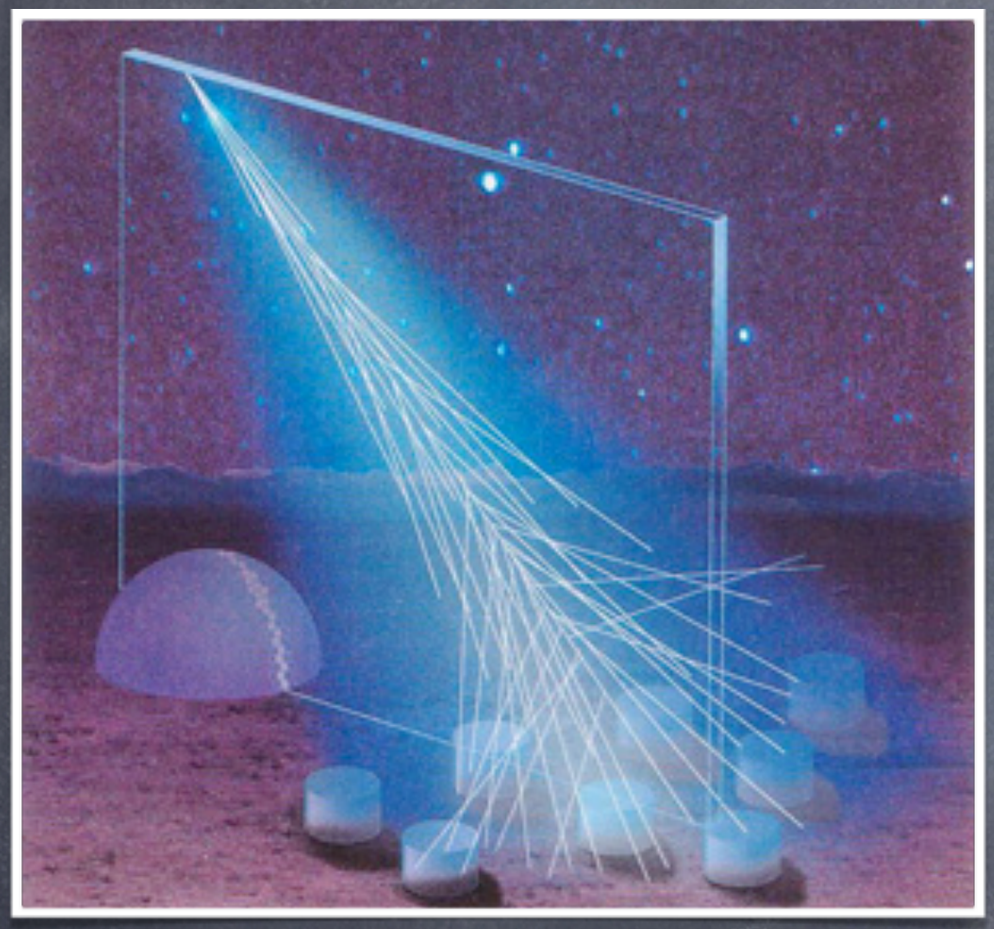
Pierre AUGER Observatory



3000 km²!

