

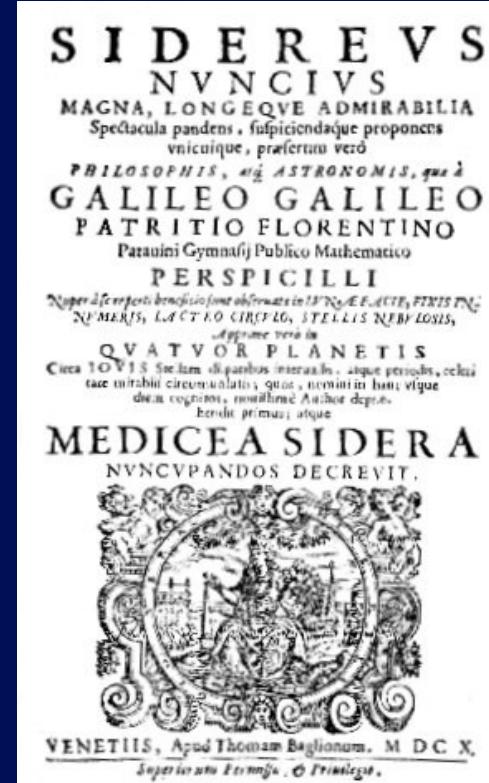
I Colori dell'Universo

Gino Tosti
Dipartimento di Fisica
Università di Perugia
INFN & INAF
tosti@pg.infn.it

Galileo Galilei - Inizia l'Astronomia Moderna



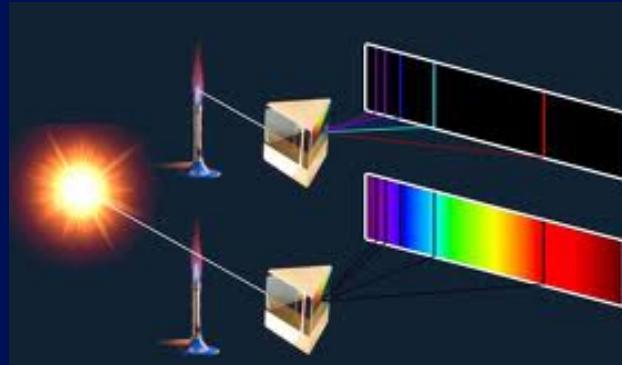
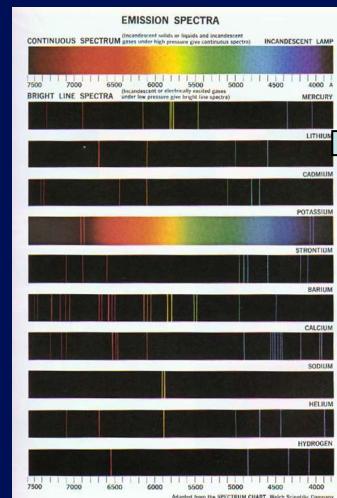
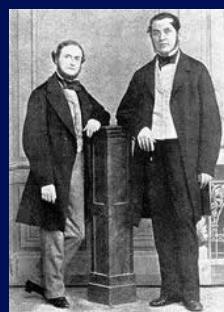
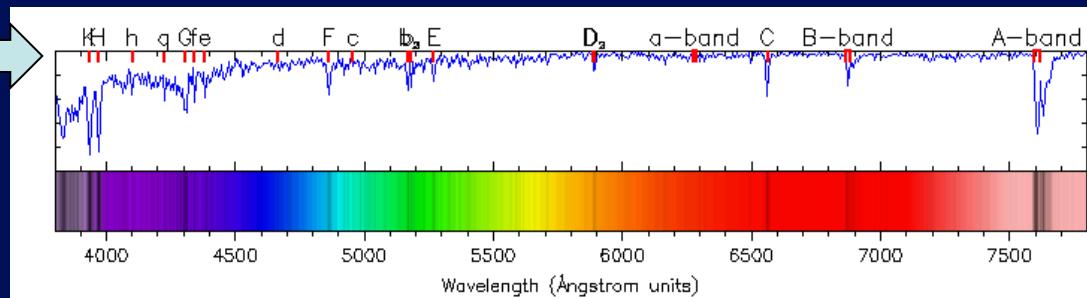
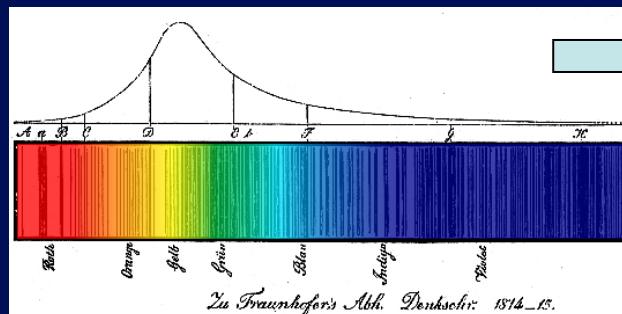
Frontespizio del Sidereus Nuncius
(edizione del 1610)



Per oltre 200 anni l'interesse primario è osservare e comprendere il moto dei corpi
Del sistema solare (comete incluse). → Leggi di Keplero → Meccanica Newtoniana →
Legge della Gravitazione Universale

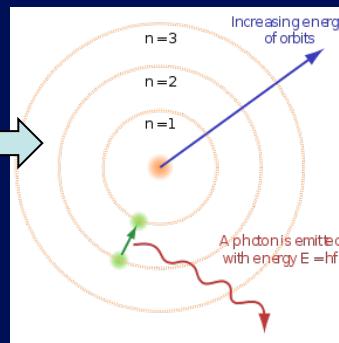
Nasce l'astrofisica e La Fisica Moderna

1800

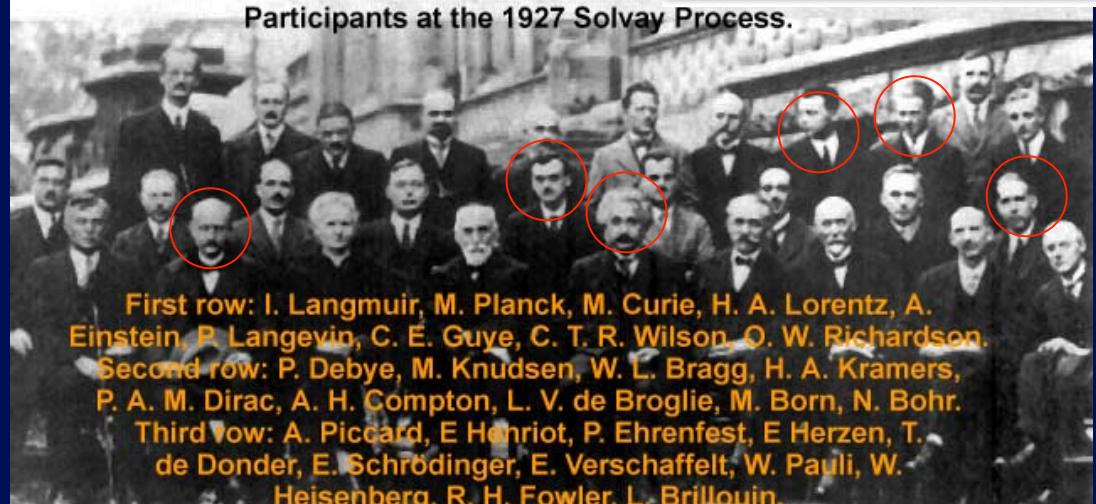


1900

$$H\Psi = E\Psi$$



Participants at the 1927 Solvay Process.



Teoria della relatività e Meccanica Quantistica

Standard Model of FUNDAMENTAL PARTICLES AND INTERACTIONS

The Standard Model is a quantum theory that summarizes our current knowledge of the physics of fundamental particles and fundamental interactions. Interactions are manifested by forces and by decay rates of unstable particles.

FERMIONS matter constituents

spin = 1/2, 3/2, 5/2, ...

Leptons spin = 1/2			Quarks spin = 1/2		
Flavor	Mass GeV/c ²	Electric charge	Flavor	Approx. Mass GeV/c ²	Electric charge
ν_e [neutrino]	(0.013-0.13) $\times 10^{-3}$	0	u [up]	0.002	2/3
e^- [electron]	0.000511	-1	d [down]	0.005	-1/3
ν_μ [neutrino]	(0.009-0.13) $\times 10^{-3}$	0	c [charm]	1.3	2/3
μ^- [muon]	0.106	-1	s [strange]	0.1	-1/3
ν_τ [neutrino]	(0.04-0.14) $\times 10^{-3}$	0	b [top]	173	2/3
τ^- [tauon]	1.777	-1	t [bottom]	4.2	-1/3

*See the neutrino paragraph below.

Spin is the intrinsic angular momentum of particles. Spin is given in units of \hbar , which is the quantum unit of angular momentum where $\hbar = h/2\pi = 6.62 \times 10^{-34}$ GeV \cdot s = 1.05×10^{-34} J.s.

Electric charges are given in units of the proton's charge. In SI units the electric charge of the proton is 1.60×10^{-19} coulombs.

The energy unit of particle physics is the electronvolt (eV), the energy gained by one electron in crossing a potential difference of one volt. Masses are given in GeV/c² (GeV/c² = eV/c²) where $1 \text{ GeV} = 10^9 \text{ eV} = 1.89 \times 10^{-10}$ Joule. The mass of the proton is $0.938 \text{ GeV}/c^2 = 1.67 \times 10^{-27}$ kg.

Neutrinos

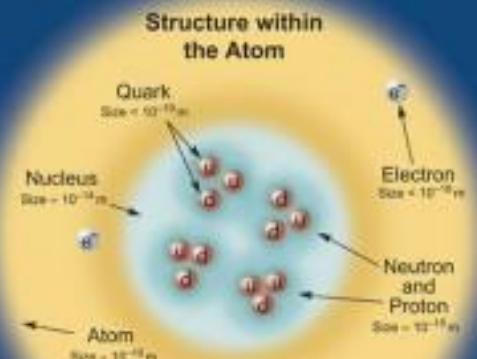
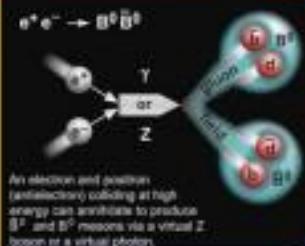
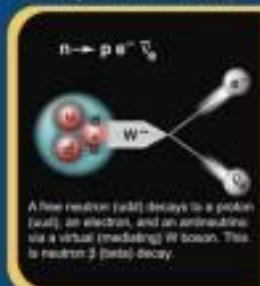
Neutrinos are produced in the sun, supernovae, reactors, accelerators, colliders, and many other processes. Any produced neutrino can be described as one of three different flavor states ν_e , ν_μ , or ν_τ , labeled by the type of charged lepton associated with its production. Each is a different quantum mixture of the three definite mass neutrinos ν_1 , ν_2 , and ν_3 for which currently allowed mass ranges are shown in the table. Further exploration of the properties of neutrinos may yield powerful clues to puzzles about matter and antimatter and the evolution of stars and galaxy structures.

Matter and Antimatter

For every particle type there is a corresponding antiparticle type, denoted by a bar over the particle symbol (unless + or - charge is shown). Particle and antiparticle have identical mass and spin but opposite charges. Some electrically neutral bosons (e.g., Z^0 , γ , and $\chi_0^{+/-0}$, but not χ_1^{00}) are their own antiparticles.

Particle Processes

These diagrams are an artist's conception. Blue-green shaded areas represent the cloud of gluons.



If the proton and neutrons in this picture were 10 cm across, then the quarks and electrons would be less than 0.1 mm in size and the entire atom would be about 10 km across.

Properties of the Interactions

Property	Gravitational Interaction	Weak Interaction (Electromagnetic)	Electromagnetic Interaction	Strong Interaction
Acts on:	Mass – Energy	Flavor	Electric Charge	Color Charge
Particles experiencing:	All	Quarks, Leptons	Electrically Charged	Quarks, Gluons
Particles mediating:	Gravity (not yet observed)	W^+ , W^- , Z^0	γ	Gluons
Strength at {	10^{-10} m	10^{-41}	0.8	25
$3 \times 10^{-17} \text{ m}$	10^{-41}	10^{-4}	1	60

Two types of hadrons have been observed in nature: mesons ($q\bar{q}$) and baryons (qqq). Among the many types of baryons observed are the proton (uud), antiproton ($\bar{u}\bar{d}\bar{d}$), neutron (uud), lambda (uud), and omega (ccc). Quark charges add in such a way as to make the proton have charge 1 and the neutron charge 0. Among the many types of mesons are the pion (π^\pm), kaon (K^\pm), η^0 ($dd\bar{u}\bar{u}$), and $\eta_8(890)$. Their charges are +1, -1, 0, 0 respectively.

Visit the award-winning web site: ParticleAdventure.org

This chart has been made possible by the generous support of:

U.S. Department of Energy
U.S. National Science Foundation
Lawrence Berkeley National Laboratory

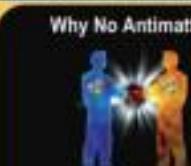
CERN European Physics Education Project, CERN is a non-profit organization of scientists, professors, and educators. For more information see:
CPEPweb.org

Unsolved Mysteries

Driven by new puzzles in our understanding of the physical world, particle physicists are following paths to new wonders and startling discoveries. Experiments may even find extra dimensions of space, mini-black holes, and/or evidence of string theory.



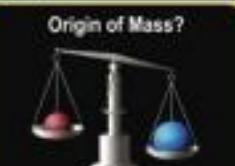
The expansion of the universe appears to be accelerating. Is this due to Einstein's Cosmological Constant? If not, will experiments reveal a new force of nature or even extra (hidden) dimensions of space?



Matter and antimatter were created in the Big Bang. Why do we now see only matter except for the tiny amounts of antimatter that we make in the lab and observe in cosmic rays?

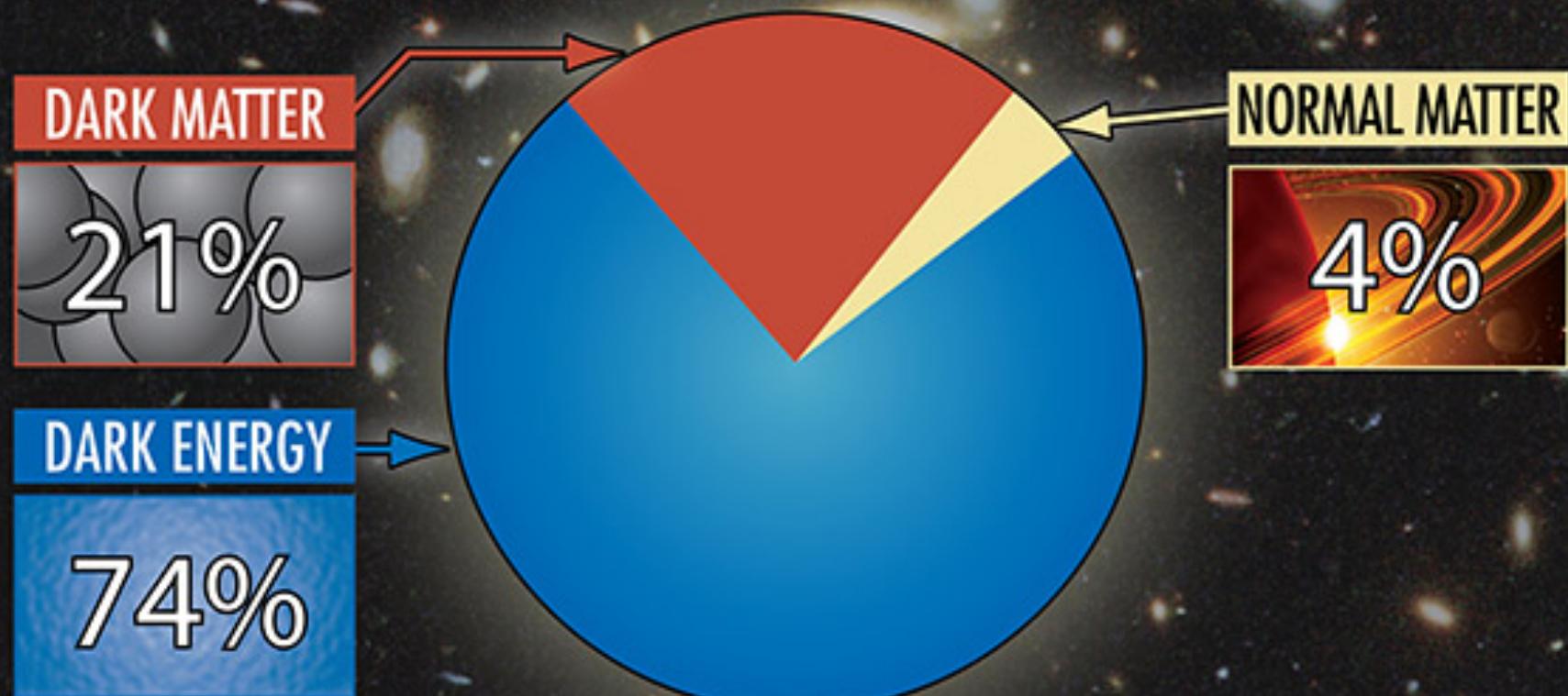


Invisible forms of matter make up much of the mass observed in galaxies and clusters of galaxies. Does this dark matter consist of new types of particles that interact very weakly with ordinary matter?



