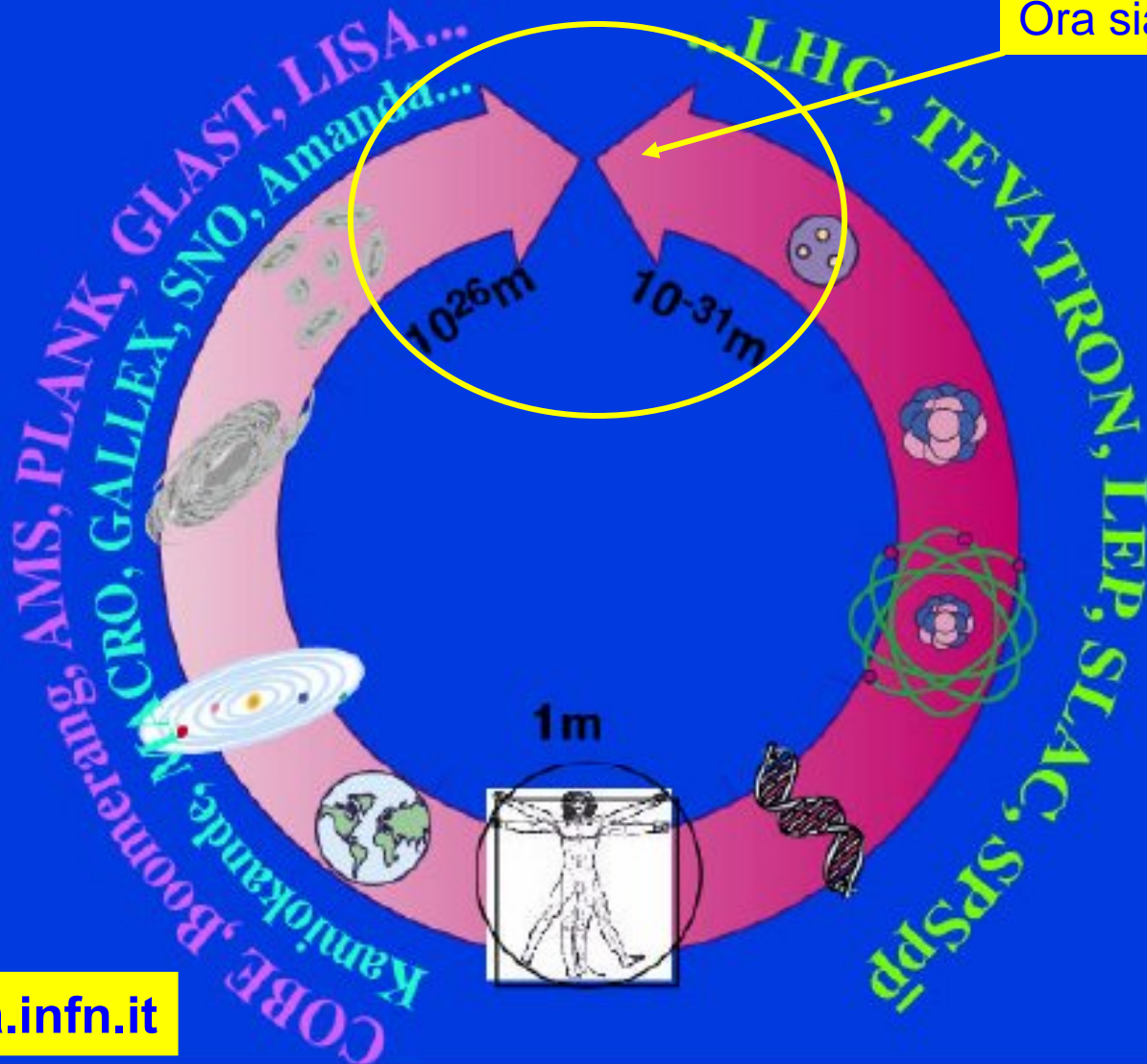


# Astro Particle Physics

La nuova Fisica

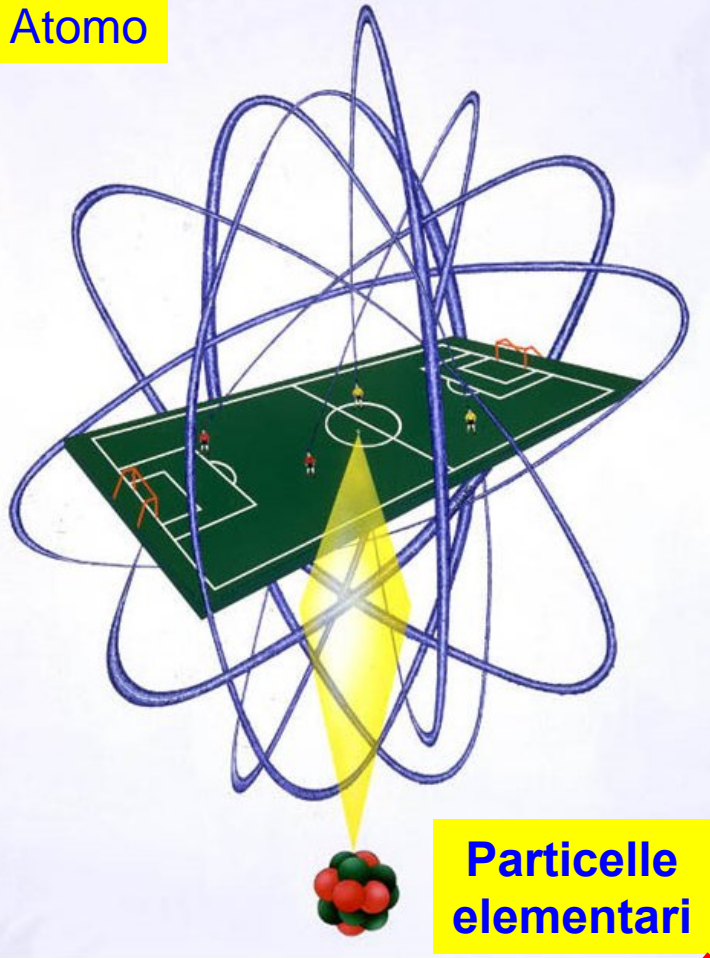
Ora siamo qui



barbarino@na.infn.it

# Estremi limiti della materia a noi nota

Atomo



Particelle  
elementari

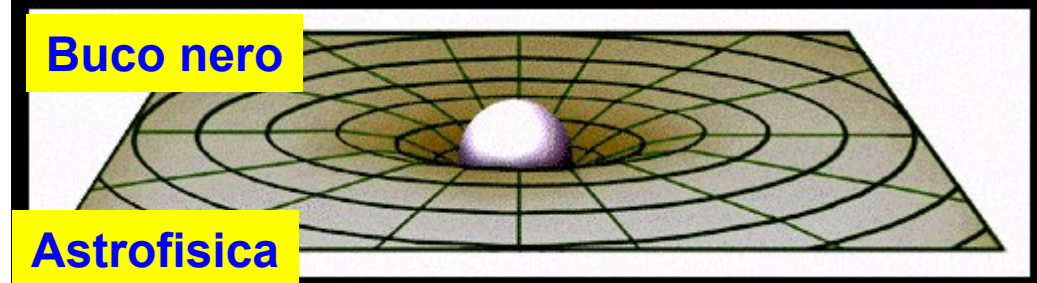
Peso un  $\text{cm}^3$  di materia  
terrestre = grammi

Verifica ad energie estreme delle  
Interazioni fondamentali delle  
**particelle elementari.**

Teorie delle interazioni fondamentali  
per spiegare **fenomeni astrofisici**

Buco nero

Astrofisica

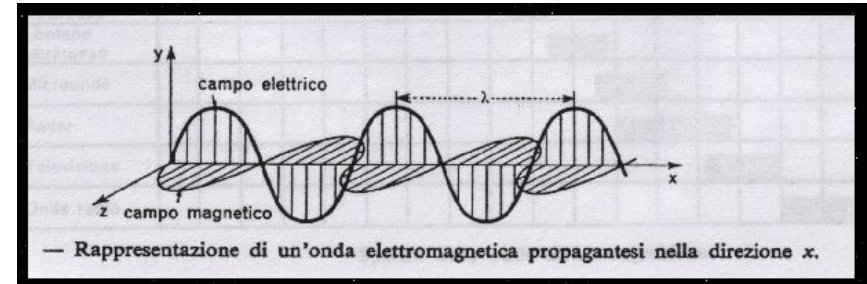
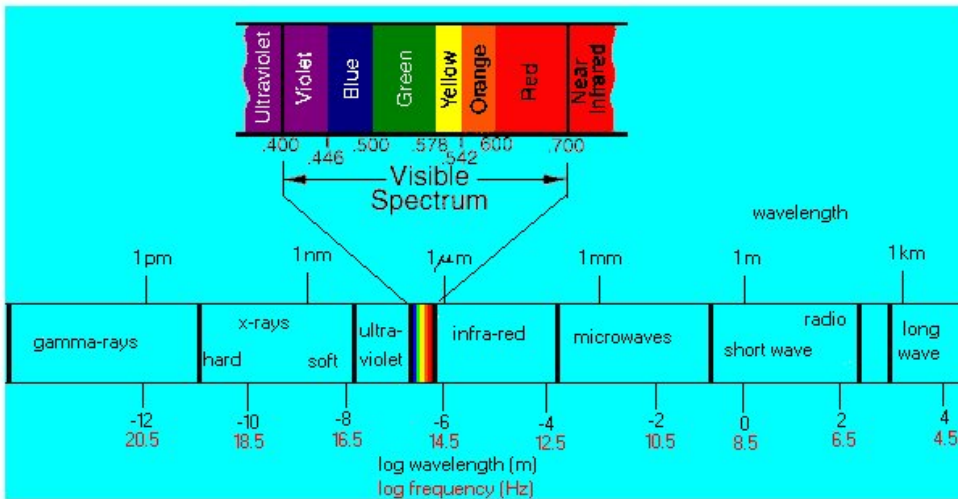


Peso un  $\text{cm}^3$  di materia  
di buco nero = 1 miliardo di  
tonnellate

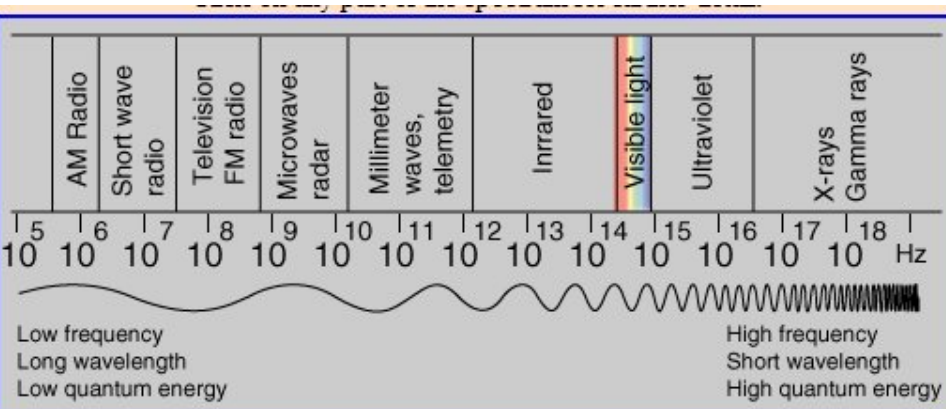
**Astroparticelle**

**L' universo diventa il nostro laboratorio: studiamone radiazioni e particelle**

# Lo spettro di frequenze della radiazione elettromagnetica dallo spazio



**RADIAZIONE = Onda elettromagnetica**  
**ma anche = flusso di particelle  $E=h\nu$**



+ Particelle elementari, p, e,  $\pi$

**Natura della radiazione**  
**Ondulatoria corpuscolare**  
**Interferenza fotoelettrico**  
**diffrazione Compton**

**$c = v\lambda$**  Also commonly written  $v = f\lambda$  Speed of light  
*velocity = frequency x wavelength*  **$c = 3 \times 10^8$  m/s**

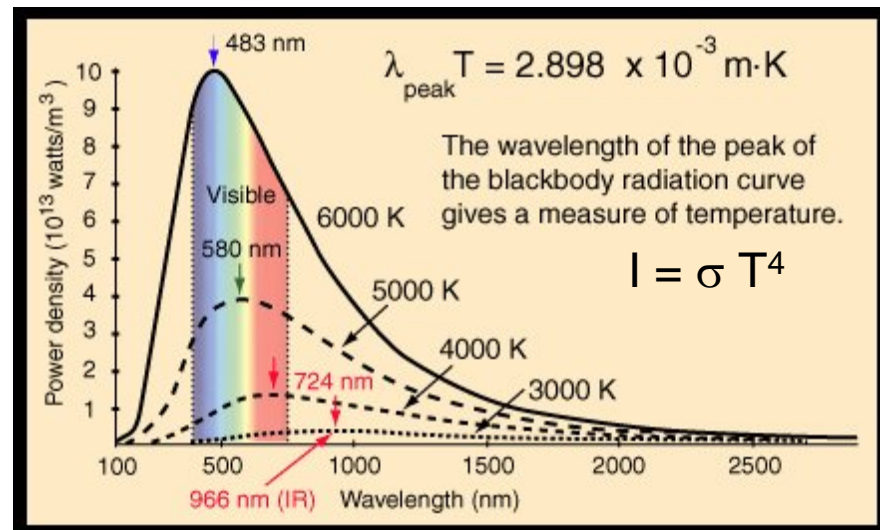
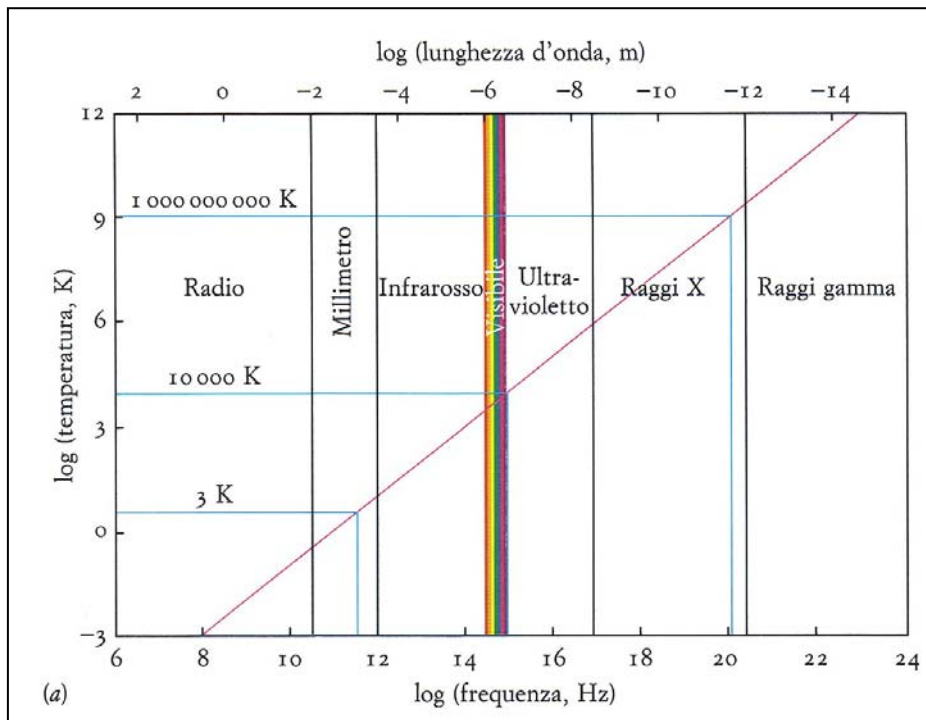
# Fisica delle Astroparticelle

## temi rilevanti di indagine

I telescopi che rivelano ogni componente dello spettro di radiazione permettono di Indagare fenomeni fondamentali ancora non compresi come:

- Radiazione Cosmica di Fondo (**CMB**)
- Gamma Ray Burst (**GRB**):  $\gamma$ , X da sorgenti astrofisiche
- Esistenza di **antimateria** nel cosmo
- Materia oscura**

# Correlazioni **frequenze-temperature** della radiazione elettromagnetica dallo spazio

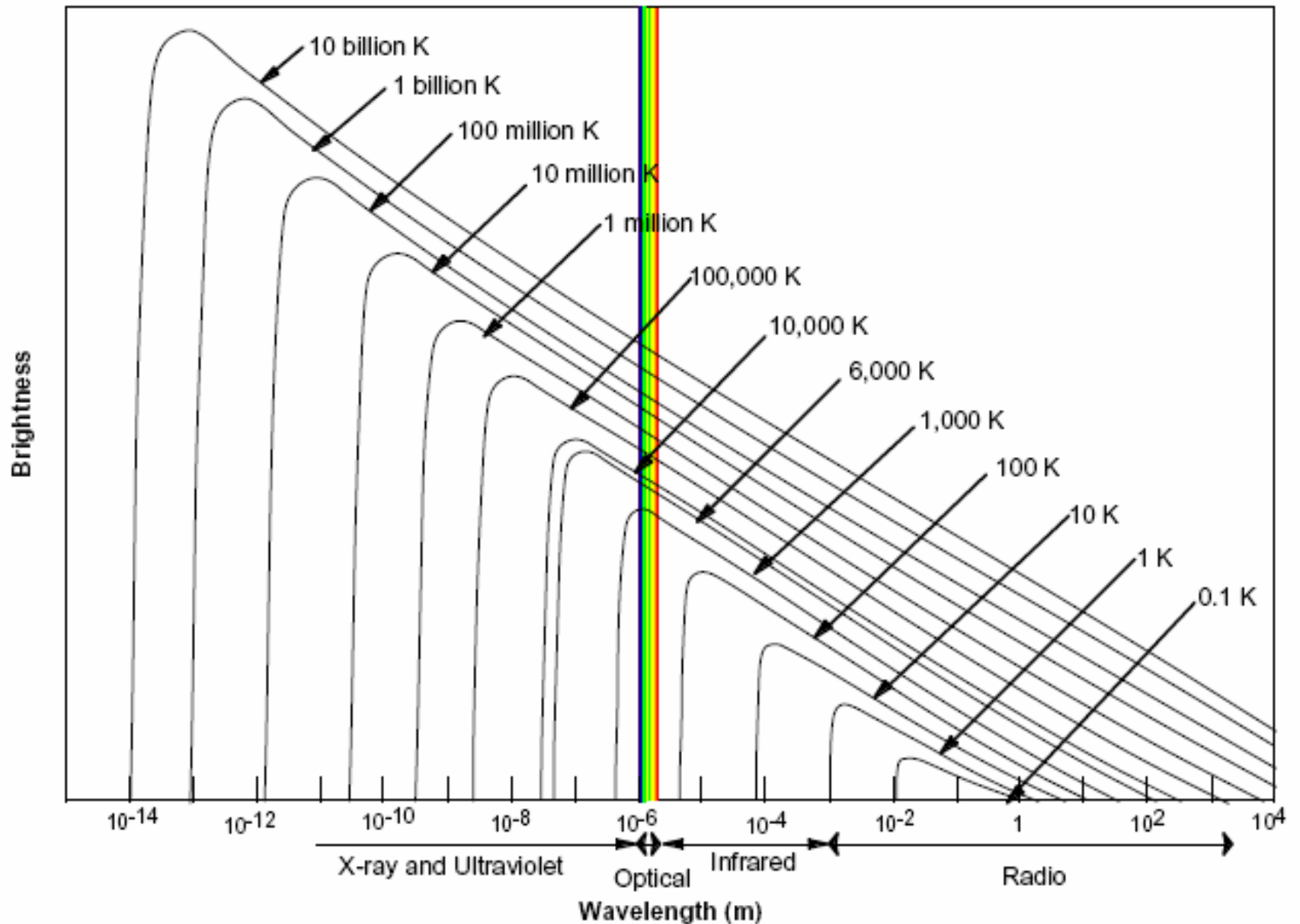


Vogliamo conoscere la attuale  
**Temperatura di insieme** dell' Universo

Corpo a temperatura **T**  
 -emette **radiazione**  
 -microoscillatori quantizzati  
 -emettono/assorbono  $E=h\nu$   
 Esempi:  
 -**radiazione cosmica di fondo**  
 -**temperatura stelle (sole)**

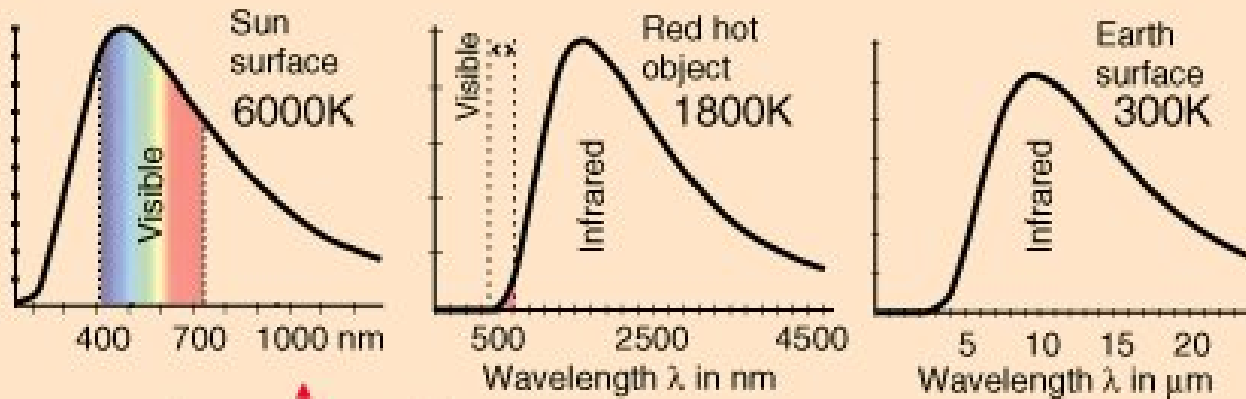
Nuove temperature accessibili in astronomia: stelle, buchi neri, galassie.....

# Brightness of Electromagnetic Radiation at Different Wavelengths for Blackbody Objects at Various Temperatures



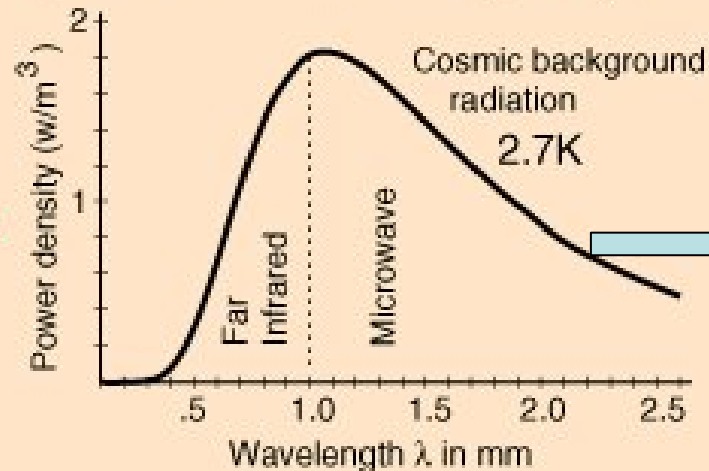
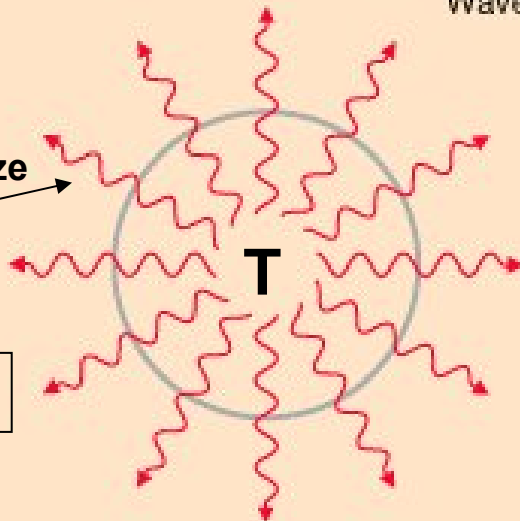
# Radiazioni da sorgenti a temperatura $T^\circ$

## The 3K Cosmic Background Radiation



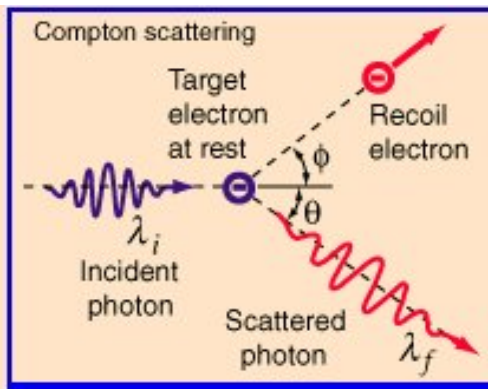
Spettro di frequenze emesso

sorgente

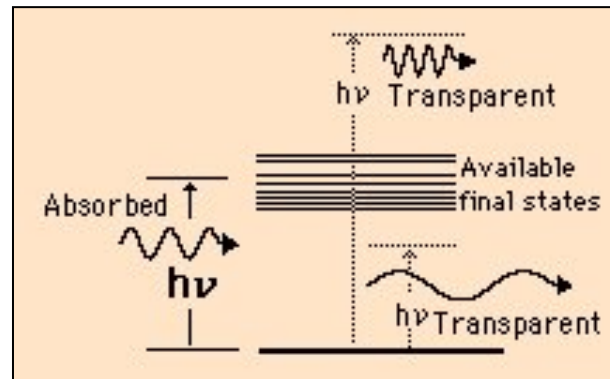


# Radiazione cosmica di fondo **CMB**

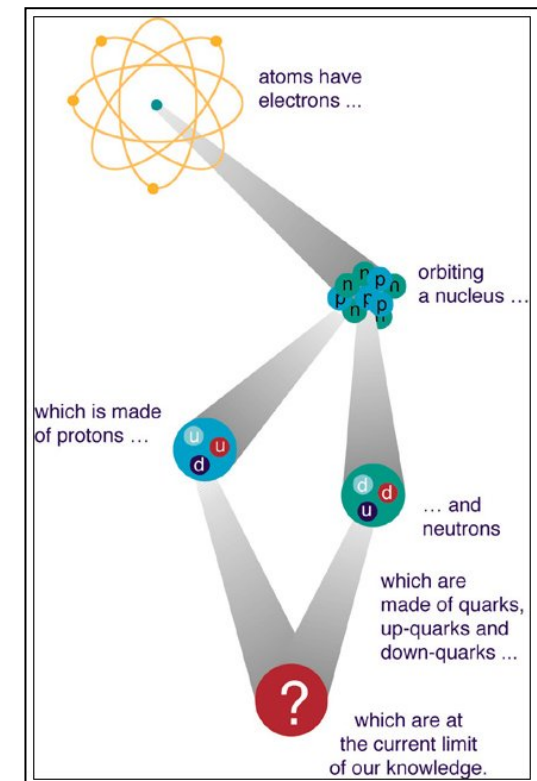
- In generale: **piu' lontano** guardiamo (distanza) **piu' indietro** andiamo (tempo) (velocita')
- ma quanto lontano?
- dopo 300000 anni** comincia la nostra era: era della **ricombinazione 3000 K°**
- prima:  
**gas ionizzato** (protoni ed elettroni separati): gas opaco, **fotoni deviati** da elettroni liberi
- dopo:  
Protoni ed elettroni formano **atomi neutri**, quasi trasparenza, i **fotoni si propagano** a noi



**Spazio opaco**  
**elettroni liberi**



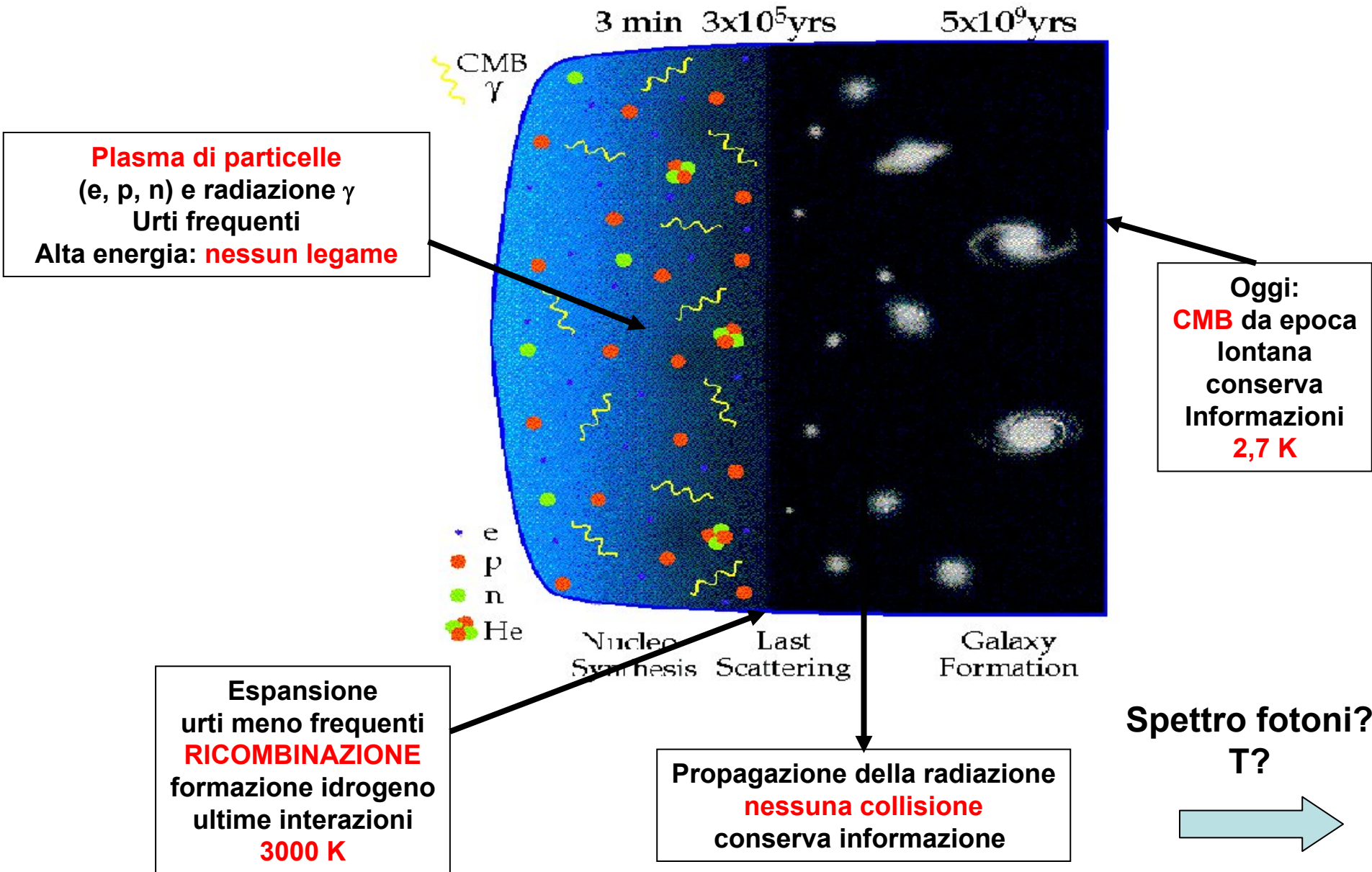
**Spazio trasparente**  
**formazione di atomi**



Vediamo ora, raffreddata per l'espansione dell'Universo, la radiazione emessa dall'ultimo scattering che non ha piu' interagito con la materia



# Radiazione cosmica di fondo CMB



**Plasma di particelle**  
(e, p, n) e radiazione  $\gamma$   
Urti frequenti  
Alta energia: **nessun legame**

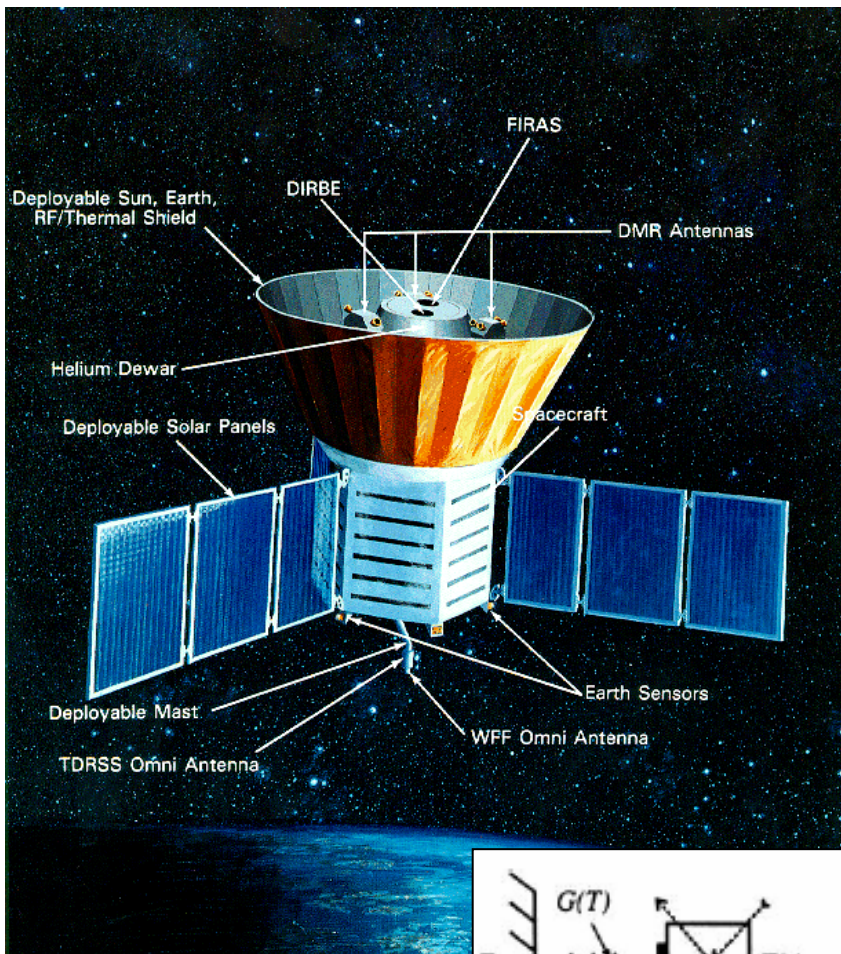
Oggi:  
**CMB** da epoca  
lontana  
conserva  
Informazioni  
**2,7 K**

Espansione  
urti meno frequenti  
**RICOMBINAZIONE**  
formazione idrogeno  
ultime interazioni  
**3000 K**

Propagazione della radiazione  
**nessuna collisione**  
conserva informazione

Spettro fotoni?  
T?  
→

# Misura della Radiazione cosmica di fondo (esperimento COBE)



3 strumenti a bordo:

DIRBE: **bolometro infrarosso**

DMR: **bolometro microonde**

FIRAS: spettrofotometro lontano infrarosso

Misurano radiazione diffusa fra:

**$1\mu\text{m} - 1\text{cm}$**

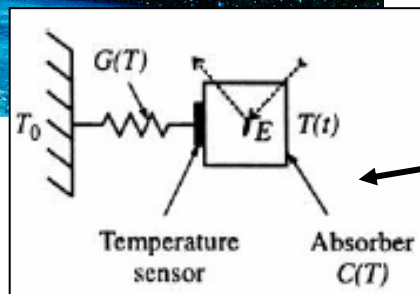
**Raffreddato** con criostato a  **$1,6\text{ K}^\circ$**

1 rot./min. Scansione del cielo/6 mesi orientato a  $90^\circ$  rispetto asse sole-terra

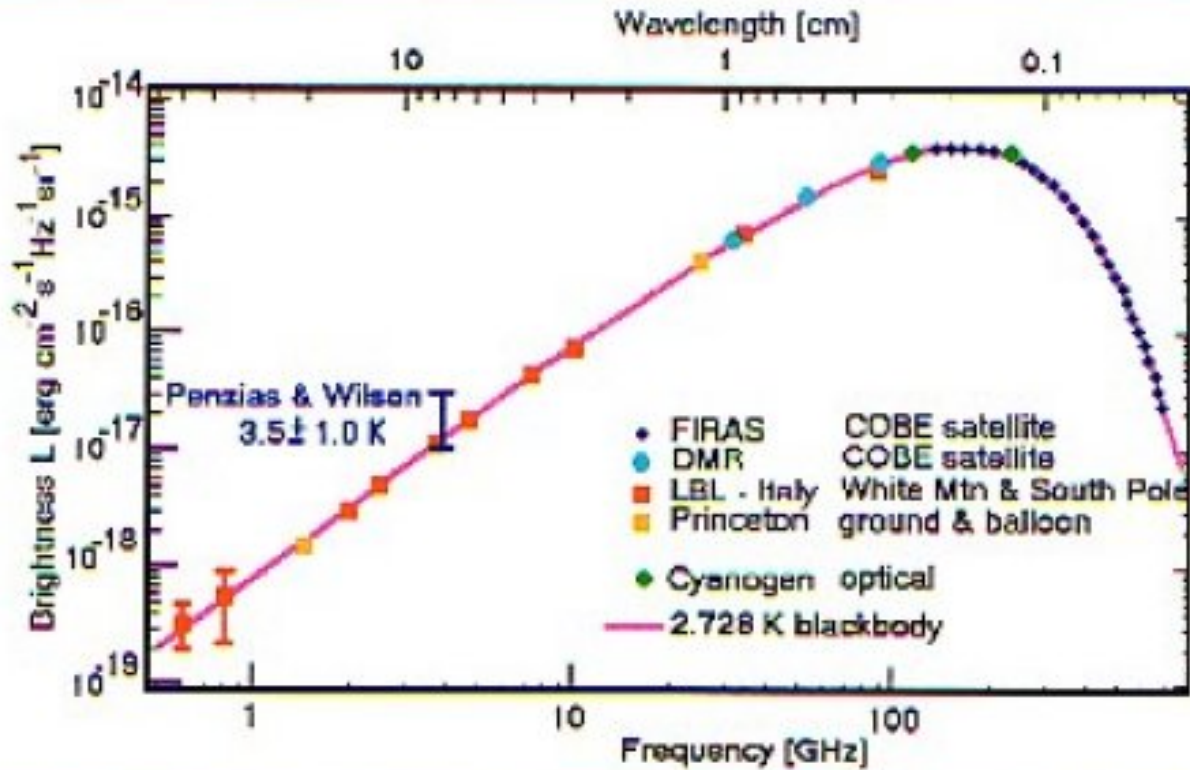
Alter missioni: successore cobe WMAP  
Boomerang, IRAS