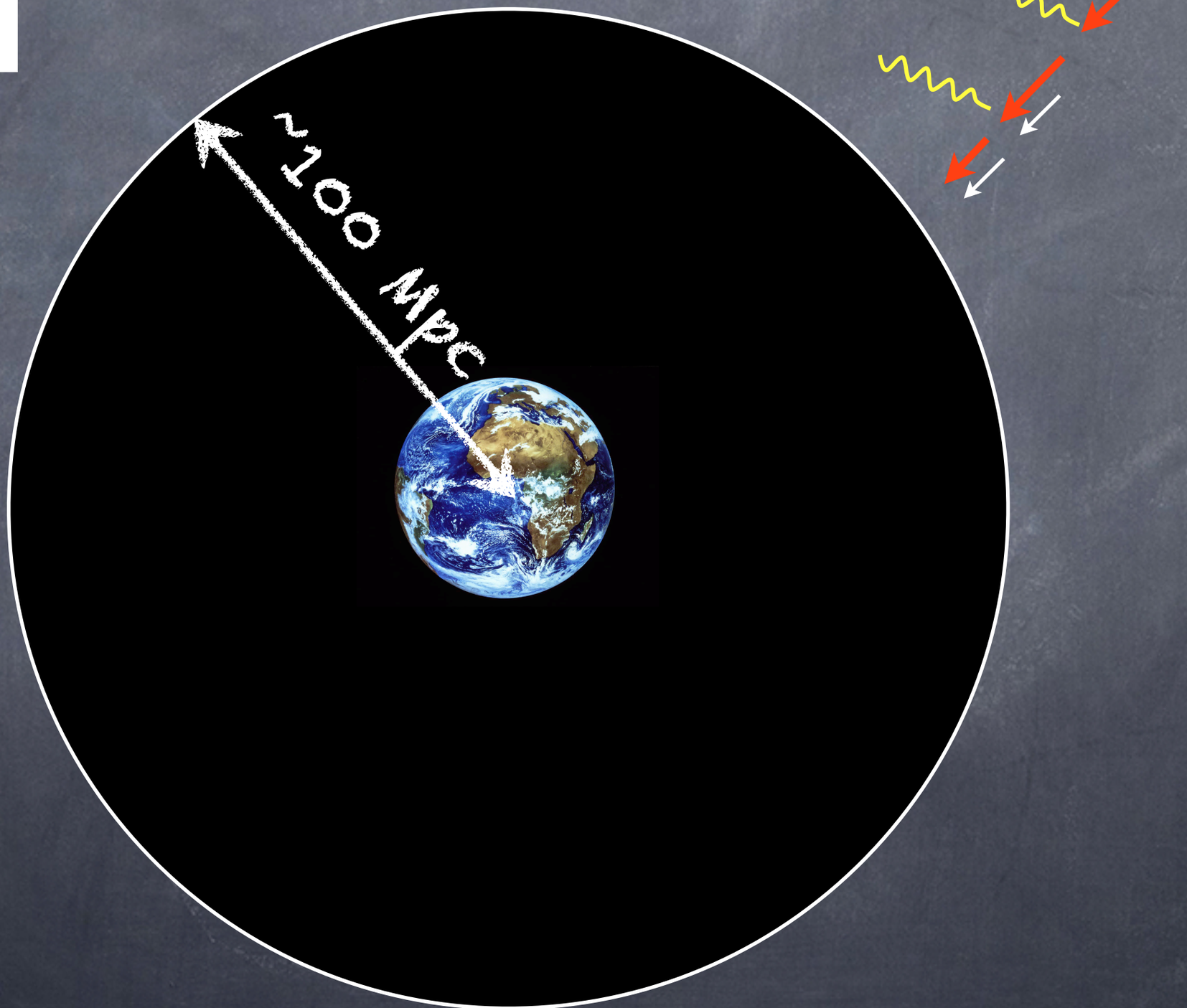
500 fisici
15 nazioni

Pierre AUGER Observatory

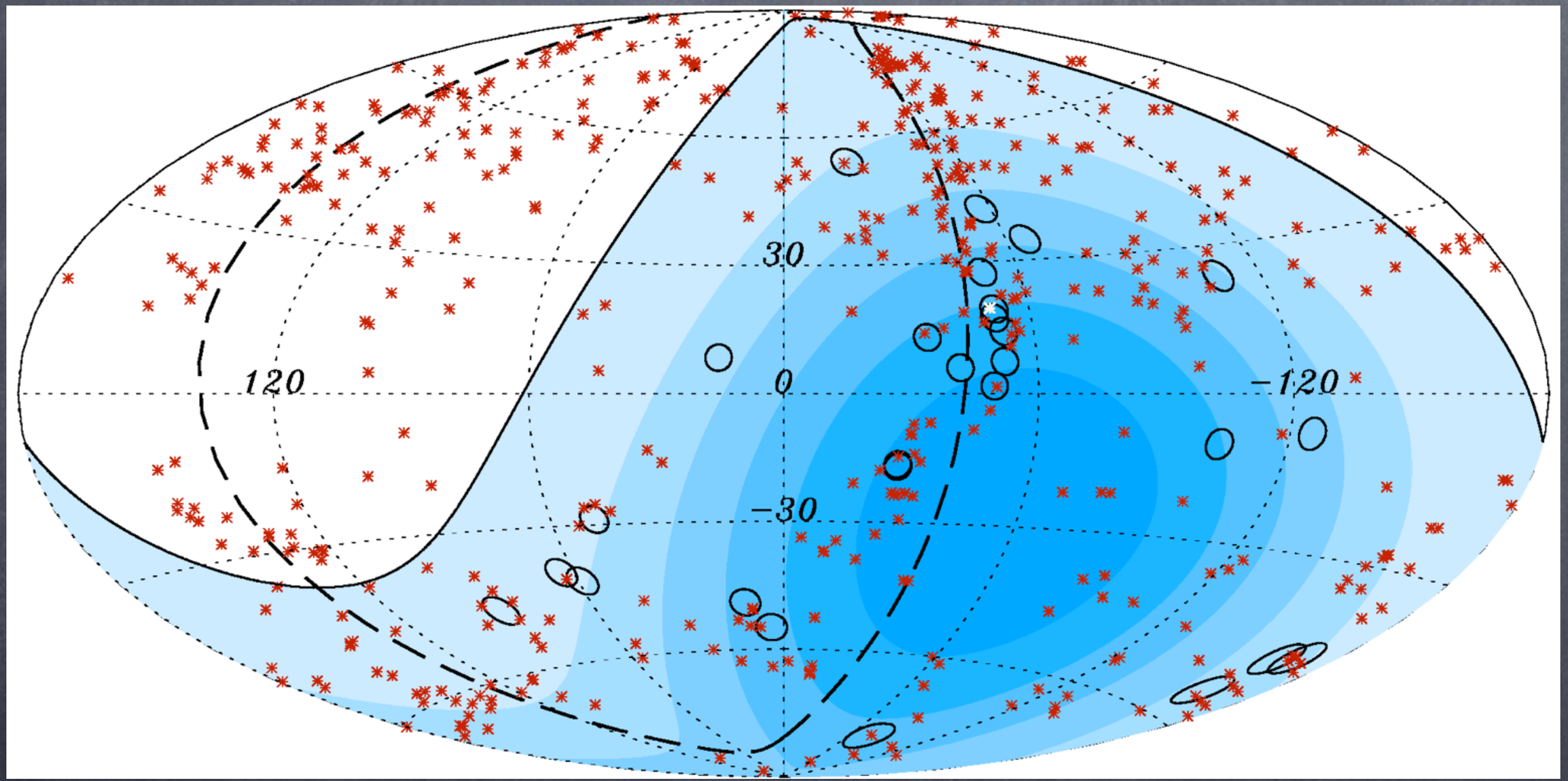


"Orizzonte degli UHECR"