In the Standard Model, for fundamental particles to have masses, there must exist a particle called the Higgs boson. Will it be discovered soon? Is supersymmetry theory correct in predicting more than one type of Higgs?

What The Universe Is Made Of



?

Come trovare risposte alle molte domande aperte?

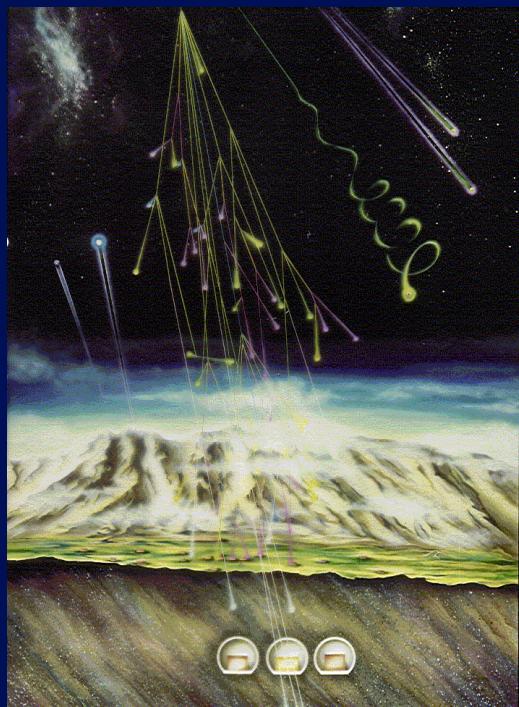


**ASTROPARTICLE Physics: Fisica delle Particelle +
Astronomia+Astrofisica + Cosmologia**

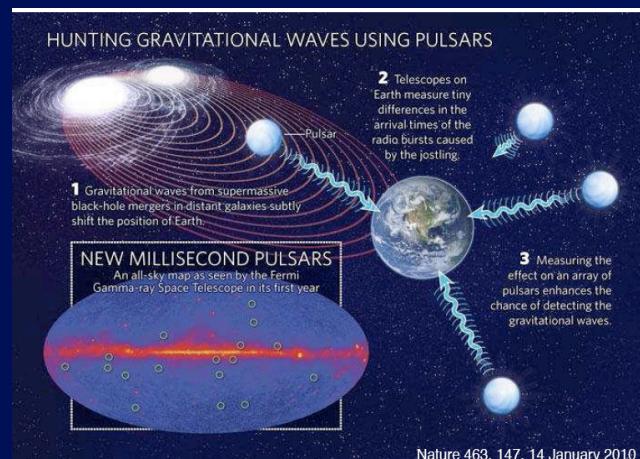
Come ottenere informazioni sul Cosmo: I MESSAGGERI

- **radiazione elettromagnetica**

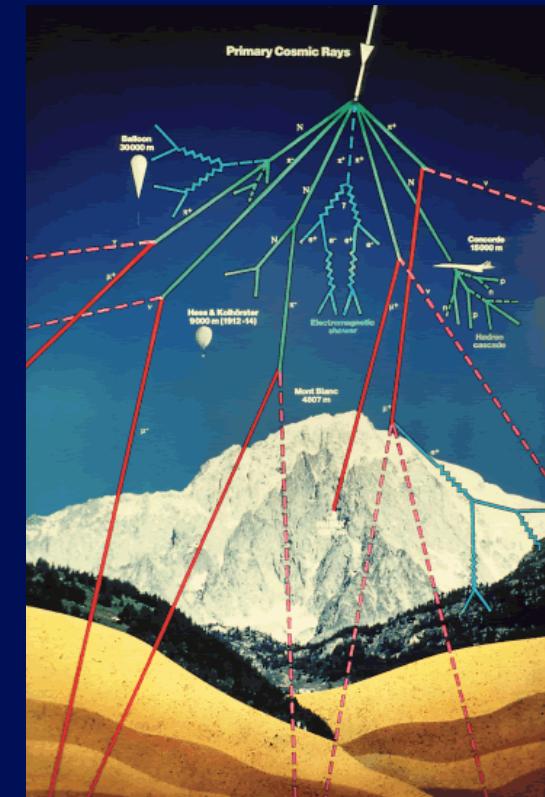
- **neutrini**



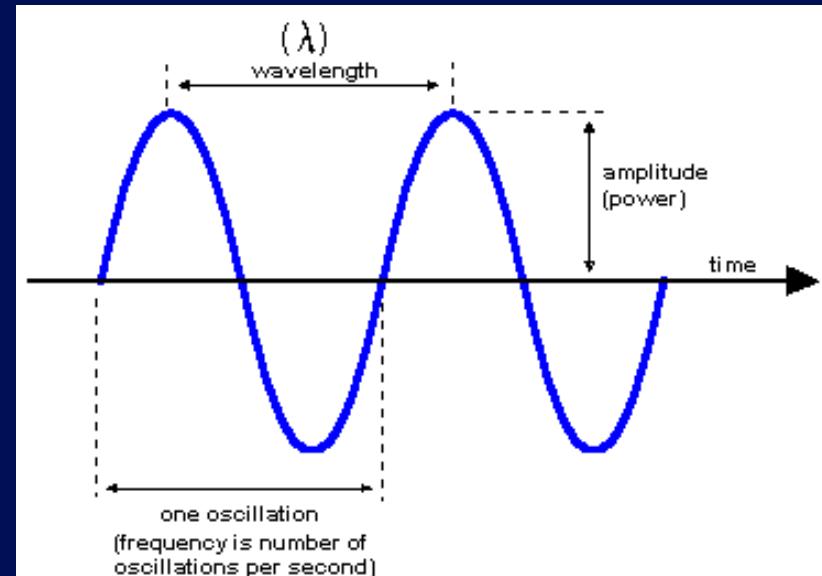
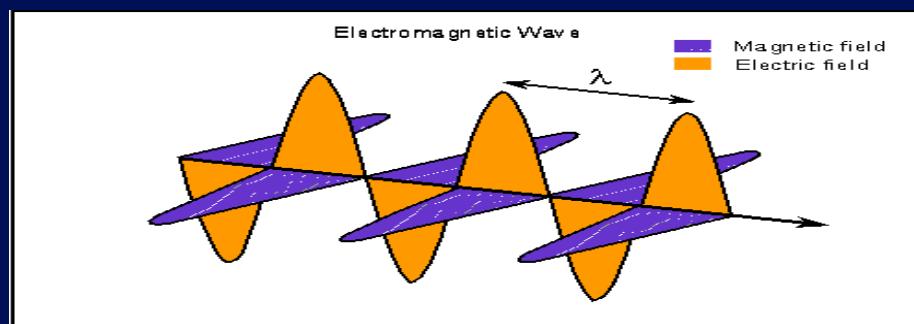
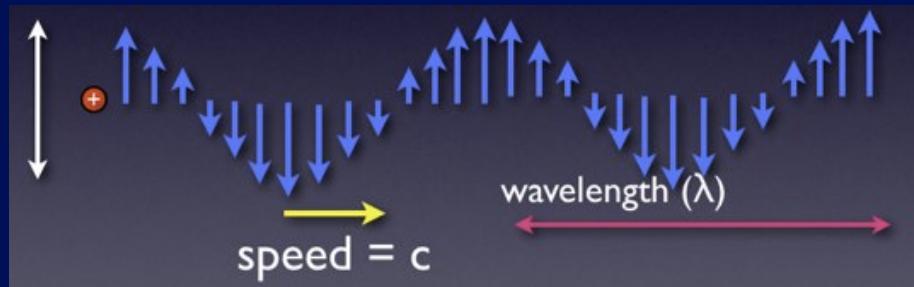
- **onde gravitazionali**



- **raggi cosmici**



Radiazione Elettromagnetica

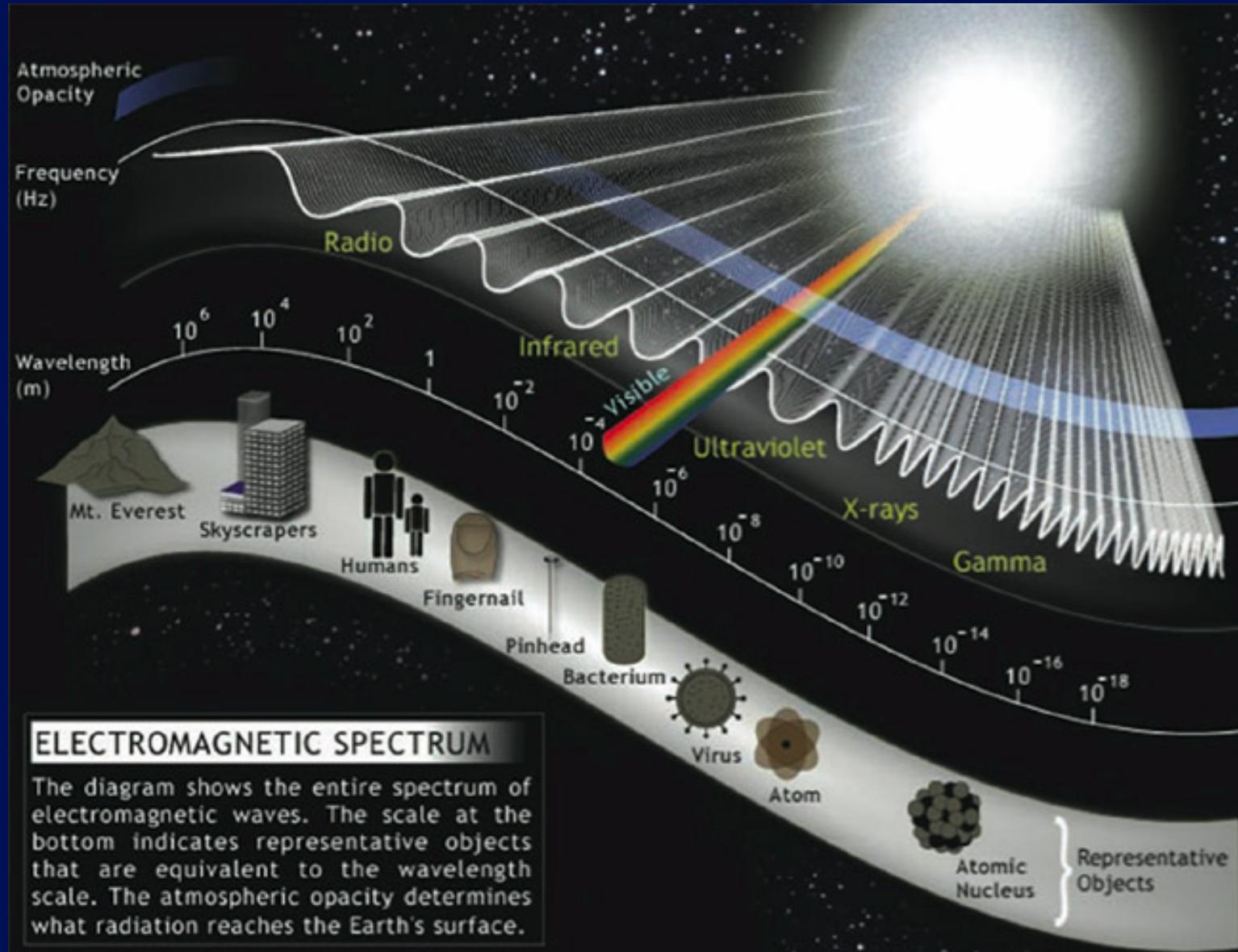


$$c = \lambda v \quad \text{velocità della luce}$$

$$E = h\nu \quad h = \text{Costante di Planck [Js]} \\ \nu = \text{frequenza [s}^{-1}\text{(Hz)]}$$

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

Lo spettro della radiazione elettromagnetica



Sorgenti di radiazione visibile

Spectra From Common Sources of Visible Light

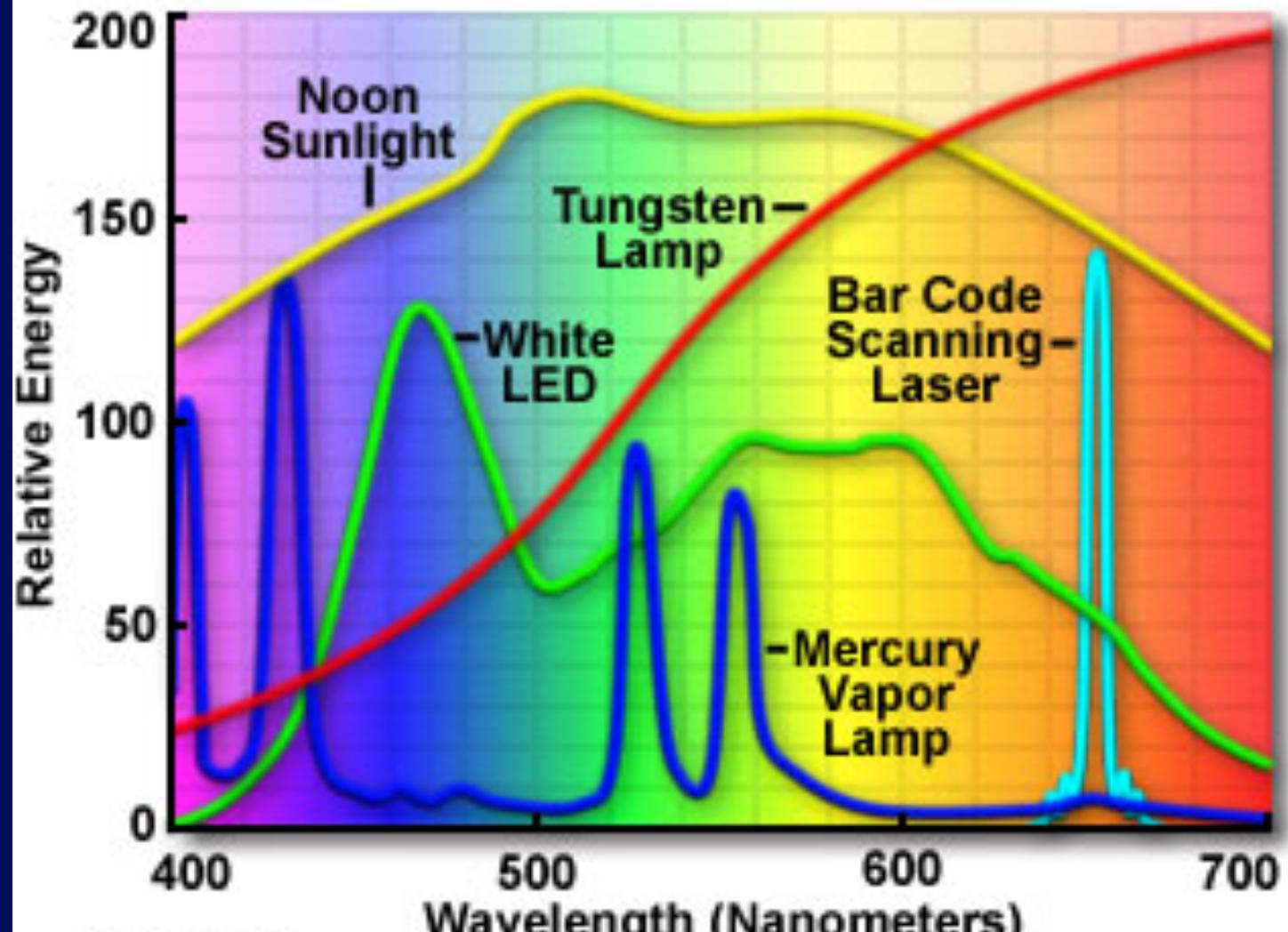
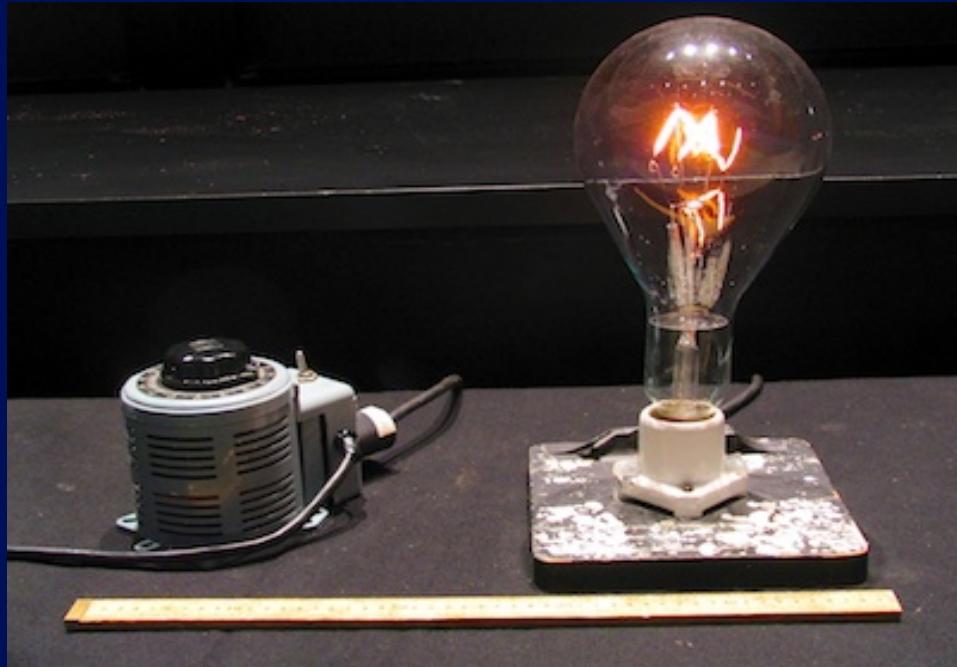