Prossima: FIRST/PLANCK (2007)

Telescopio raffreddato e bolometri

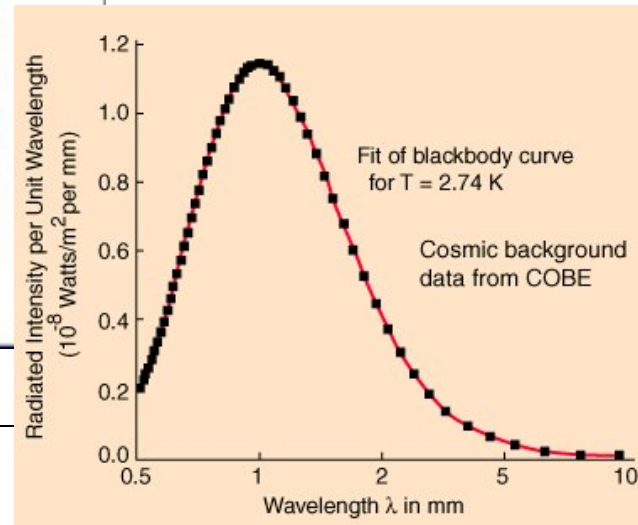


# Radiazione cosmica di fondo CMB (spettro)(esperimento COBE)



**$T = 2,73 \text{ K}^\circ$**   
**piccole anisotropie**  
**deviazioni  $1/100000$**   
**da corpo nero**

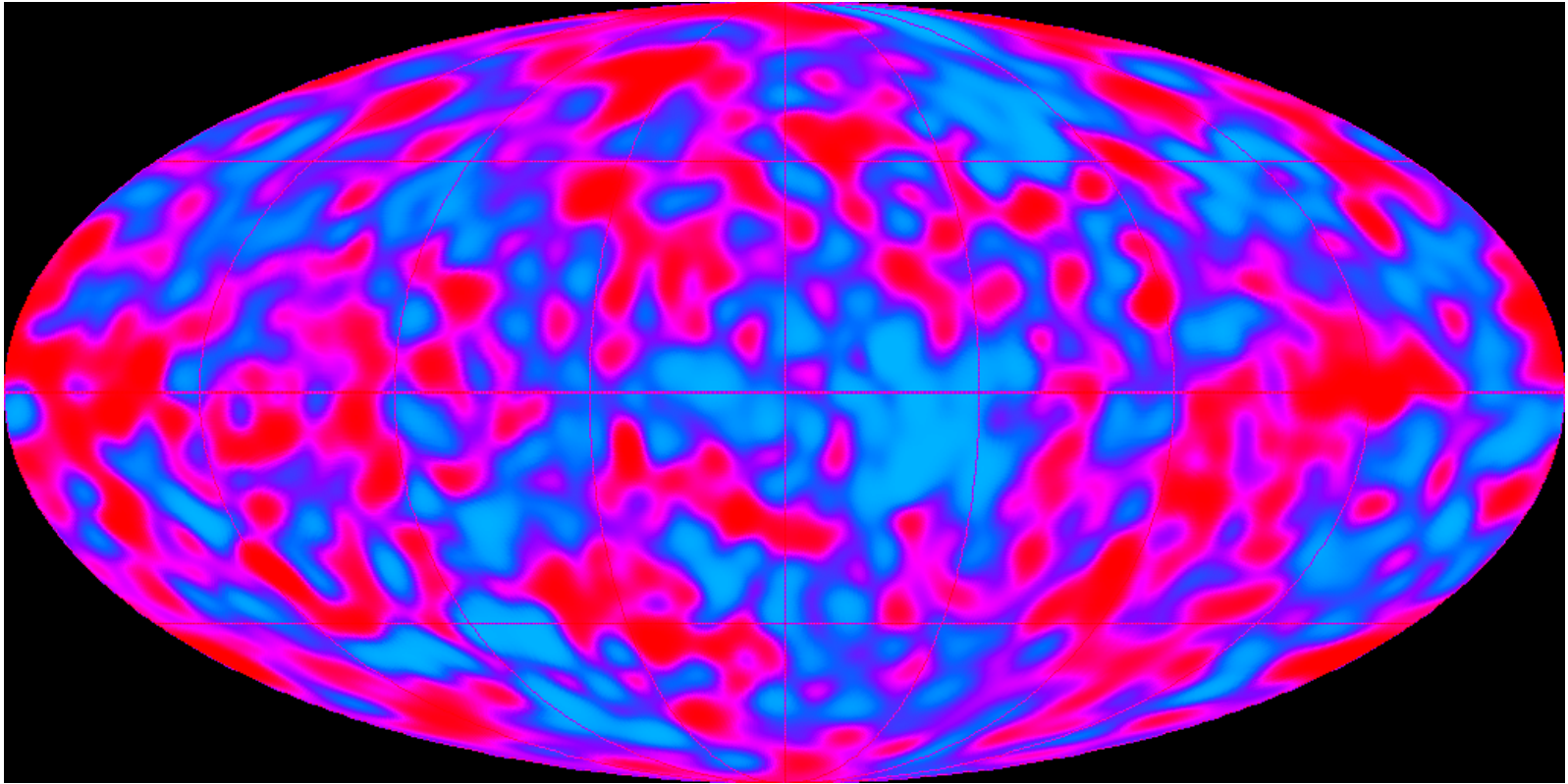
**Misure precise  
nello spazio**



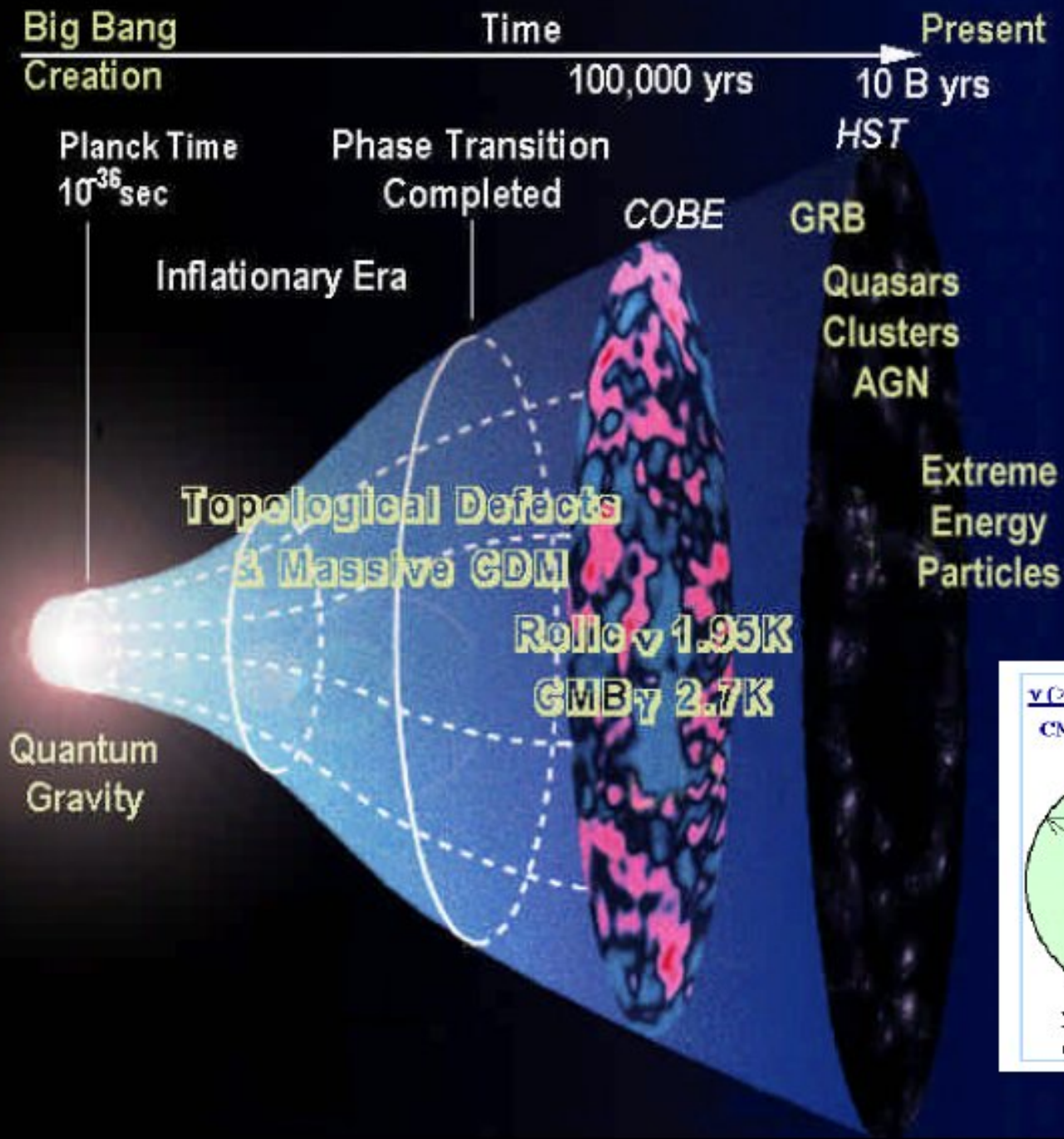
**Flusso di fotoni dal lontano universo (diffusa)**

**Differente da luce delle stelle (locale e dovuto a reazioni nucleari)**

# Misura della Radiazione cosmica di fondo (esperimento COBE)



- Mappa **temperatura del cielo** prodotta da COBE: foto del plasma particelle e radiazione (miliardi di anni fa) formazioni di atomi di idrogeno e fotoni non piu' interagenti
- Disomogeneita'(1/100000): **fluttuazioni primordiali** nella uniformita' della materia
- Instabilita' gravitazionale: inizio formazione galassie, stelle.....
- Fluttuazioni: spiegabili con le attuali teorie delle particelle? **Nuove interazioni?**



$\nu (> \text{ZeV}) + \nu_{1.95\text{K}} \rightarrow Z_0 \rightarrow 30 \gamma + 2.7 N + 28 \pi$

CNB in Cluster generates Super-GZK cosmic rays

$R_{\text{GZK}} < 50 \text{ Mpc}$

**ZeV Cosmic  $\nu$  from TD, CDM, GRB & AGN**

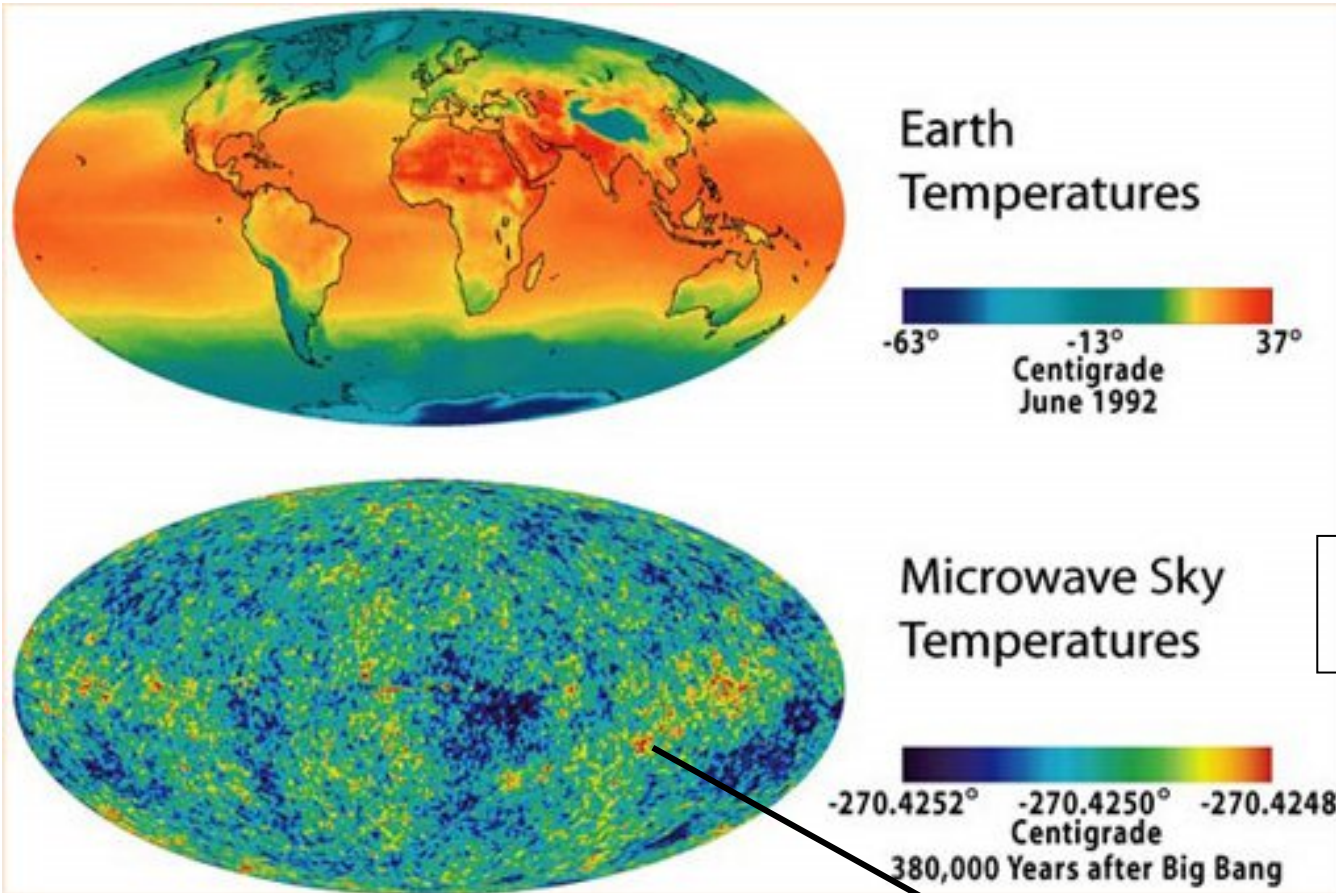
Relic  $\nu$

$\gamma, N$  Cascade

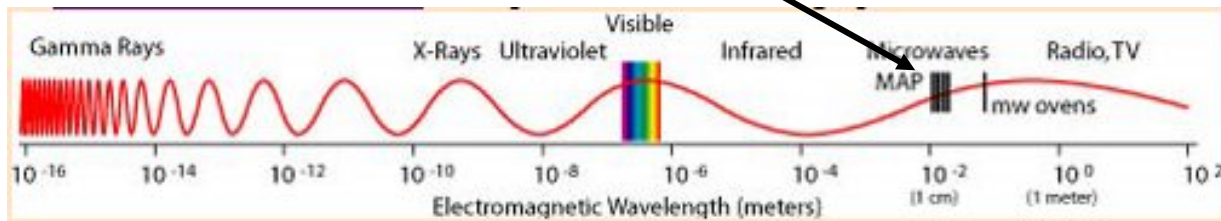
$N_\nu (\text{Relic}) > 100 \times 54/\text{cc}$   
( $L/\lambda_{\nu\nu} \approx 1\%$ )

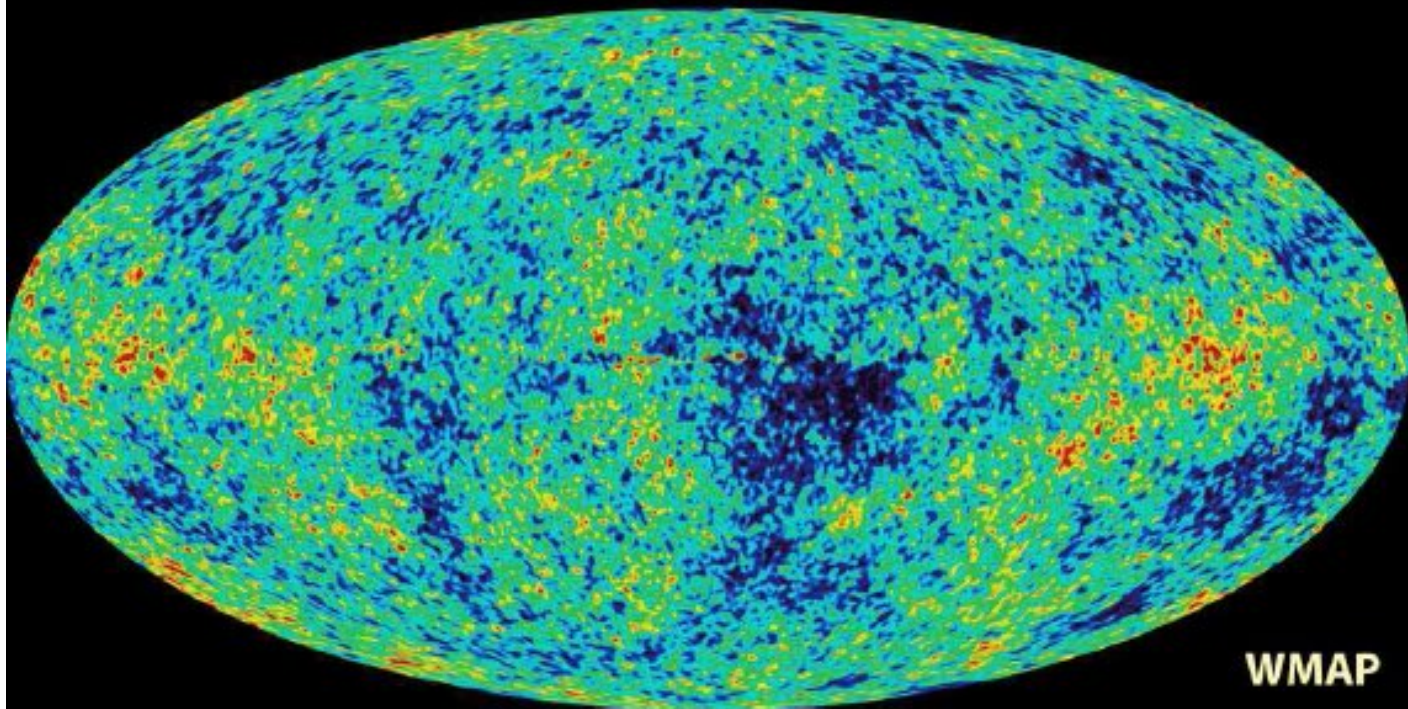
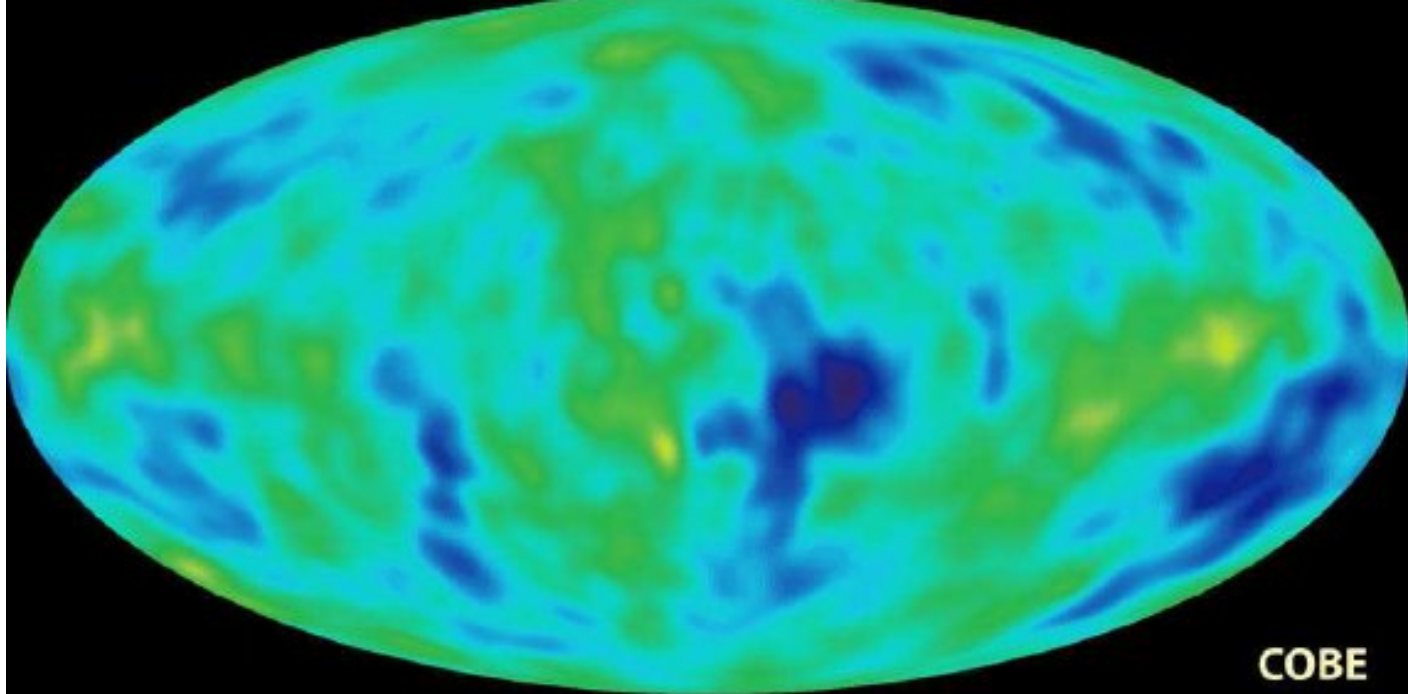
$\nu + \bar{\nu} \rightarrow Z_0 \rightarrow \gamma + \gamma$

# Misura della Radiazione cosmica di fondo (esperimento WMAP)



**T = 2,73 K°**  
**Sensibilita' 20mk°**





# Prossima missione per la misura della radiazione cosmica di fondo:

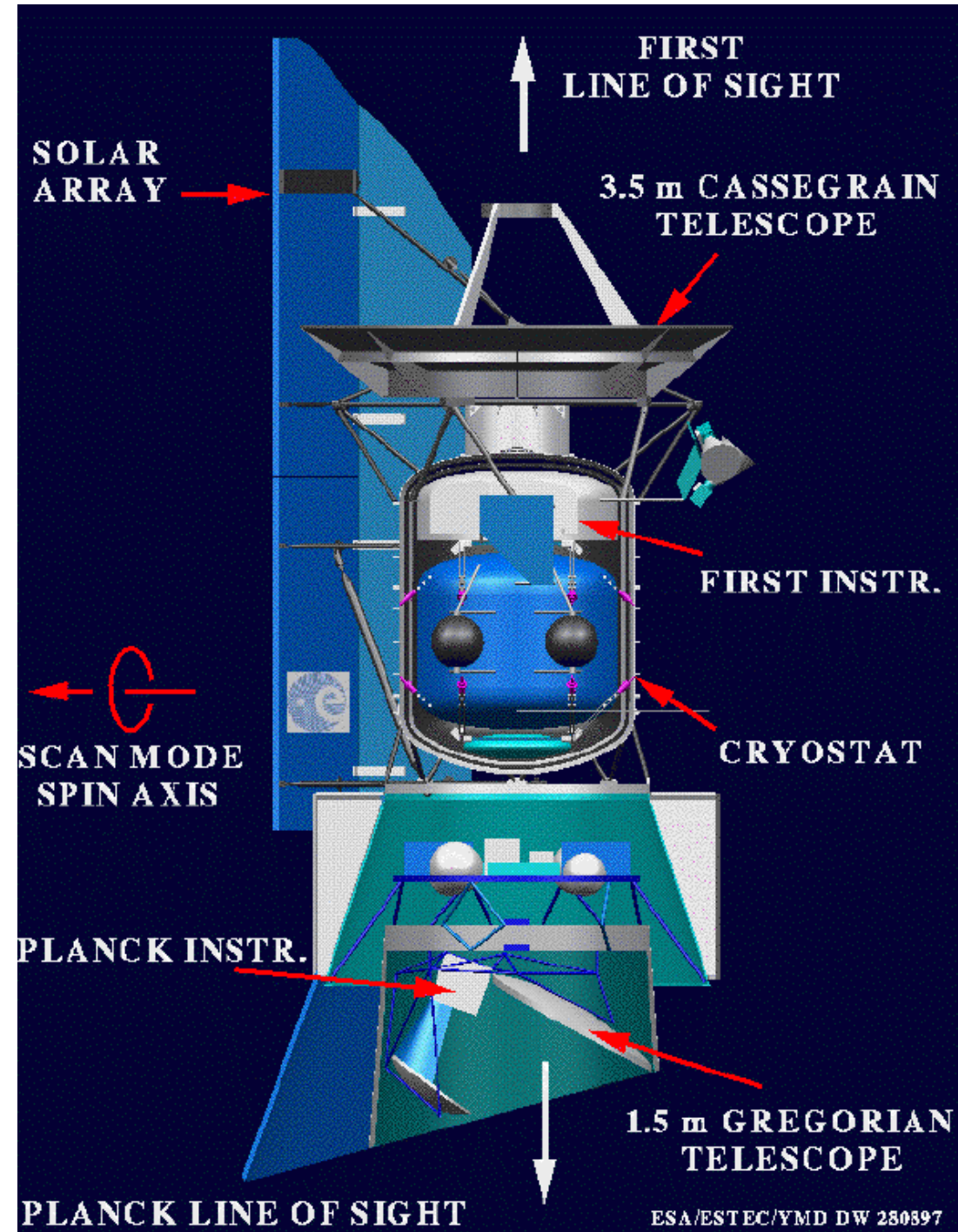
## PLANCK



- Rivelatore radio a  $T = 20$  K
- Rivelatori a bolometri a  $T = 0,1$  K
- Telescopio da 1,5 metri diametro  
1 rot/min.

**$-\Delta T/T = 10^{-6}$**  (misura e origine  
fluttuazioni radiazione  
cosmica di fondo)

- Fisica delle particelle a  
 $E > 10^{15}$  GeV
- materia oscura?





# PLANCK



# Lo spettro di osservazione dei processi astrofisici

Il cielo appare **diverso** a seconda della parte di **spettro elettromagnetico** osservato

Esistono numerose fasi **evolutive stellari non visibili nell'ottico** tipicamente fasi turbolente invisibili ai nostri occhi



L'Astronomia **visibile** osserva la parte più "tranquilla e stabile dell'Universo"  
Luce emessa dalle **superfici** delle sorgenti (galassie, stelle) fasi stabili

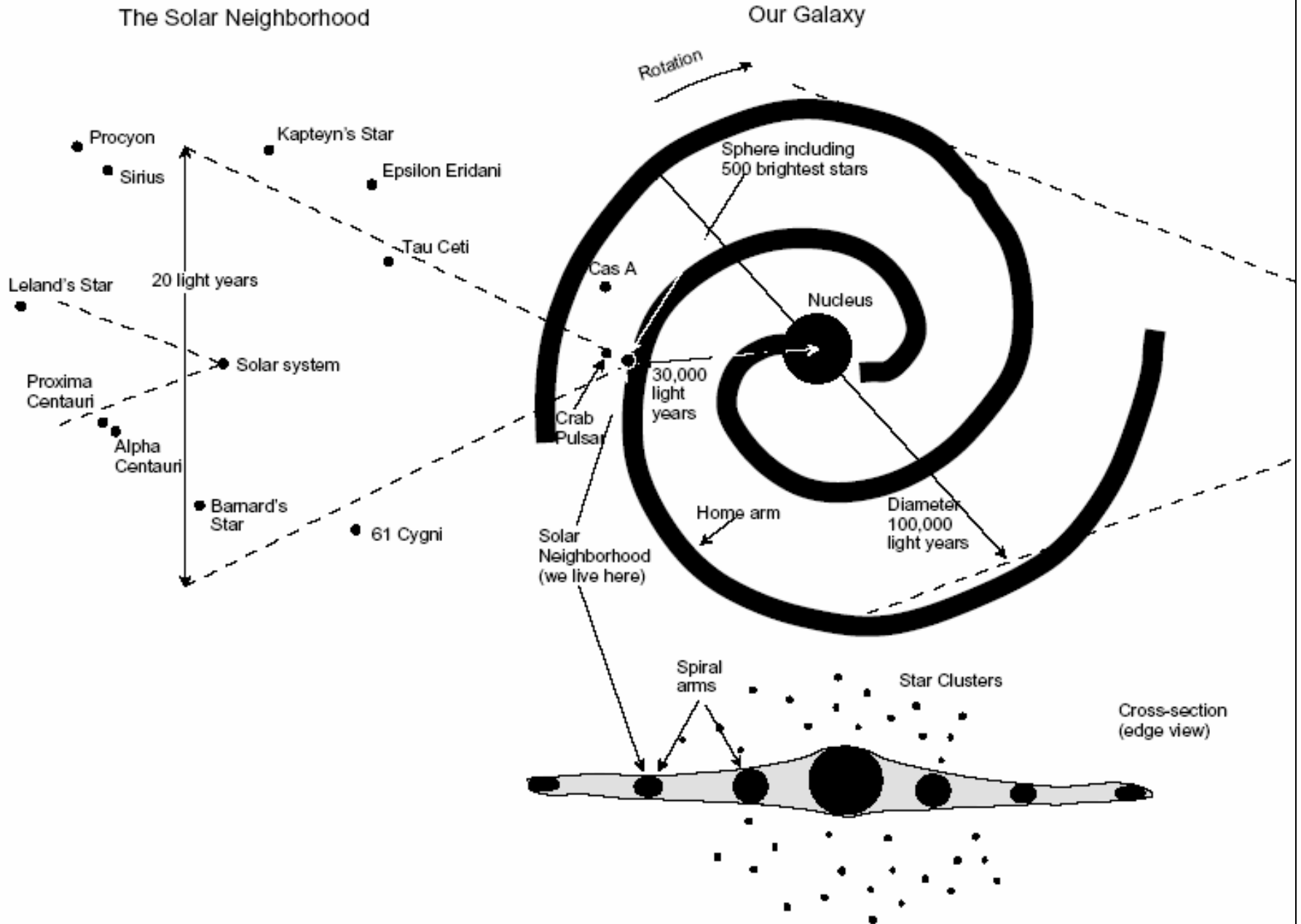


Astronomia **infrarossa** studia il debole calore emesso dalle grandi distese di **gas interstellare**. Materia fredda che collassa a formare galassie e stelle.  
Basse energie: grandi regioni di polvere interstellare

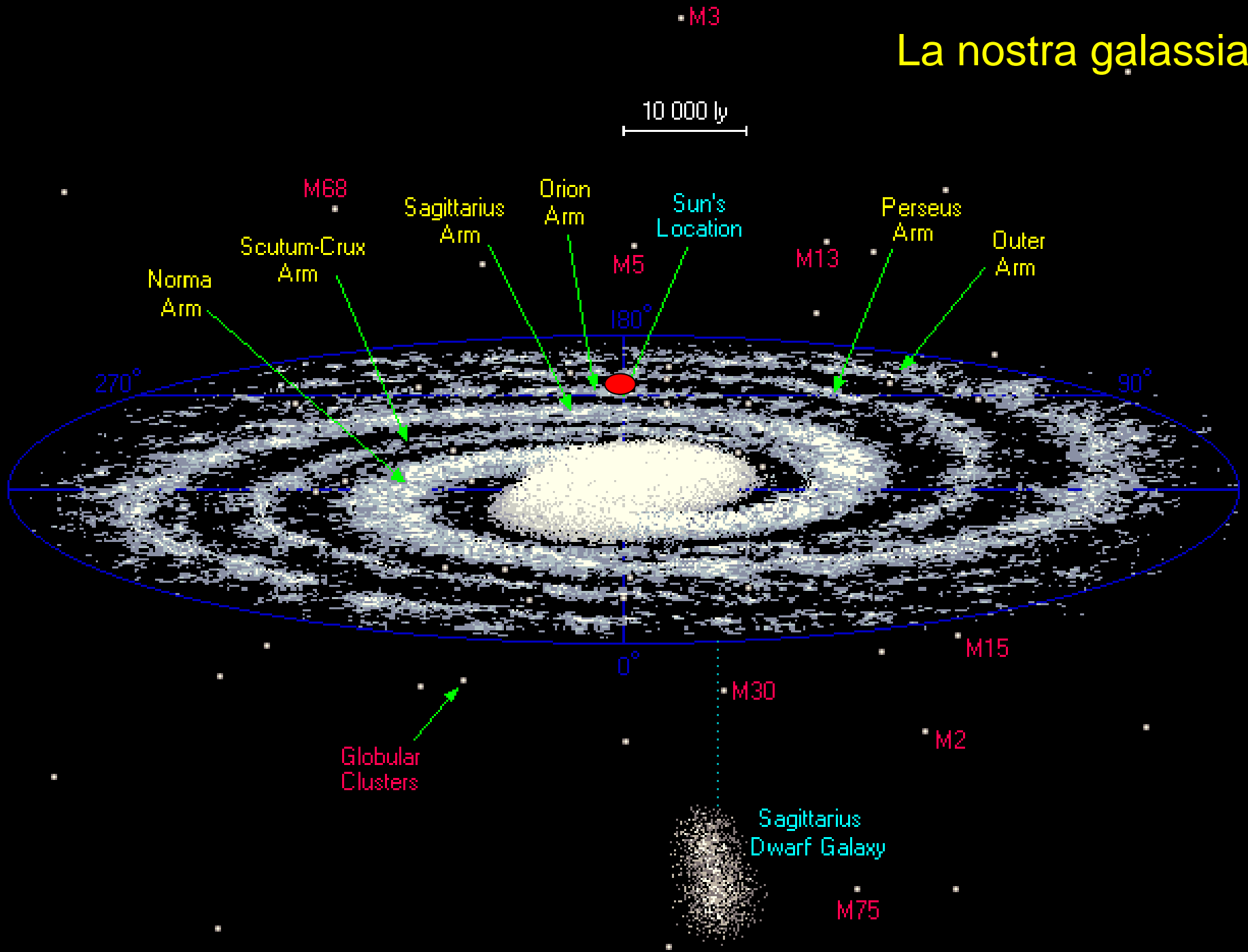


Produzione di **raggi X,  $\gamma$**  coinvolgono enormi energie. Queste astronomie studiano **regioni tormentate** che sono e furono sedi di esplosioni.  
Alte energie = **fenomeni locali intensi (vita di una stella)**