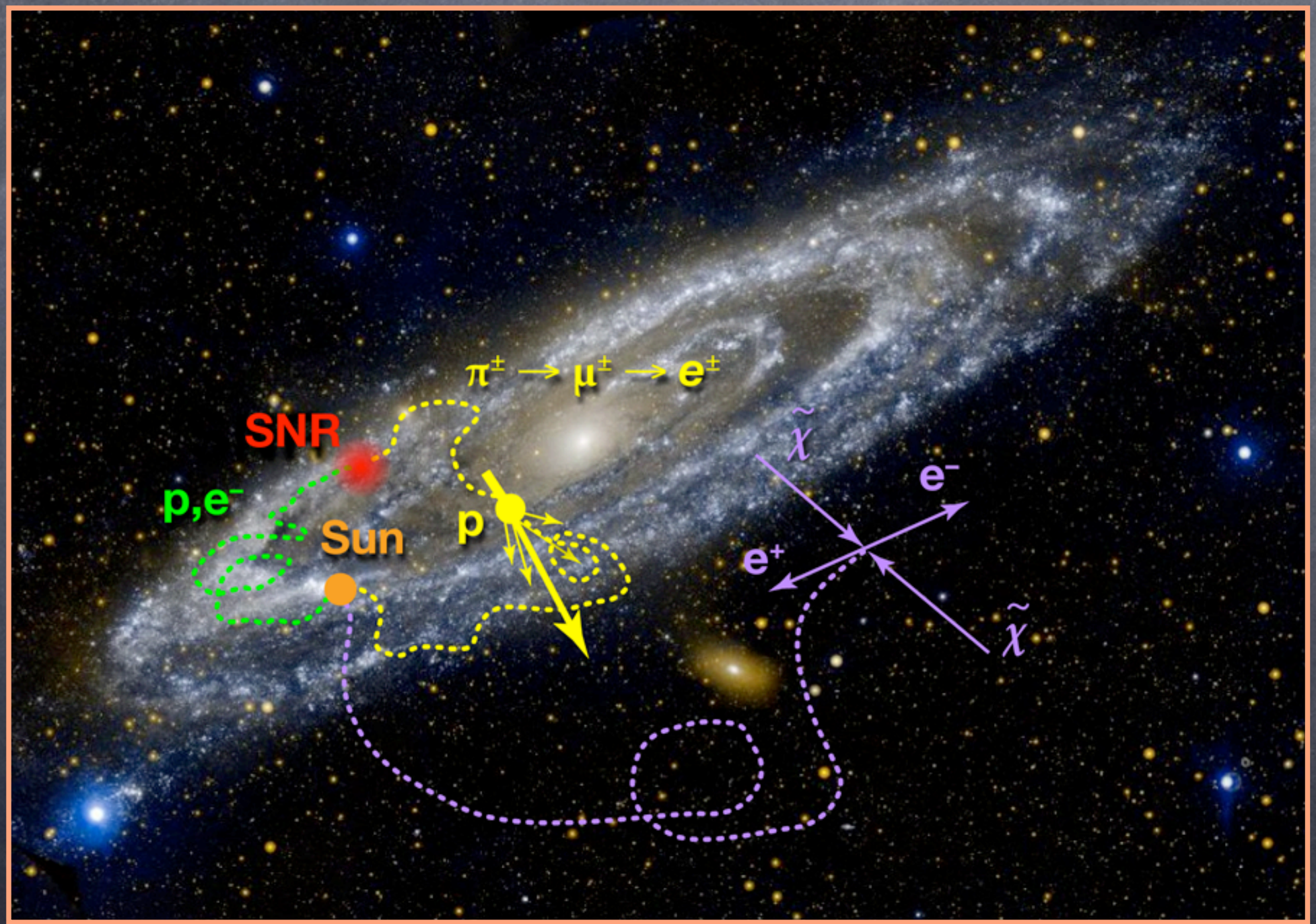
$$p + \gamma \rightarrow \Delta^{+} \rightarrow \begin{cases} n + \pi^{+} \\ p + \pi^{0} \end{cases}$$