Figure 3

Radiazione termica – Radiazione Non Termica



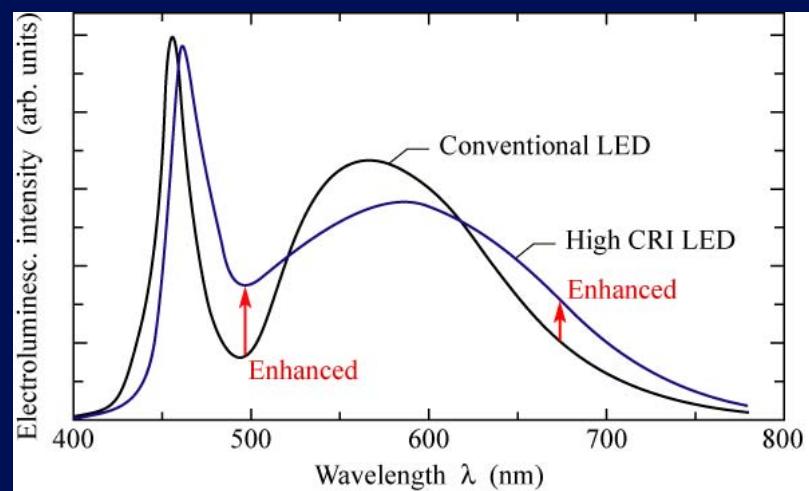
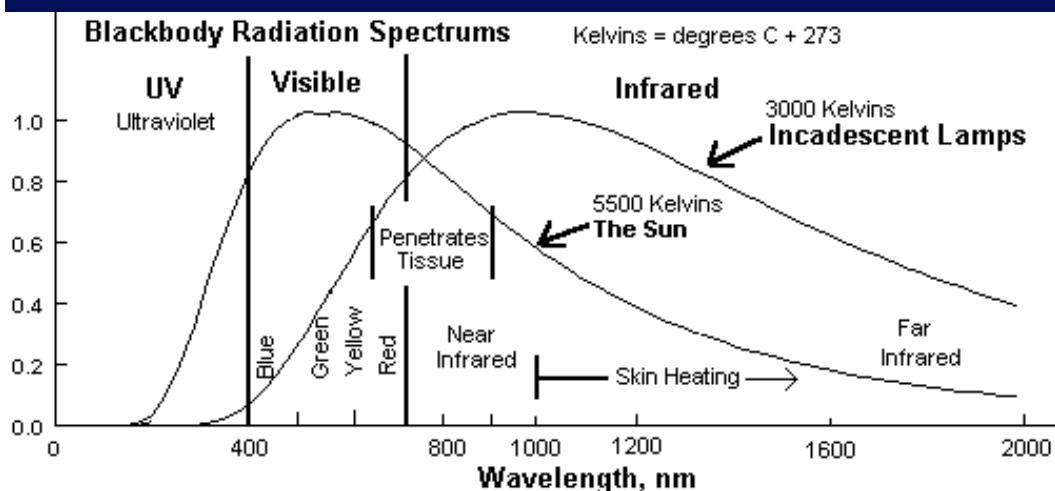
E27 5W LED

- ★ 85V~265V E27 5W LED Bright White Light Bulb Lamp
- ★ Semicircular cup can be turned off, 5 LED inside
- ★ Low power consumption and energy-saving
- ★ Easy to install, provide bright and soft light
- ★ Fits the standard E27 thread connector
- ★ Impact resistance, non-thermal radiation, safe and reliable
- ★ Suits for office, dance ball, restaurants, studio, exhibition and home use etc...

© LD Imaging Working Group

Light Color: White

Height: 122mm



RADIATIONE TERMICA

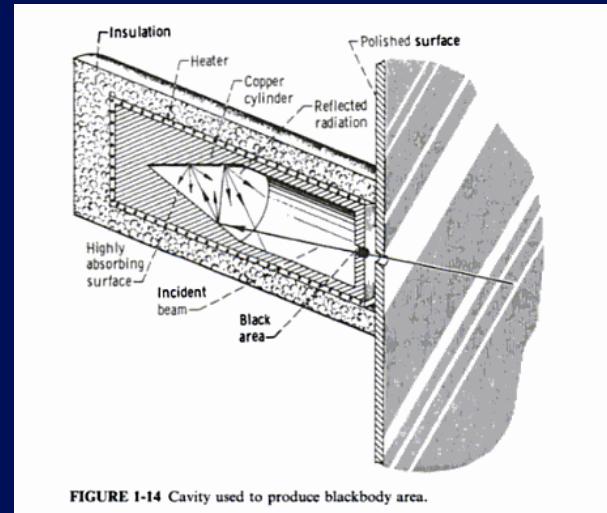
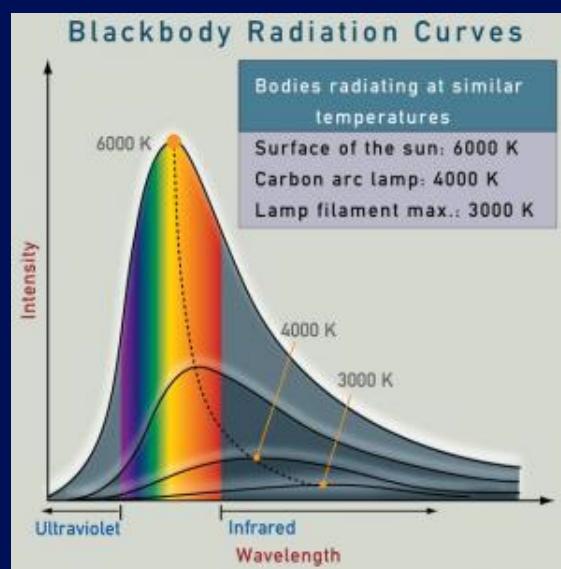
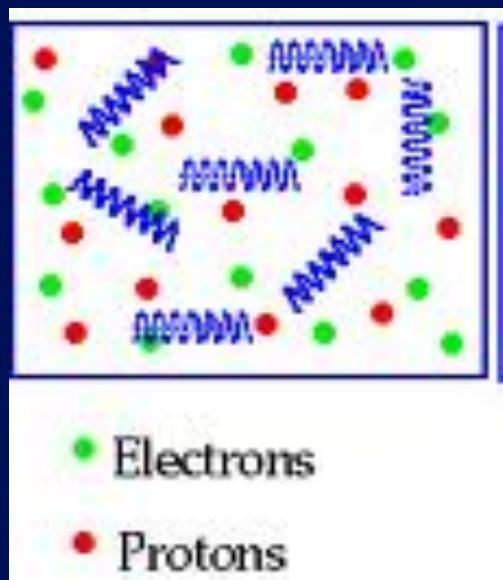
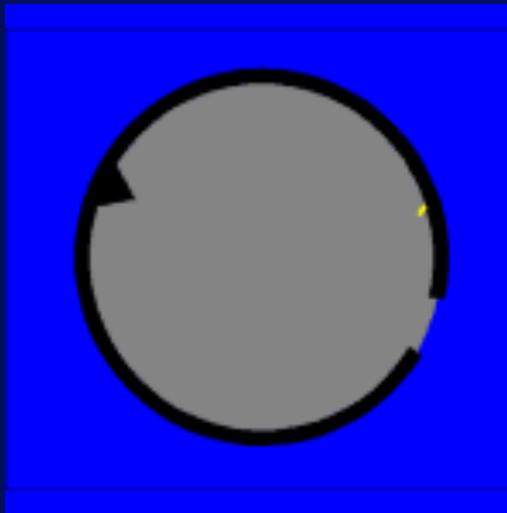


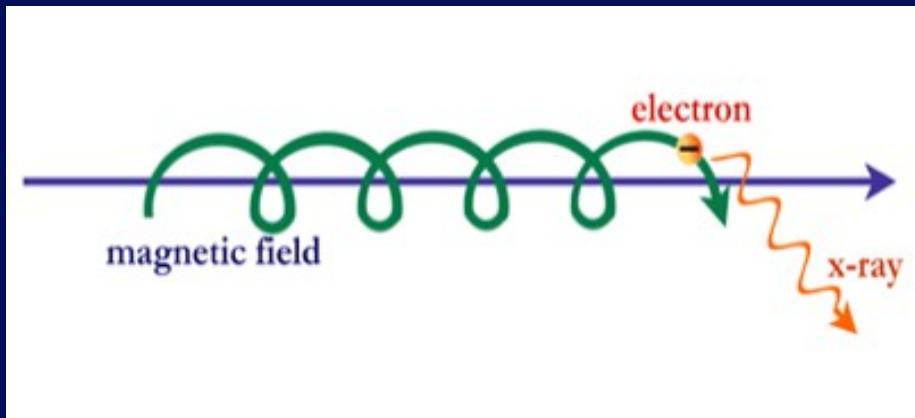
FIGURE 1-14 Cavity used to produce blackbody area.



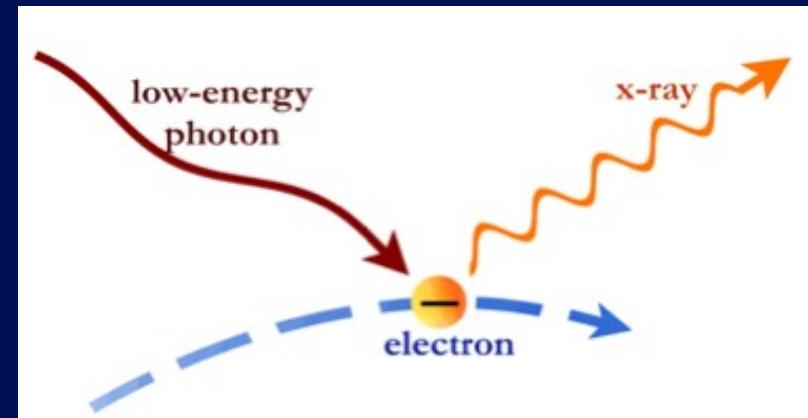
Materia e radiazione sono in equilibrio termico (cioè hanno la stessa energia media). In queste condizioni l'energia dei fotoni è distribuita secondo la legge del corpo nero di Planck.

RADIAZIONE NON TERMICA

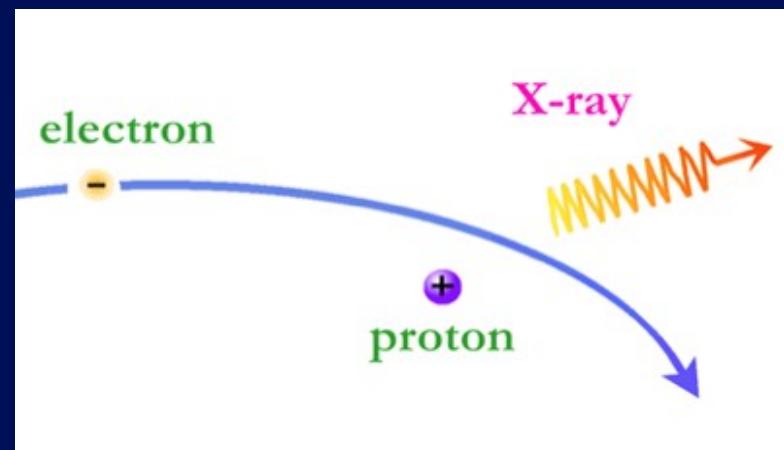
synchrotron radiation



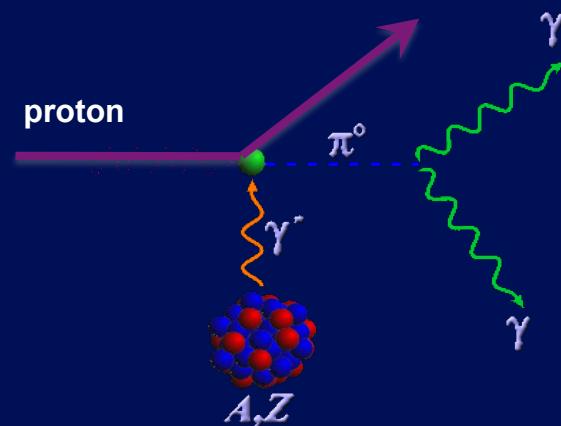
Inverse Compton scattering



bremsstrahlung radiation



pion photoproduction



Astrofisica Multifrequenza: Ottico

Circa **80** anni fa lo scenario cambia improvvisamente e si scopre che esiste una *Astronomia non ottica*

1933: astronomia *radio*

1962: astronomia *X*

1964: astronomia *microonde*

Perché così tardi ?