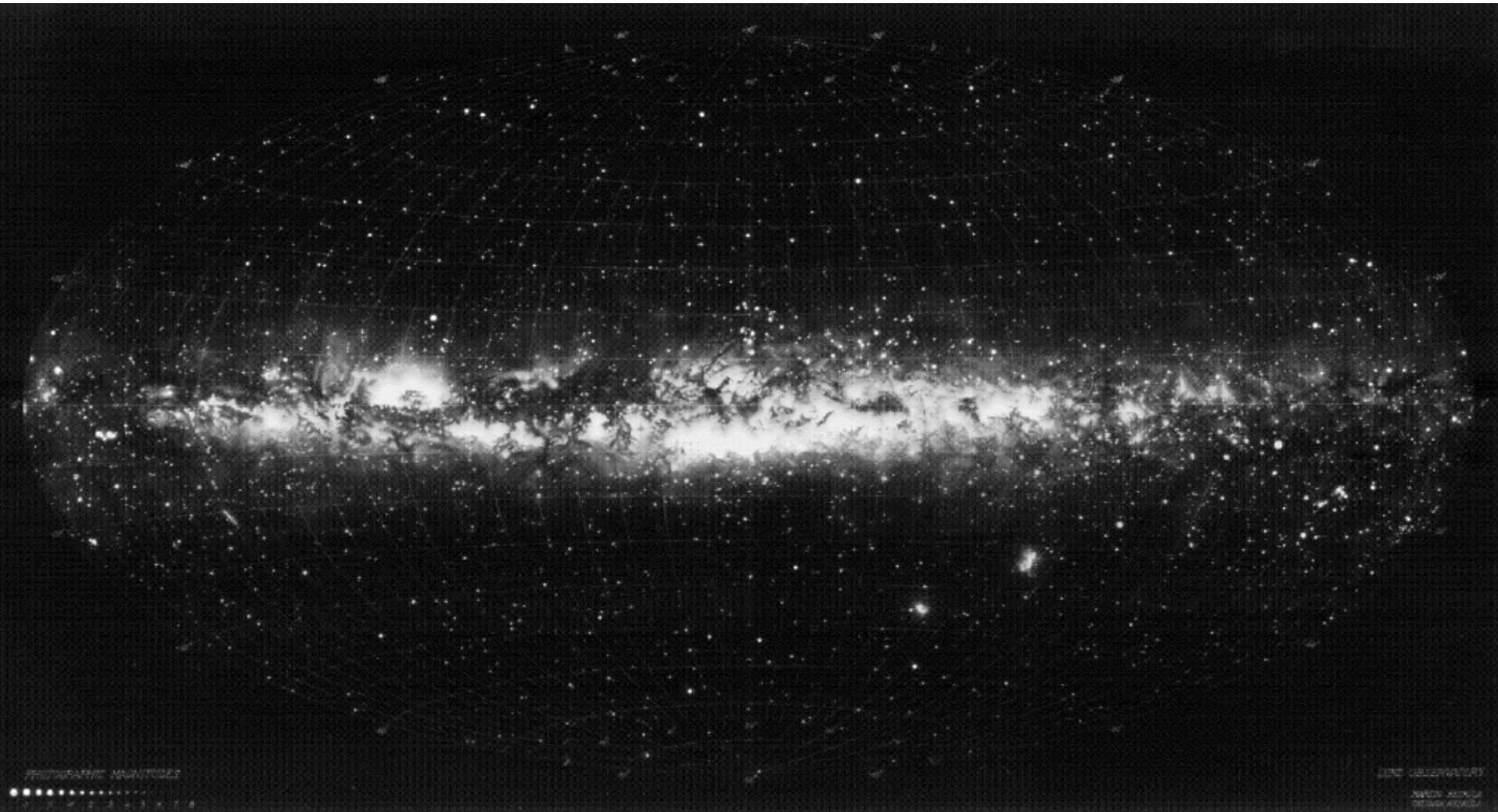
# La nostra galassia



# La nostra galassia



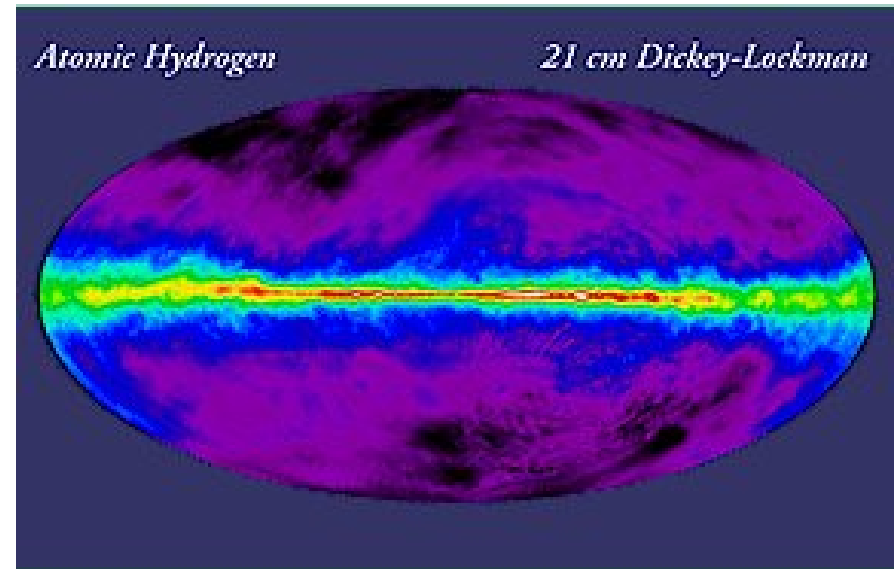
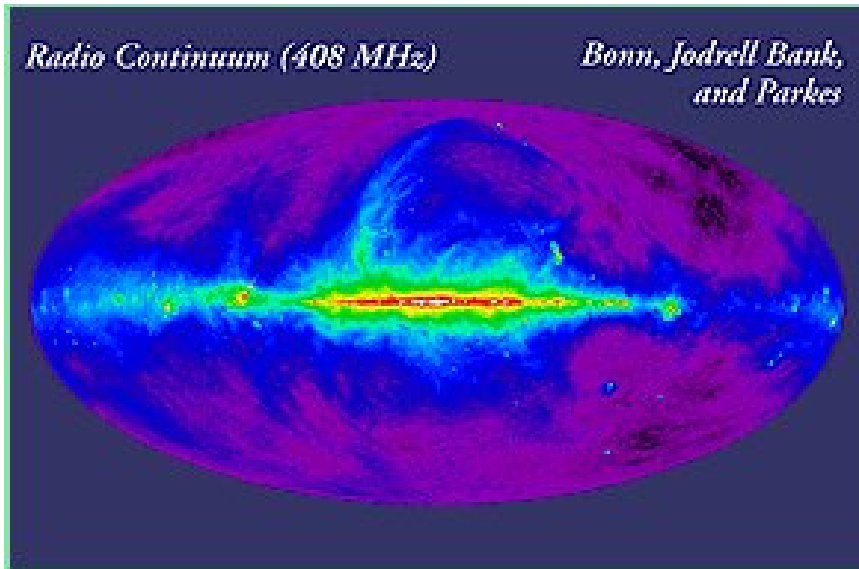
# La nostra galassia alle frequenze ottiche



# Evoluzioni stellari (1)

**Galassie:** fatte di stelle e mezzo interstellare tenuti insieme da **forze gravitazionali**

**Stelle:** nascono da **contrazioni di nubi molecolari:** gas e polveri. Le regioni piu' dense collassano per **gravita':** regioni di emissione radio, microonde, **infrarosso 10-20 K°.**



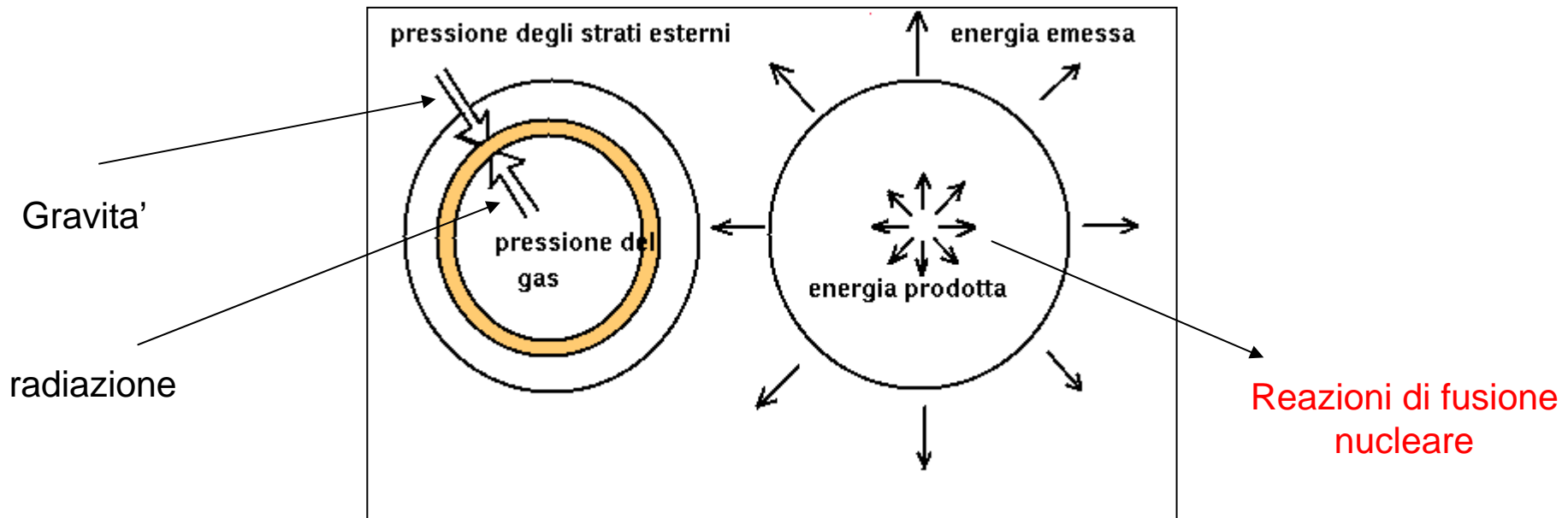
Formazione di **protostella** al centro della nube, **per gravita' la densita' aumenta**, il gas diventa opaco e la **temperatura sale**. Inizio **reazioni nucleari H, He**. Per  $T = 10^6$  K **Equilibrio fra forza gravitazionale e e pressione interna di riscaldamento**. Rimozione mediante riemissione termica dell'energia cinetica del materiale di caduta.

Emissione **Infrarossa** e microne dal materiale, tipicamente **100-300 K°**

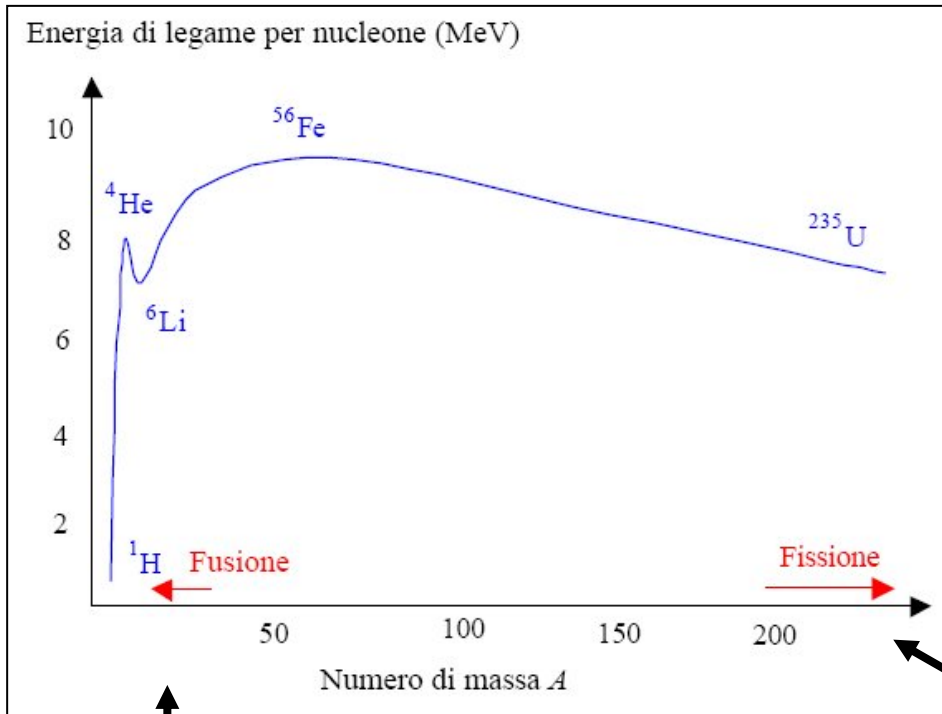
# Evoluzioni stellari (2)

## Fine della vita di una stella

- Processo fondamentale all'interno della stella: **reazioni di fusione nucleare** → **M**
- Stelle di grande massa: **maggiore massa collassante-maggiore temperatura interna-** maggiori **fusioni nucleari** (T) → maggiore raggio e **superficie** per equilibrio termico-maggiore luminosita'
- Continuo **equilibrio tra forza gravitazionale e pressione del gas**
- Grandi masse (>60 MSole) e piccole masse (<0,08MSole) instabili.

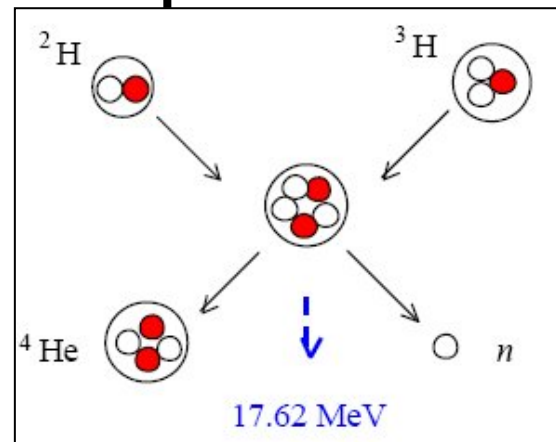
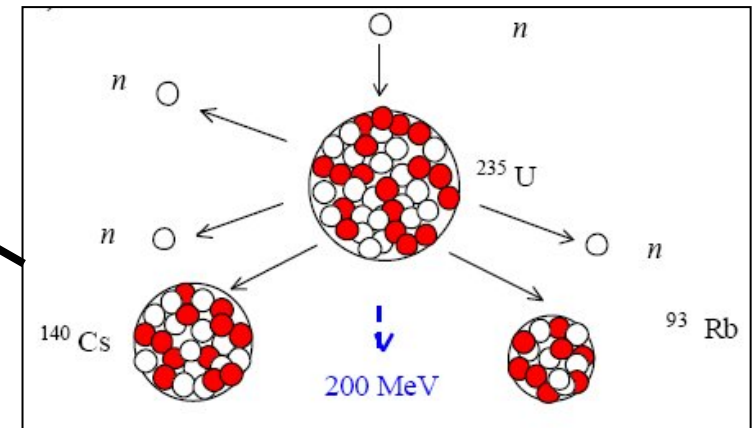


# Evoluzioni stellari (3): la fusione nucleare



Nuclei costituiti da masse **protoni** e **neutroni**. Per essere legati una parte di massa va in energia di legame  $mc^2$

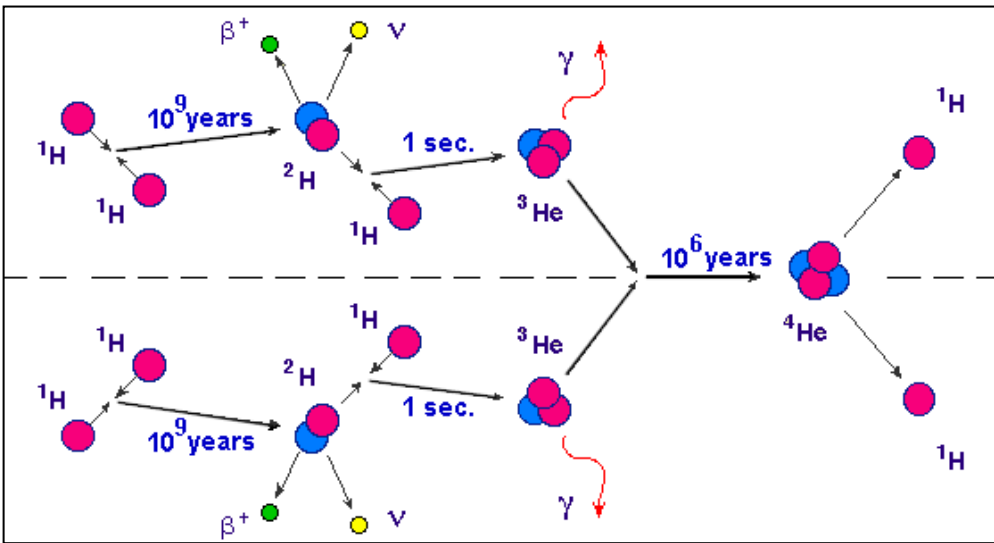
**Fissione:** rottura di nuclei pesanti  $M_i > M_f \rightarrow \Delta E$



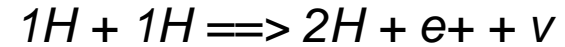
**Fusione** di nuclei leggeri:  
 $M_i > M_f \rightarrow \Delta E$



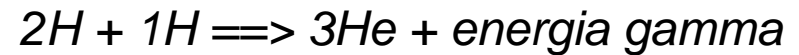
# Evoluzioni stellari (4): cicli di fusione nella stella



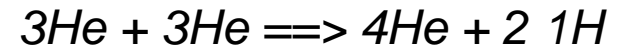
## Catena protone-protone



(protone + protone  $\implies$  deuterio + positrone + neutrino)  
6 ML K° 10<sup>10</sup> anni

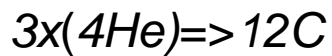


(deuterio + protone  $\implies$  elio 3 + fotone)  
15 ML K° sec.

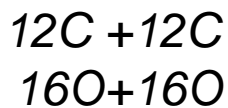
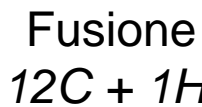


(elio 3 + elio 3  $\implies$  elio 4 + protone + protone)  
10<sup>6</sup> anni

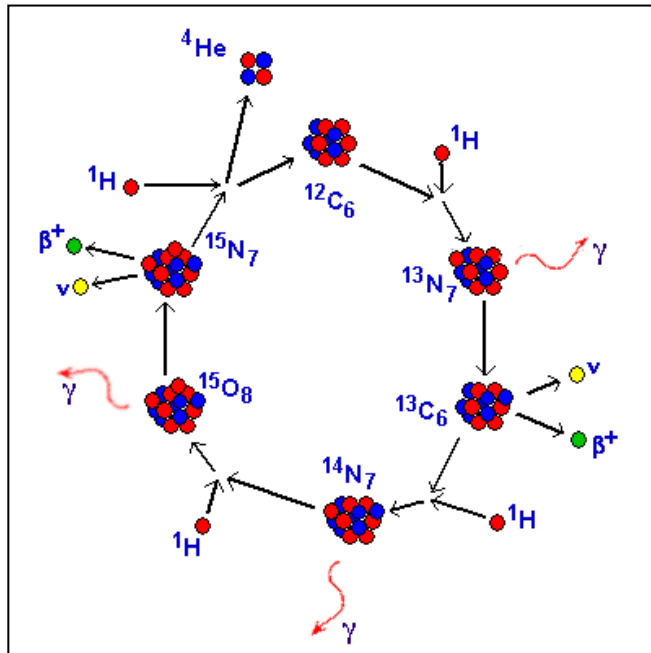
## Ciclo CNO



Nella stella 12C



GL K°

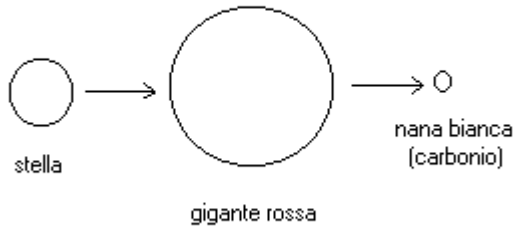


- Contrazione **gravitazionale**
- Aumento di **temperatura**
- Innesco **reazioni termonucleari**
- Espulsione di **radiazione**
- Per stelle di **grande massa:**  
Fusione fino al **ferro**
- collasso** per gravita'
- Nuovi equilibri

# Successive evoluzioni stellari

3 tipi di evoluzione legati alla massa della stella

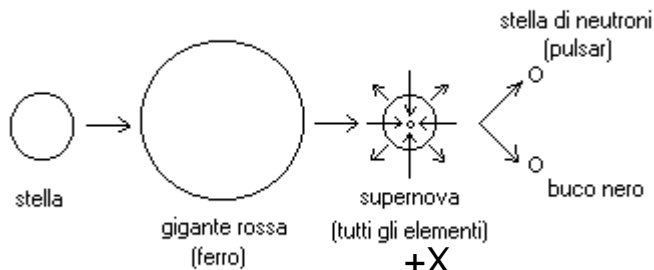
massa < 7 masse solari



(dimensioni non in scala)

**Stelle da 1-4 masse Sole:** Fusione fino a Carbonio, Ossigeno, **NANE BIANCHE** stabilita' data dalla pressione di elettroni 1,4 Masse Sole. **Emissione X e materia**

massa > 7 masse solari



(dimensioni non in scala)

**Stelle da 4-10 masse Sole:** Fusione fino a Ferro e Nichel e gusci di elementi leggeri, H, He. Se La massa > 1.4 masse Sole, forte contrazione,  $p + e^- \Rightarrow n + \nu_e$  neutronizzazione, riduzione pressione elettronica, alta temperatura, **rottura nuclei Fe**, stella di neutroni, **implode**, T sale, **esplosione**. Emissione particelle, **N, X,  $\gamma$**

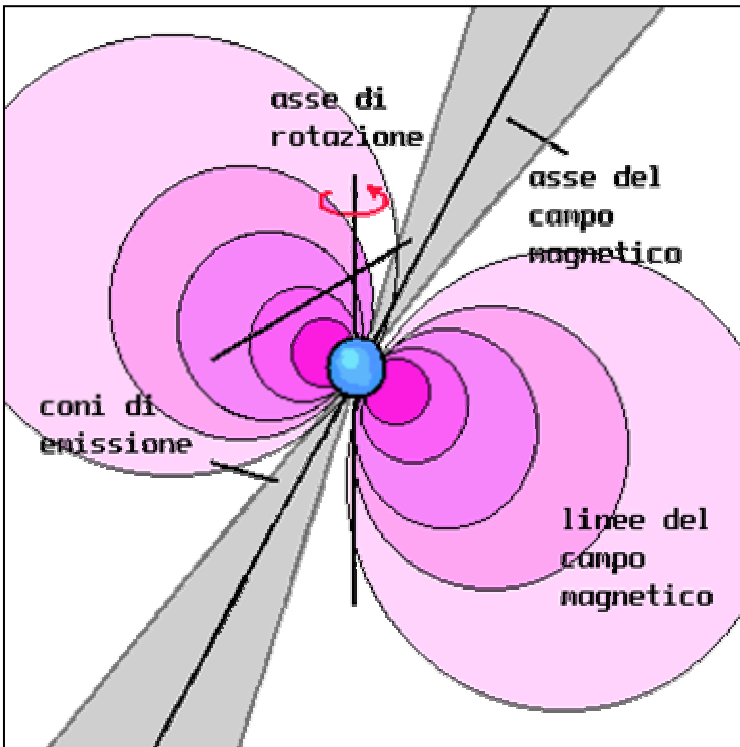


**Stelle da 5-10 masse Sole.** Nucleo con massa Residua > 3 masse Sole. Continua **collasso**. Altissima energia tale da formare materia-antimateria Annichilazione o assorbimento di una componente. **Emissione particelle X,  $\gamma$**

# Come osservare le evoluzioni stellari

Raramente direttamente. Spesso da effetti che producono

**PULSAR ISOLATE**  
stelle di neutroni in rotazione



**Magnete rotante non allineato**: dipolo magnetico  
**Campi elettrici indotti** intensi: plasma ed **elettroni**  
che **sfuggono a jets**.  $H = 10^8 \text{ T}$ .  $V = 10^{16} \text{ V}$ .  
 $E_e \sim \text{MeV} \rightarrow \gamma \rightarrow e^+ e^- \rightarrow \gamma \gamma \dots\dots$   
Rotazioni: msec - sec  
**Acceleratore** cosmico di particelle: anche **protoni**

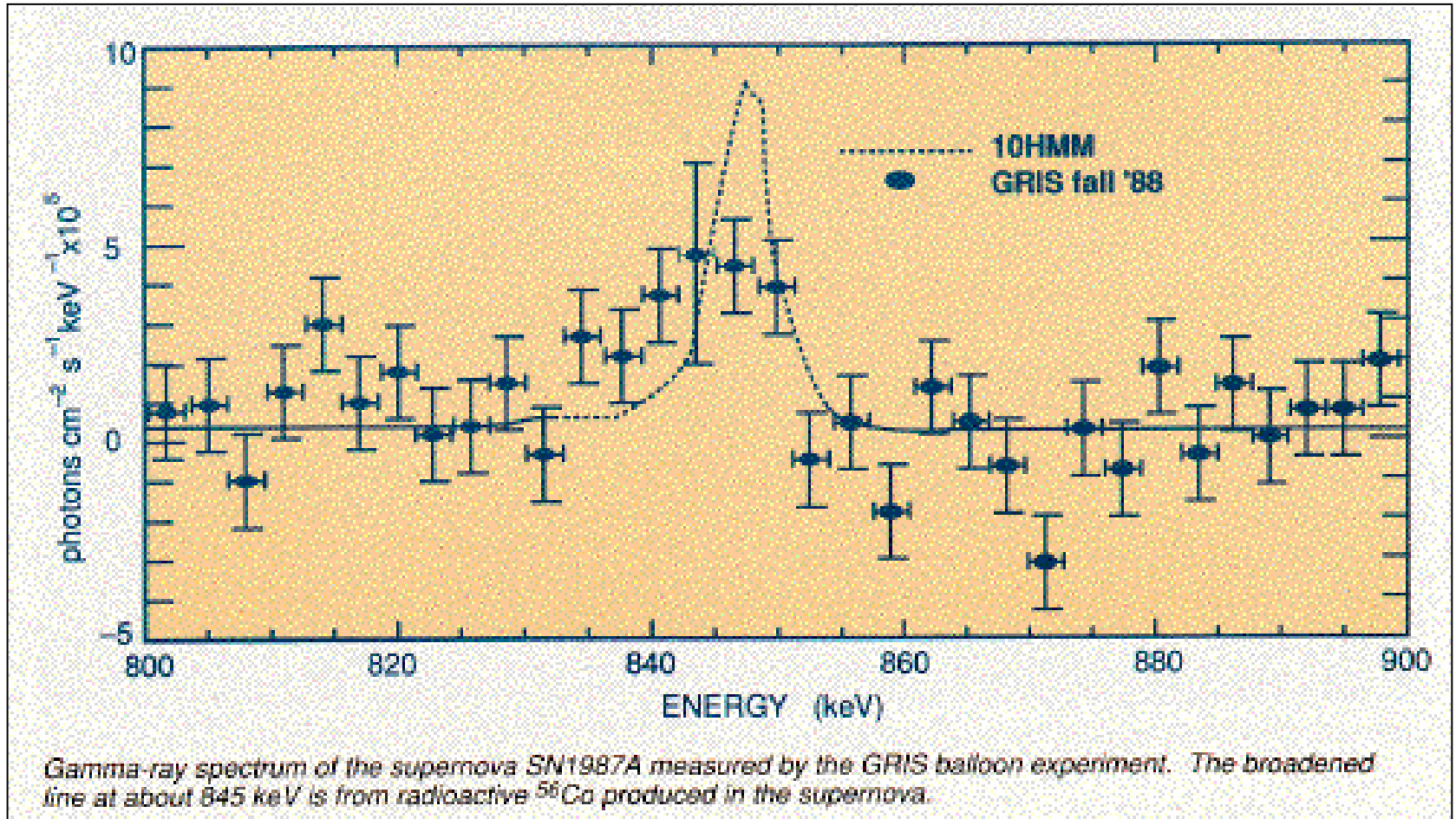
**Esperimenti**  
per **rivelare**  
**X,  $\gamma$**

**Parte espulsa** dalla stella: esplosione di **supernova**



# RESTI di SUPERNOVA

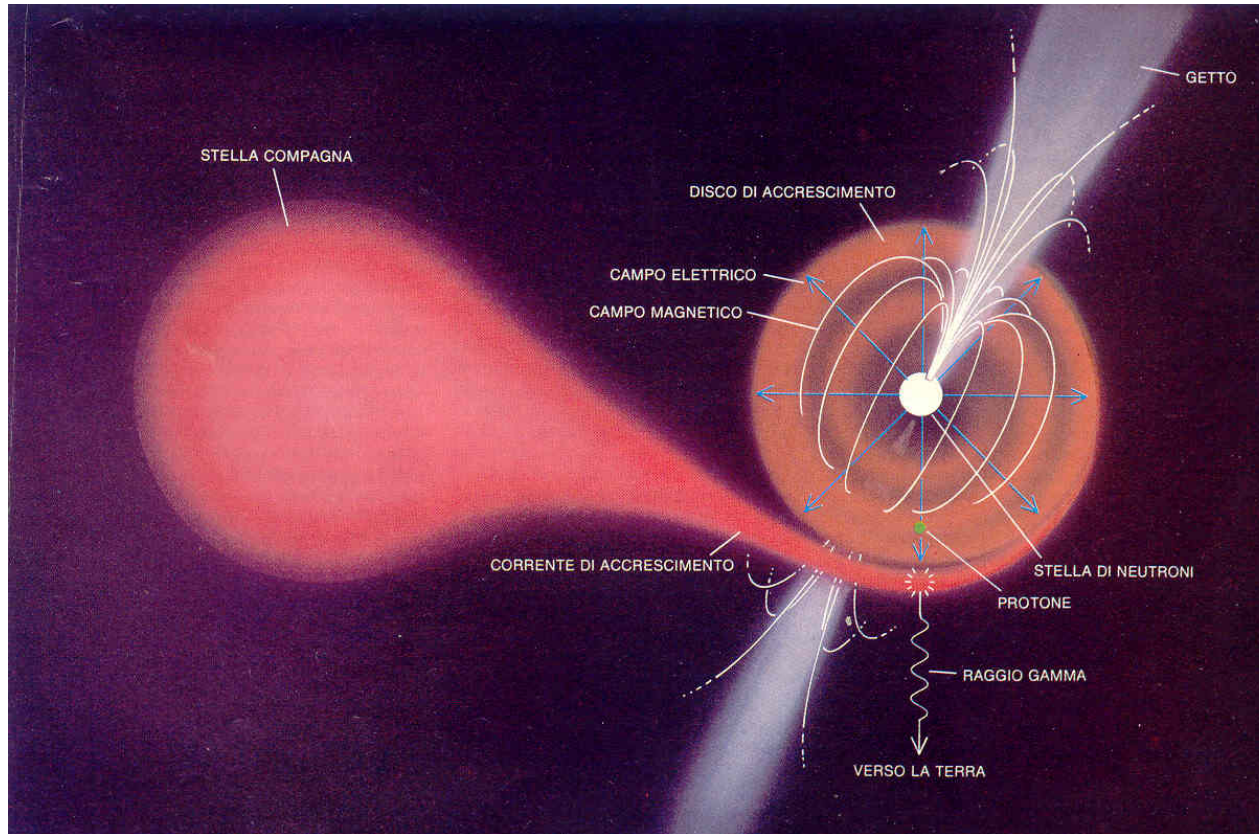
produzione di nuclei, raggi X, particelle alta energia, neutrini



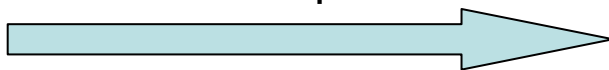
Acceleratore di particelle

# Come osservare le evoluzioni stellari

## SISTEMI BINARI

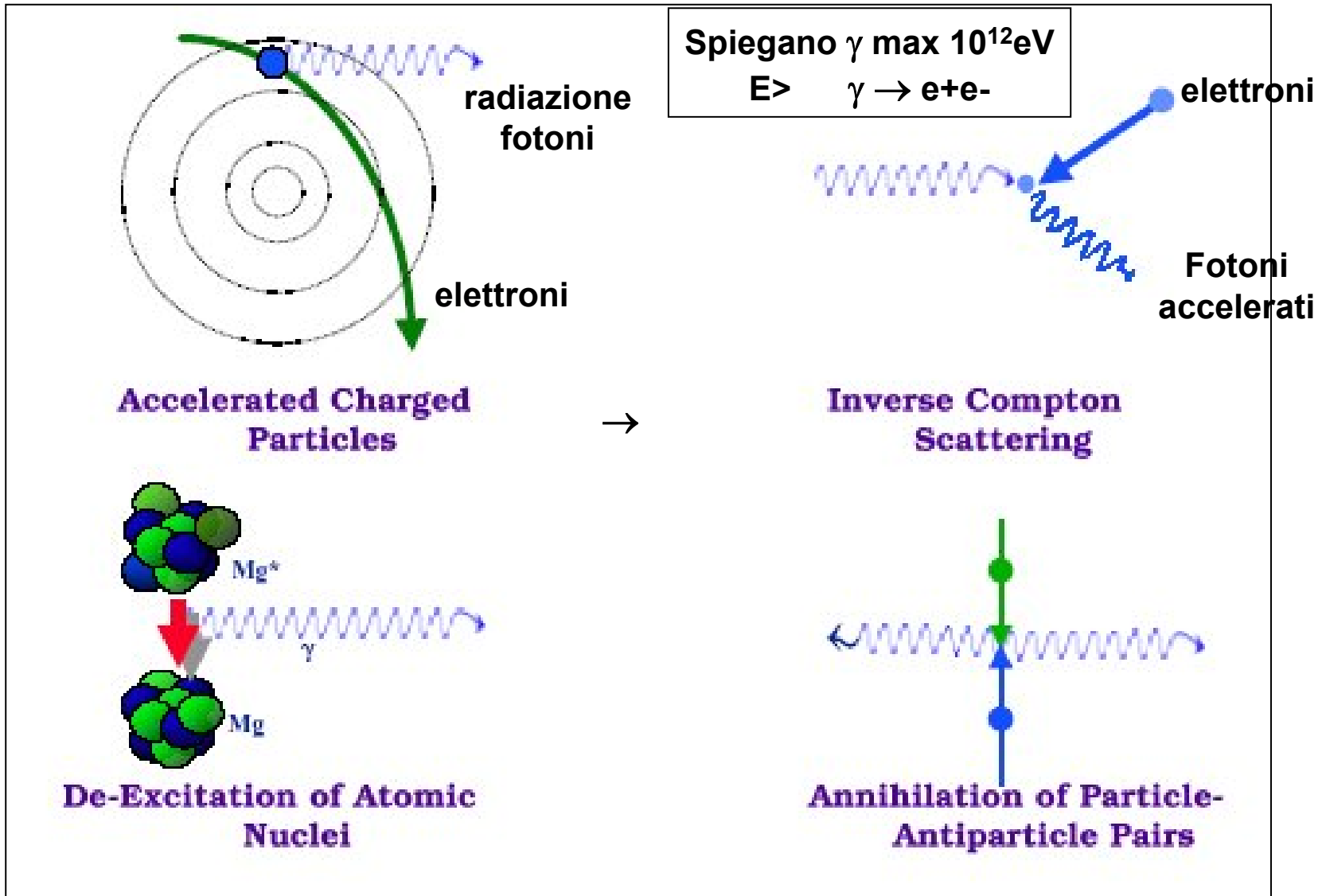


50% delle stelle sono binarie: sorgenti di raggi X associata **trasferimento di materia** dalla stella primaria **alla stella di neutroni**. Disco di accrescimento. Osservati anche lampi di **radiazione gamma**. Cygnus X-3 e' un sistema binario X, periodo 4,8 ore, che emette raggi gamma di alta energia e pulsar gamma con periodo 12,6 msec. Possibile interazione di protoni accelerati nel campo magnetico della pulsar su protoni



# Processi che generano raggi X e gamma

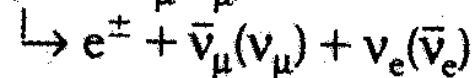
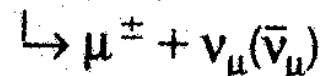
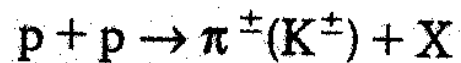
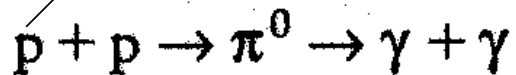
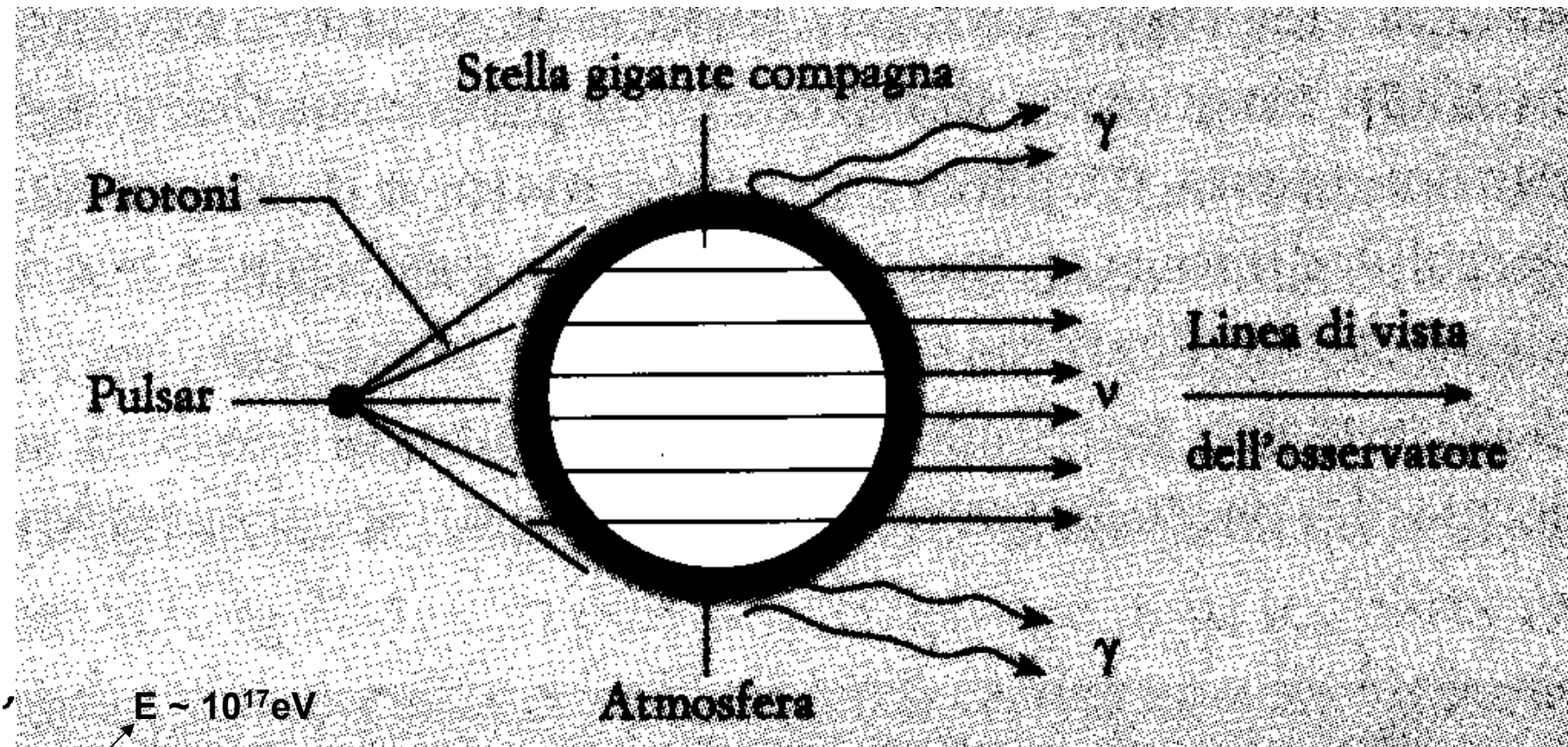
processi elettromagnetici