Il "cielo" di Auger



Altri tipi di radiazione



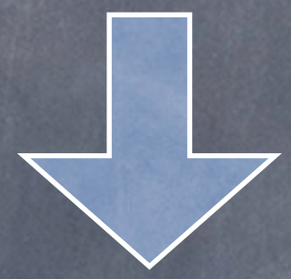
Neutrini

"Sottoprodotto" di reazioni dei raggi cosmici

-Atmosfera
-Galassia
-Spazio extragalattico
-Sorgente

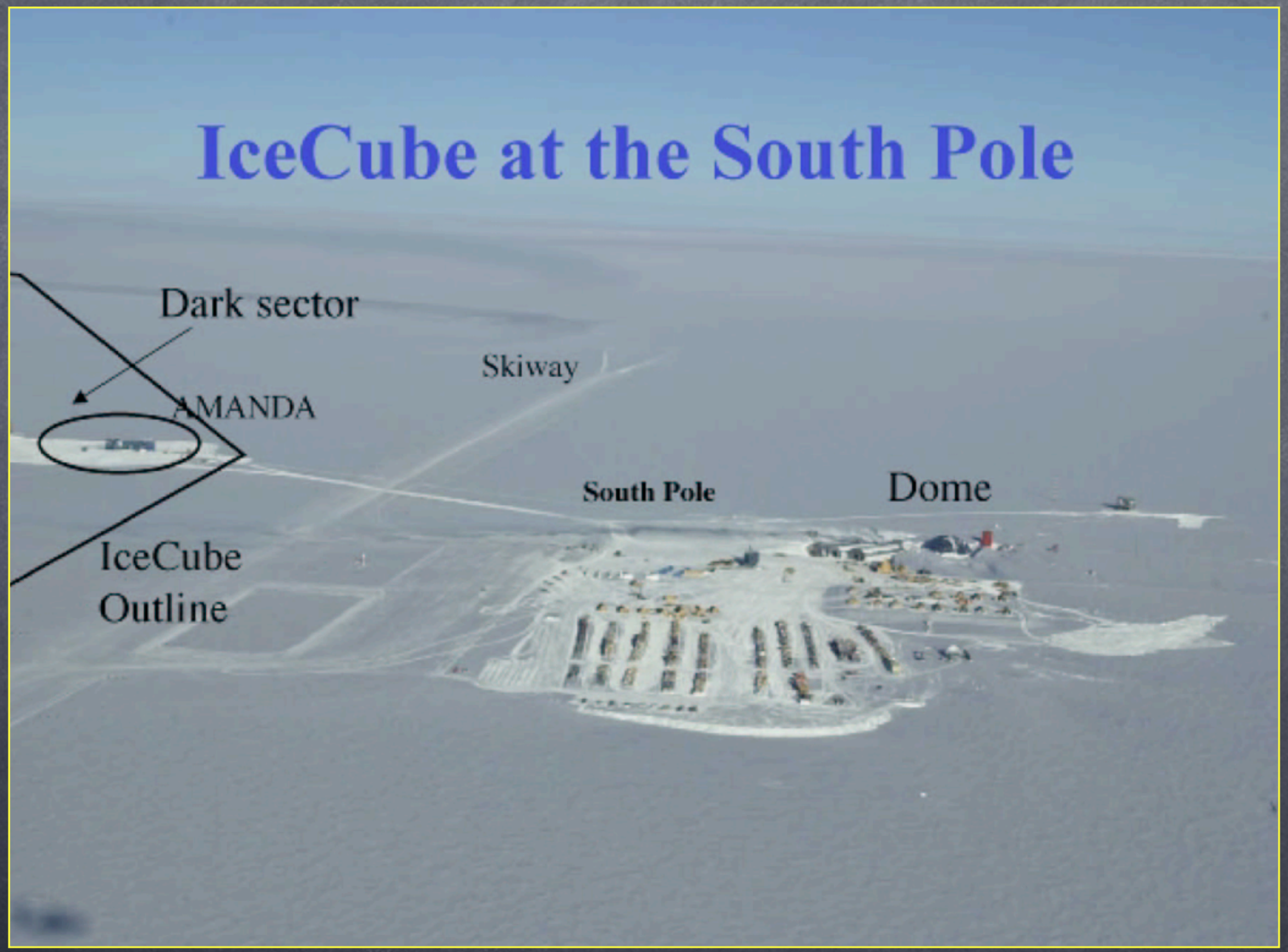
Neutrini

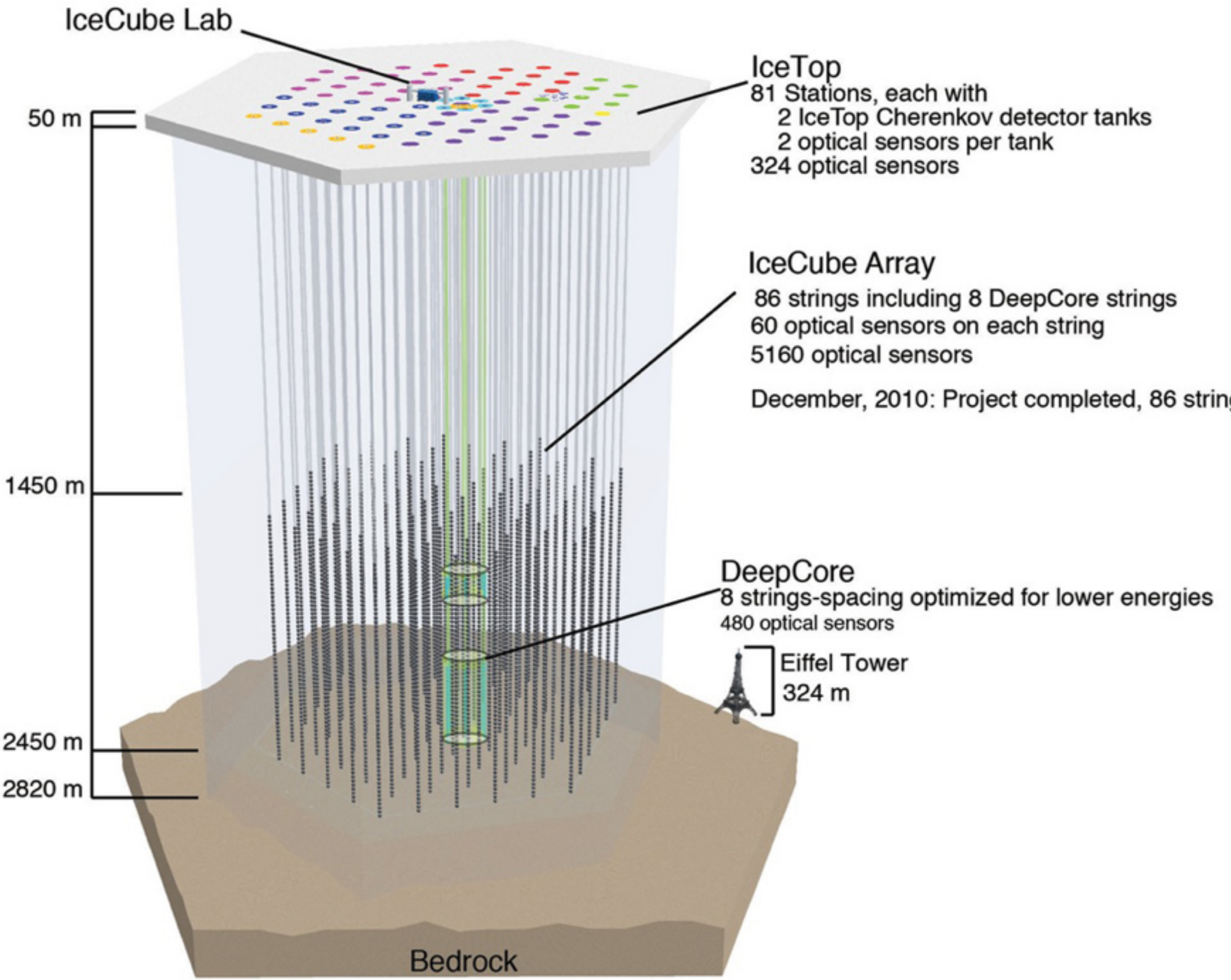
Pochissimo propensi ad interagire (forza "debole")