- 1 - Molte bande e.m. schermate dall'atmosfera
- 2 - Non si ne sospettava l'esistenza di sorgenti non visibili in ottico

Power of multi wavelength observations



Power of multi wavelength observations



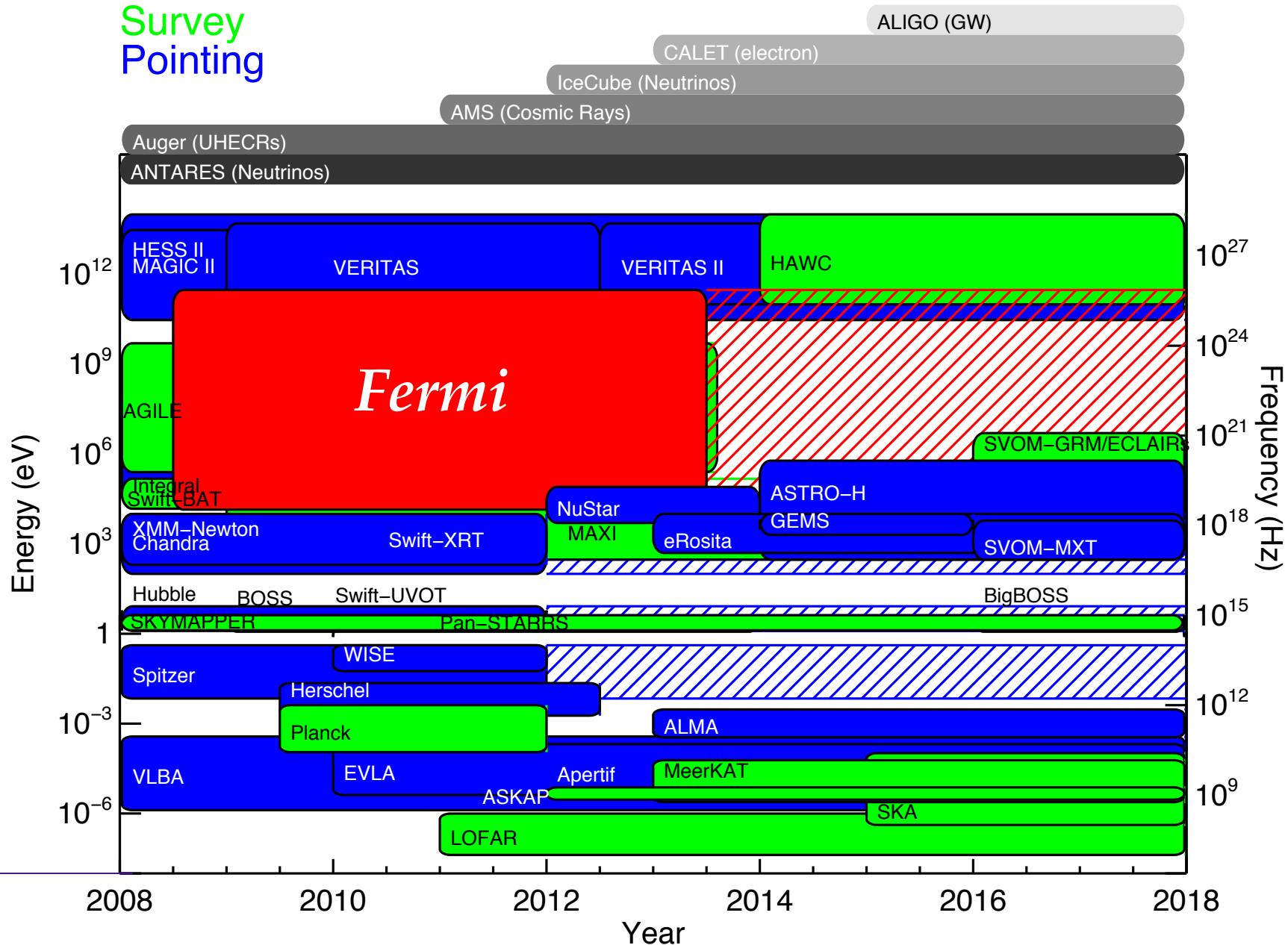
Power of multi wavelength observations



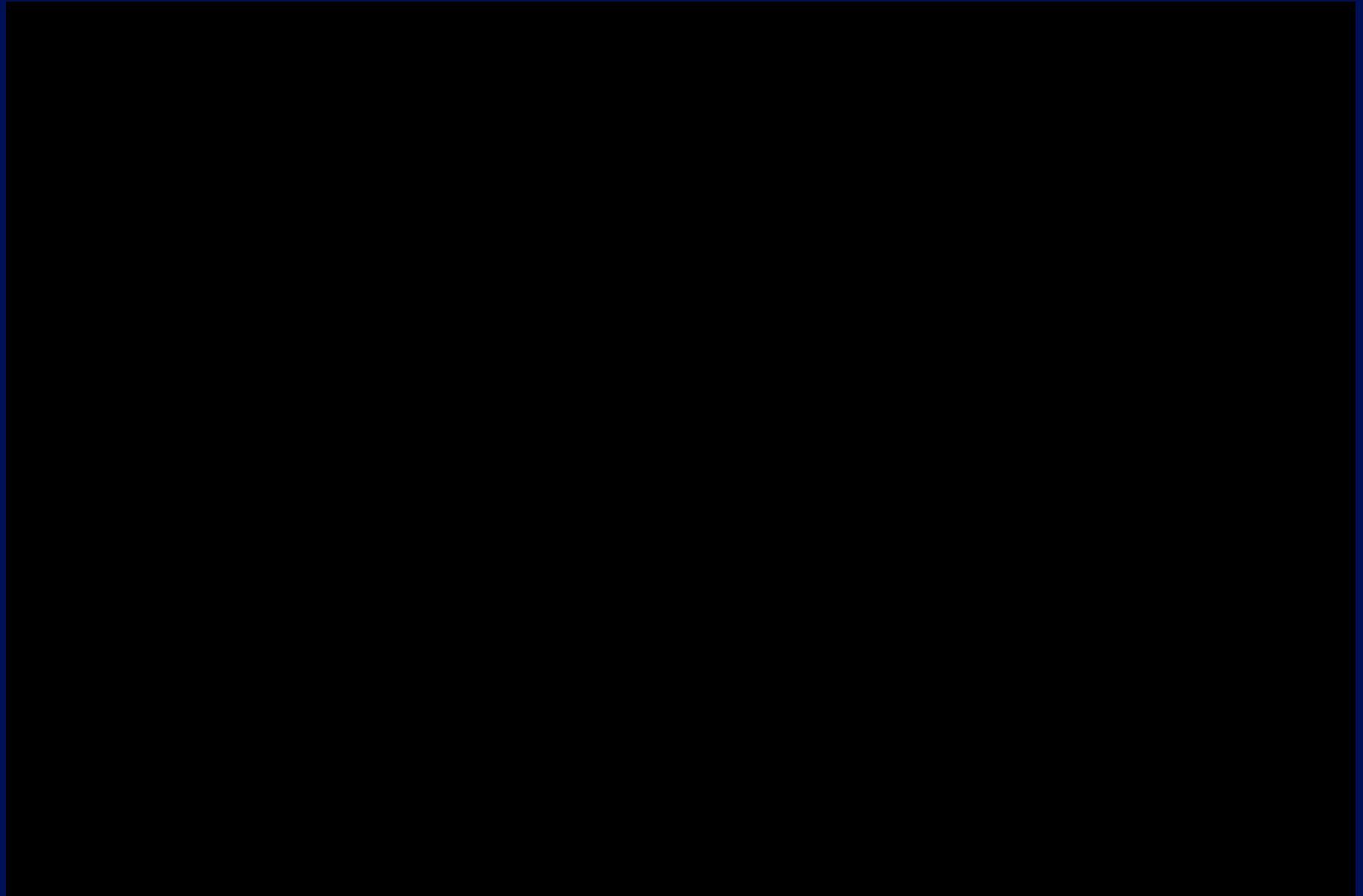
Power of multi wavelength observations



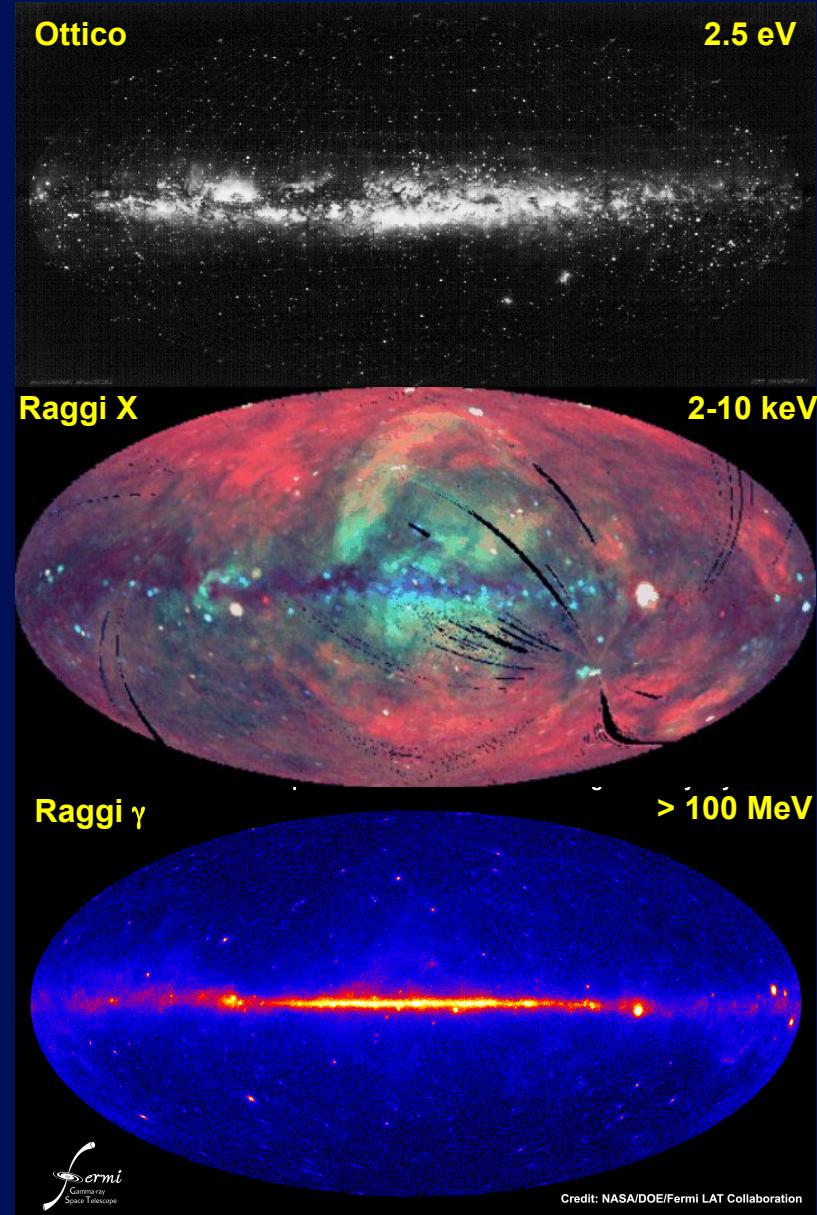
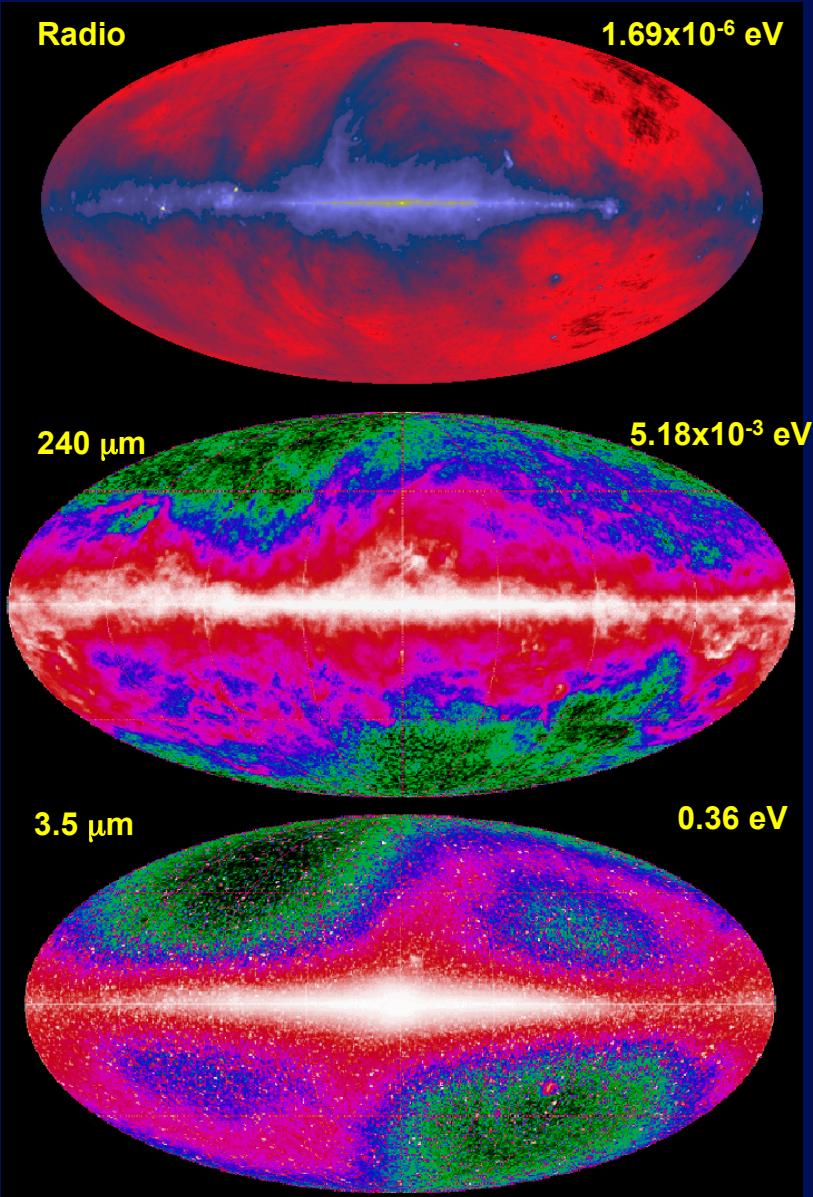
Survey Pointing