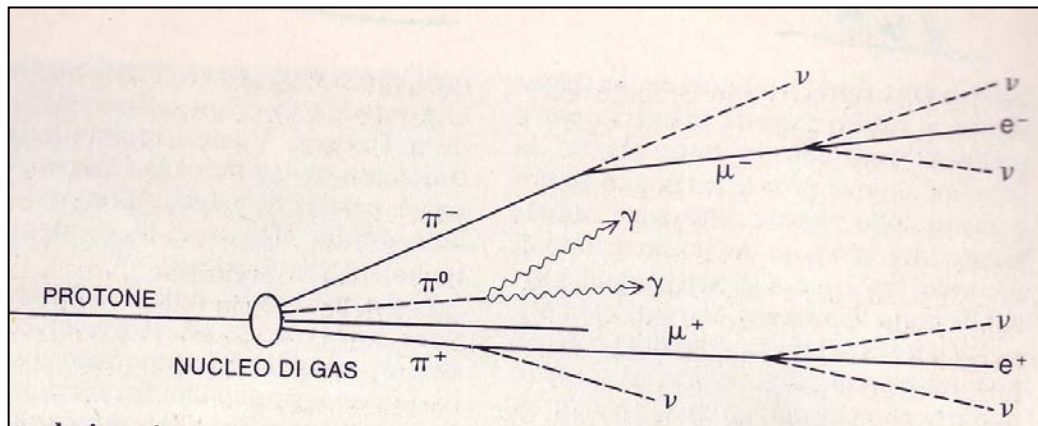
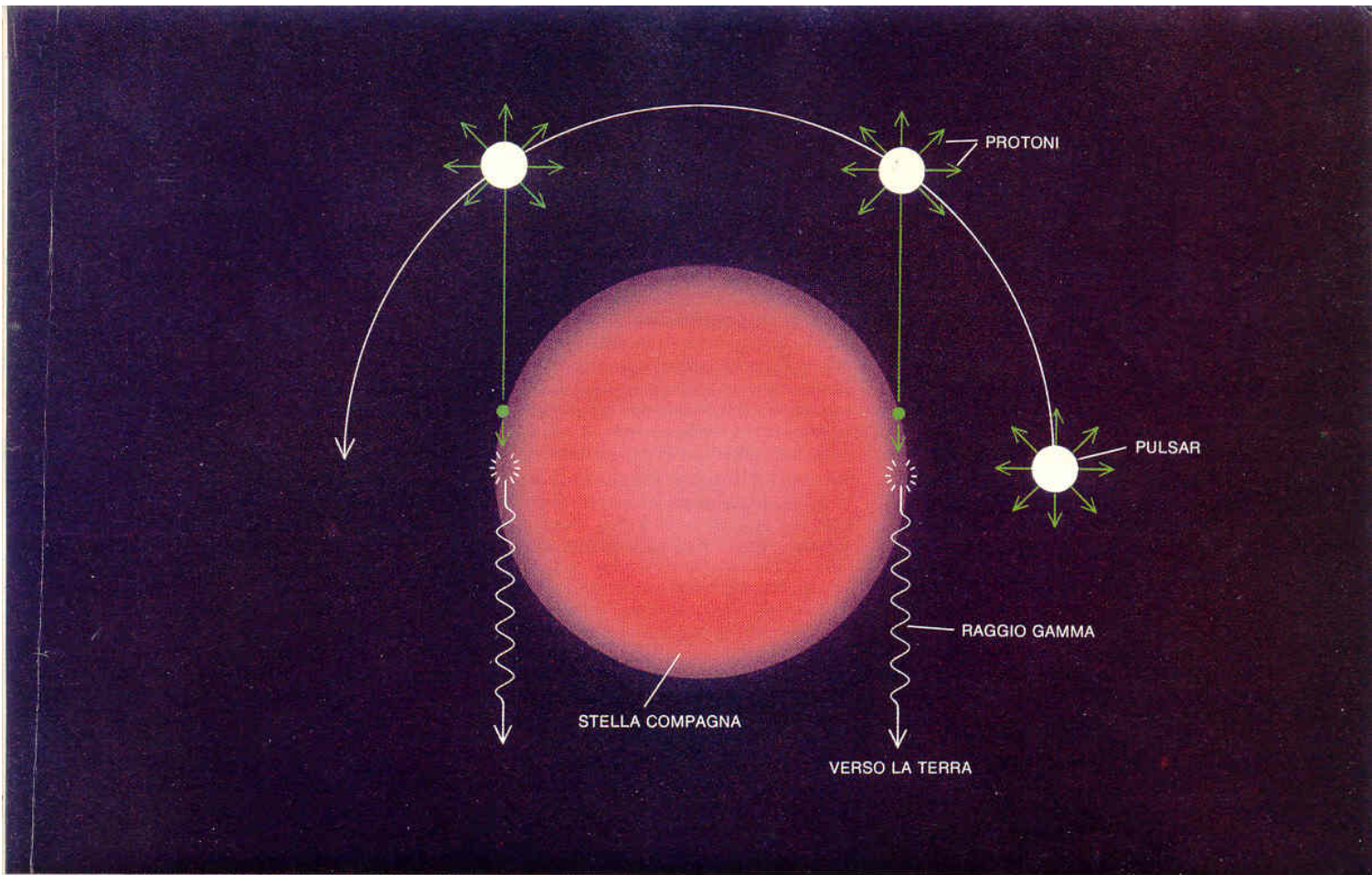
Lo studio di X e gamma ci permette di risalire al processo fisico

# Emissione gamma da sorgenti

interazioni forti



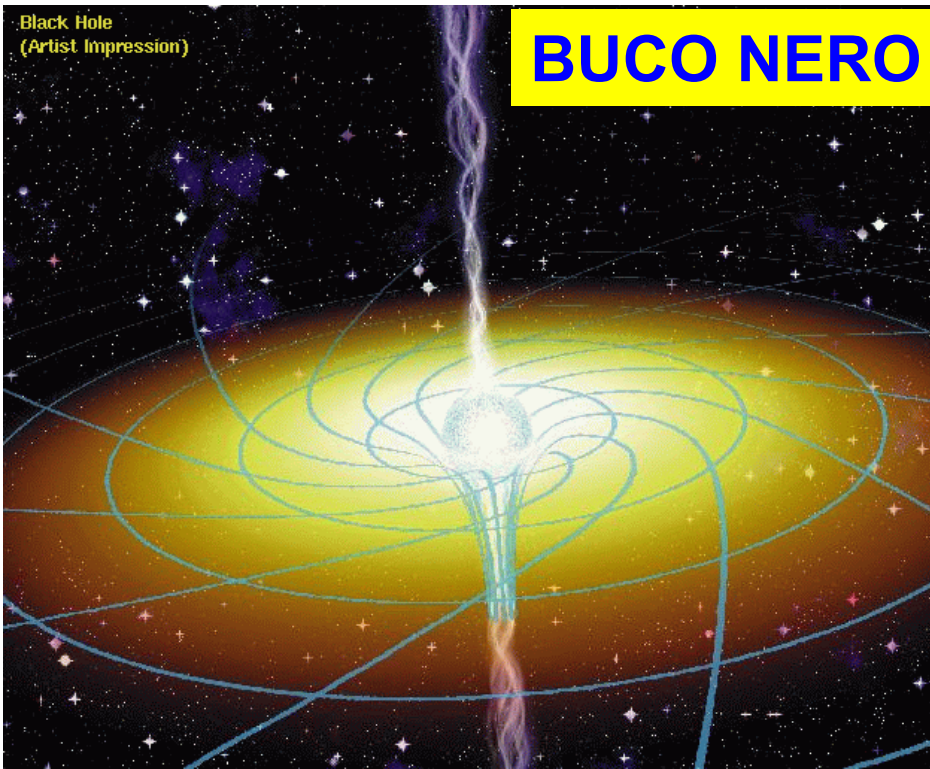
Spiegano  $\gamma \sim 10^{15} \text{ eV}$



Burst di **gamma**, **neutrini** di alta energia

Esperimenti nello **spazio**  
Esperimenti a **terra**





## Modello per Gamma Ray Burst Collapsar model $\gamma$ -ray burst di lunga durata

1° step: collasso di una stella **20-30 masse** solari che forma **buco nero e supernova**  
 $\gamma$ -ray burst avviene quando il buco nero espelle materia formando un disco di accrescimento. **Rotazione** piu' veloce interna  
piu' lenta esterna  
del fluido conduttore genera **un campo magnetico** che produce due jets di materia-antimateria (e, e+,p..)

2° step: relativistic "fireball" shock model  
iet e' un **fireball** che genera una **onda d'urto** trasportando **materia gamma rays** prodotti in **scontri di materia**. La luce e' emessa dopo raffreddamento del jet che diventa trasparente alla luce.

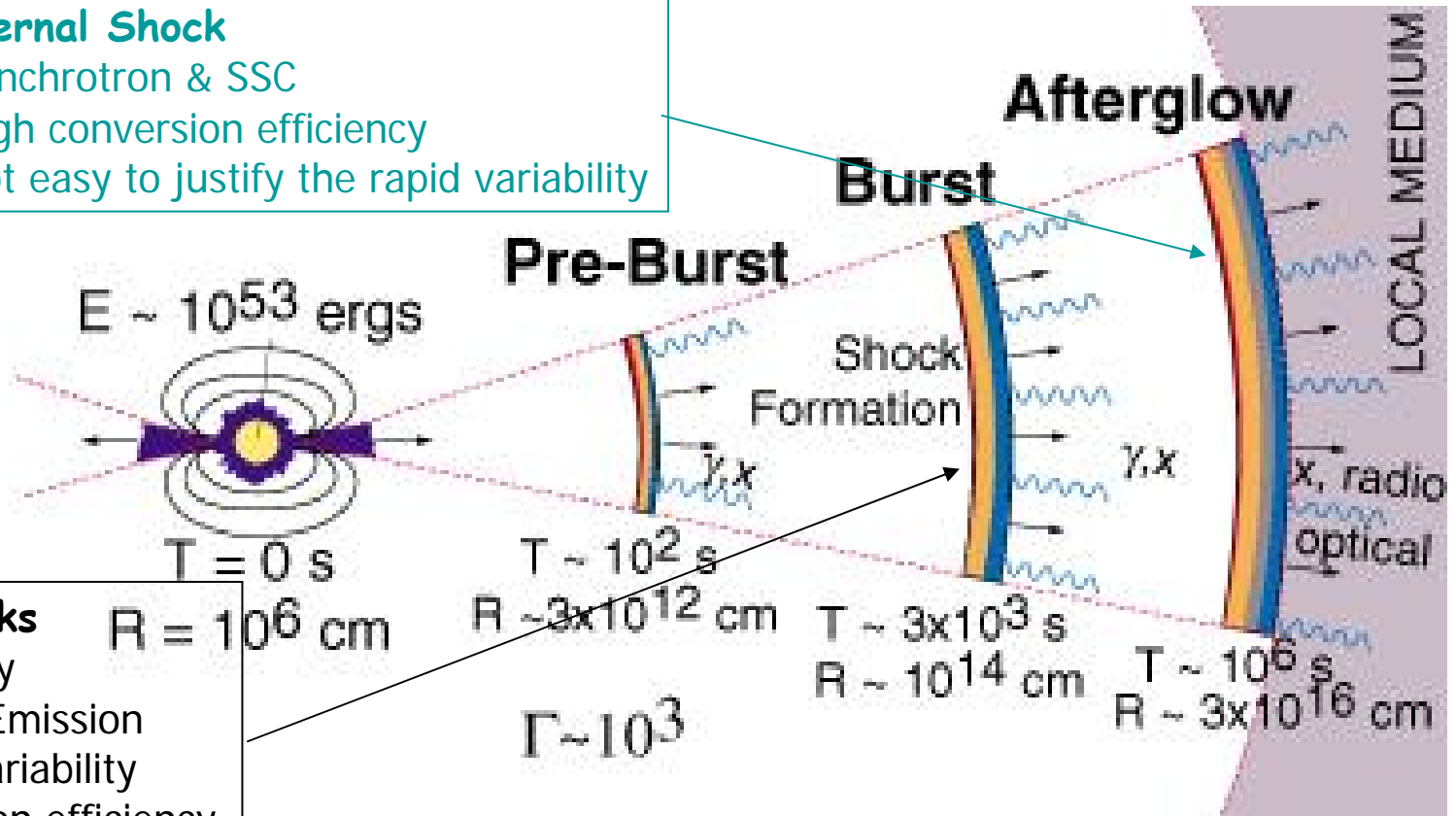
3°step: **afterglow**, continua perdita di energia del jet nella regione X (urti di materia)

# The Fireball “standard” model

- Relativistic motion of the emitting region
- Shock mechanism converts the kinetic energy of the shells into radiation.
- Baryon Loading problem

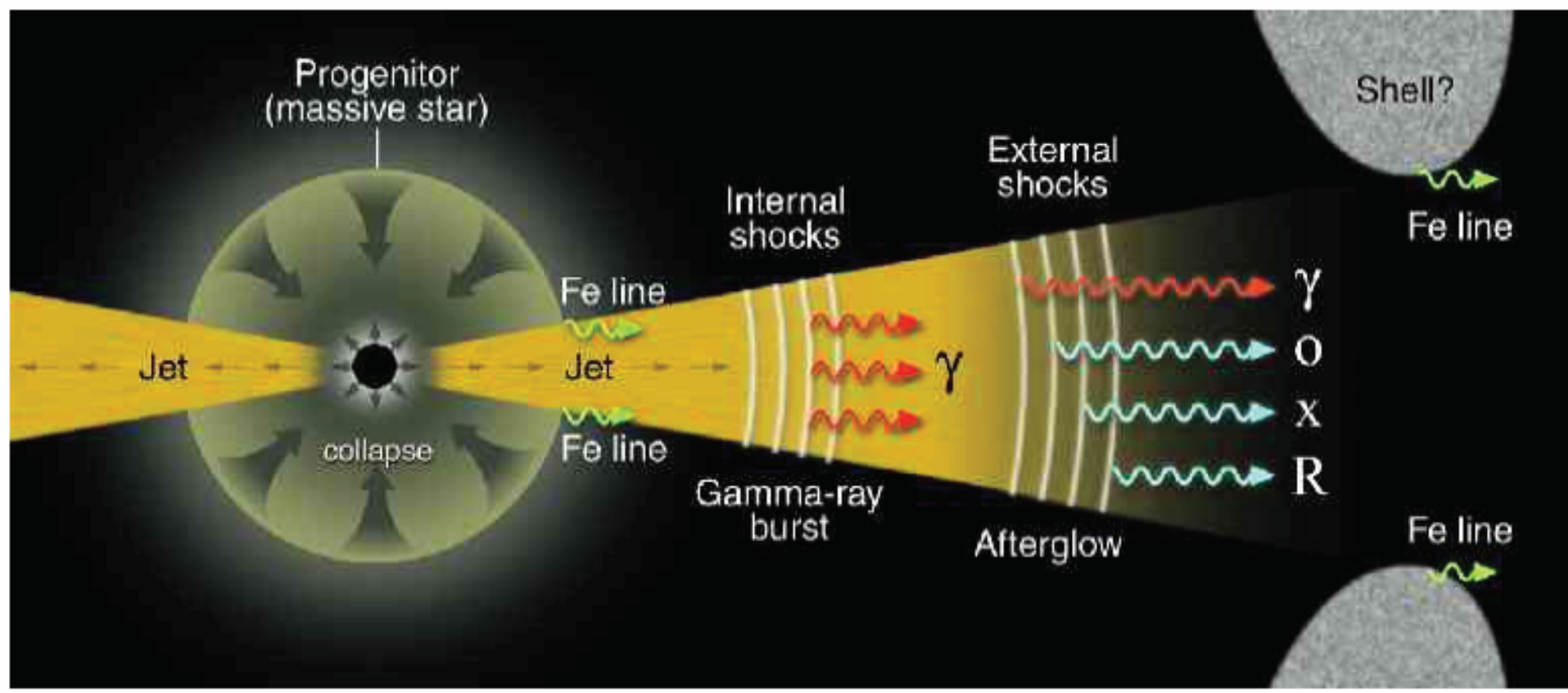
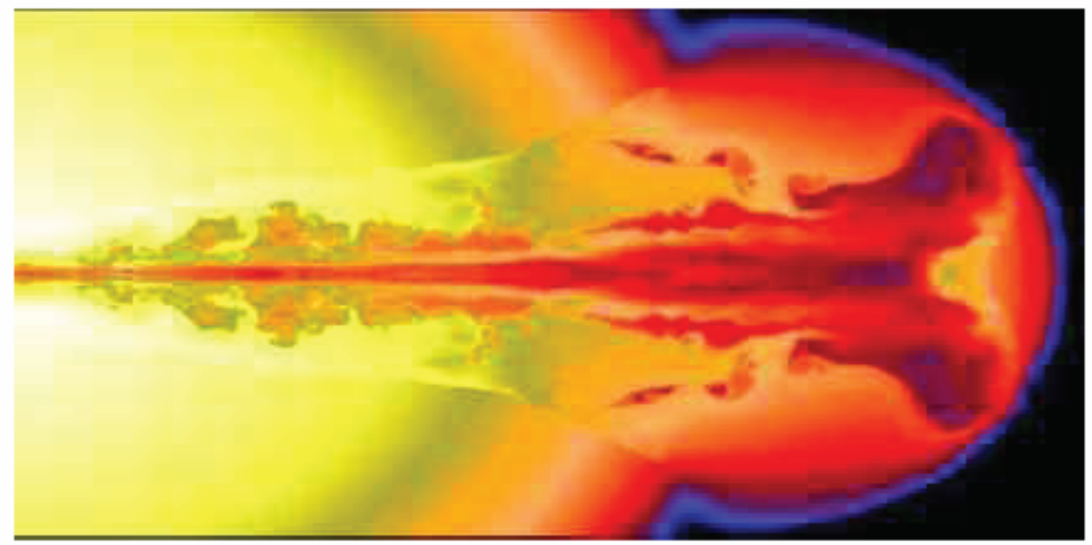
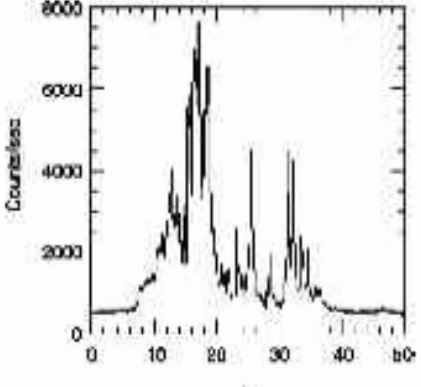
## External Shock

- Synchrotron & SSC
- High conversion efficiency
- Not easy to justify the rapid variability



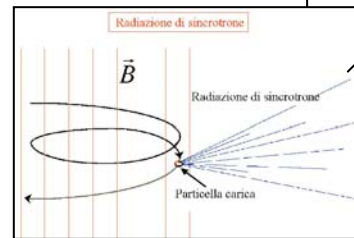
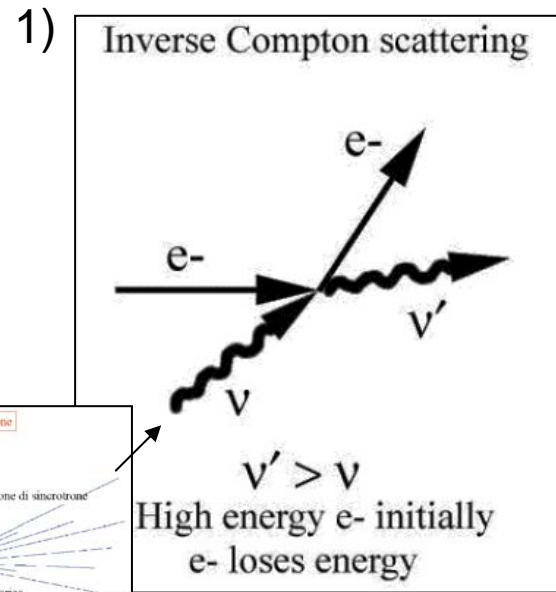
## Internal Shocks

- Source activity
- Synchrotron Emission
- Rapid time Variability
- Low conversion efficiency

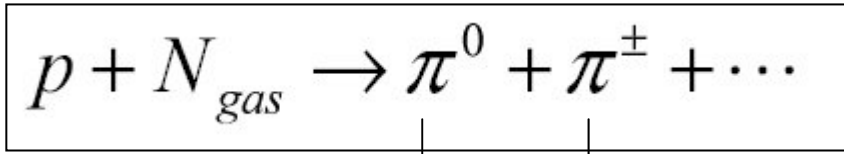


# Modello simile per AGN (nucleo galattico attivo)

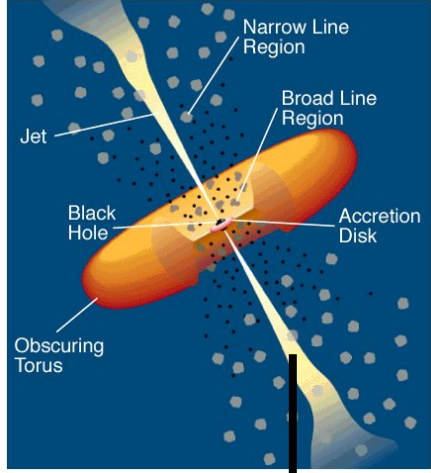
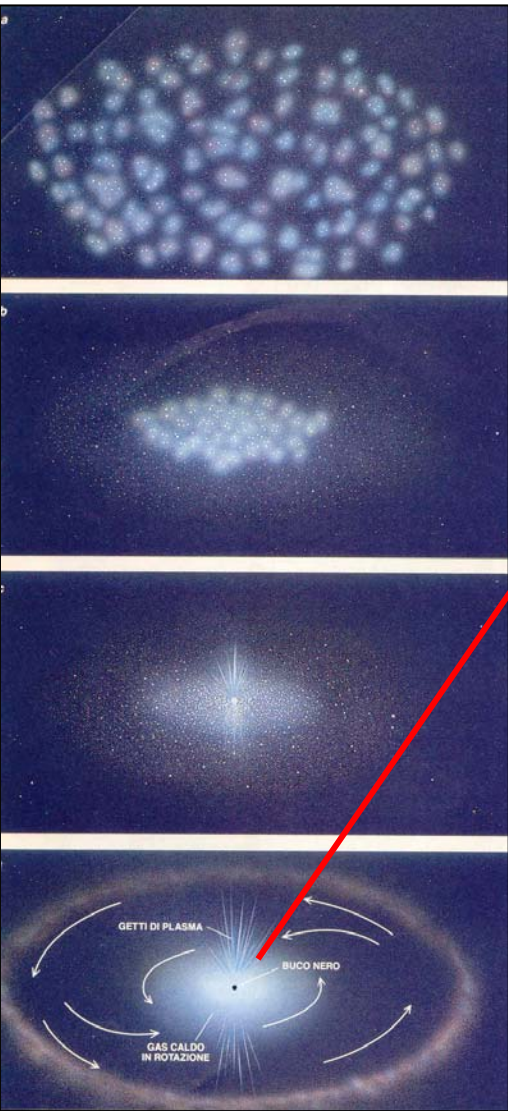
Processi che determinano la produzione di radiazione gamma alta energia:



Jets di radiazione e particelle



$\gamma\gamma$        $\mu e \nu \nu$



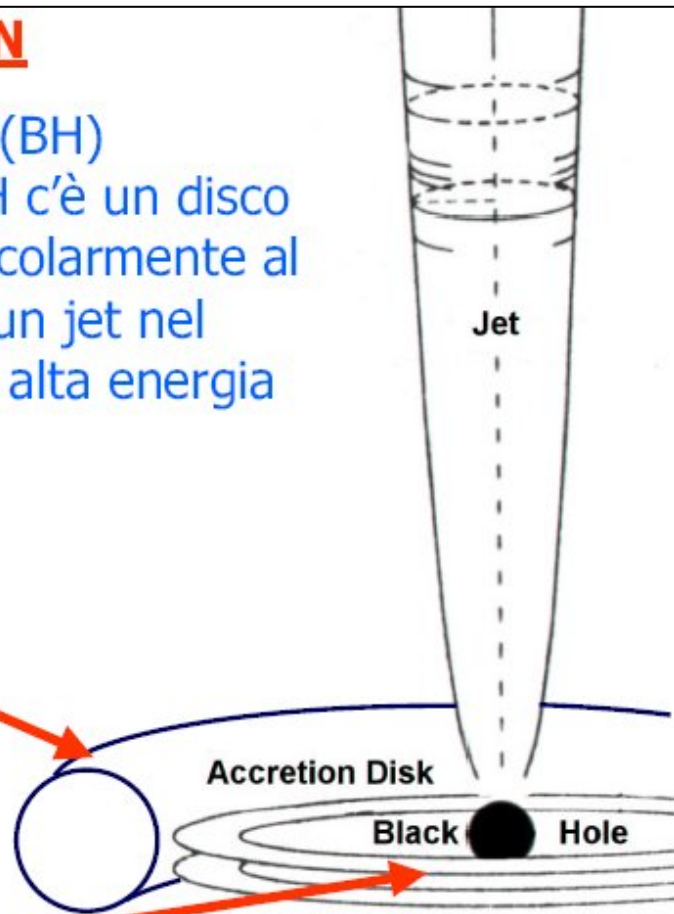
**Buco nero** di grande massa che acquista materia da stelle e gas che orbitano attorno

## Modello unificato di AGN

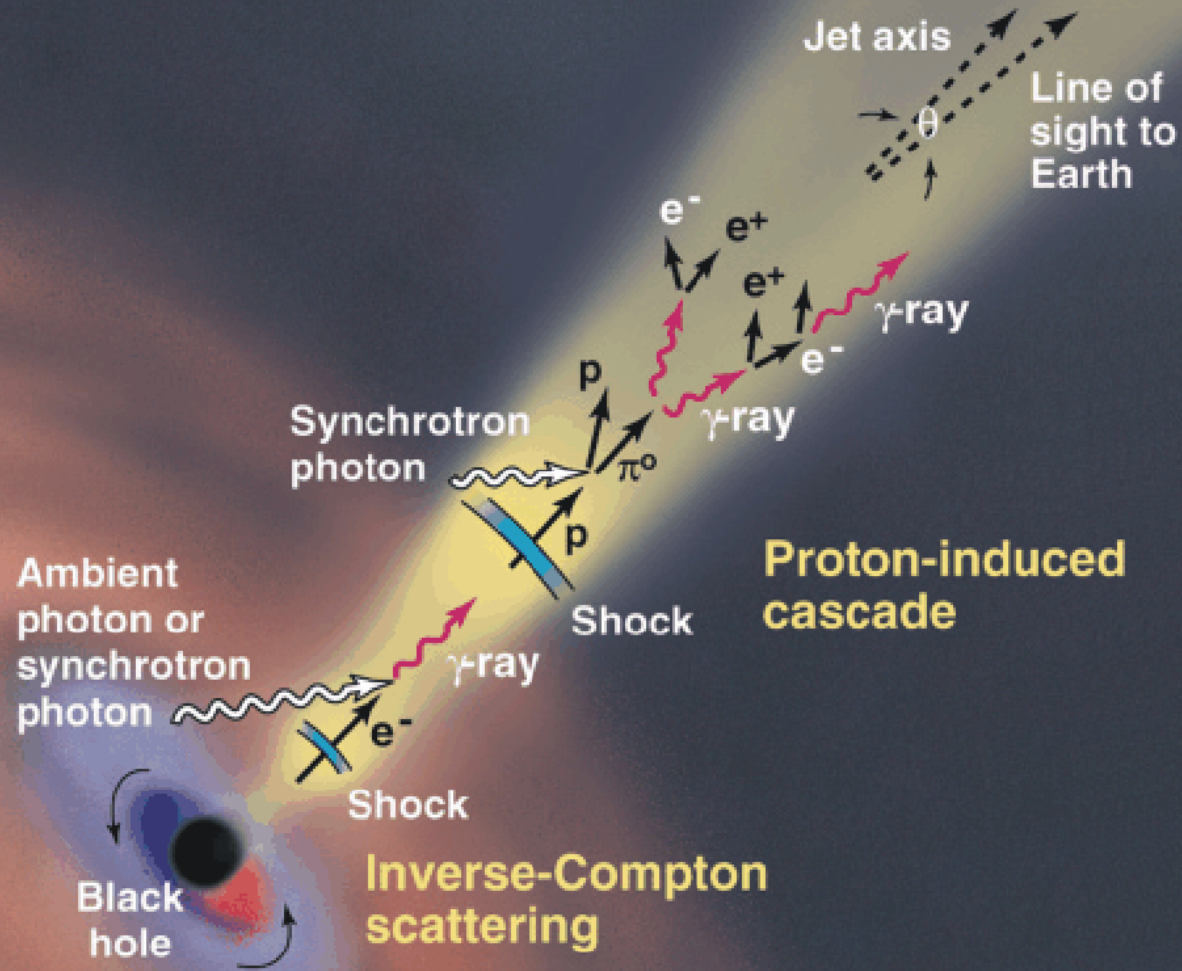
Al centro c'è un black hole (BH) supermassivo attorno al BH c'è un disco di accrescimento. Perpendicolarmente al disco di accrescimento c'è un jet nel quale si hanno particelle di alta energia (TeV)

Toro polveri.  
Emissione I.R.

B.H. *supermassivo*  
 $10^7 \div 10^{10} M_{\odot}$



# AGN



( J. H. Buckley )

# Esperimenti sui **Gamma Ray** burst dal cosmo

- Intensa **radiazione gamma** di durata variabile **msec-100 sec** mai nello stesso punto
- presenza di **afterglow nell'ottico, X-ray, radio** dopo ore-settimane.
- la maggior parte dei GRB durano 2-10 sec e presentano afterglow.

## Fenomeni che originano i **GRB**

- Formazione di buchi neri** in una esplosione di stella massiva( GRB > 2 sec.)
- Collisione di due stelle di neutroni** o buchi neri (GRB di breve durata < 2 sec.)
- Studio di prime stelle nell'Universo** con massa 100-1000 volte il Sole fatte di H ed He.
- Studi di afterglow nell'X** per capire l'origine sulla base dell'assorbimento o meno.
- All sky X survey.**
- Nuovi fenomeni?**

GRB: energia > 100 volte Supernova e  $10^{11}$  volte energia del Sole in un anno.

# GRB History

- Vela satellites discovery (1967 - 1973)

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## OBSERVATIONS OF GAMMA-RAY BURSTS OF COSMIC ORIGIN

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Received 1973 March 16; revised 1973 April 2

### ABSTRACT

Sixteen short bursts of photons in the energy range 0.2–1.5 MeV have been observed between 1969 July and 1972 July using widely separated spacecraft. Burst durations ranged from less than 0.1 s to  $\sim 30$  s, and time-integrated flux densities from  $\sim 10^{-5}$  ergs  $\text{cm}^{-2}$  to  $\sim 2 \times 10^{-4}$  ergs  $\text{cm}^{-2}$  in the energy range given. Significant time structure within bursts was observed. Directional information eliminates the Earth and Sun as sources.

Subject headings: gamma rays—X-rays—variable stars

### I. INTRODUCTION

On several occasions in the past we have searched the records of data from early *Vela* spacecraft for indications of gamma-ray fluxes near the times of appearance of supernovae. These searches proved uniformly fruitless. Specific predictions of gamma-ray emission during the initial stages of the development of supernovae have since been made by Colgate (1968). Also, more recent *Vela* spacecraft are equipped with much improved instrumentation. This encouraged a more general search, not restricted to specific time periods. The search covered data acquired with almost continuous coverage between 1969 July and 1972 July, yielding records of 16 gamma-ray bursts distributed throughout that period. Search criteria and some characteristics of the bursts are given below.

### II. INSTRUMENTATION

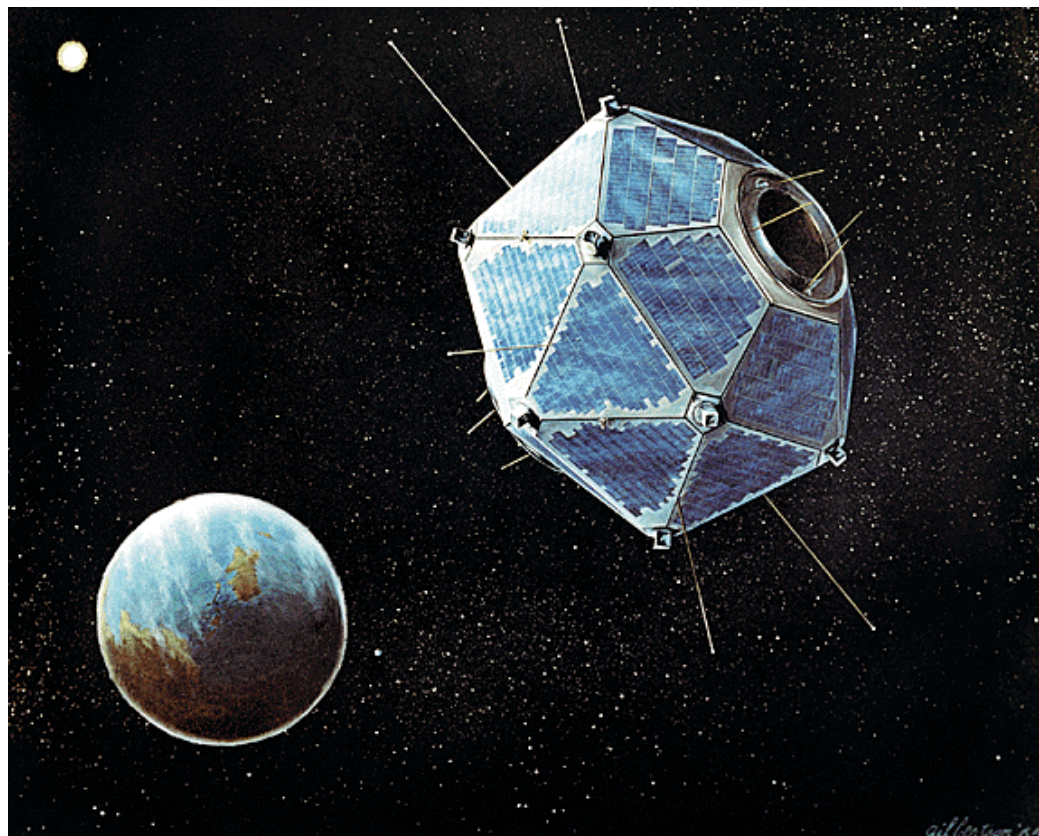
The observations were made by detectors on the four *Vela* spacecraft, *Vela 5A*, *5B*, *6A*, and *6B*, which are arranged almost equally spaced in a circular orbit with a geocentric radius of  $\sim 1.2 \times 10^6$  km.

On each spacecraft six  $10 \text{ cm}^3$  CsI scintillation counters are so distributed as to achieve a nearly isotropic sensitivity. Individual detectors respond to energy depositions of 0.2–1.0 MeV for *Vela 5* spacecraft and 0.3–1.5 MeV for *Vela 6* spacecraft, with a detection efficiency ranging between 17 and 50 percent. The scintillators are shielded against direct penetration by electrons below  $\sim 0.75$  MeV and protons below  $\sim 20$  MeV. A high- $Z$  shield attenuates photons with energy below that of the counting threshold. No active anticoincidence shielding is provided.

Normalized output pulses from the six detectors are summed into the counting and logic circuitry. Logical sensing of a rapid, statistically significant rise in count rate initiates the recording of discrete counts in a series of quasi-logarithmically increasing time intervals. This capability provides continuous coverage in time which, coupled with isotropic response, is unique in observational astronomy. A time measurement is also associated with each record.

The data accumulations include a background component due to cosmic particles and their secondary effects. The observed background rate, which is a function of the energy threshold, is  $\sim 150$  counts per second for the *Vela 5* spacecraft and  $\sim 20$  counts per second for the *Vela 6* spacecraft.