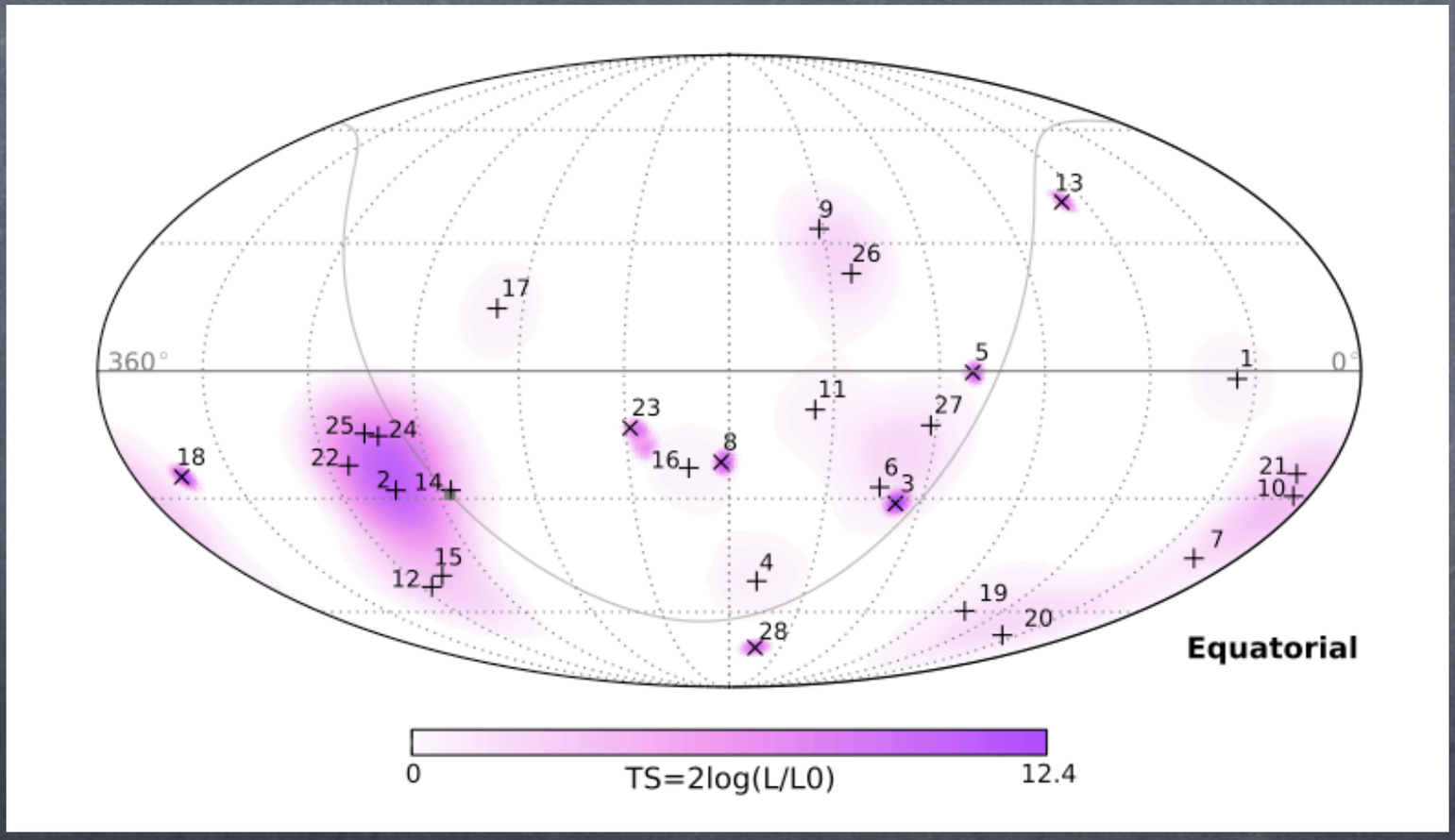
Rivelatori di grandi volumi

Neutrini


IceCube at the South Pole
Dark sector
Skiway
AMANDA
South Pole
Dome
IceCube
Outline