Astrofisica Multifrequenza



Il cielo multifrequenza



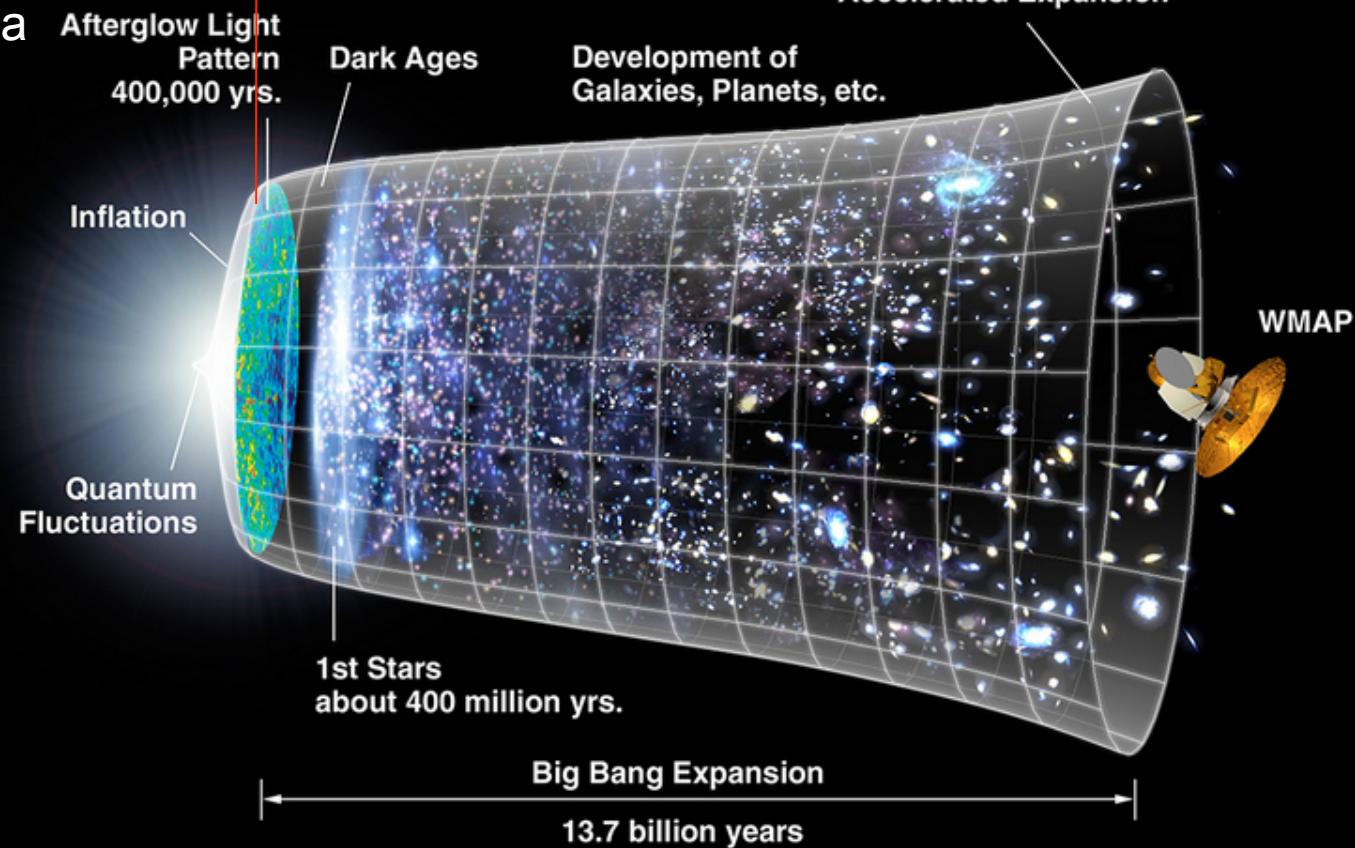
Astrofisica Multifrequenza:Infrarosso



Fisica particelle
Teoria
Fantasia

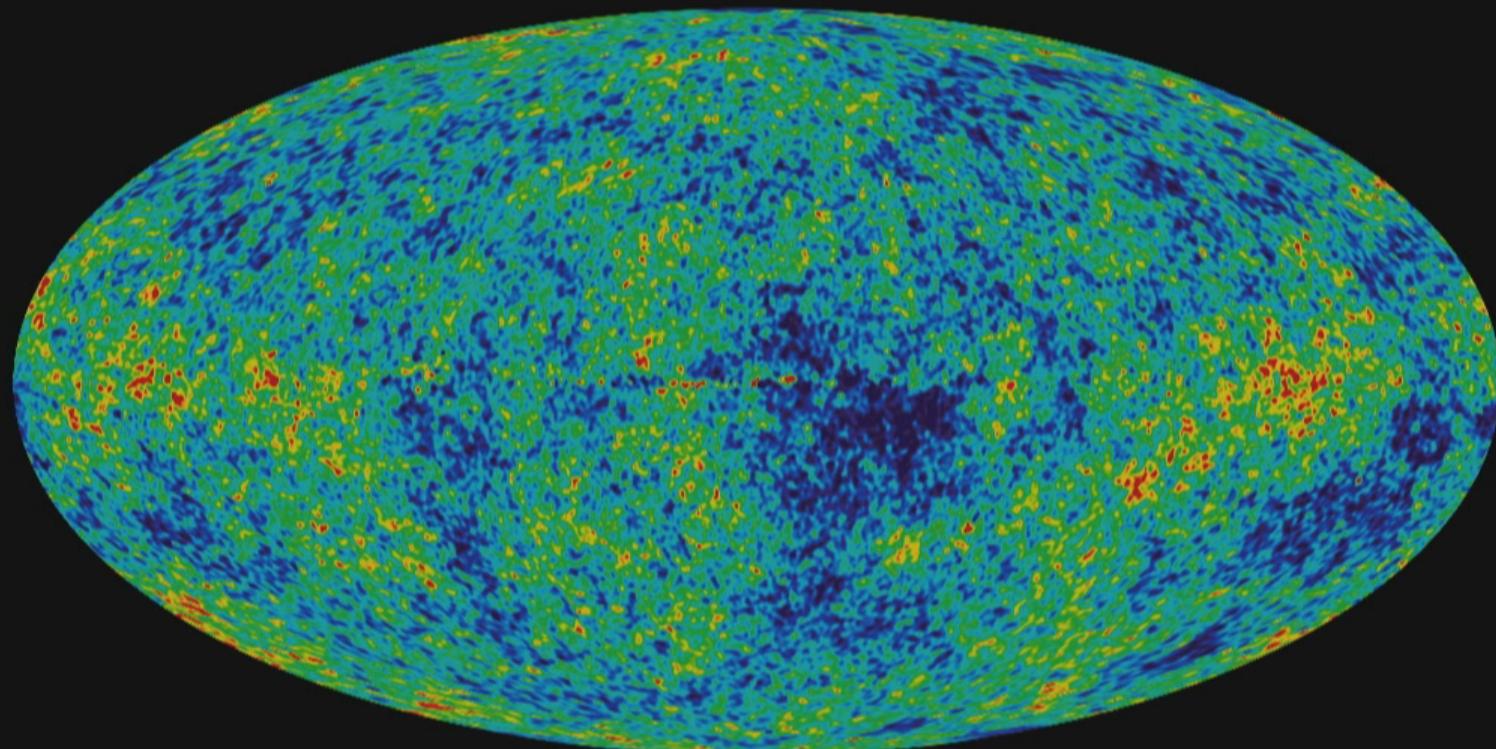
Astrofisica

Dark Energy
Accelerated Expansion



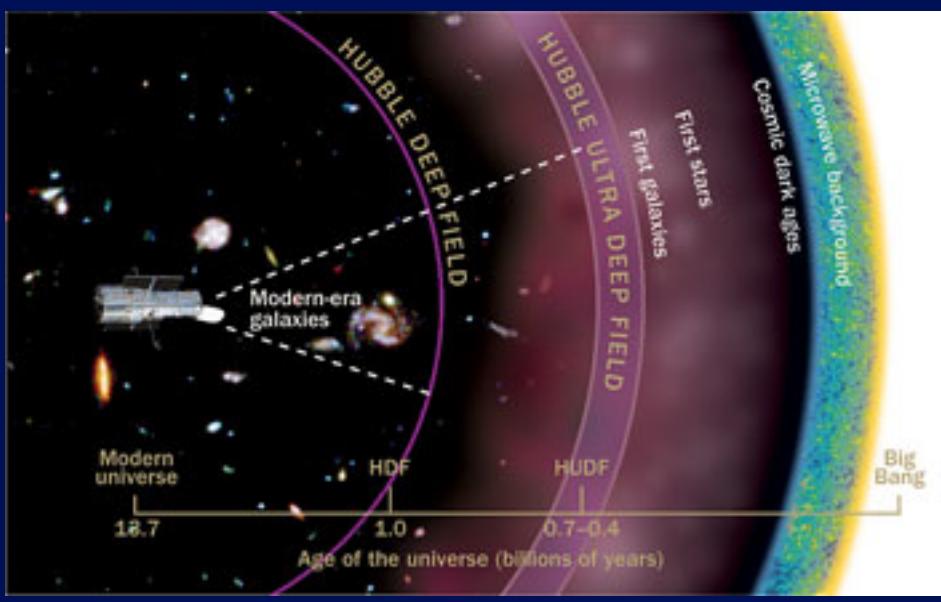
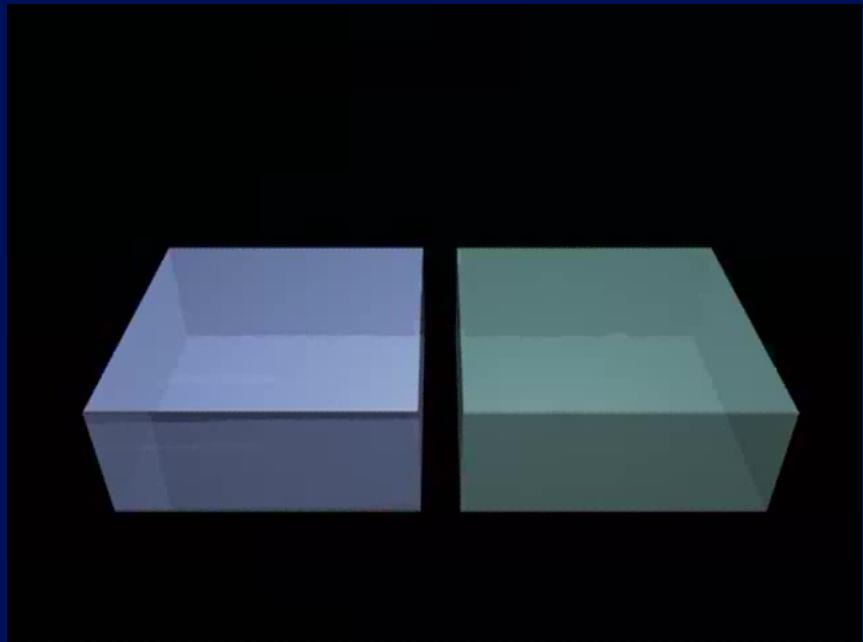
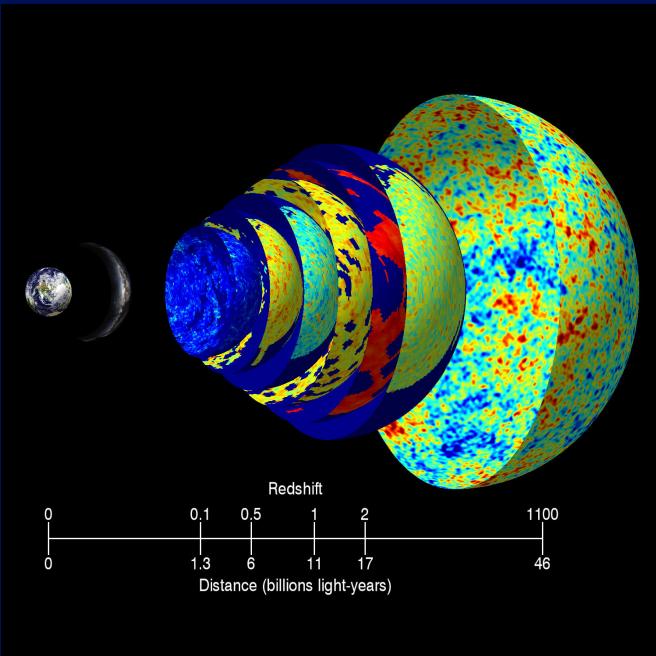
NASA/WMAP Science Team

Il primo Universo Visibile



Radiazione cosmica di Fondo $T=2.7 \text{ K}$ $\Delta T/T \sim 10^{-5}$

Il primo Universo Visibile



Formazione delle strutture

La materia oscura ha avuto un ruolo determinante nella formazione delle strutture

Astrophysical Evidence for Dark Matter

- Majority of mass in galaxies is *dark*

- Coma Cluster + Virial Theorem

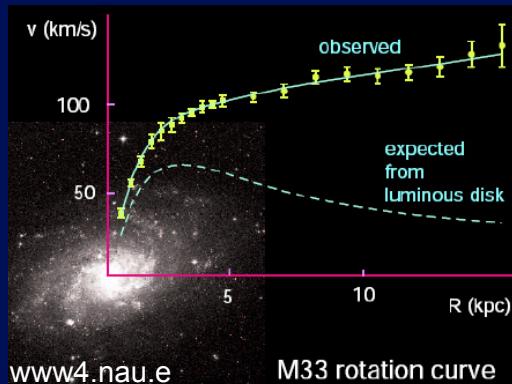
- F. Zwicky (1937)



- Dark Matter clumps in large *halos* around galaxies

- Galactic Rotation Curves

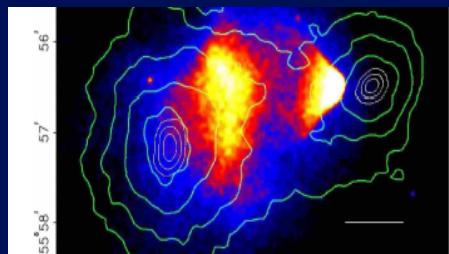
- V. Rubin et al (1980)



- Dark Matter is virtually *collisionless*

- The Bullet Cluster

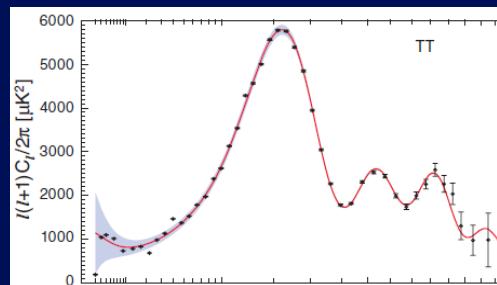
- D. Clowe et al (2006)



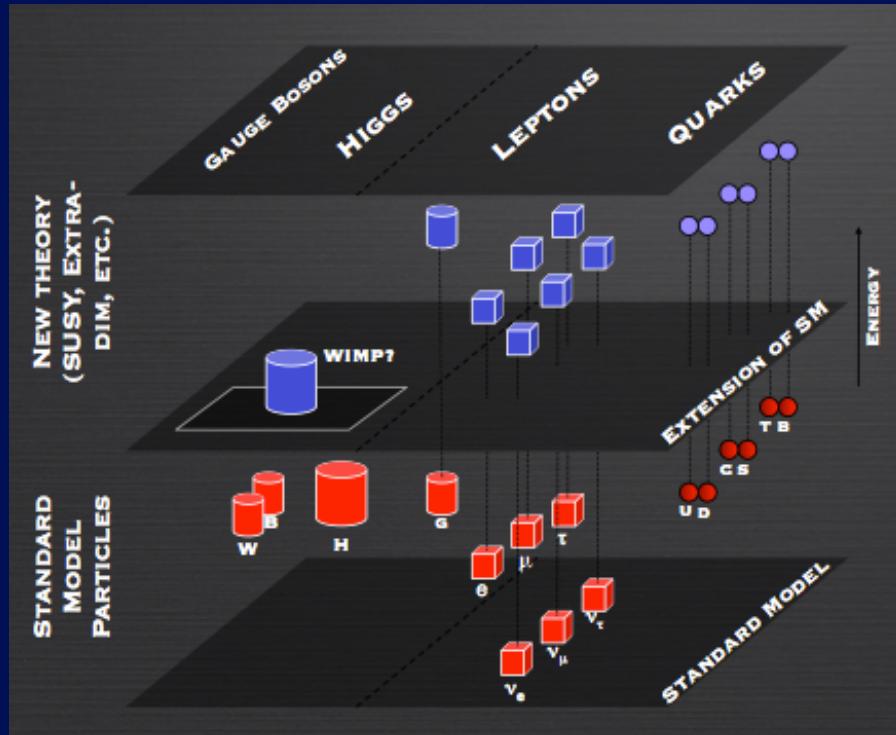
- Dark Matter is *non-baryonic*

- CMB Acoustic Oscillations

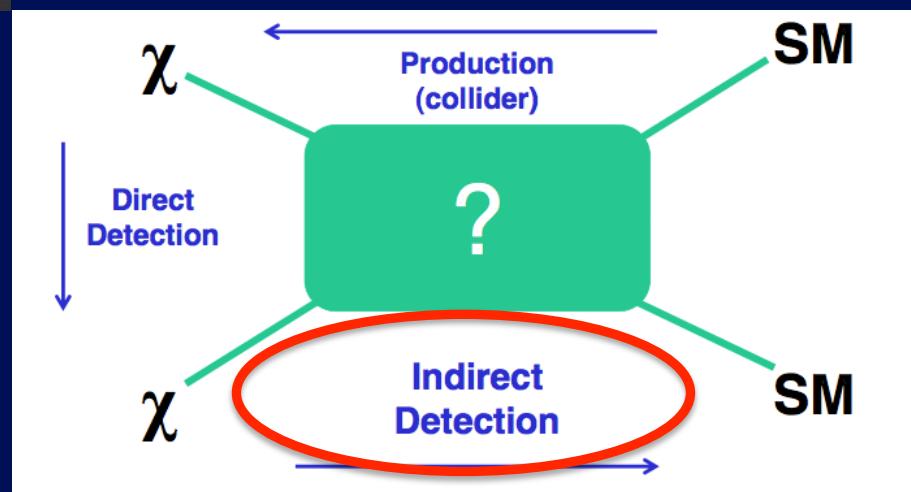
- WMAP (2010)



Materia oscura e Nuova Fisica



- Dark Matter candidates are Weakly Interacting Massive Particles (WIMPs)
 - Extensions of Standard Model of Particle Physics (ex: SUSY)
- Look for WIMP annihilations spectra (lines)



Acceleratori/altri rivelatori

γ -rays Probe the Extreme, Non-Thermal, Universe

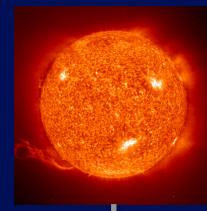
Dark Nebula



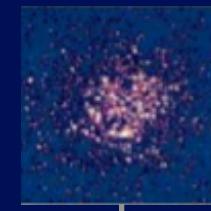
Dim, young star



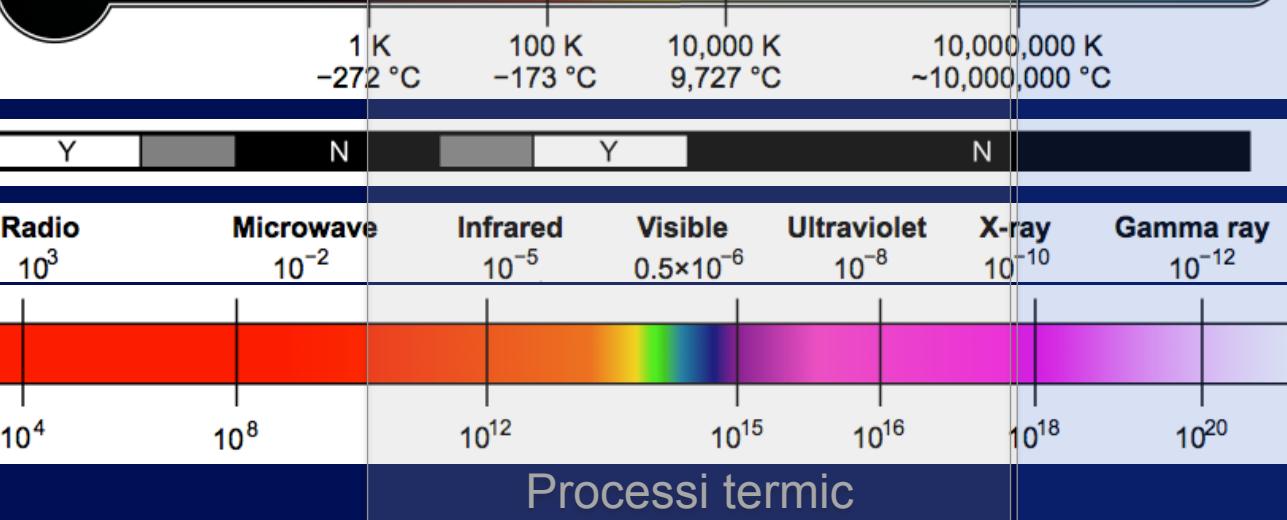
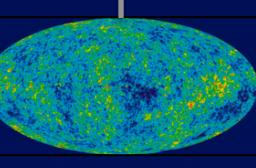
Our Sun