L85

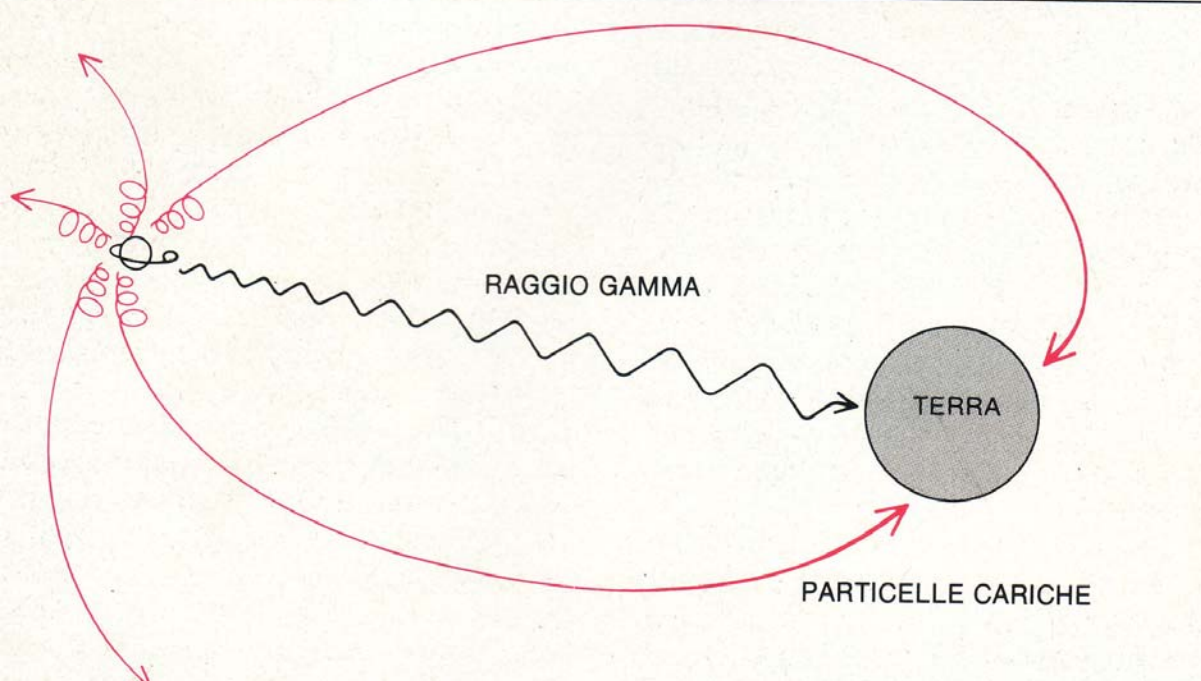
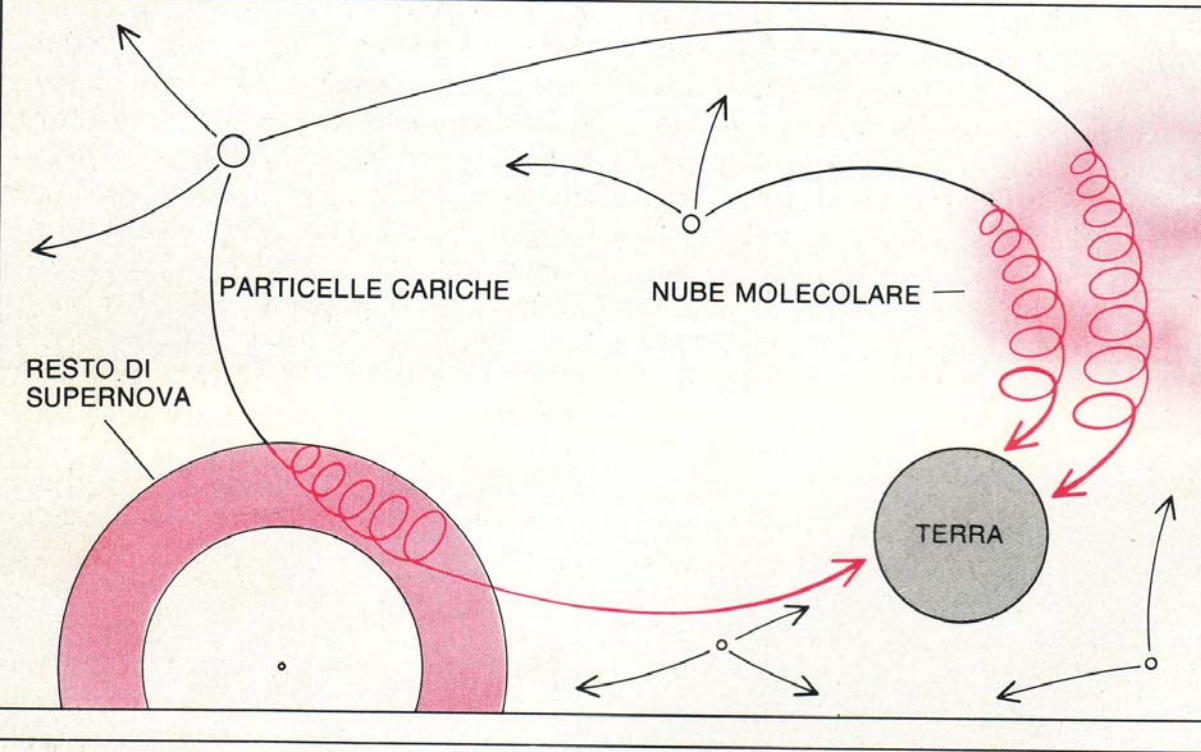


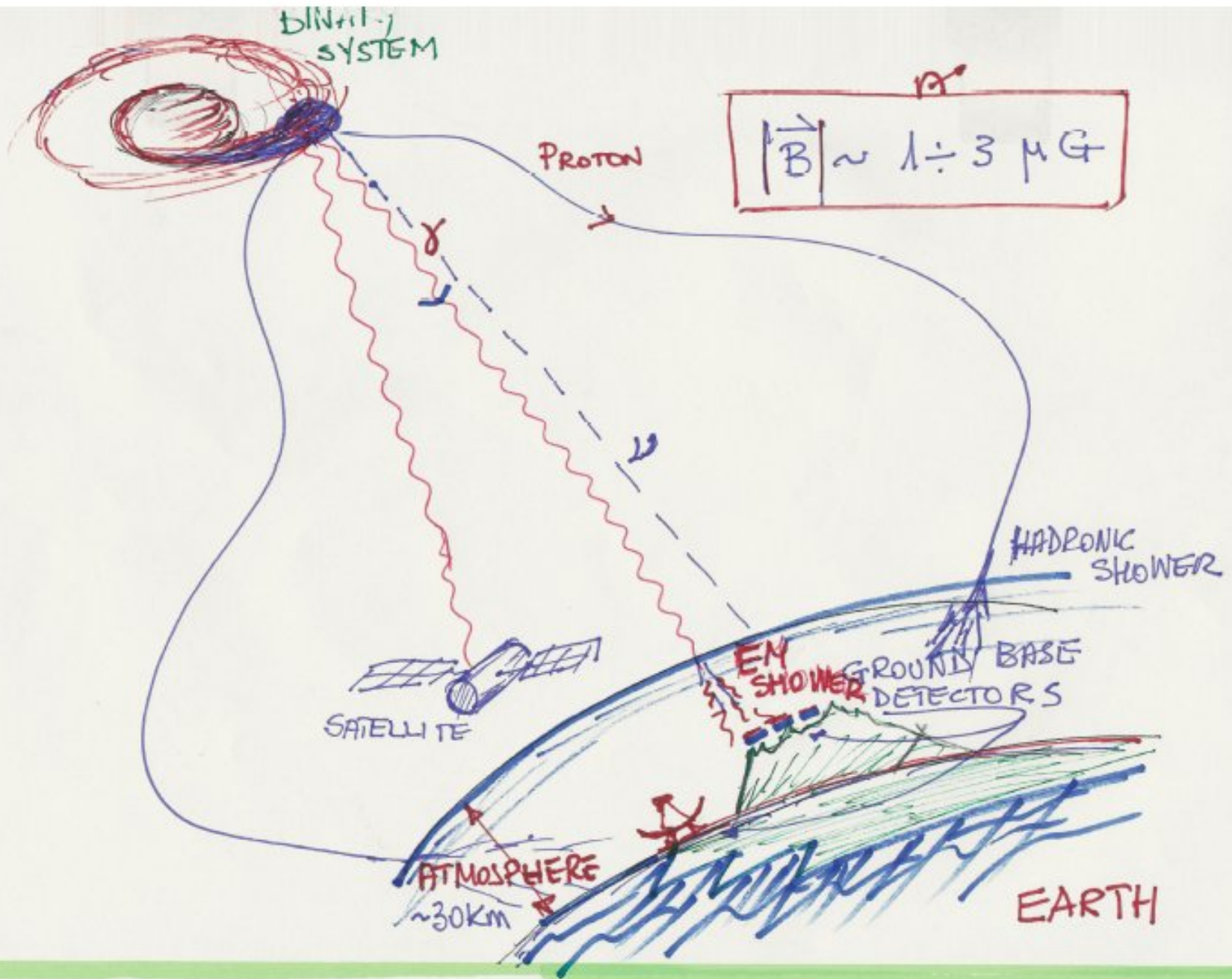


## Osservazione dalla terra

-particelle cariche (p, e, N)  
deviate dal campo  
magnetico **non utili**  
per cercare le  
sorgenti

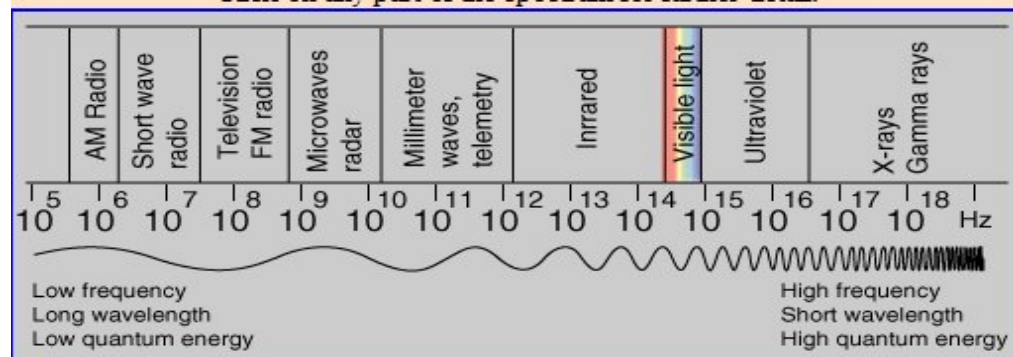
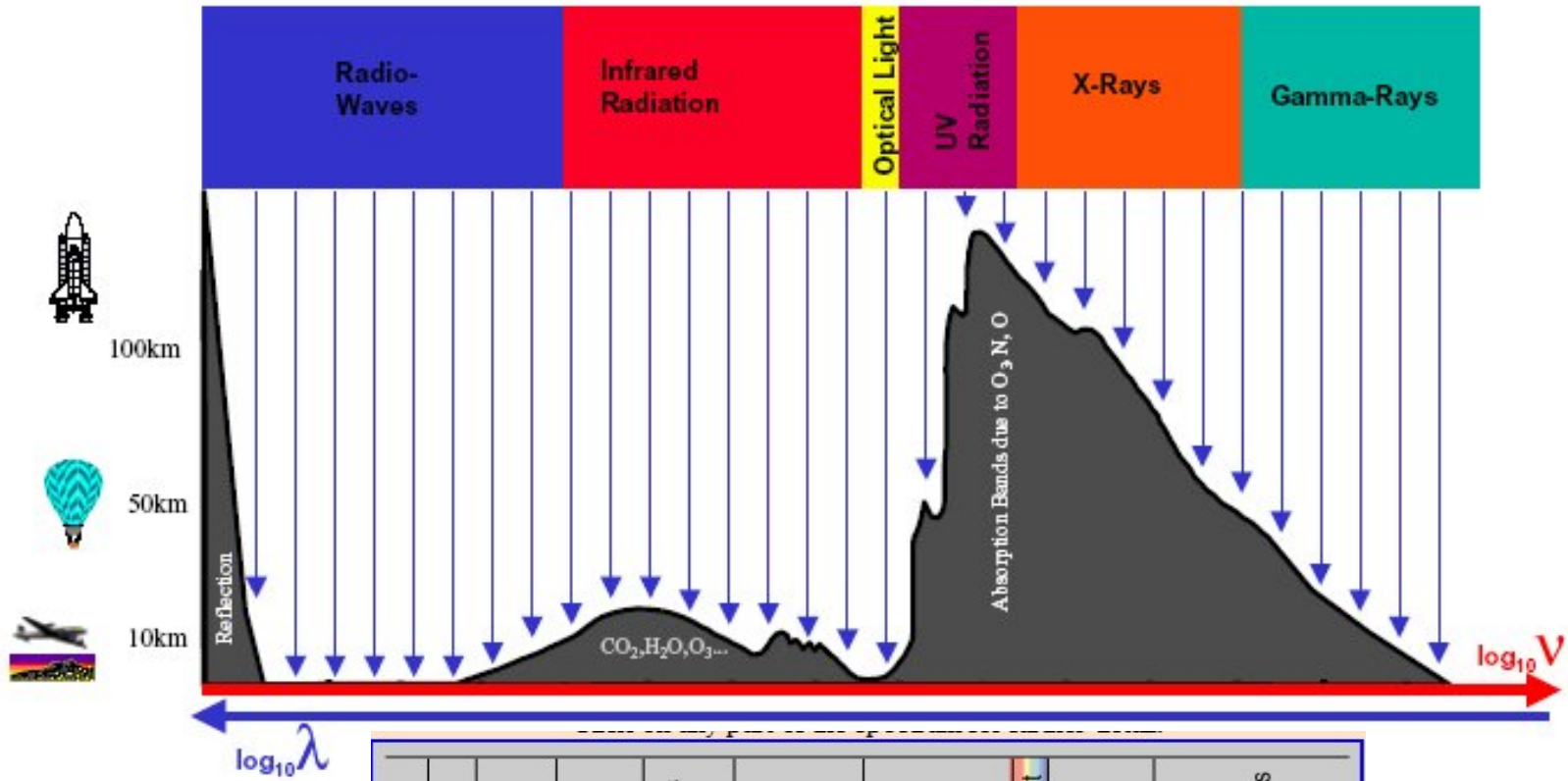
-particelle neutre ( $\gamma$ ,  $\nu$ )  
puntano sulle  
sorgenti **non deviate**  
da campi elettrici  
e magnetici





# Influenza dell'atmosfera sulla sperimentazione con telescopi

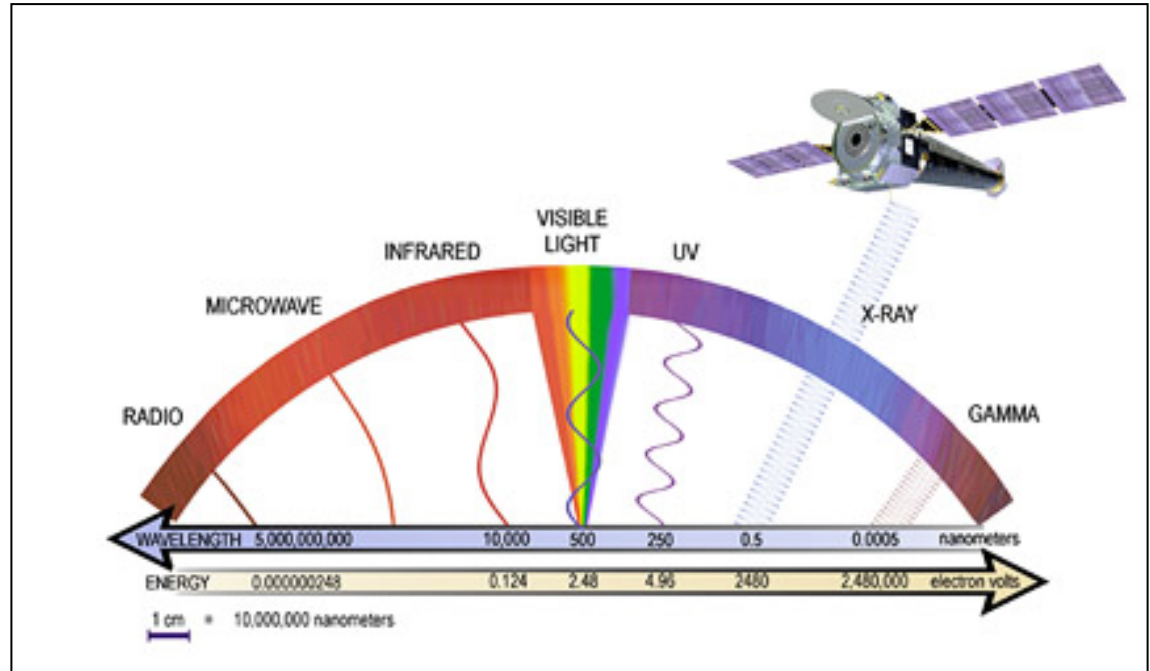
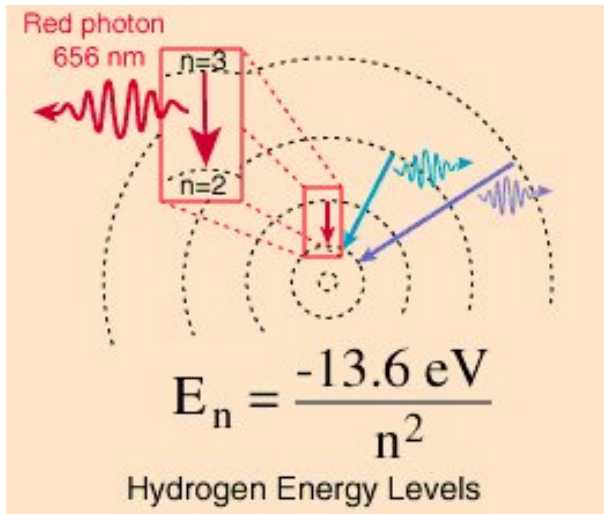
## Radio, Infrarossi, Ultravioletti, Raggi X, Raggi $\gamma$



$$c = v\lambda$$
 Also commonly written  $v = f\lambda$

$$velocity = frequency \times wavelength$$

$$c = 3 \times 10^8 \text{ m/s}$$
 Speed of light



### Frequency and Wavelength of Energy in the Electromagnetic Spectrum

Energy	Frequency in hertz	Wavelength in meters
gamma-rays	$10^{20}$ - $10^{24}$	$<10^{-12}$ m
x-rays	$10^{17}$ - $10^{20}$	1 nm-1 pm
ultraviolet	$10^{15}$ - $10^{17}$	400 nm-1 nm
visible	$4$ - $7.5 \times 10^{14}$	750 nm-400 nm
near-infrared	$1 \times 10^{14}$ - $4 \times 10^{14}$	2.5 $\mu$ m-750 nm
infrared	$10^{13}$ - $10^{14}$	25 $\mu$ m-2.5 $\mu$ m
microwaves	$3 \times 10^{11}$ - $10^{13}$	1 mm-25 $\mu$ m
radio waves	$<3 \times 10^{11}$	$>1$ mm

# Rivelazione X, gamma indiretta: attraverso gli effetti prodotti

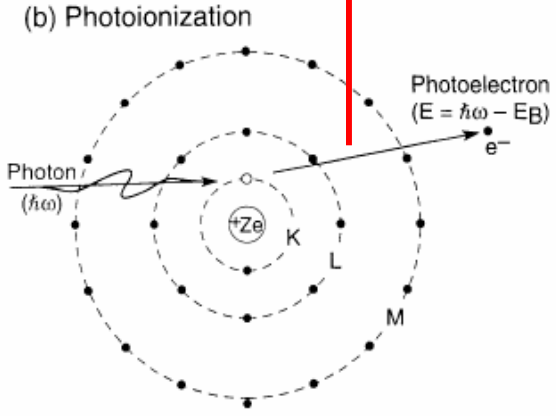
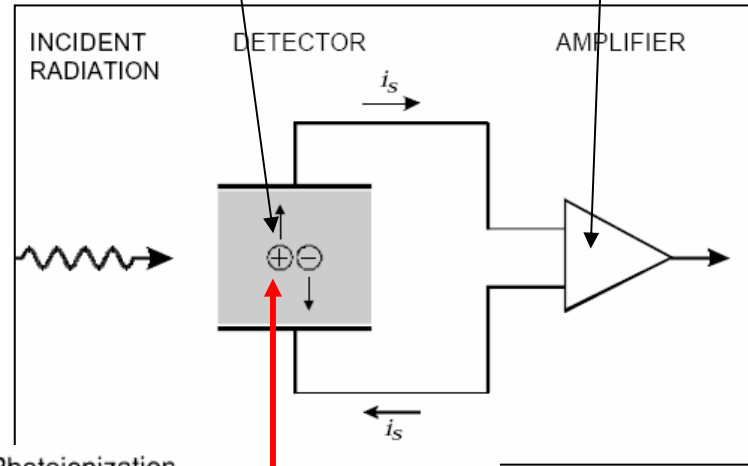
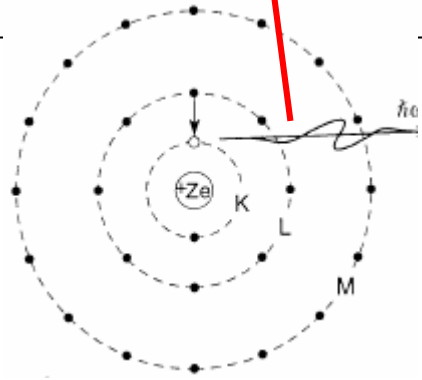
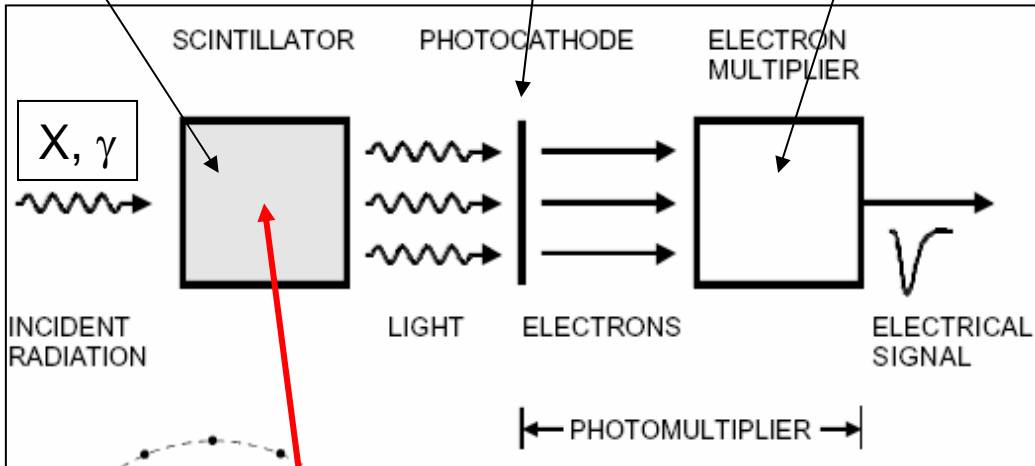
**Eccitazione atomi di sostanze liquide e solide: emissione di luce**

**la luce produce corrente di elettroni per effetto fotoelettrico**

**Amplificazione Segnale elettrico**

**Ionizzazione del materiale: corrente di elettroni. Gas, liquido, semiconduttore**

**Misura diretta Della corrente di elettroni**

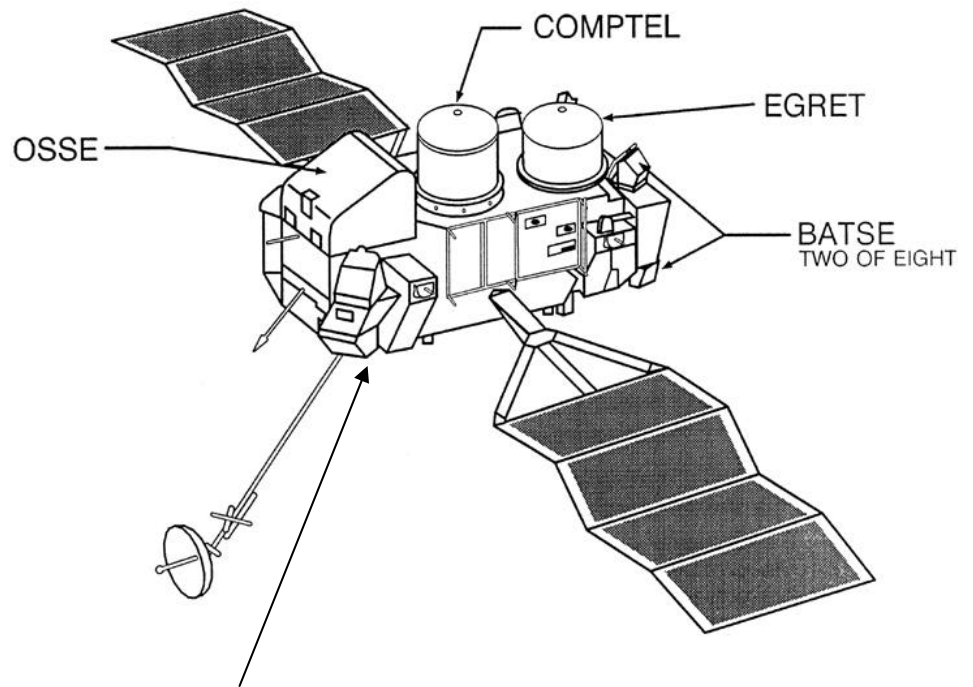


# CGRO-BATSE (1991-2000)

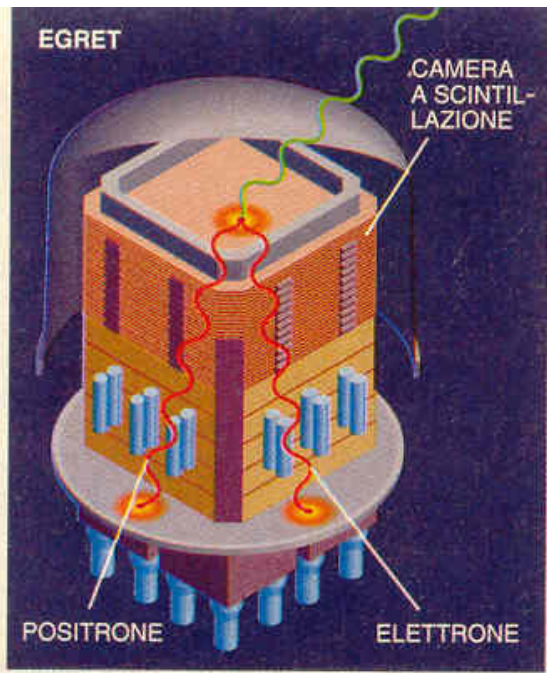
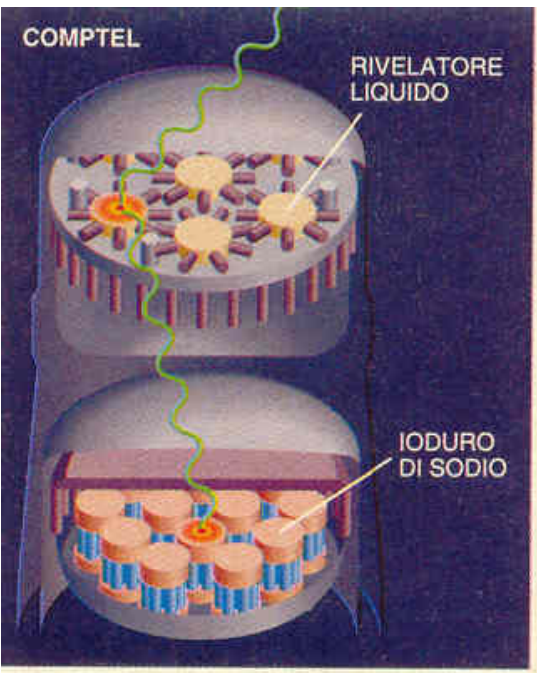
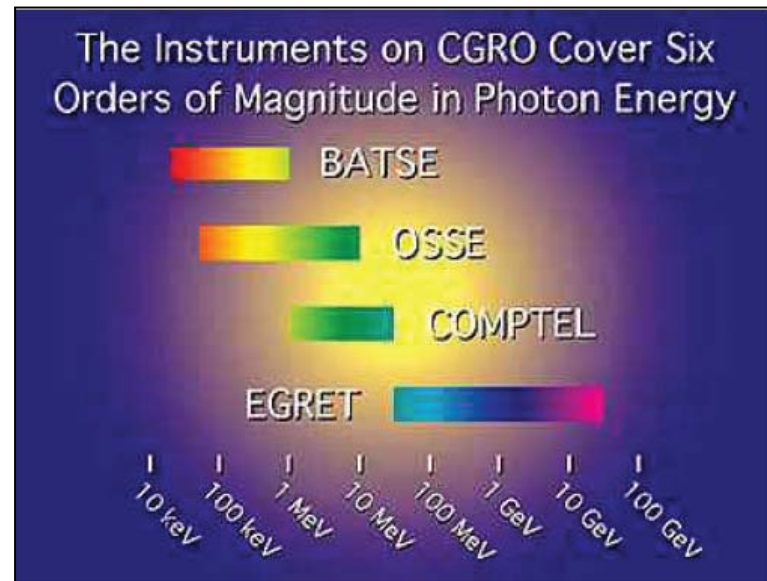
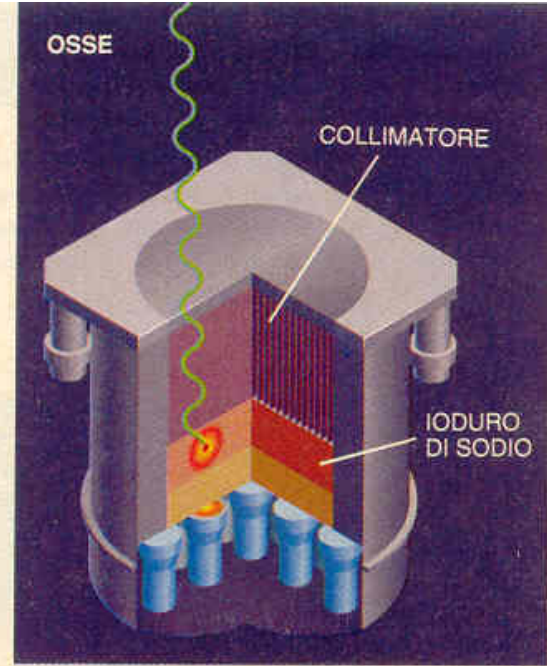
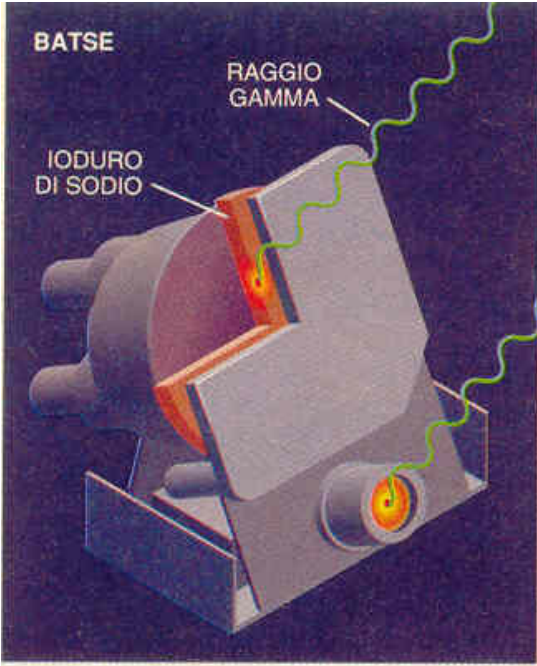
(Compton Gamma Ray Observatory)



## COMPTON OBSERVATORY INSTRUMENTS



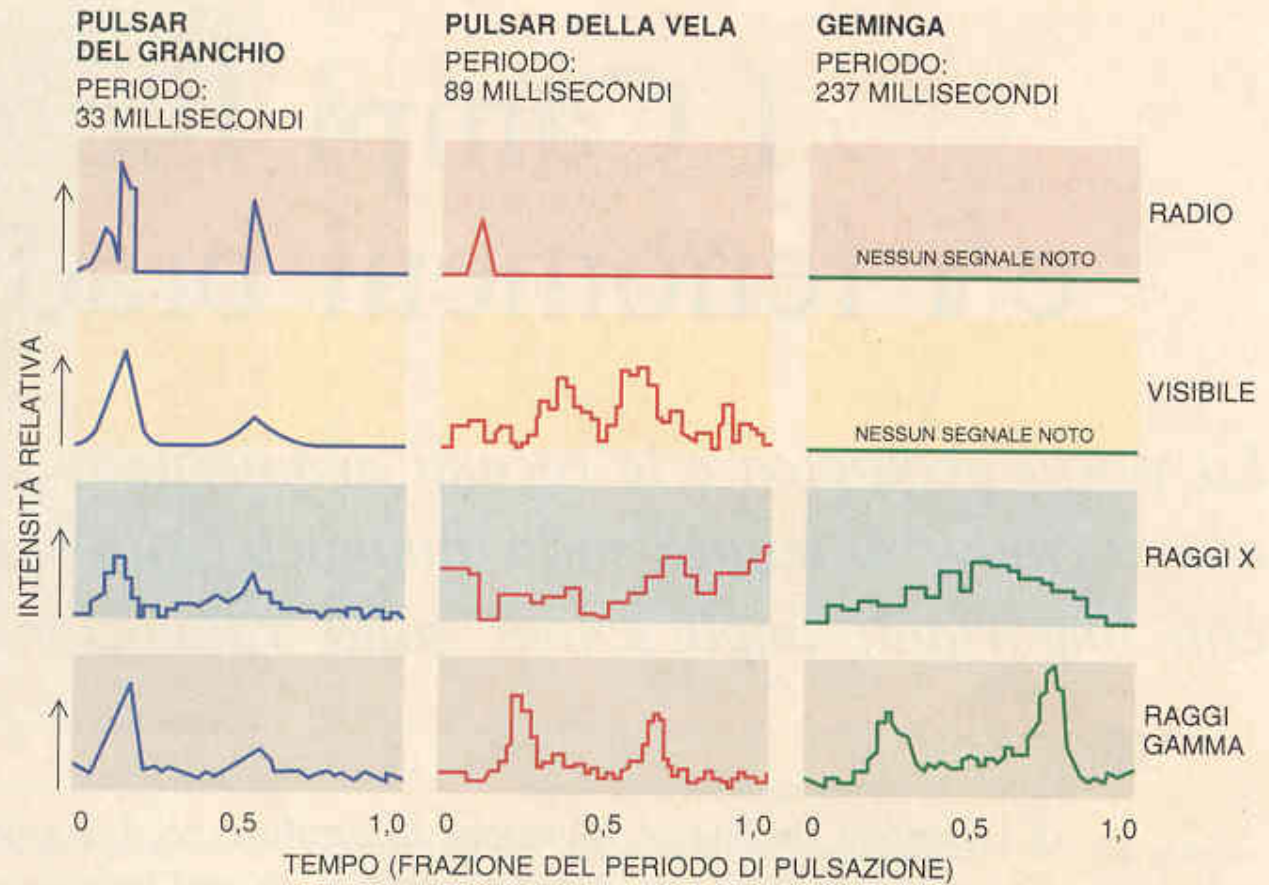
CGRO/BATSE (25 KeV ÷ 10 MeV)



Raggi gamma misurati dagli effetti prodotti:

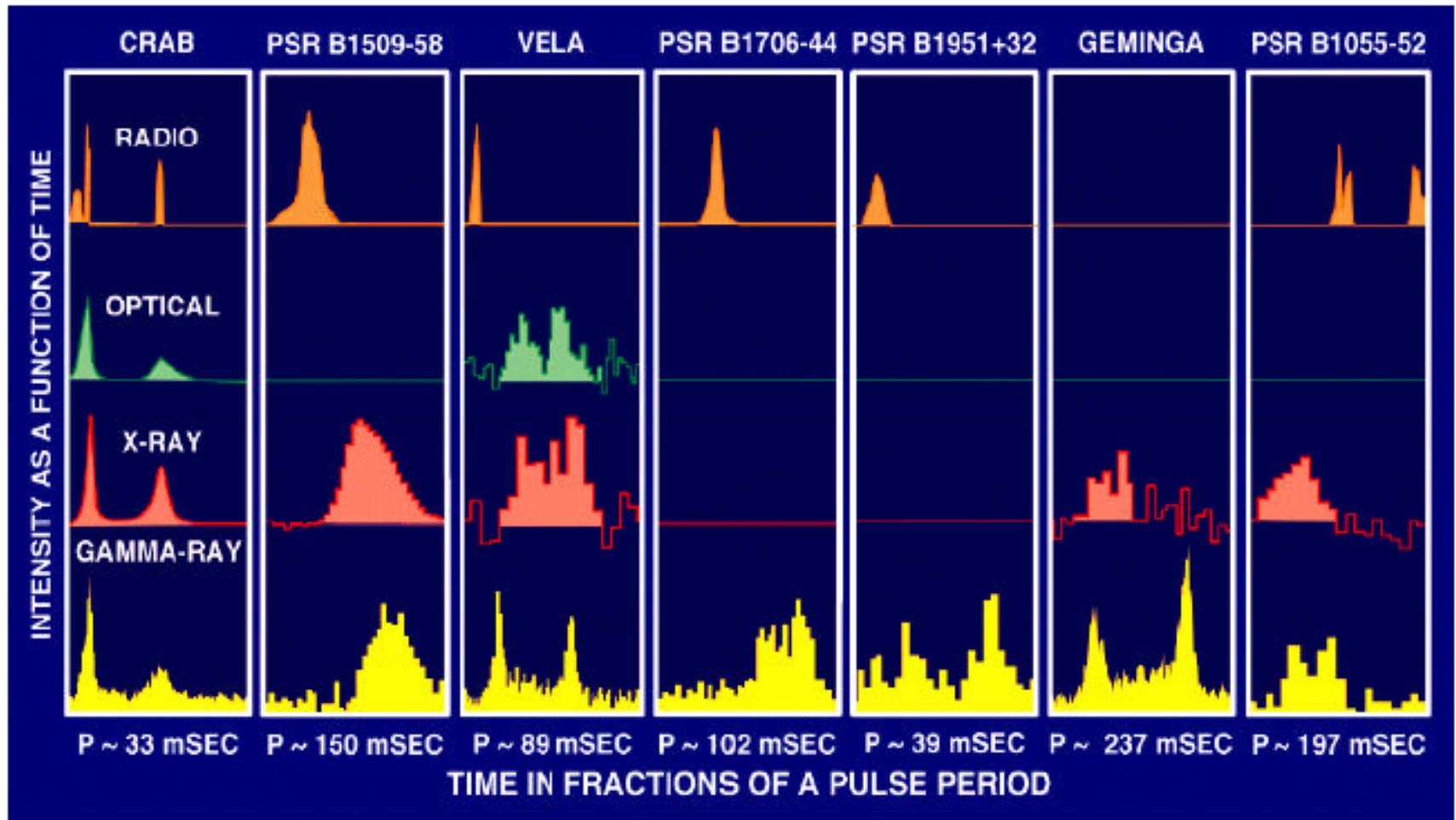
- effetto fotoelettrico  $\gamma \rightarrow e$
- effetto Compton  $\gamma \rightarrow e + \gamma$
- creazione di coppie  $\gamma \rightarrow e + \gamma$

# Brillamento delle Pulsar





# P U L S A R S

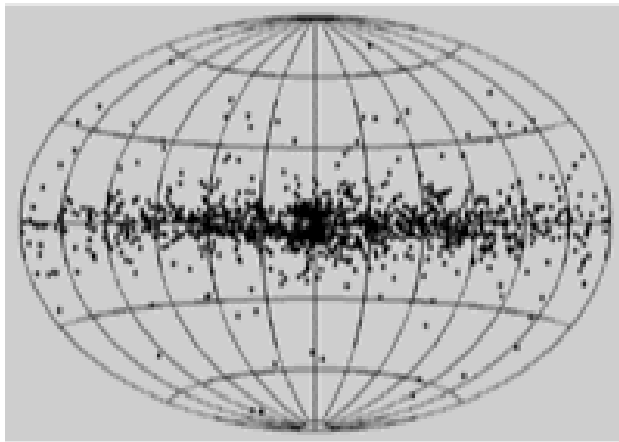


Multiwavelength light curves of the seven pulsars detected by GRO.