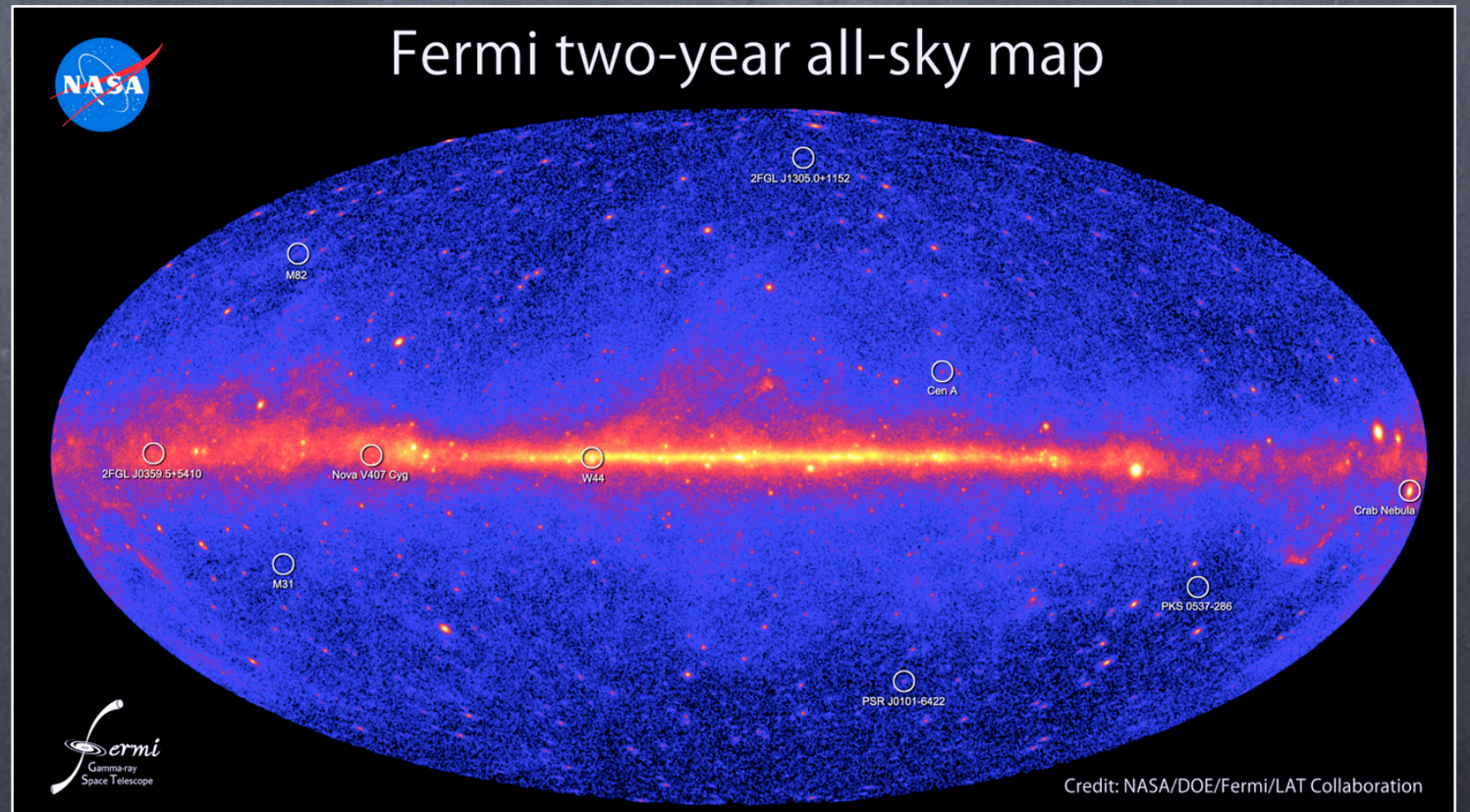

IceCube Lab
50 m
1450 m
2450 m
2820 m
IceTop
81 Stations, each with
2 IceTop Cherenkov detector tanks
2 optical sensors per tank
324 optical sensors
IceCube Array
86 strings including 8 DeepCore strings
60 optical sensors on each string
5160 optical sensors
December, 2010: Project completed, 86 strings
DeepCore
8 strings-spacing optimized for lower energies
480 optical sensors
Eiffel Tower
324 m
Bedrock