Globular Cluster



CMB



Accretion Disk



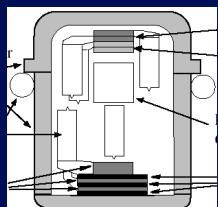
Universo estremo

Breve storia

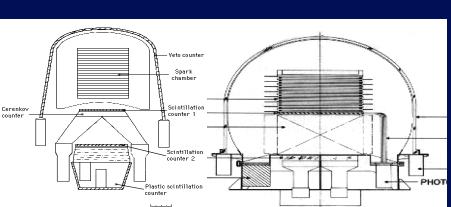
Rivelazione dallo spazio

- **Prima generazione 1960 – 1972**
 - Spark Chamber
 - Palloni Aerostatici
- **Seconda Generazione 1972-1991**
 - Spark Chambers
 - Piccoli satelliti
 - SAS-II, COS-B
- **Terza Generazione 1991-2007**
 - Spark Chamber
 - Grandi dimensioni
 - EGRET (CGRO)
- **Quarta Generazione 2007-2012+**
 - Nova tecnologia: Stato solido
 - AGILE (2007 ->)
 - FERMI (2008 ->)

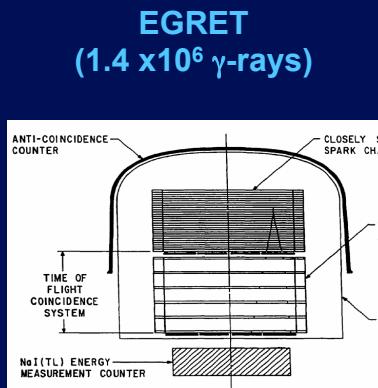
OSO-3
(621 γ -rays)



SAS-2
(~8k γ -rays)



COS-B
(~200k γ -rays)



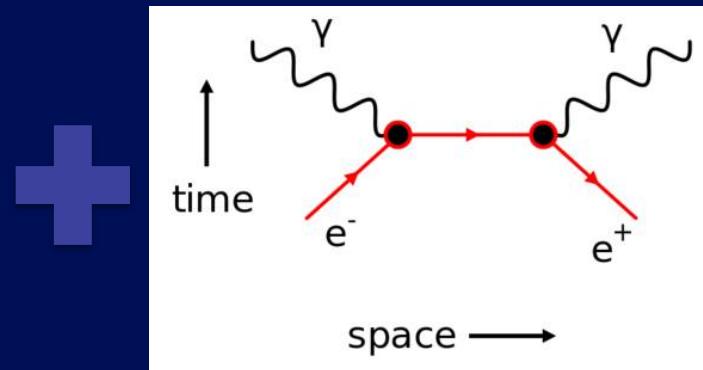
tosti@pg.infn.it

Rivelazione da terra

- **Prima Generazione 1960 – 1985**
 - Discriminazione fondo debole o assente
 - Lebedev, Glencullen, Whipple, Narrabri, Crimea
- **Seconda Generazione 1985 – 2004**
 - Imaging Atmospheric Cherenkov Telescopes
 - Whipple, Crimea, CAT, HEGRA, Durham, CANGAROO
 -
- **Terza Generazione 2004 – 2010**
 - IACT di grandi dimensioni e stereoscopici
 - MAGIC-2, HESS-5, CANGAROO-III, VERITAS-4
- **Quarta Generazione 2010 –**
 - CTA.....



Non-thermal γ ray emission



Energy source

Acceleration
mechanism

γ -ray production
mechanism

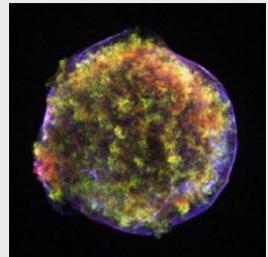


Foreground absorption

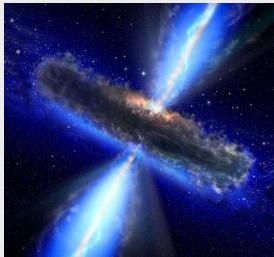
γ rays

Many Mechanisms Involved in Producing γ rays

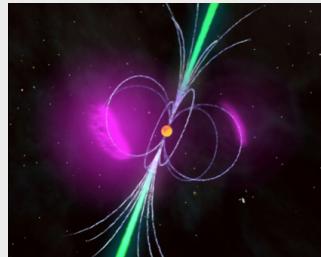
Energy Sources



Explosions



Accretion

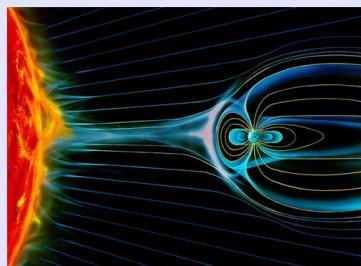


Rotating Fields

Many of these mechanisms will produce radiation at other, non γ -ray, wavelengths

WIMP Dark Matter interactions produce different broad-band spectra.