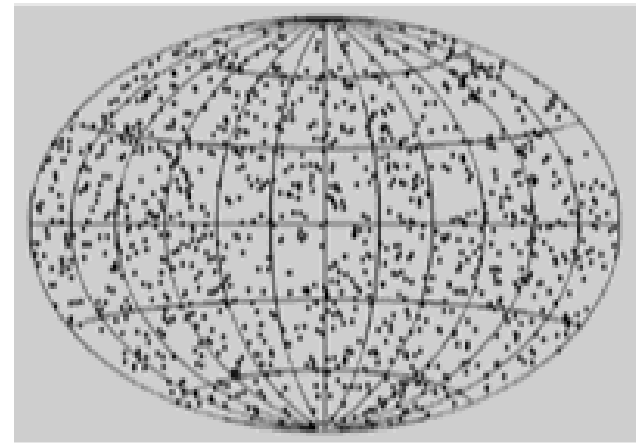
Multiwavelength observations of more will severely constrain theoretical model for pulsar emission. High energy gamma-ray may dominate and can provide unique information on the map of pulsar magnetosphere and emission mechanism.

# GRB History

## Distribution of Gamma-Ray Bursts on the Sky



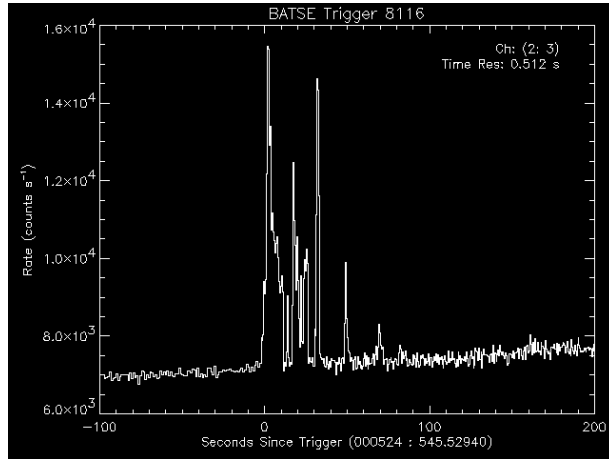
Expected



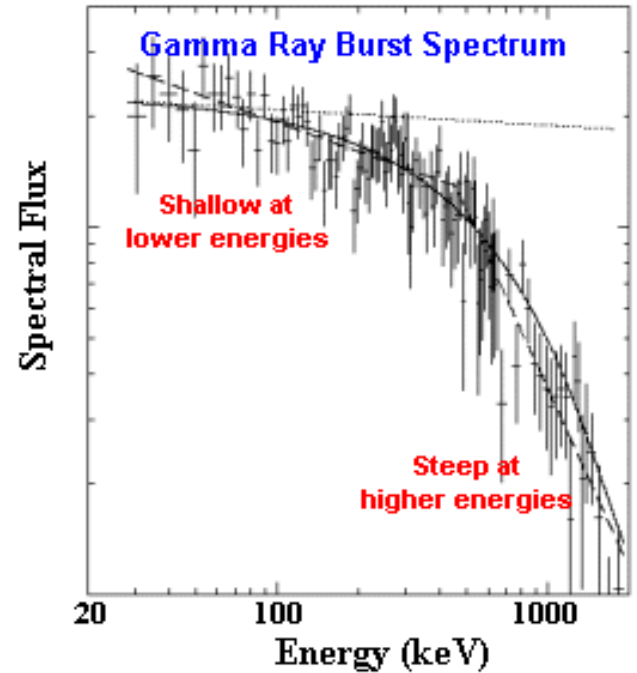
Observed

# Gamma-Ray Bursts

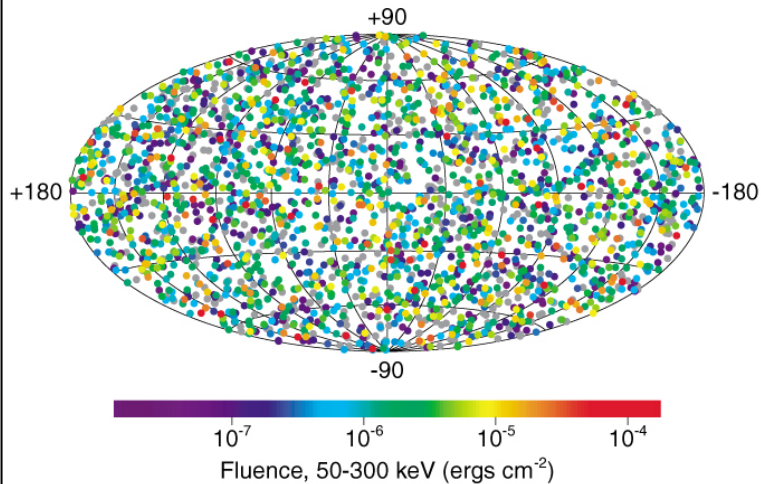
Temporal behaviour



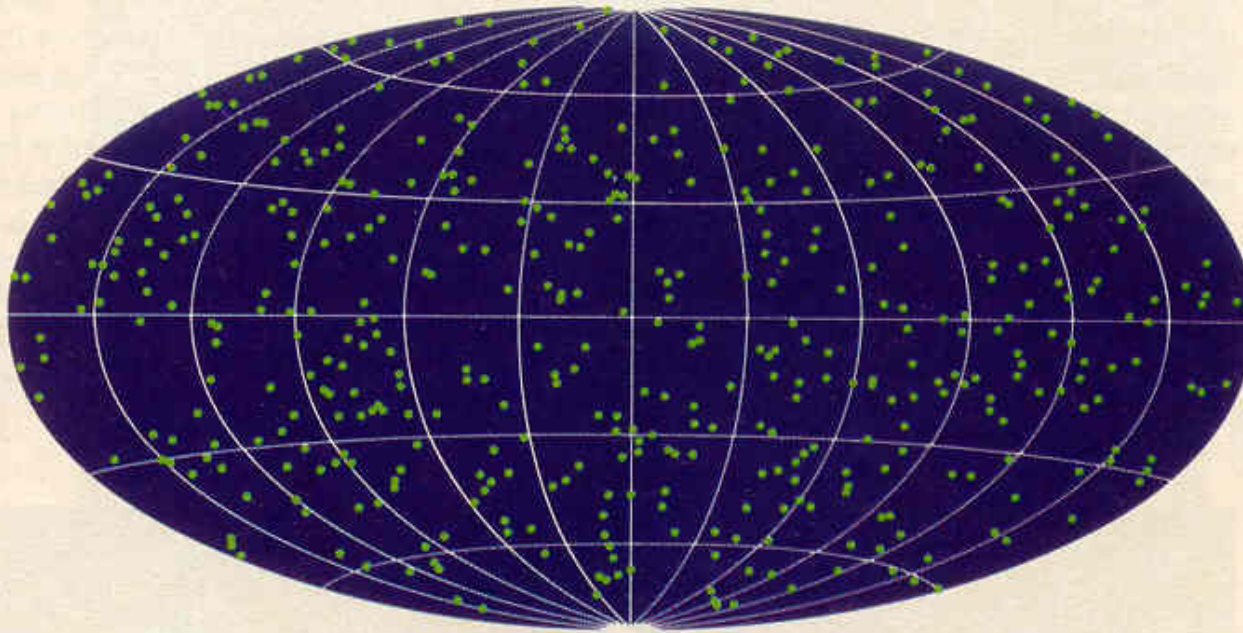
Spectral shape



2704 BATSE Gamma-Ray Bursts

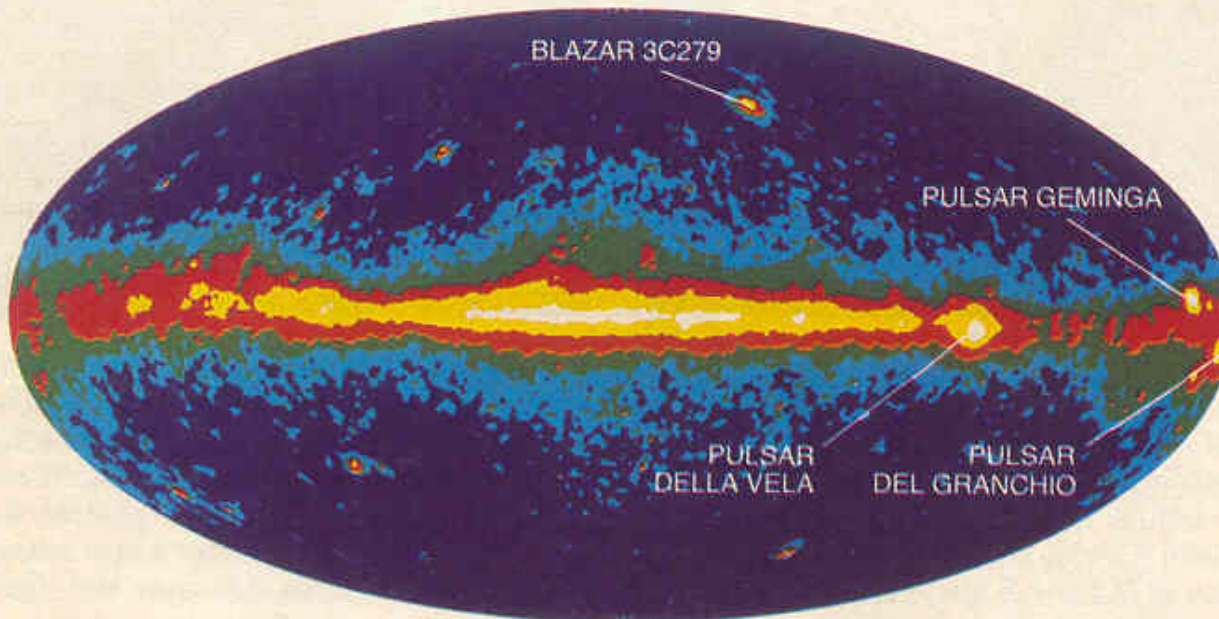


Spatial distribution



**Distribuzione  
di sorgenti  
rivelata da BATSE**

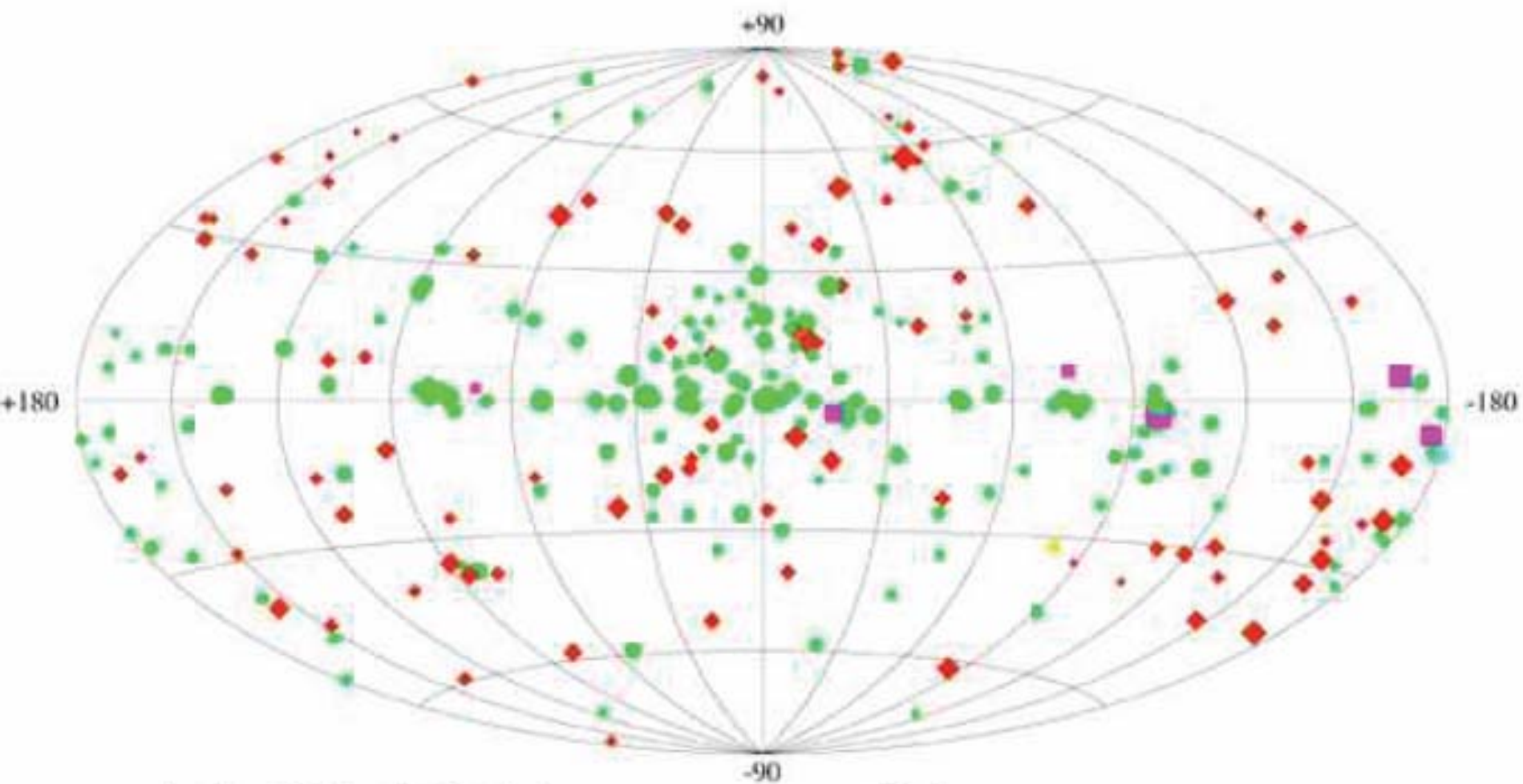
**-isotropa  
-galassie lontane**



**Gamma di alta  
Energia rivelati da  
EGRET**

# Third EGRET Catalog

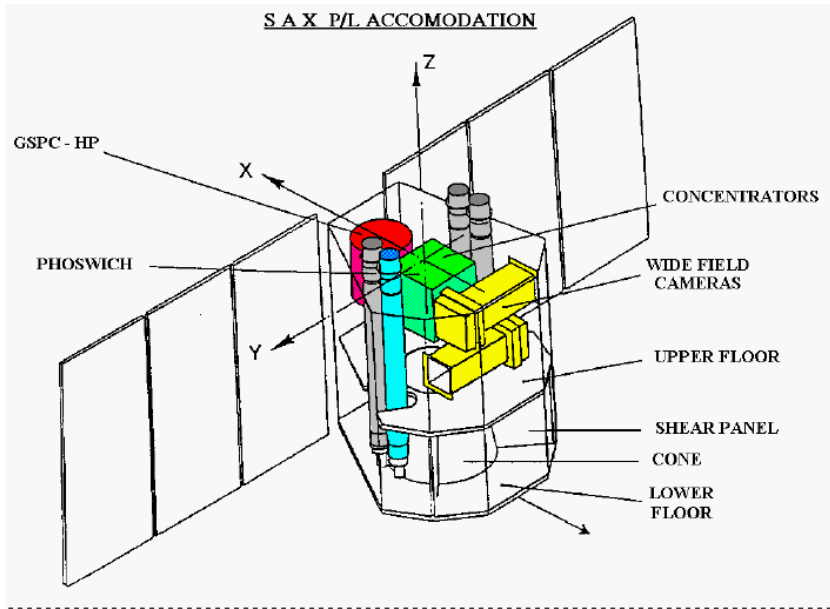
$E > 100 \text{ MeV}$



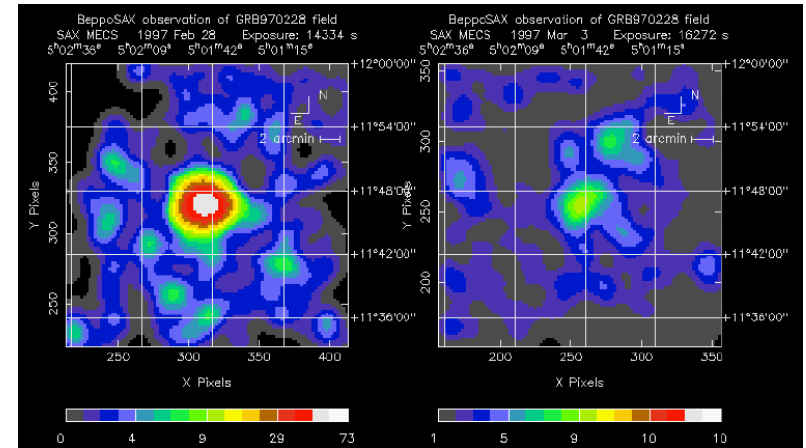
◆ Active Galactic Nuclei  
● Unidentified EGRET Sources

■ Pulsars  
● LMC  
● Solar FLare

# The Afterglow

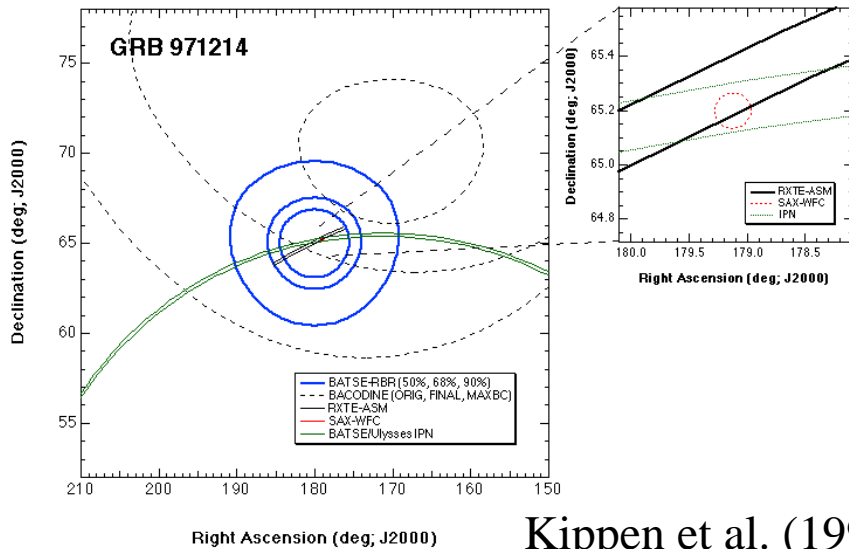


- Good Angular resolution ( $< \text{arcmin}$ )
- Observation of the X-Afterglow

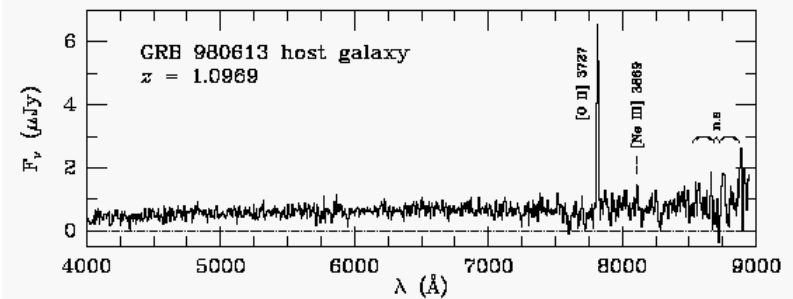


Costa et al. (1997)

- Optical Afterglow (HST, Keck)
- Direct observation of the host galaxies
- Distance determination

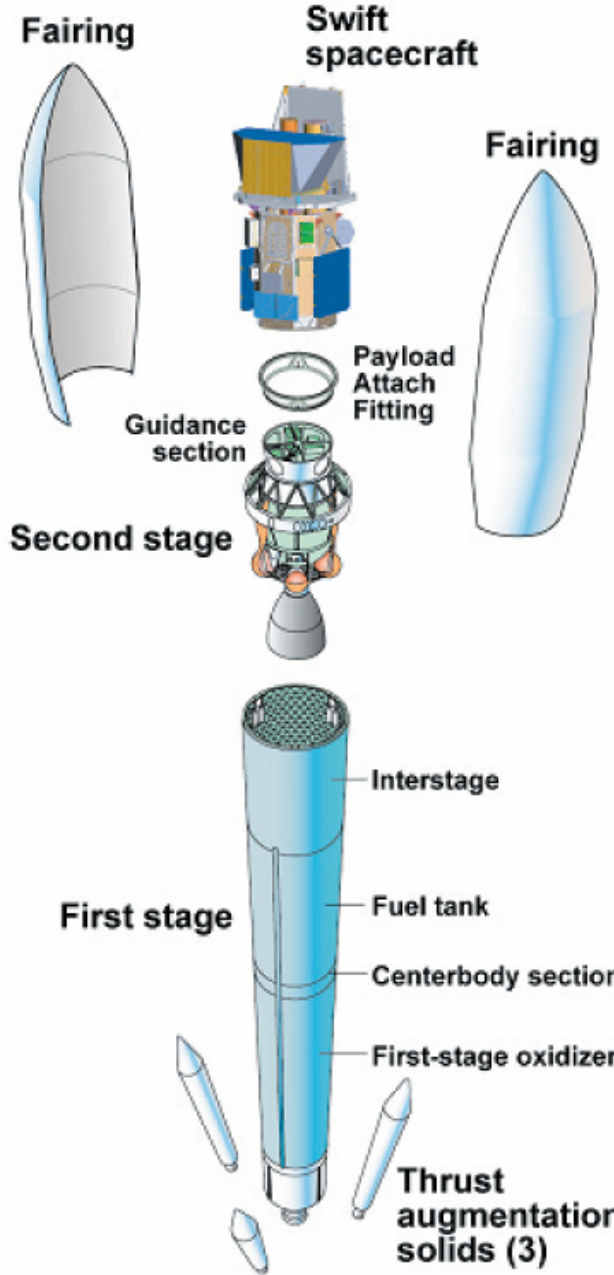
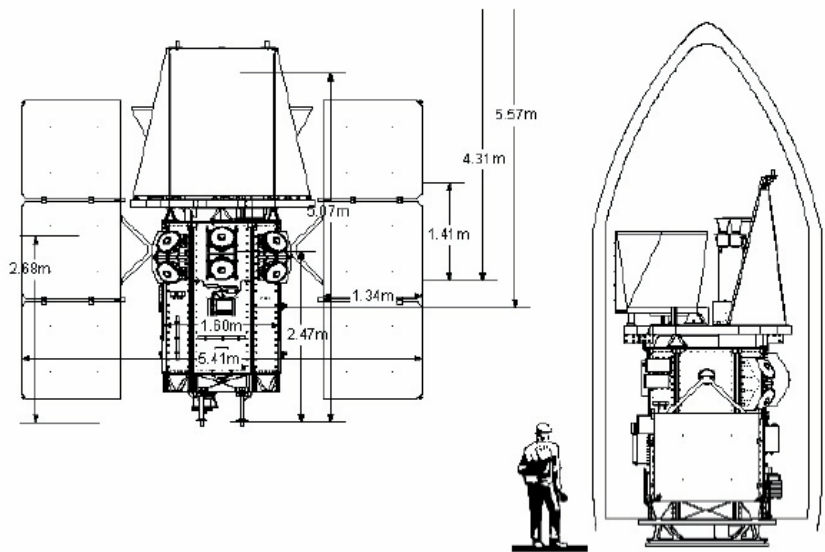
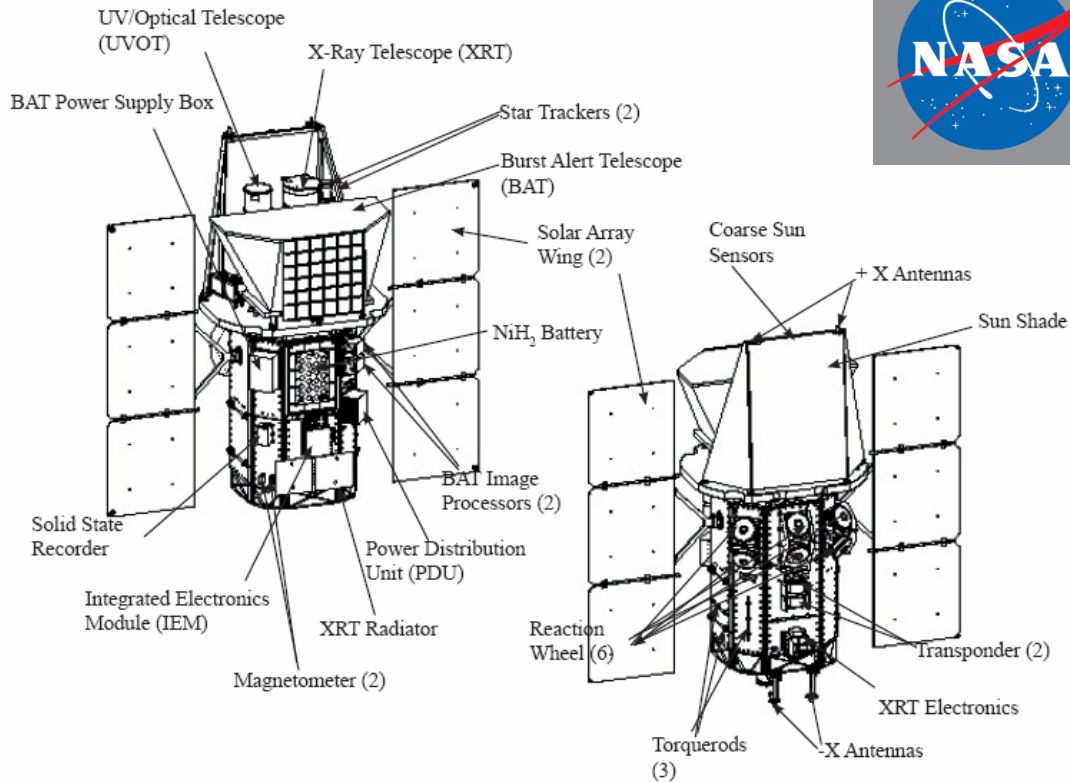
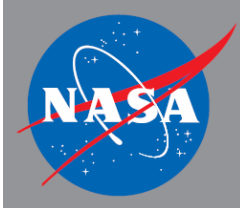


Kippen et al. (1998)



Djorgoski et al. (2000)

# Swift Satellite Schematic



Payload module



**Integral**

IBIS coded mask

JEM-X coded mask

OMC

SPI

Instrument computers and electronics

IBIS detector

JEM-X detectors

Power regulation

Reaction wheels for pointing the spacecraft

Data handling and telecommunication

Star trackers

Instrument computers and electronics

Detector bench

Attitude control electronics

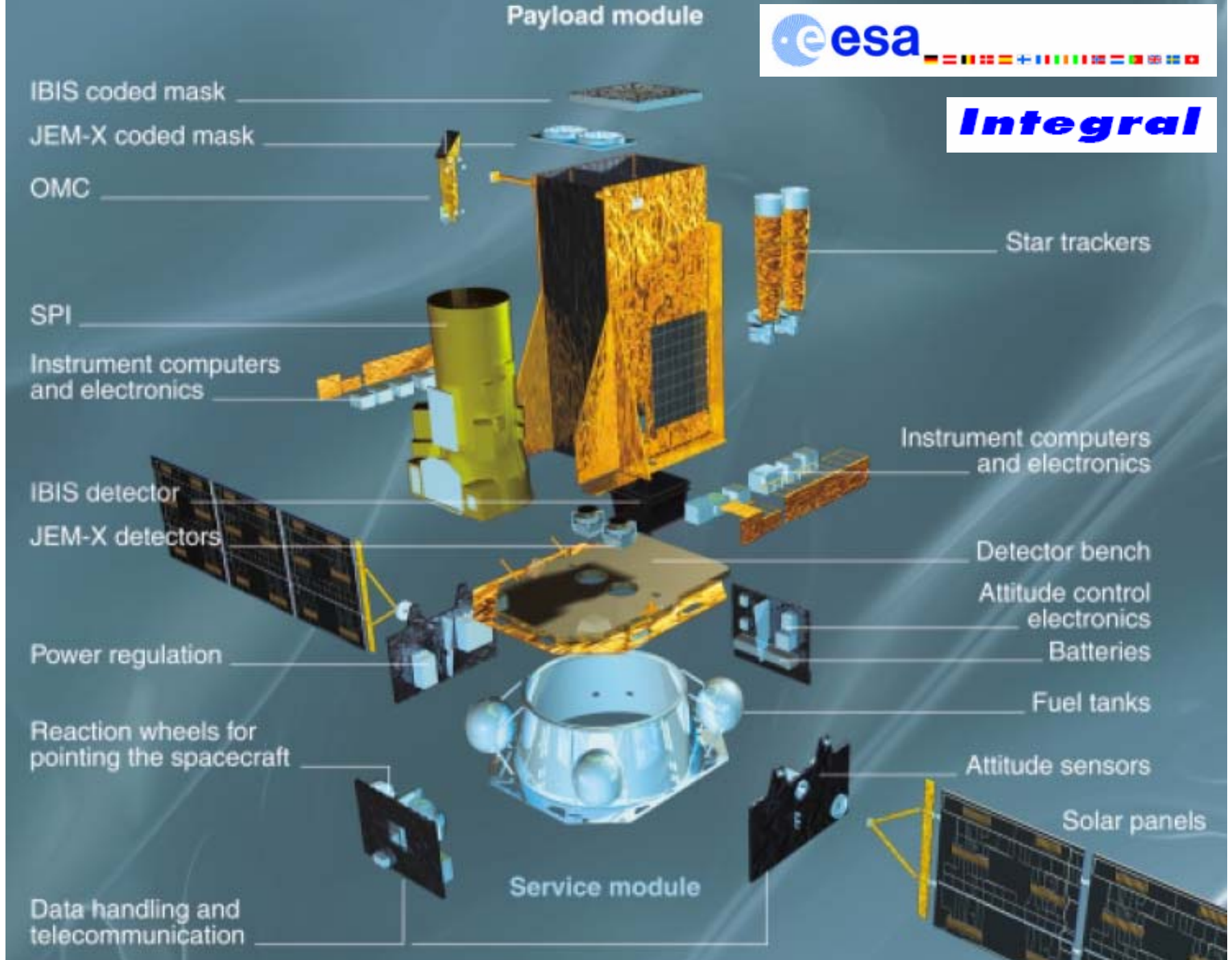
Batteries

Fuel tanks

Attitude sensors

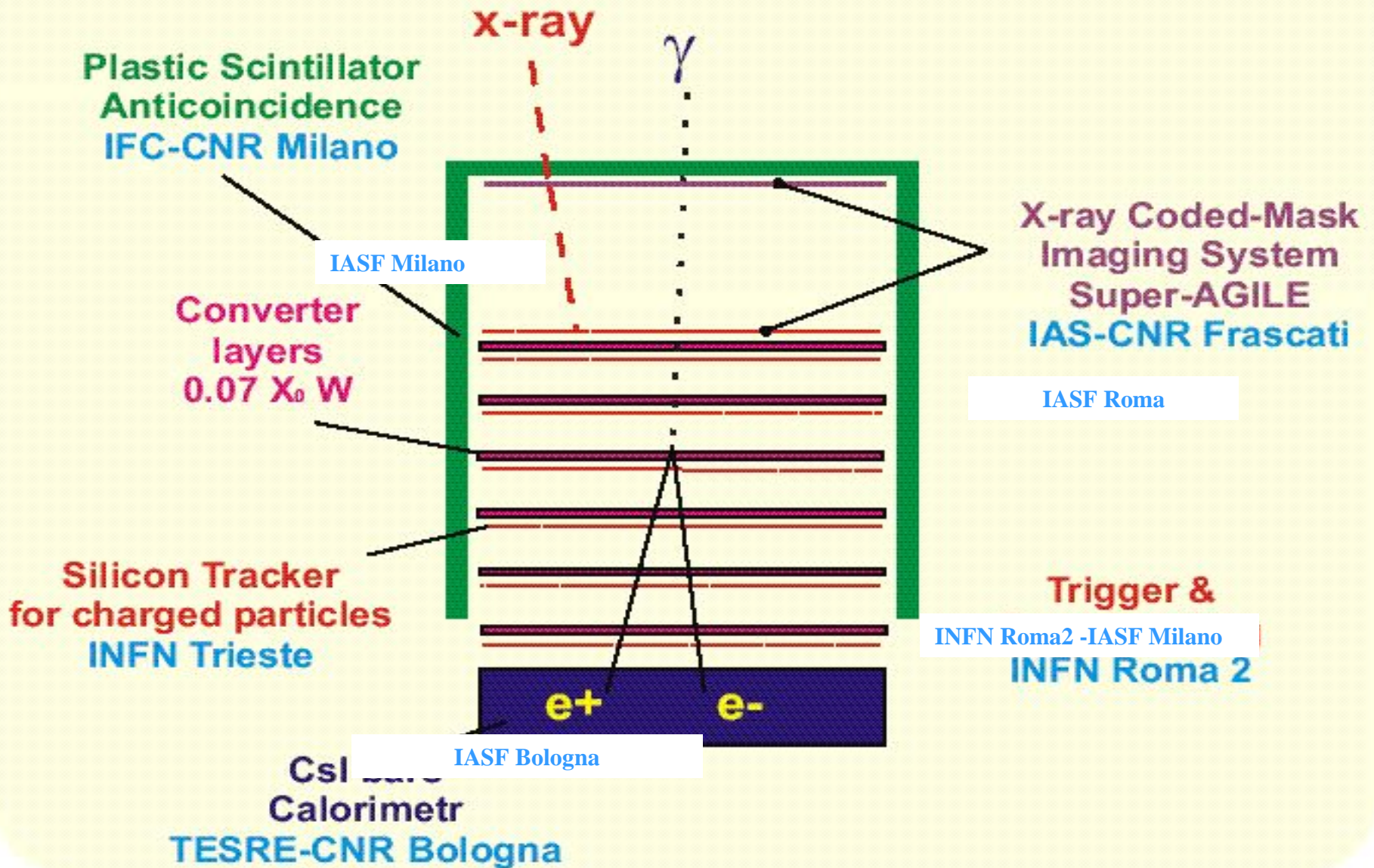
Solar panels

Service module





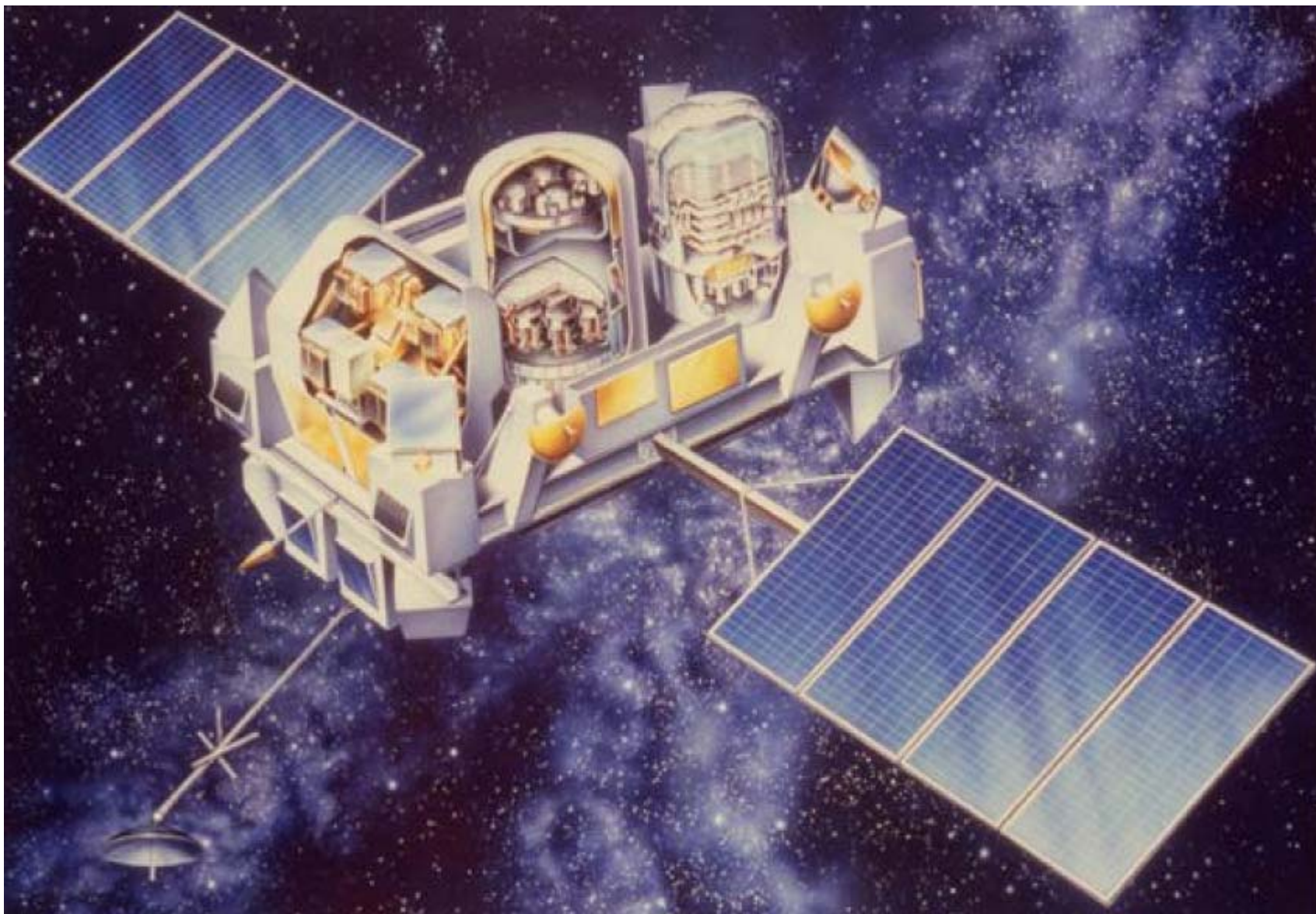
# AGILE payload



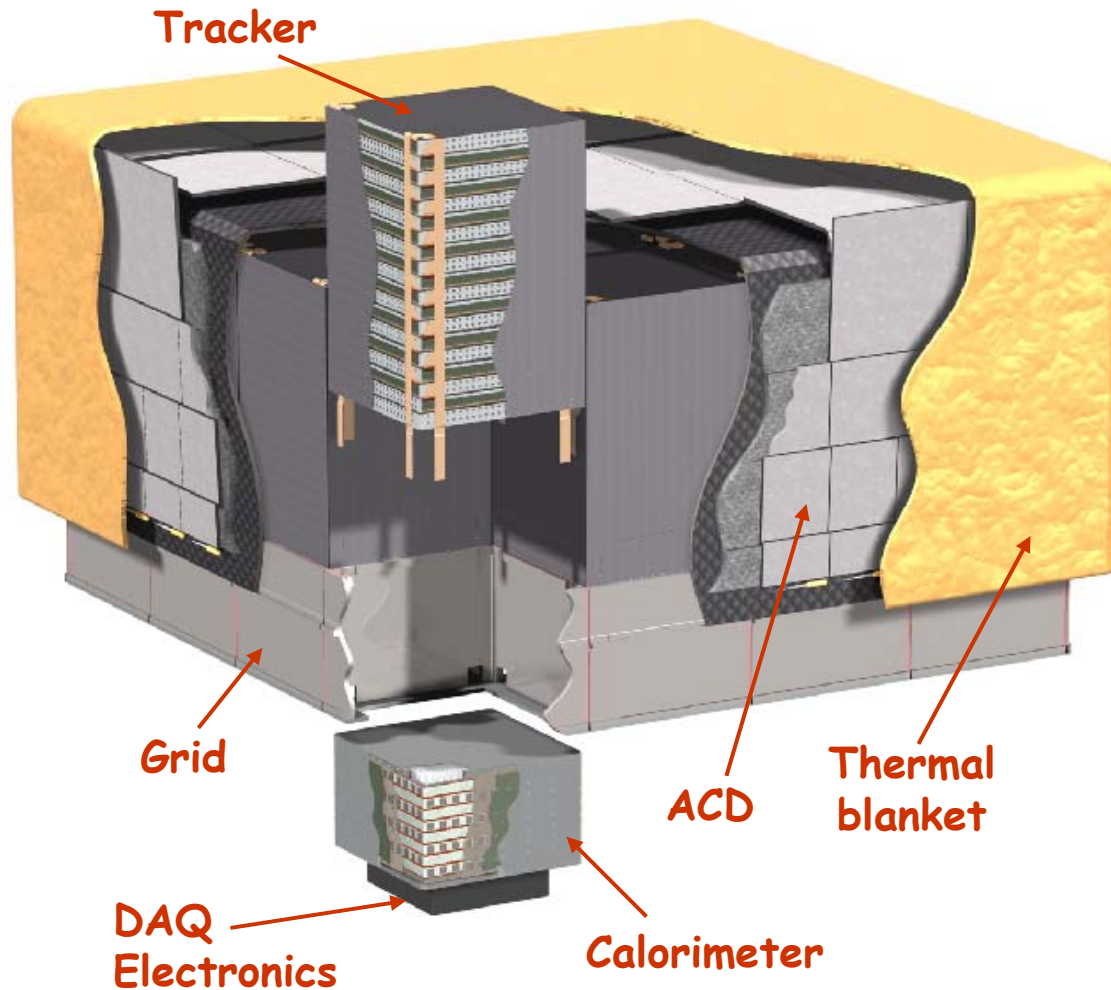
# Modello tecnologico



# GLAST



# Lo Strumento principale di GLAST : il Large Area Telescope



TKR  
CAL  
ACD



CAL



TKR



TKR



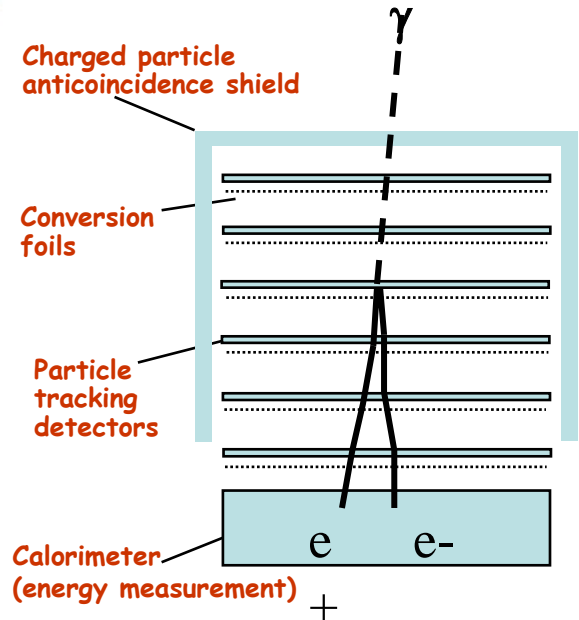
CAL

TKR (auto-triggerante)