2012: prima evidenza di 28 neutrini molto probabilmente **cosmici**

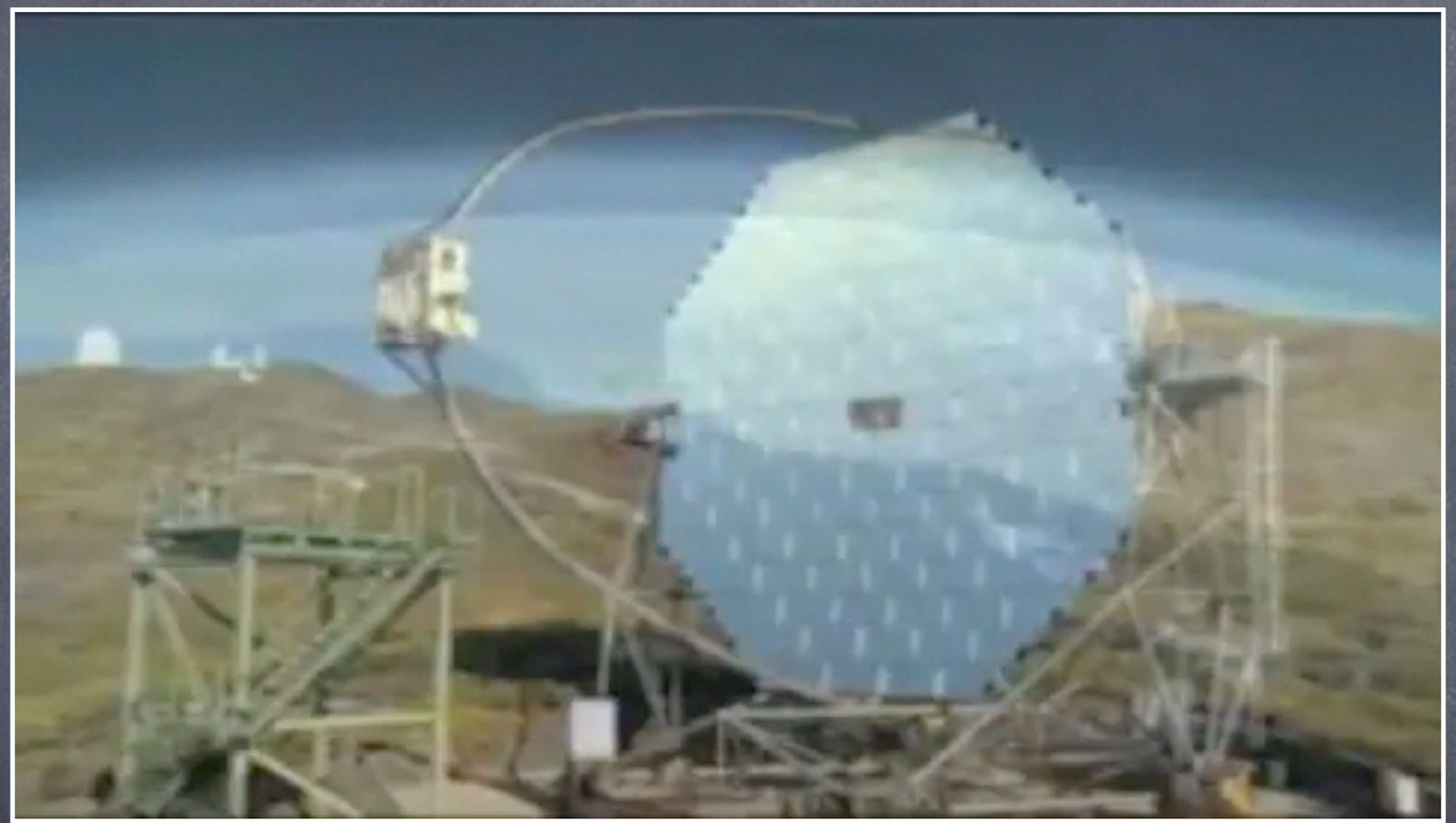


Raggi gamma

Telescopi su satellite:
Fermi/LAT



Raggi gamma



Telescopi a terra:
Cherenkov

Domande!?