Acceleration Mechanisms



Reconnection

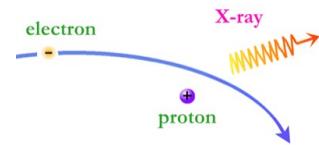


Caustics



Other Shocks

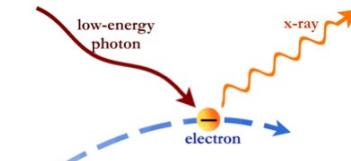
γ -ray Emission Mechanisms



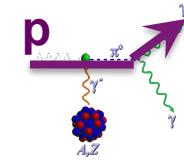
bremsstrahlung



synchrotron

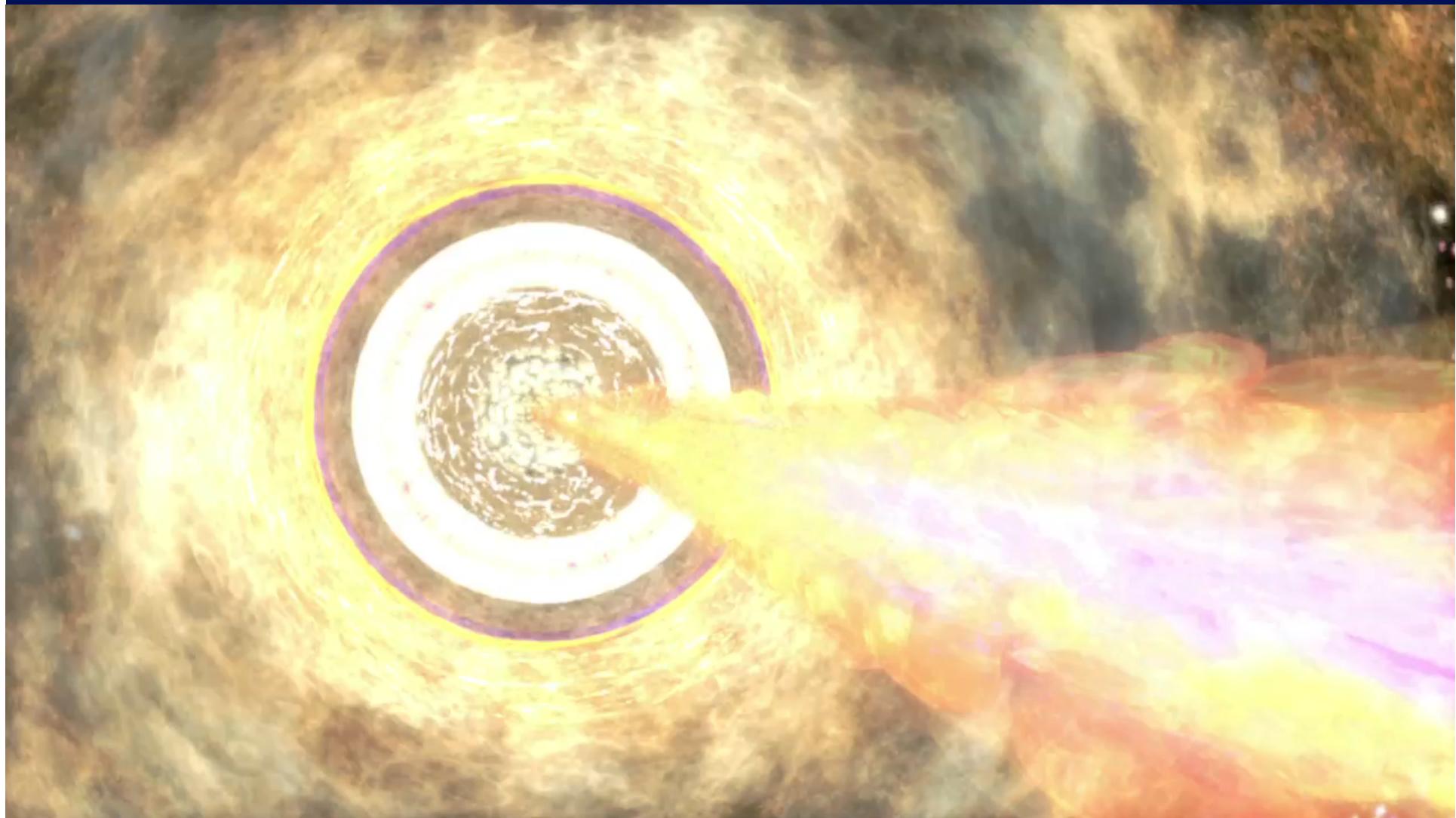


inverse Compton

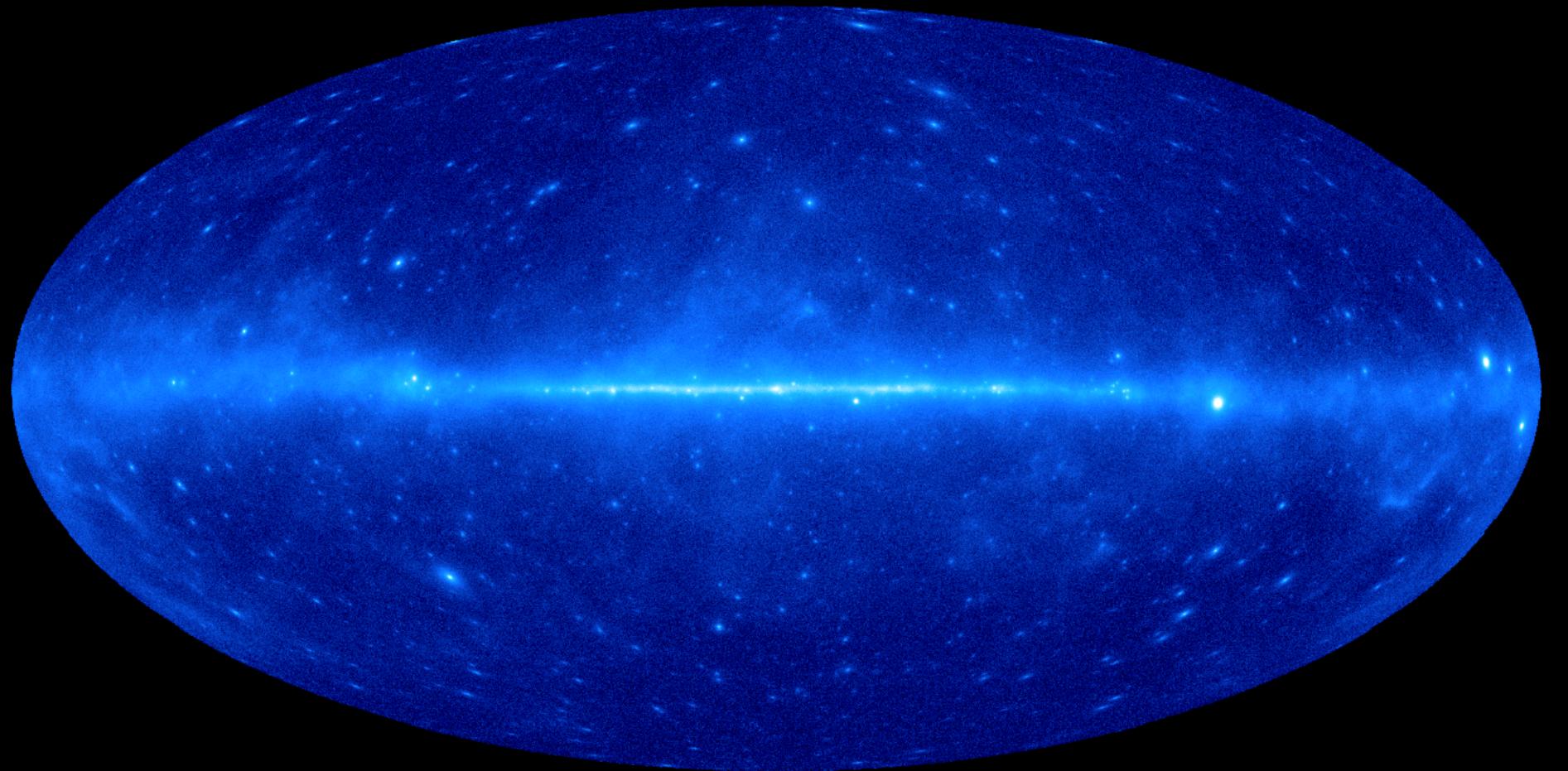


π^0 production

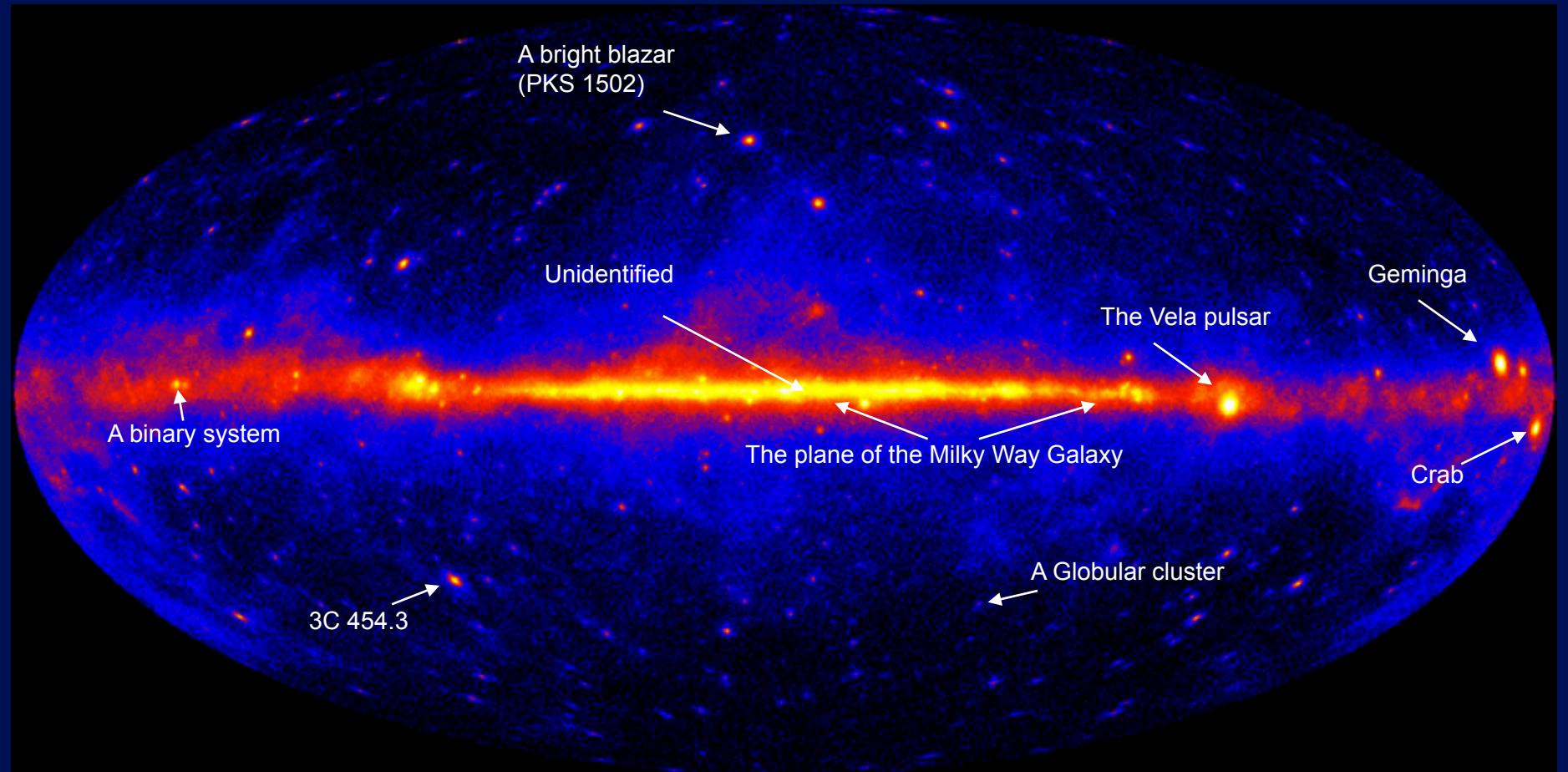
Come osservare la radiazione gamma



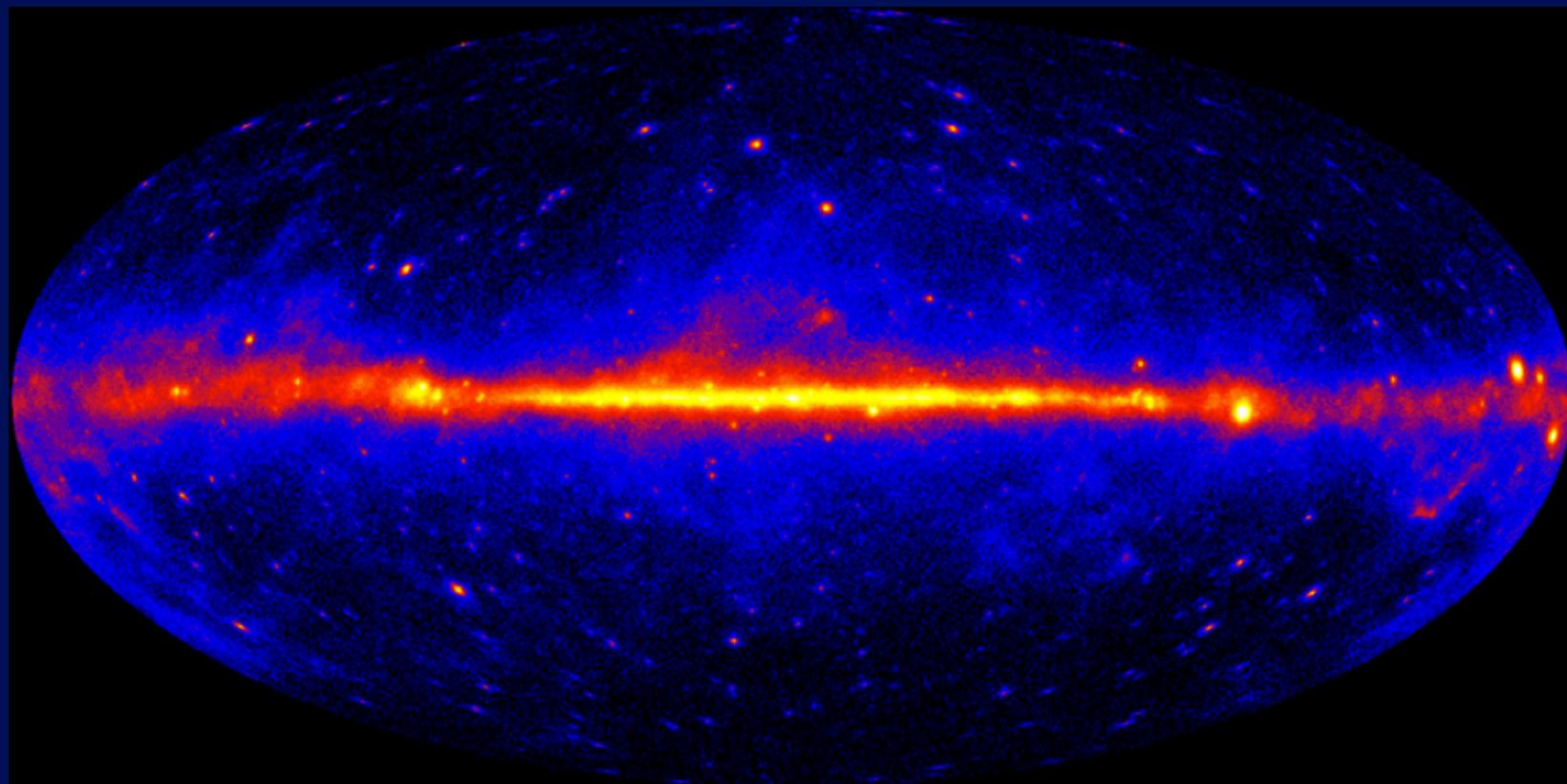
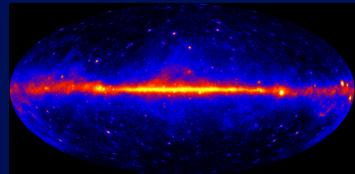
Come appare il cielo gamma?



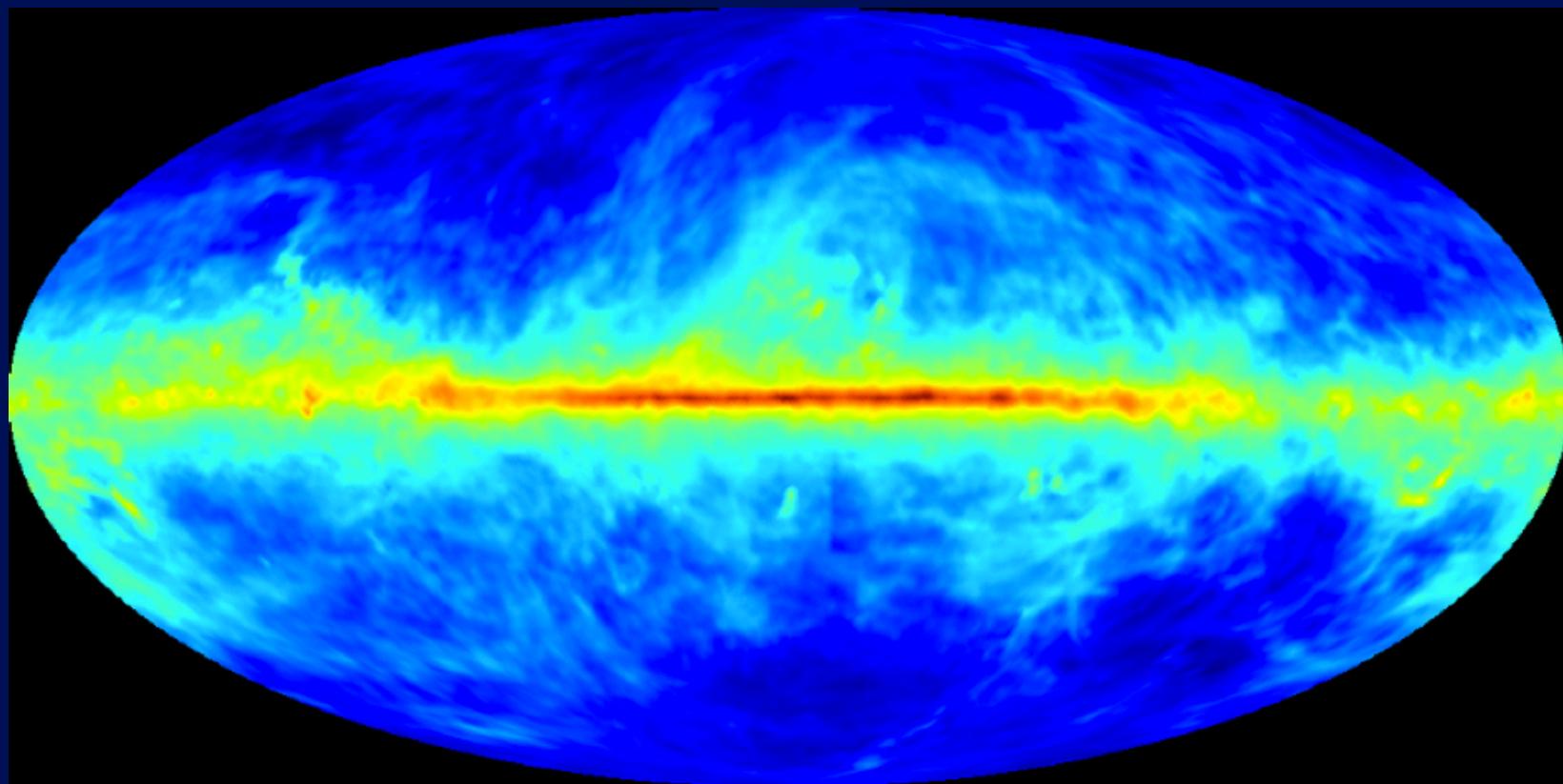
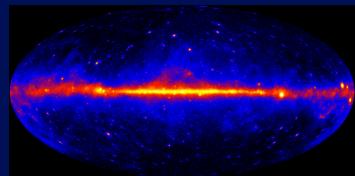
Cosa si vede nel cielo gamma?



Da cosa è composto il cielo gamma?

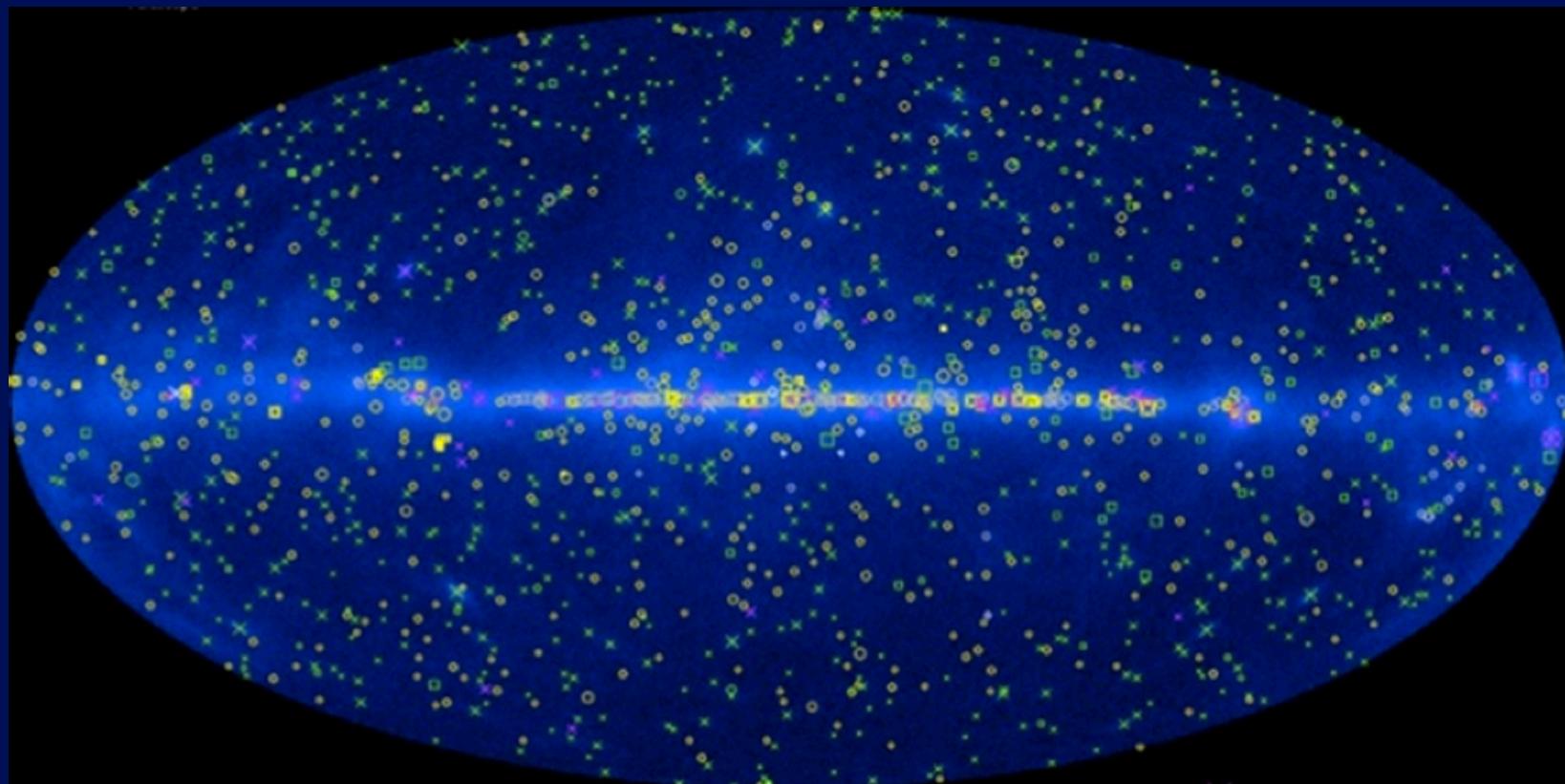
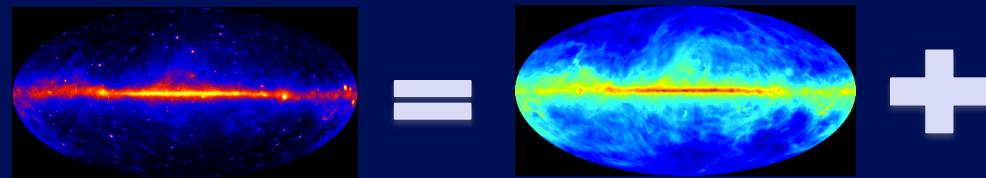