- 16 "torri"
- 83m<sup>2</sup> di Si complessivi
- 11500 SSD, ~ 1M canali

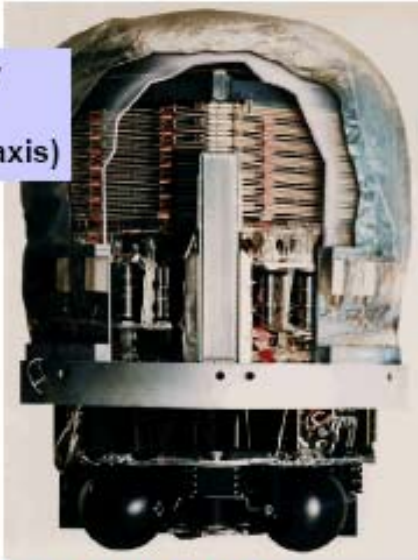
CAL (imaging)

- 96 cristalli di CsI per torre
- 8 strati of 12 cristalli ciascuno
- ciascun strato ruotato di 90°

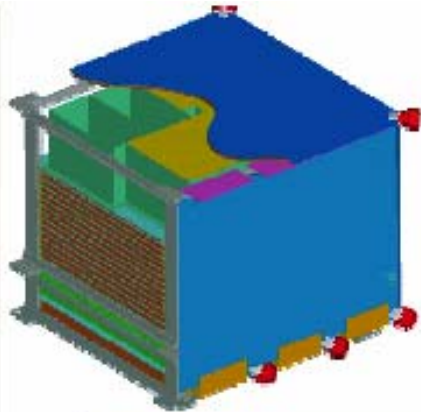


GLAST e' caratterizzato da un utilizzo su vasta scala di moderne tecnologie di rivelazione provate con successo nel campo della fisica delle particelle : rivelatori al silicio e calorimetro elettromagnetico con cristalli di CsI

30Mev-30GeV  
Peak  $A_{\text{eff}}$   
 $1500\text{cm}^2$  (on-axis)

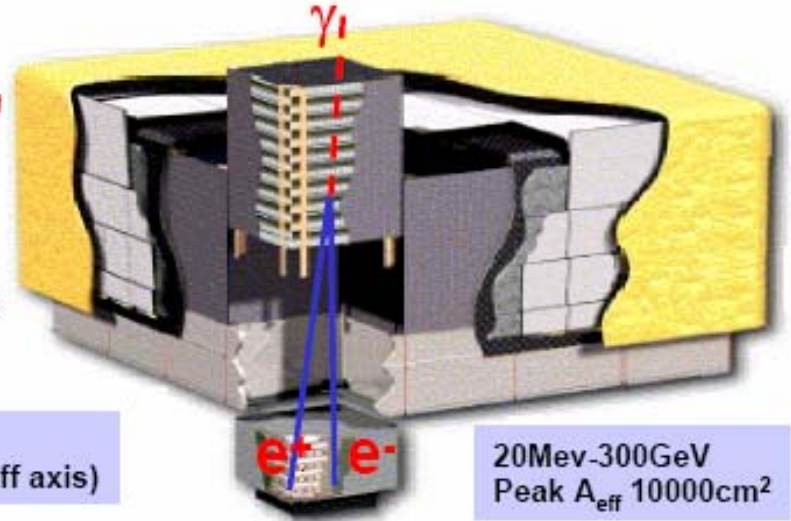


**EGRET 1991-2000**



30Mev-50GeV  
Peak  $A_{\text{eff}}$   $600\text{cm}^2$  (on/off axis)

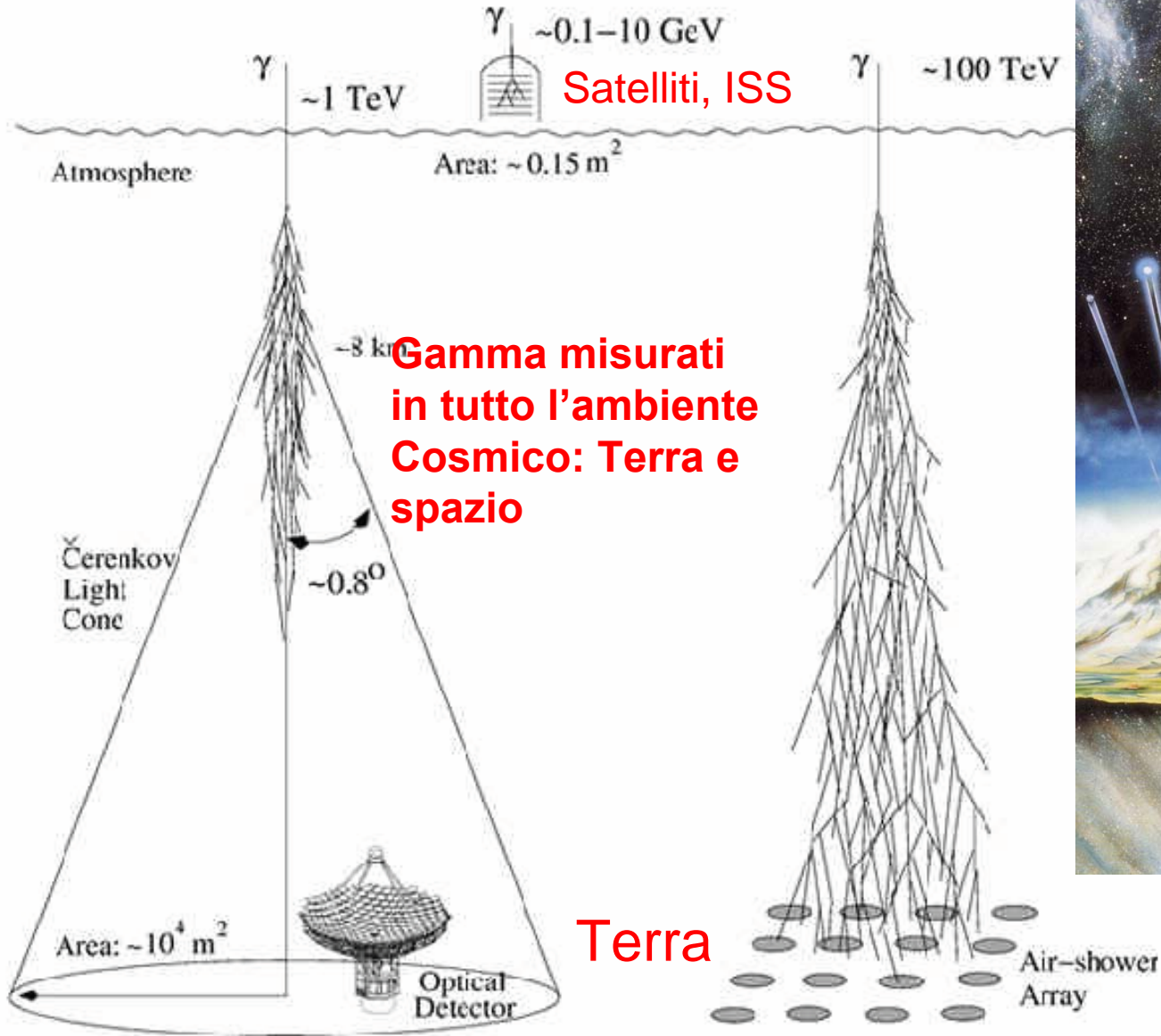
**AGILE 2005 on ...**



20Mev-300GeV  
Peak  $A_{\text{eff}}$   $10000\text{cm}^2$

**GLAST 2007 on ..**

# Gamma misurati in tutto l'ambiente Cosmico: Terra e spazio

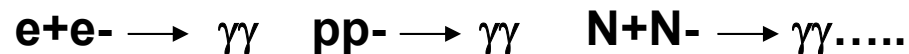


**Gamma misurati  
in tutto l'ambiente  
Cosmico: Terra e  
spazio**



# Ricerca di antimateria nello spazio

La materia va a coppie: per ogni particella esiste una antiparticella:  $e/e^-$ ,  $p/p^-$ ,  $N/N^-$ -  
-particella e antiparticella hanno stessa massa ma carica elettrica opposta  
-usualmente si crea in reazioni nucleari dove materia ed antimateria si conserva  
-fuori dei laboratori sulla terra non si trova antimateria. E nell'Universo?  
-materia e antimateria incontrandosi si annichila:



-stella di materia ed antimateria si annichilerebbe  
-i raggi cosmici sono costituiti prevalentemente da materia:  $p$ ,  $e$ ,  $N \dots$   
-Le sorgenti astrofisiche le osserviamo con particelle neutre  $X$ ,  $\gamma$ ,  $\nu$  e non ci danno informazione. Anche l'antimateria emette  $X$ ,  $\gamma$ ,  $\nu$

## Possibile spiegazione

Al Big Bang esisteva materia ed antimateria  
Successivamente una simmetria ha fatto prevalere la materia

Esiste ancora antimateria primordiale?: Ricerca diretta





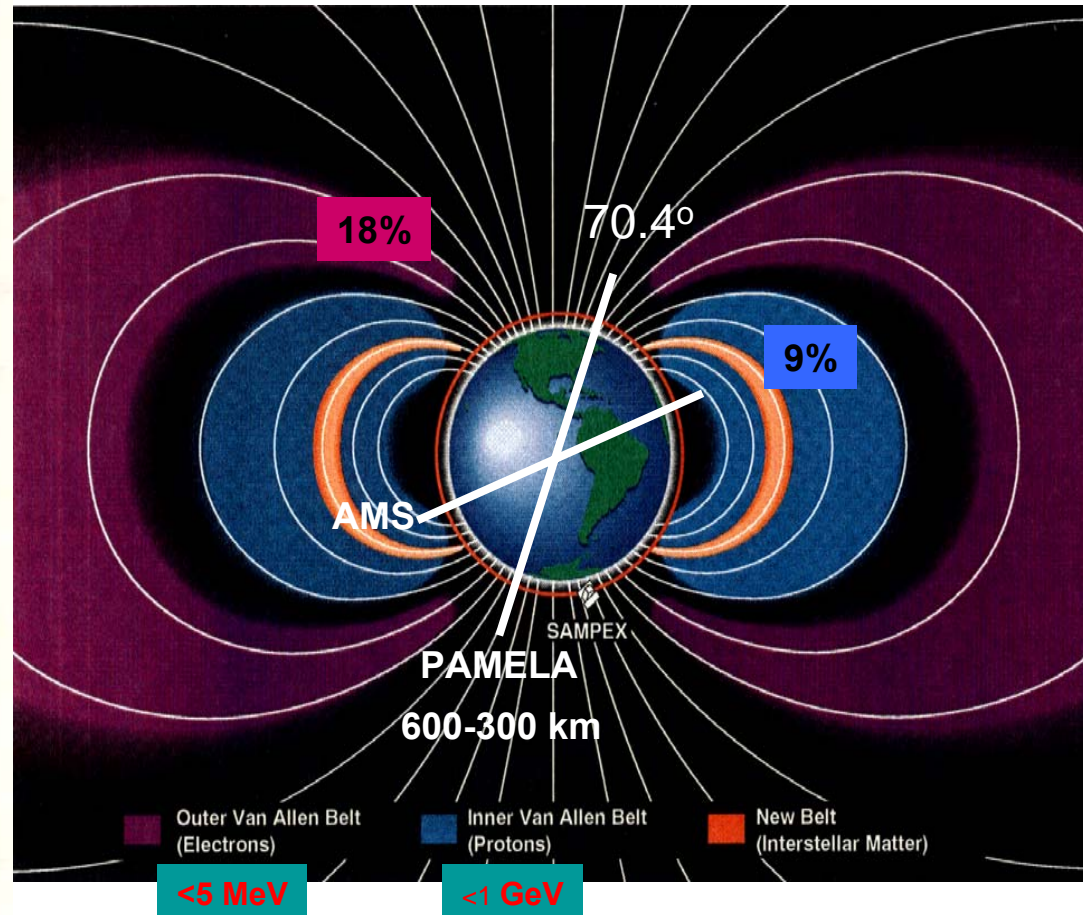
# The PAMELA Space Mission

a **P**ayload for **A**ntimatter **M**atter **E**xploration and **L**ight-nuclei **A**strophysics



# Base di lancio: Baikonur

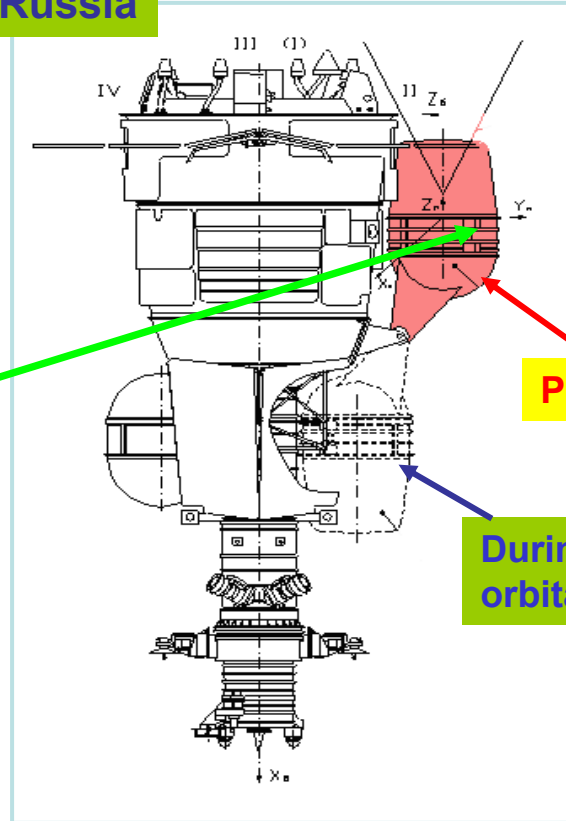
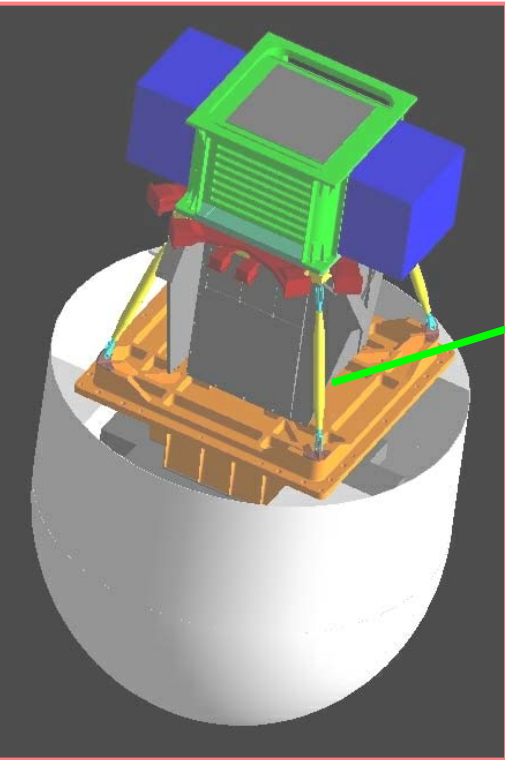
# Orbita del satellite Resurs DK1/Pamela



Basso taglio geomagnetico: particelle <math>< 100 \text{ MeV}</math>

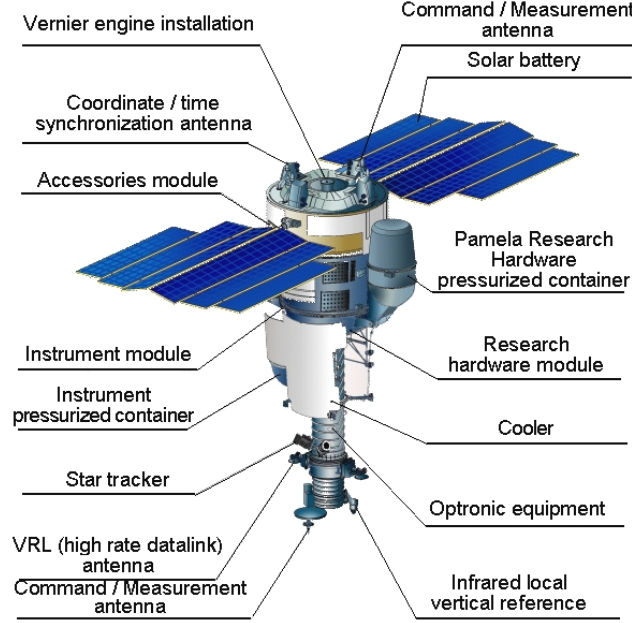
# Satellite Resurs-DK1

TsKB-Progress-Samara-Russia



**Pamela**

**During launch / orbital manoeuvres**



**Alloggiamento a pressione ~ atmosferica (2 mm Al)**  
**Temperature = 5°C - 40°C**

**Tutti i sottosistemi devono resistere alle vibrazioni di lancio e riposizionamento**

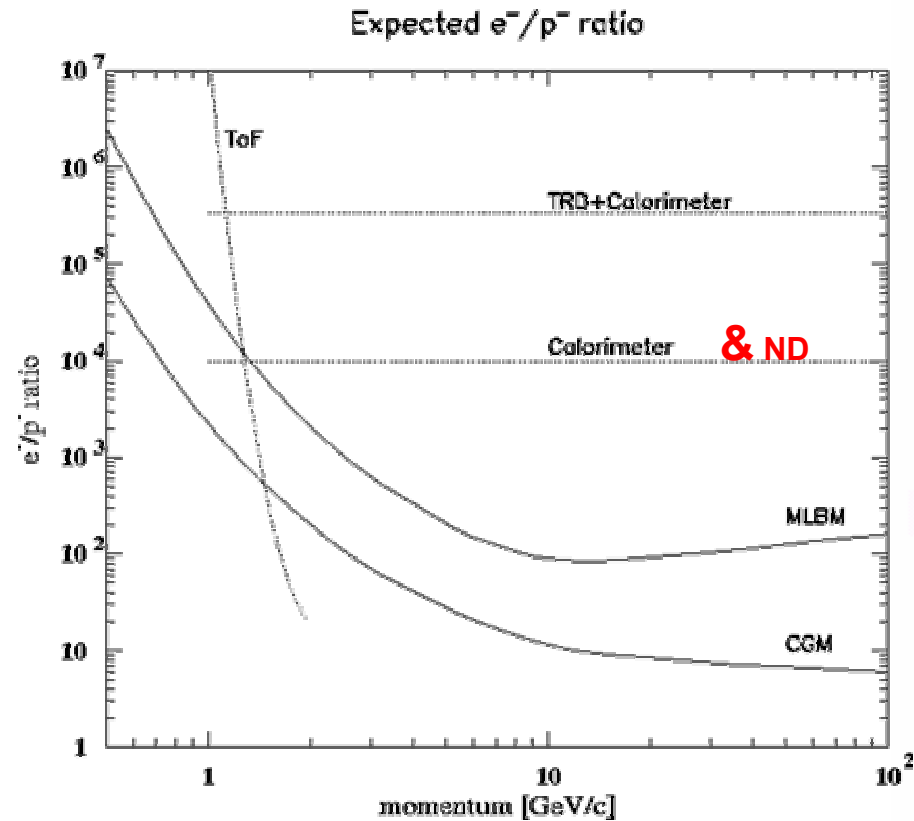
**Satellite Resurs Dk1 (~10 tons)**  
**Osservazione della Terra**  
**orbita = 350 - 610 km**  
**Inclinazione massima = 70°**  
**Vita ~ 3 anni**



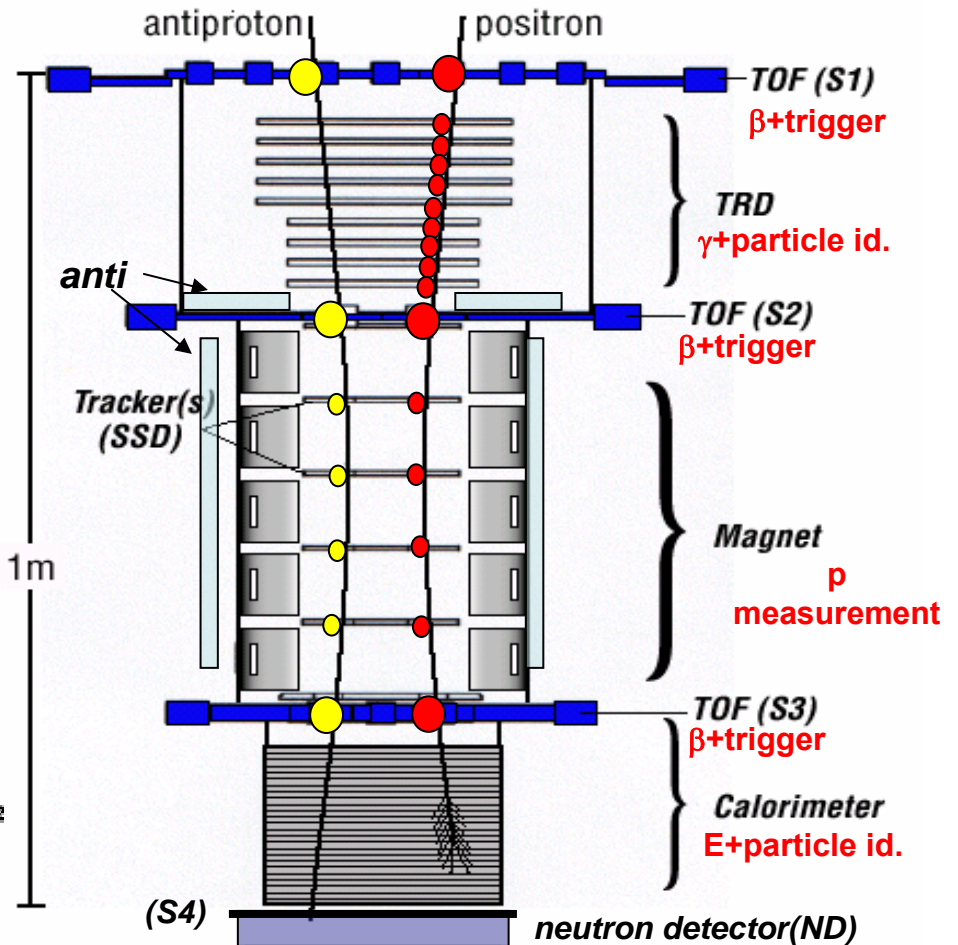
**Lanciatore Soyuz 2**  
**Sito di lancio Baikonur**  
**Data di lancio 2005**

# Disegno concettuale dell'esperimento

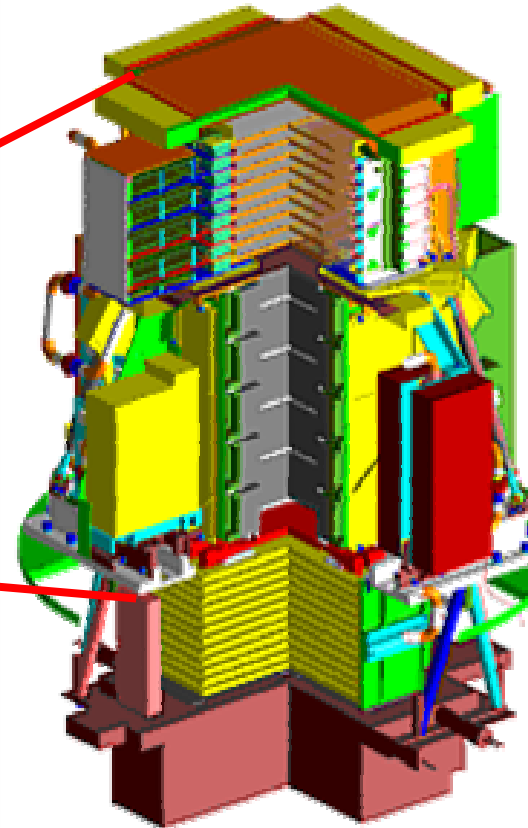
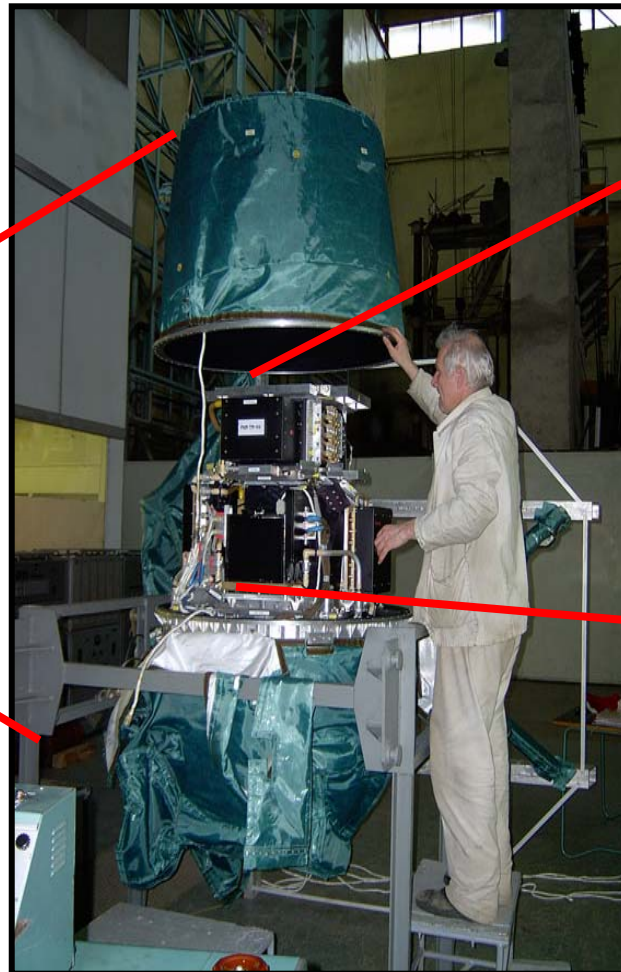
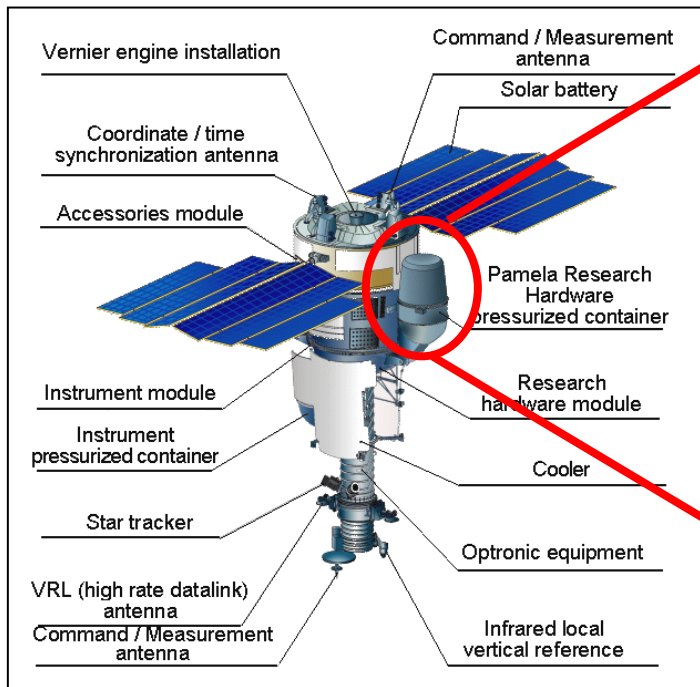
**Elevata reiezione p/e  
+ misura nuclei**



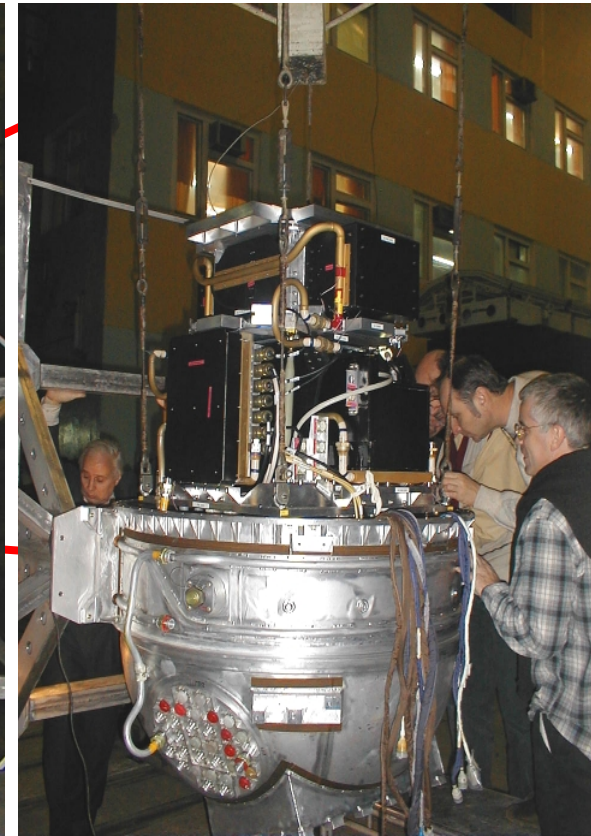
**-Ridondanza TRD + CALO ad alta energia (+ND)**  
**-Marcatura antiprotone, antinuclei**



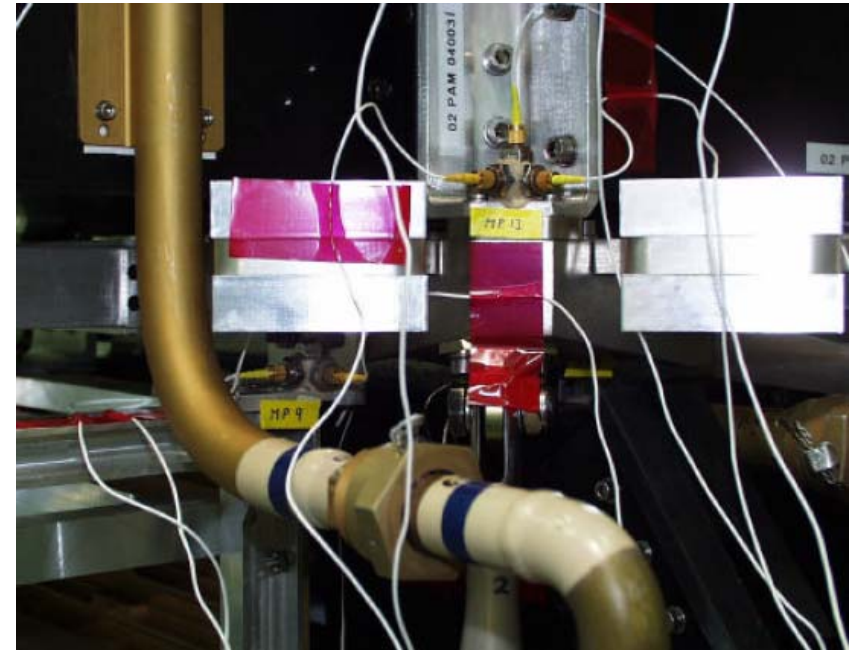
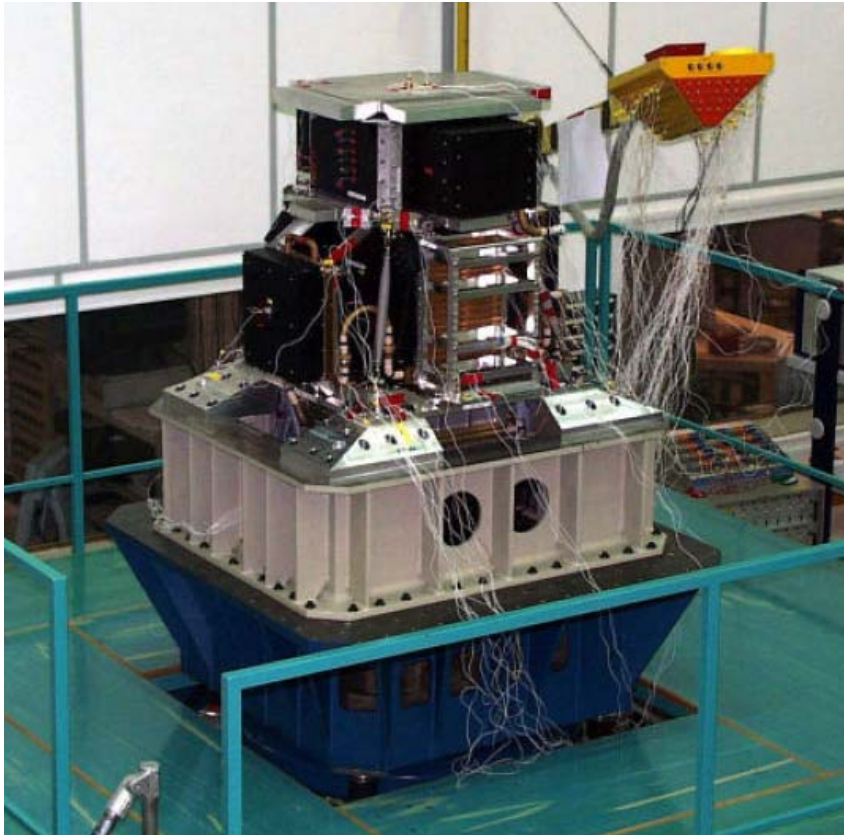
# PAMELA – Integrazione