Emissione diffusa della Galassia

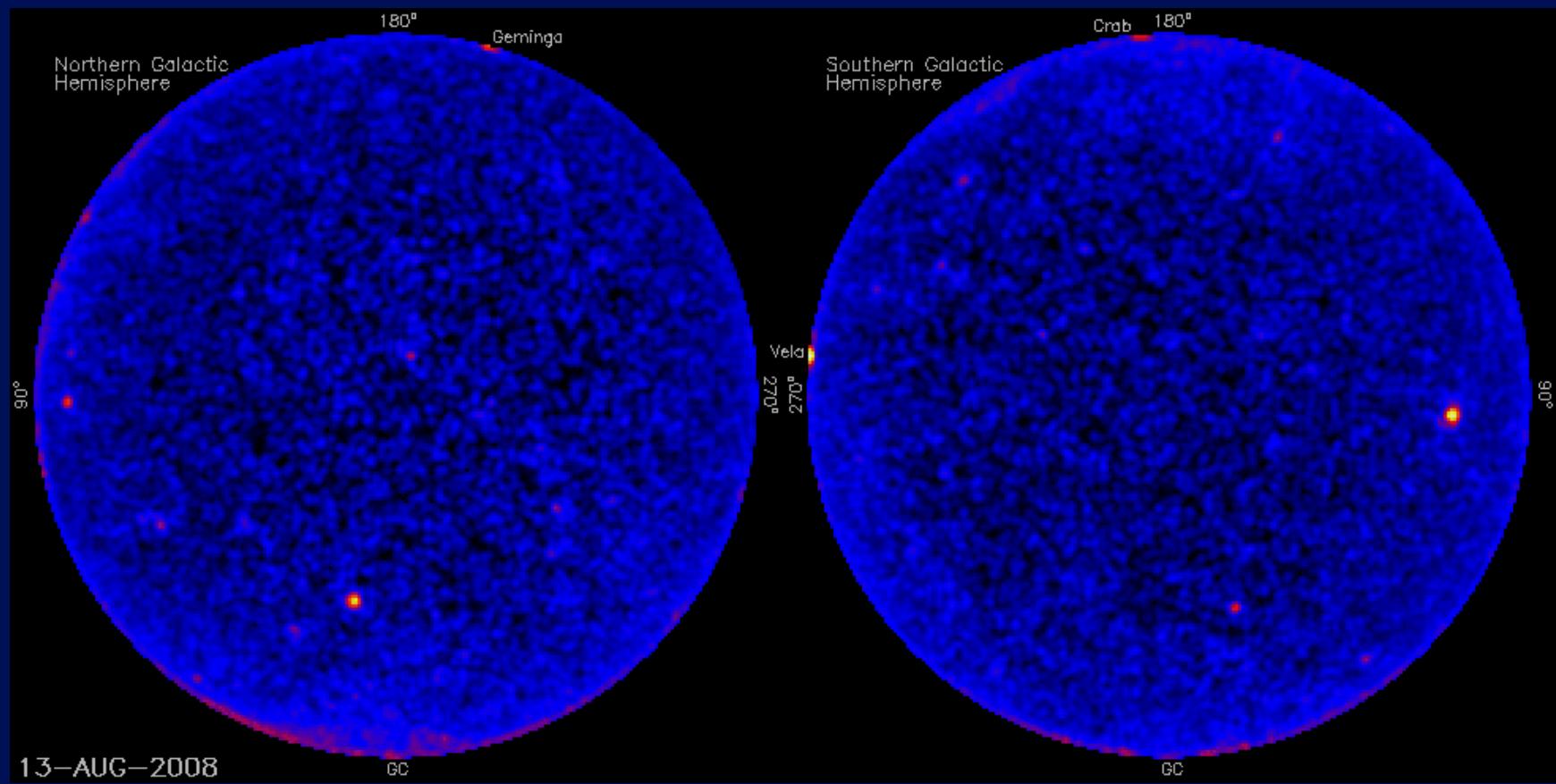
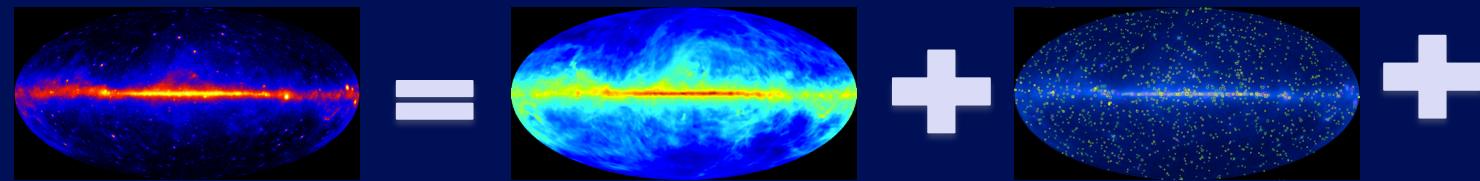


γ -rays from interactions between cosmic rays and gas in the galaxy

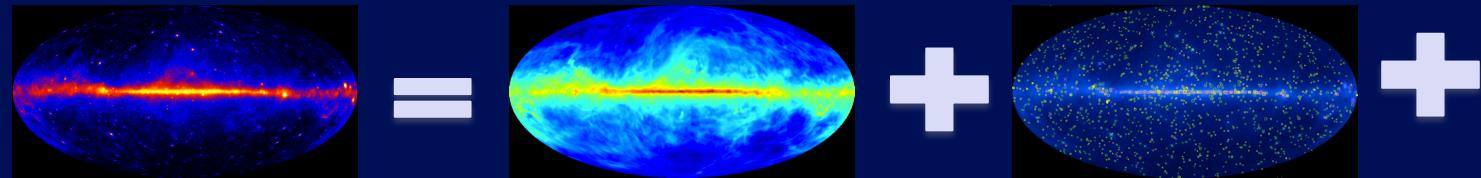
Sorgenti puntiformi Galattiche ed Extragalattiche



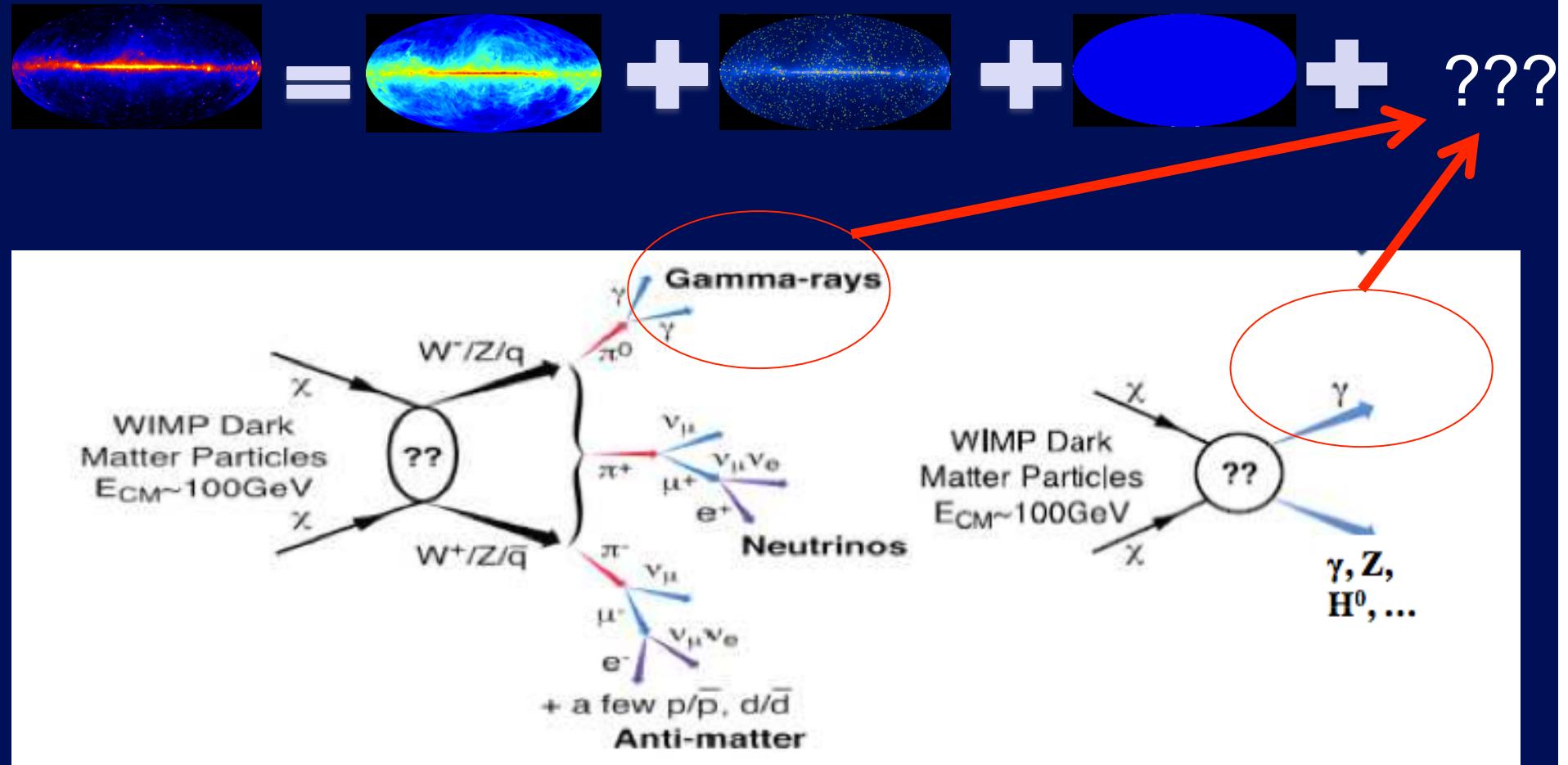
Variabilità



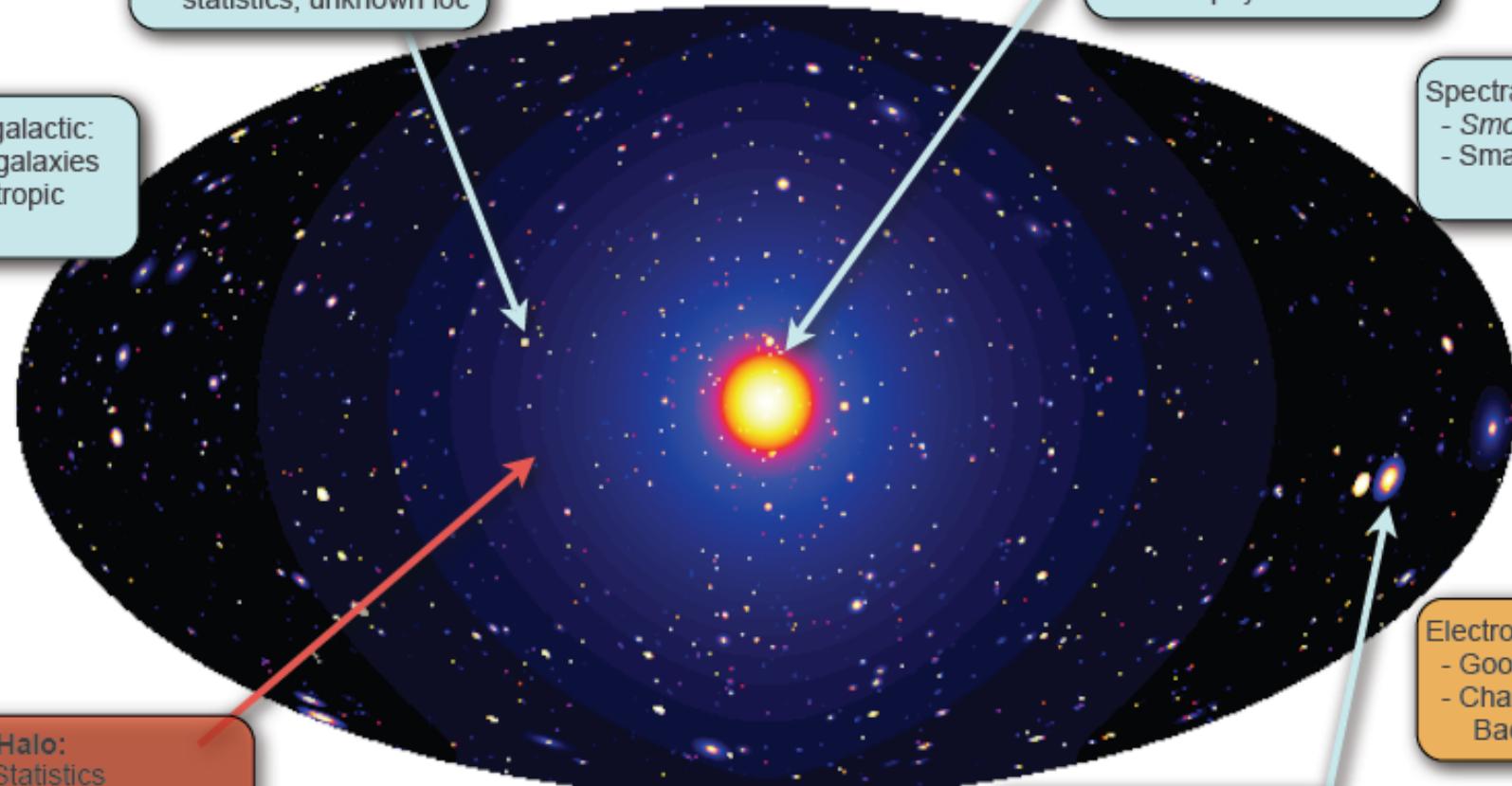
Radiazione isotropica: emissione da sorgenti non risolte



Dark matter



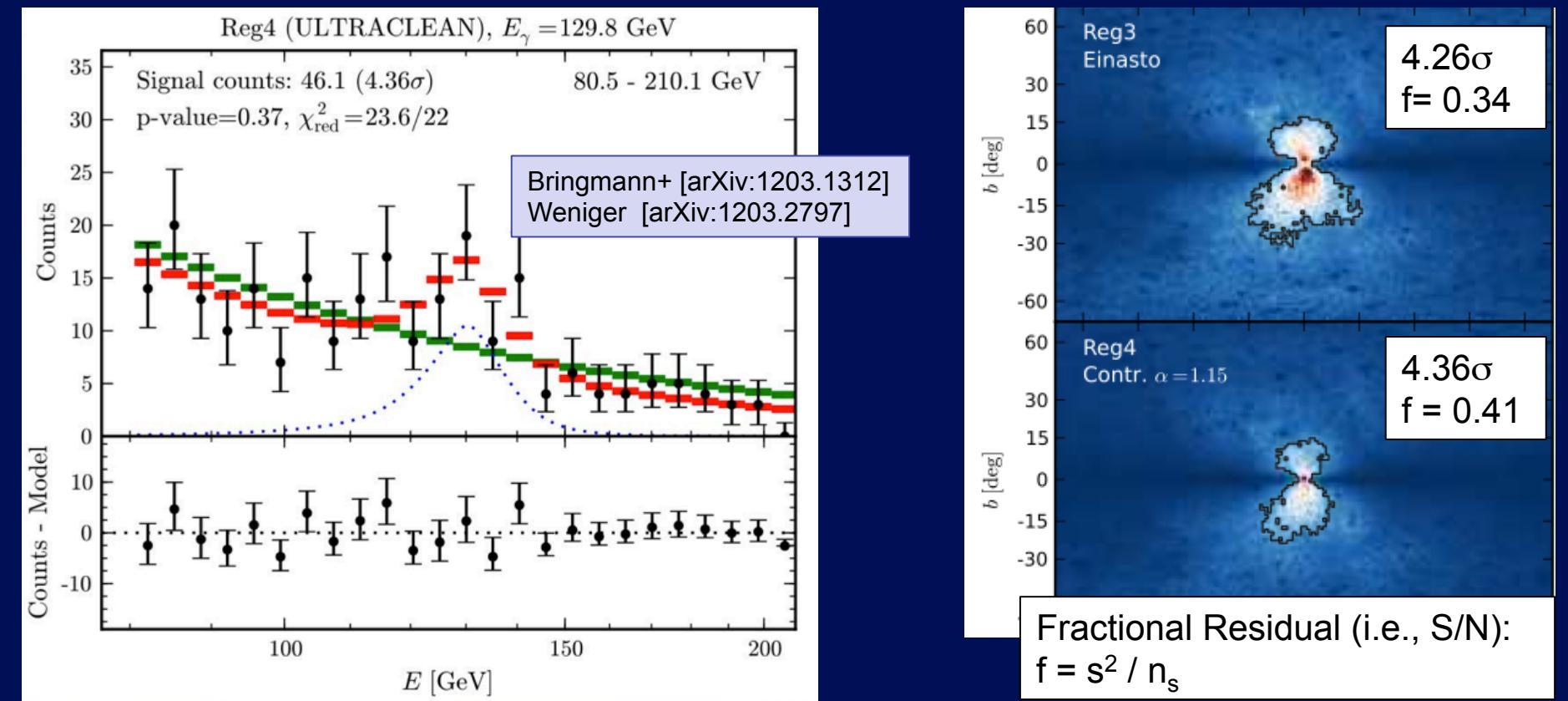
Dark Matter Searches with the Fermi LAT



Milky Way Halo simulated by Taylor & Babul (2005)

All-sky map of DM gamma ray emission (Baltz 2006)

Narrow Spectral Feature at 130 GeV



Bringmann et al. and Weniger showed evidence for a narrow spectral feature near 130 GeV near the Galactic center (GC) in the LAT data.

- Signal is particularly strong in 2 out of 5 test regions, shown above.
- Over 4σ local significance with $S/N > 30\%$, up to $\sim 60\%$ in optimized ROI.
- Some indication of double line (111 & 130 GeV).

Too early for conclusive answers.

More and More results.....



<http://fermi.gsfc.nasa.gov/science/mtgs/symposia/2012/program.html>

Tutti I dati (e relativo software) di Fermi pubblici e accessibili a tutti
<http://fermi.gsfc.nasa.gov/ssc/>



Grazie per l'Attenzione

**Gino Tosti
Dipartimento di Fisica
Università di Perugia
INFN & INAF
tosti@pg.infn.it**