# Pamela Container + Pamela Mass-Thermal-Model at TsSKB Samara / Russia



# Test di vibrazione e shock del Mass-thermal model a IABG (Monaco)

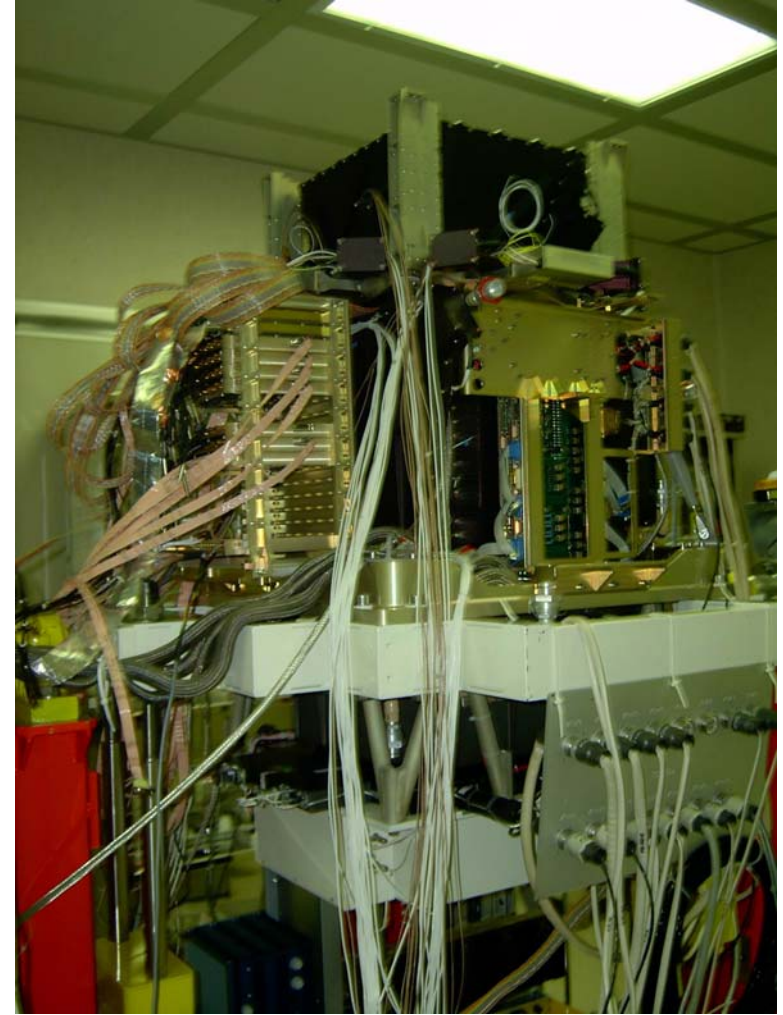
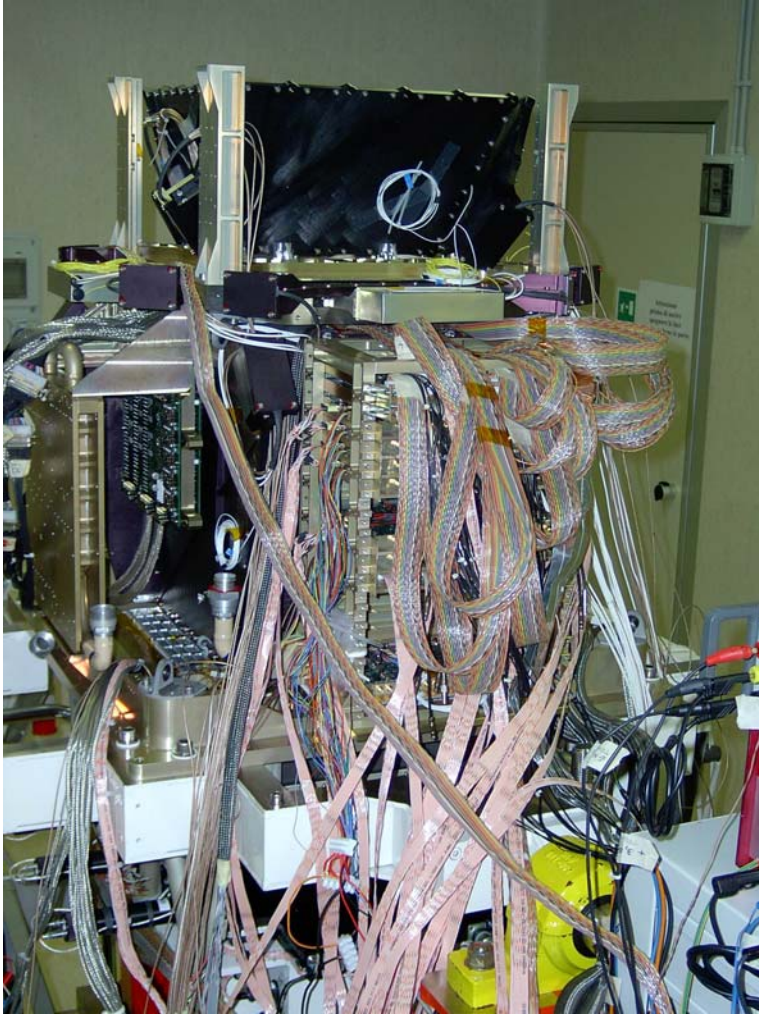


Crack in una pipe del cooling loop



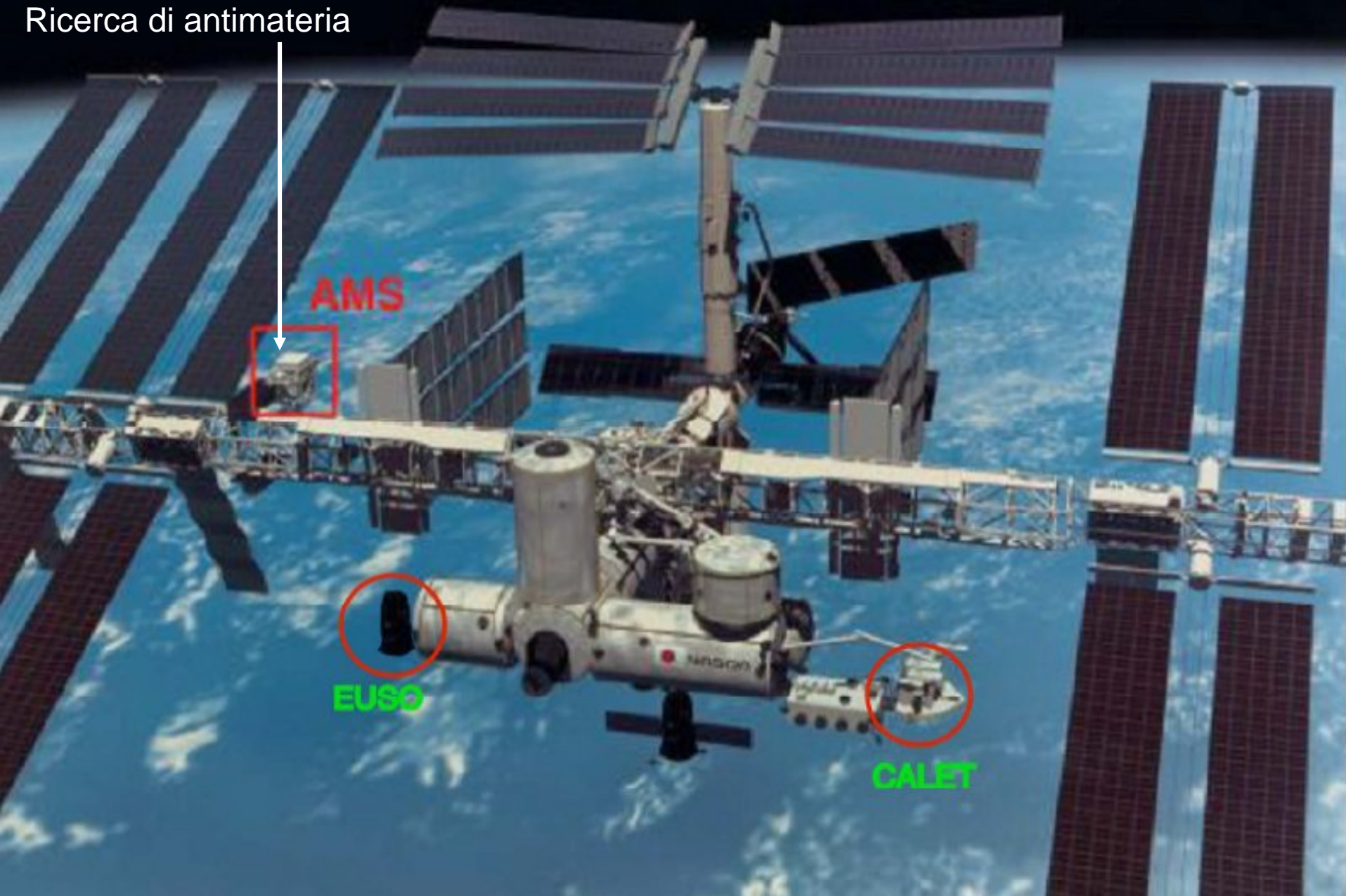
# Flight Model

**Avanzata fase di completamento: partenza per TsSKB  
(Samara) gennaio 2005 per integrazione su  
Satellite Resurs DK1**



# The International Space Station

Ricerca di antimateria



AMS

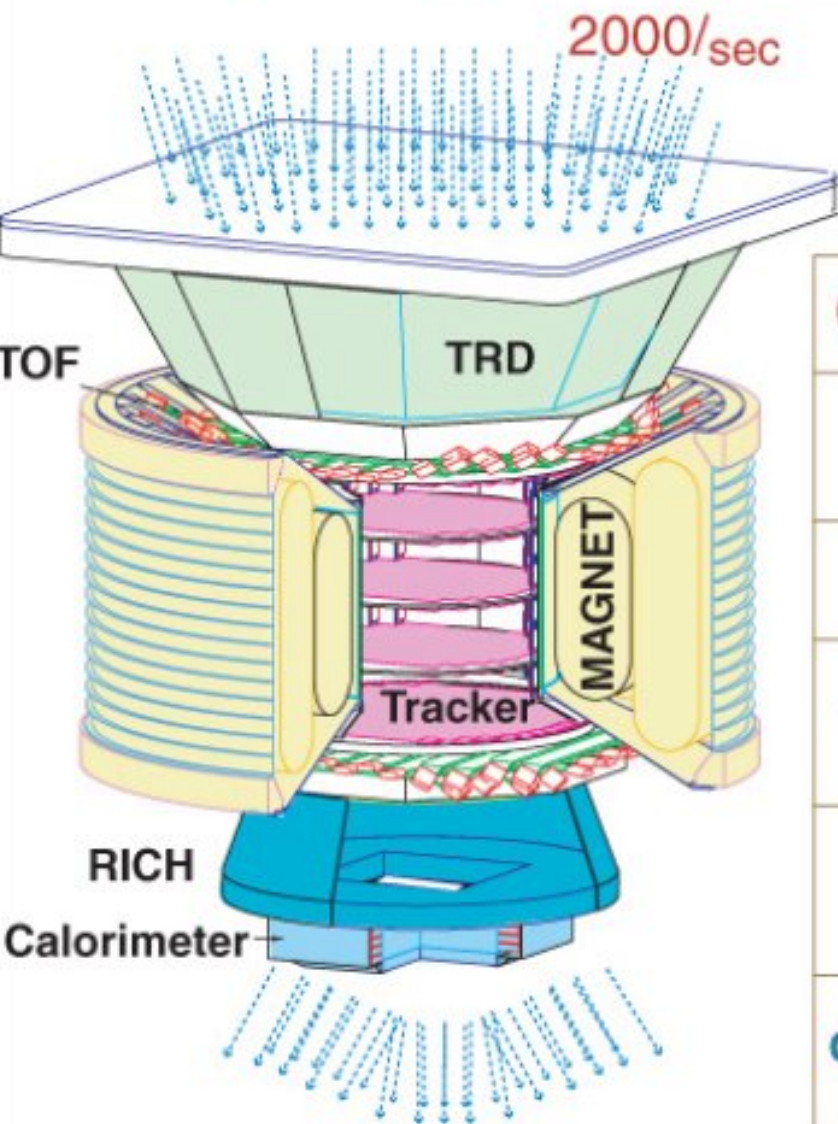
EUSO

CALET





# AMS: A TeV Magnetic Spectrometer in Space

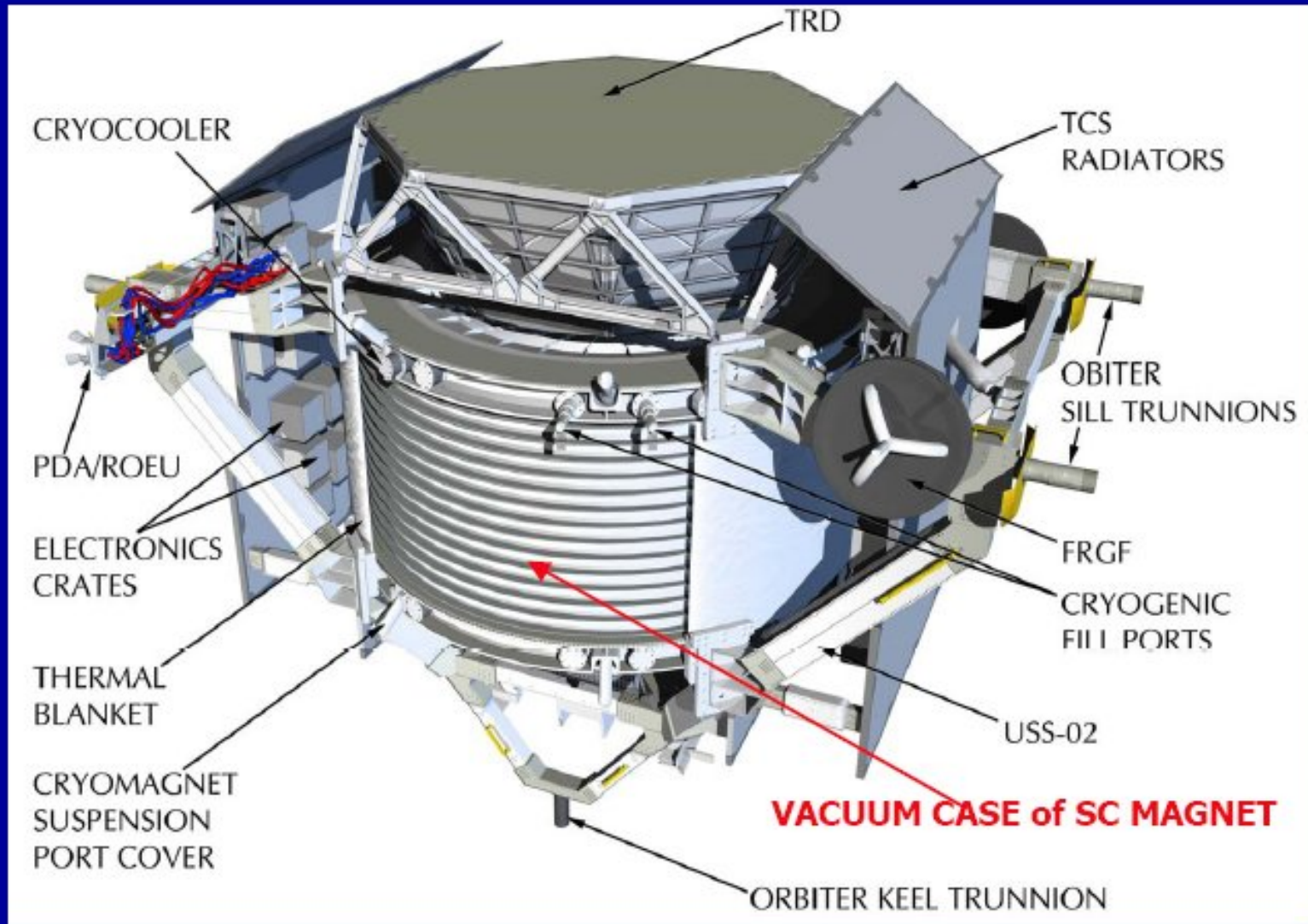


**G.F. 5000 cm<sup>2</sup> sr**  
**Exposure > 3 yrs**

0.3 TeV	e <sup>-</sup>	e <sup>+</sup>	P	He	γ
TRD					
TOF					
Tracker					
RICH					
Calorimeter					

**$h/e = 10^{-6}$  ECAL + TRD combined**

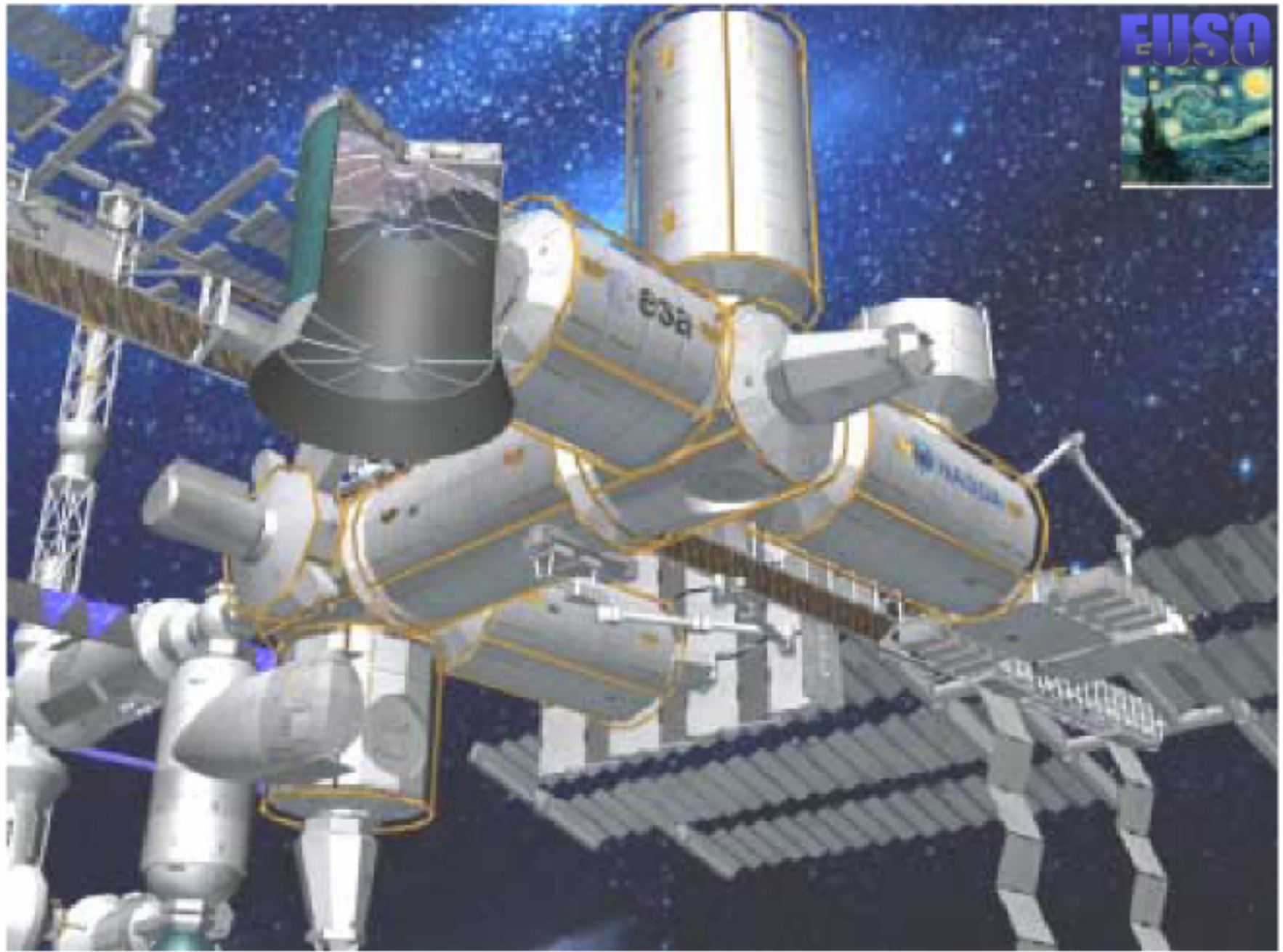
# AMS-02 Detector



**ISS**



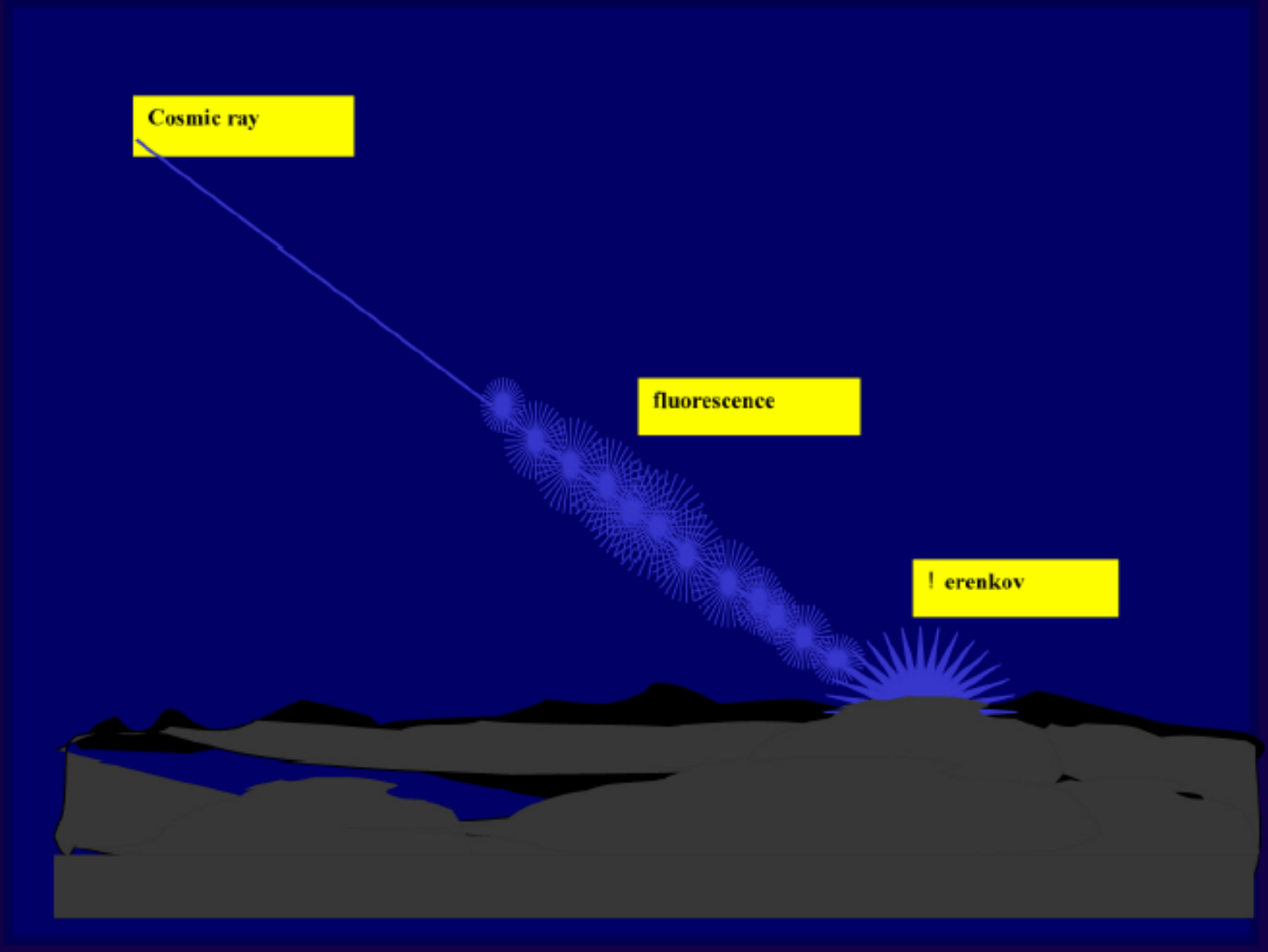
# *Extreme Universe Space Observatory - EUSO*

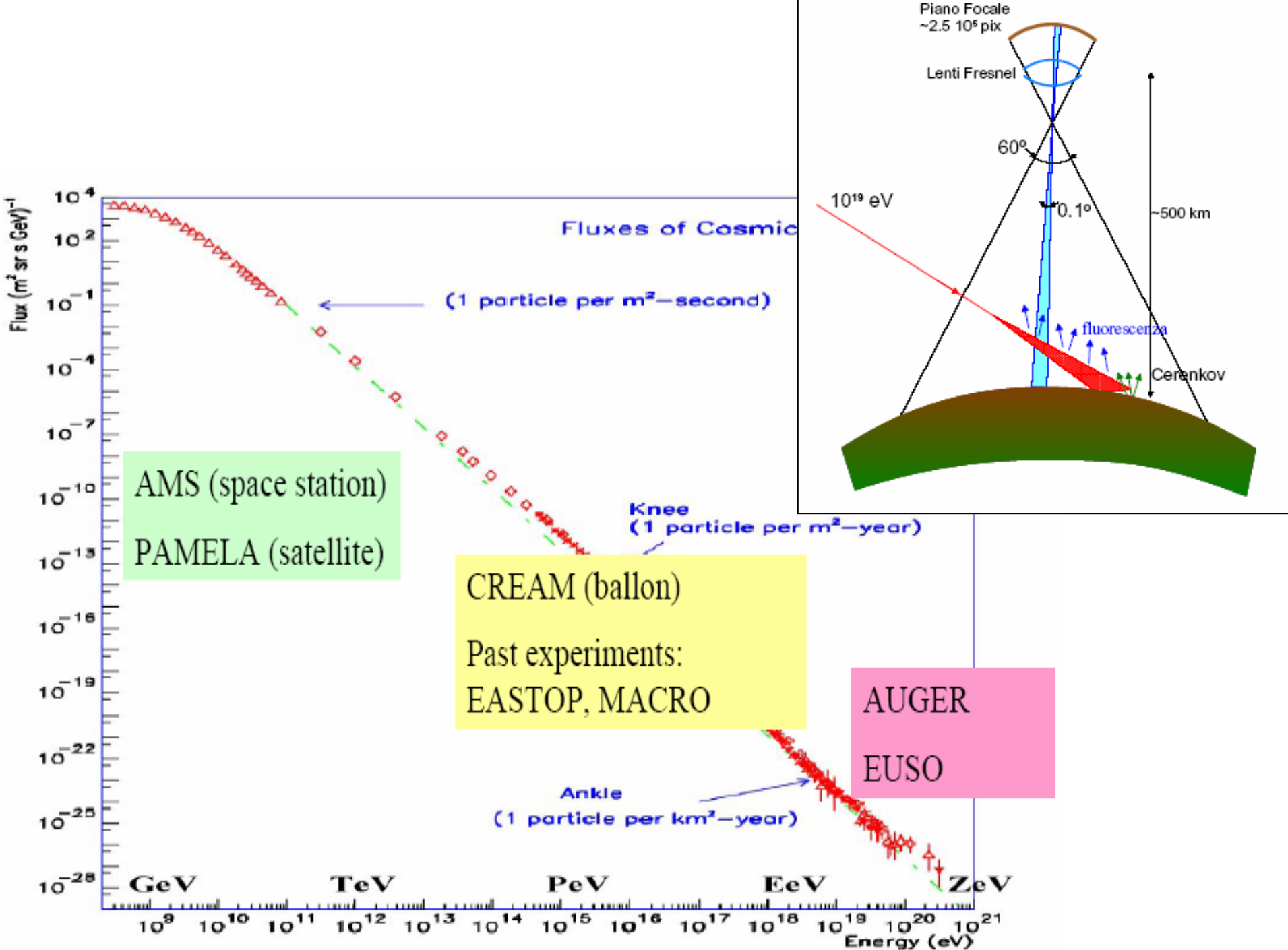


Cosmic ray

fluorescence

Cherenkov





# Materia Oscura (dark matter)

## What is the Universe made of ?

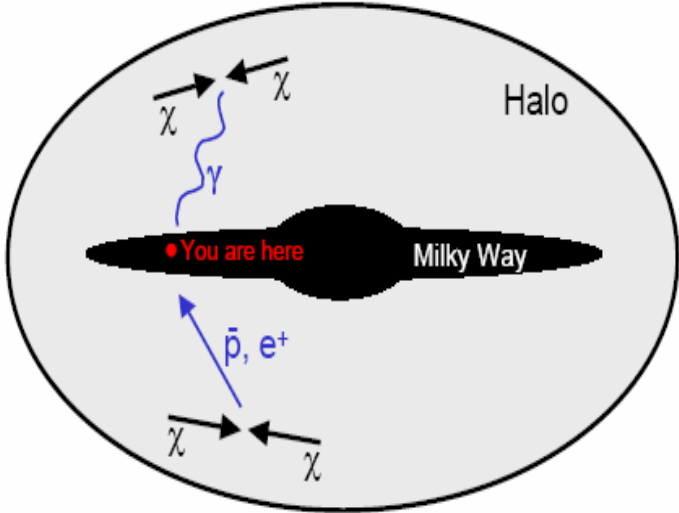
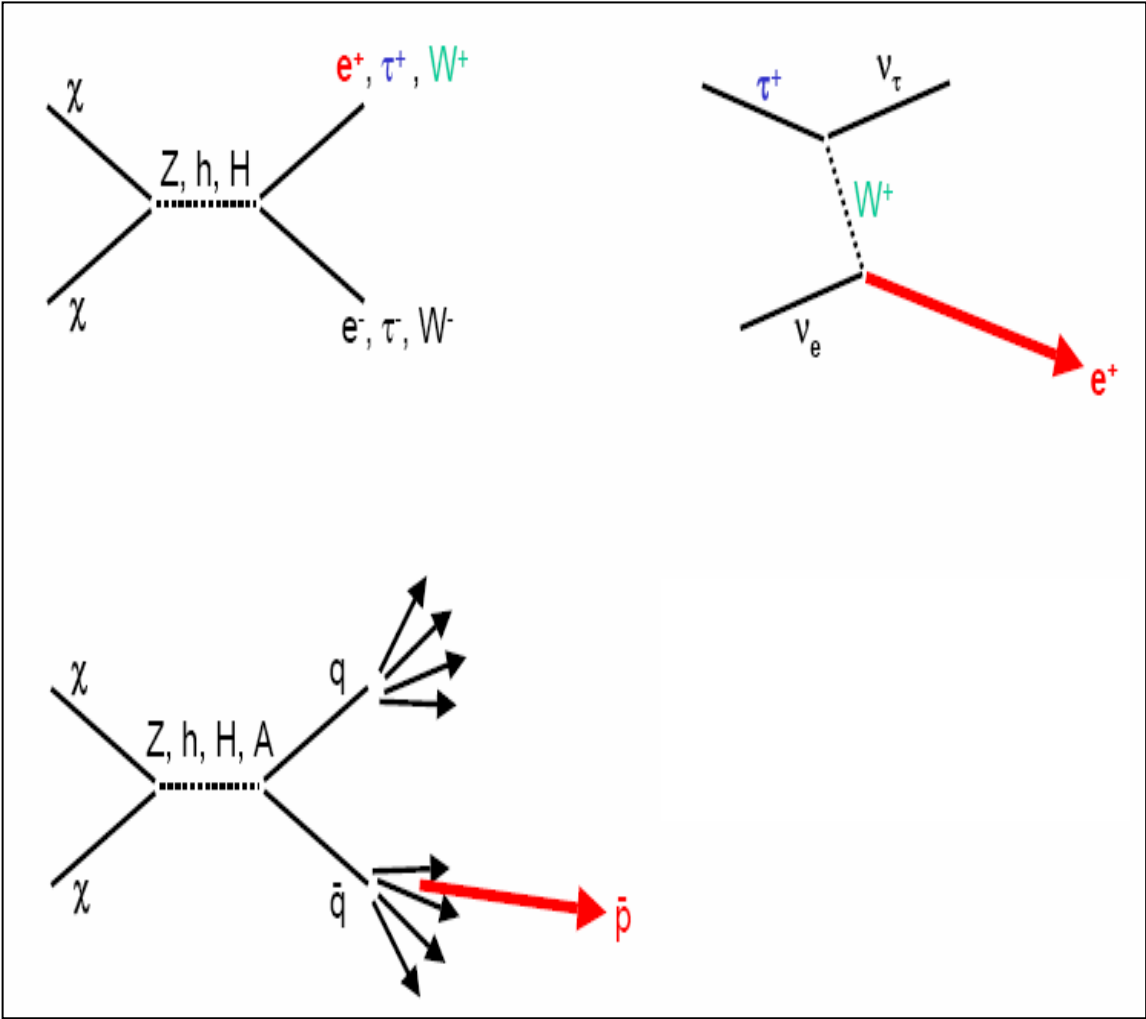
We know that there is dark matter, which is needed to explain the dynamics of stars in Galaxies and of galaxies in clusters. This dark matter does not interact with light, and we do not know which particles it is made of.



The peripheral stars of the galaxy M63 rotate around the center so fast that they would fly away in space without the presence of additional mass inside the galaxy. This is indirect evidence for the presence of dark matter



# Annichilazione di neutralino

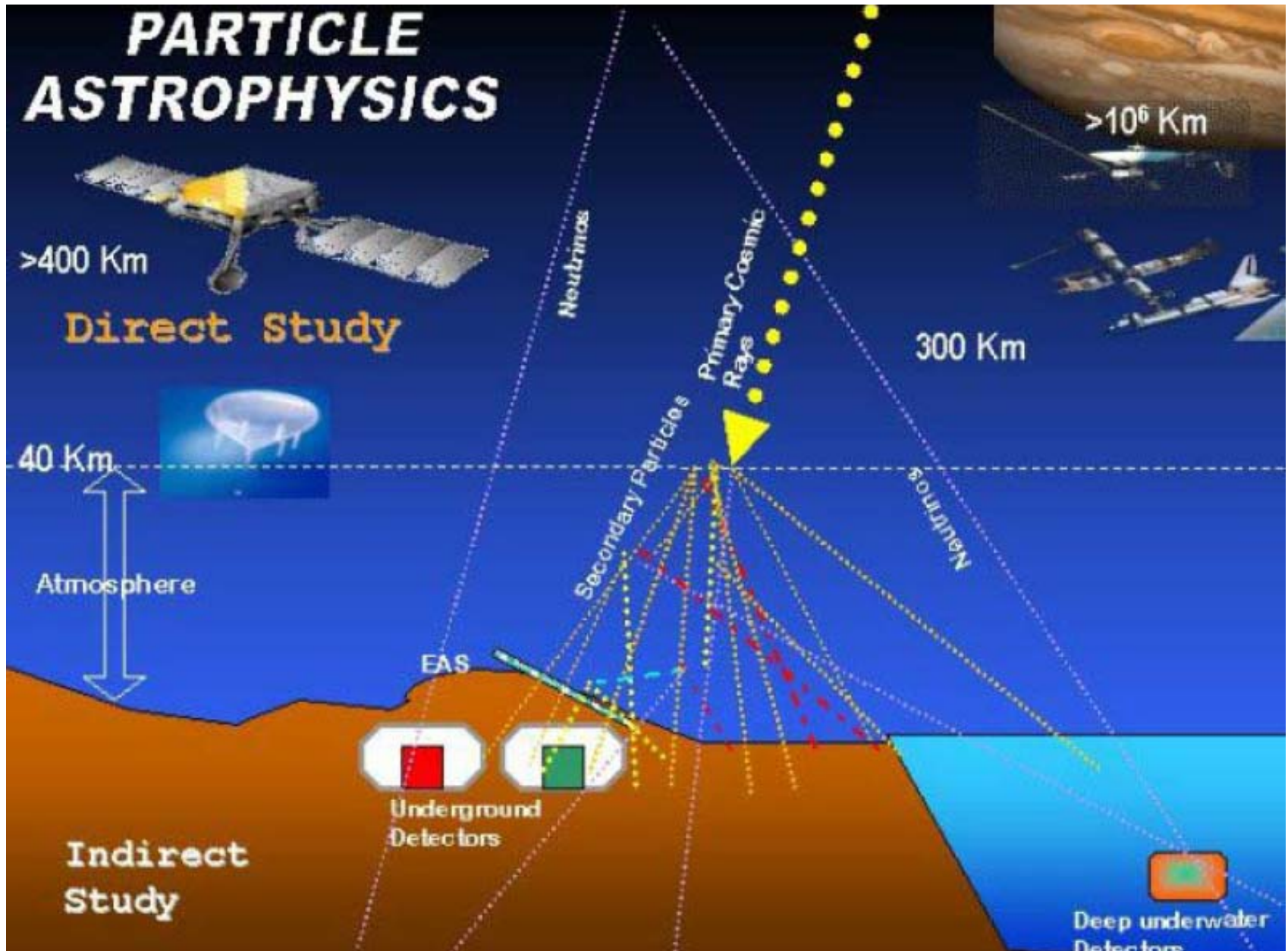


Glast	$\chi + \bar{\chi} \rightarrow X + \gamma$
Amanda/Ice Cube	$+ \nu$
Pamela AMS	$+ \bar{p}$
	$+ e^+$

**Distorsione dello spettro di antiprotoni e positroni oltre la pura produzione secondaria**



# Il laboratorio cosmico



# Programma 2015-2025

**Dopo i palloni, i satelliti,  
la stazione spaziale internazionale  
la tecnologia e' matura per realizzare  
il laboratorio estremo sulla luna**

**Una affascinante corsa alla scoperta dell'Universo**

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Dept. Of Physical Sciences-University Federico II Napoli  
INFN – Napoli Unit**