Il lato violento dell'Universo

L'astrofisica dei raggi gamma dallo spazio

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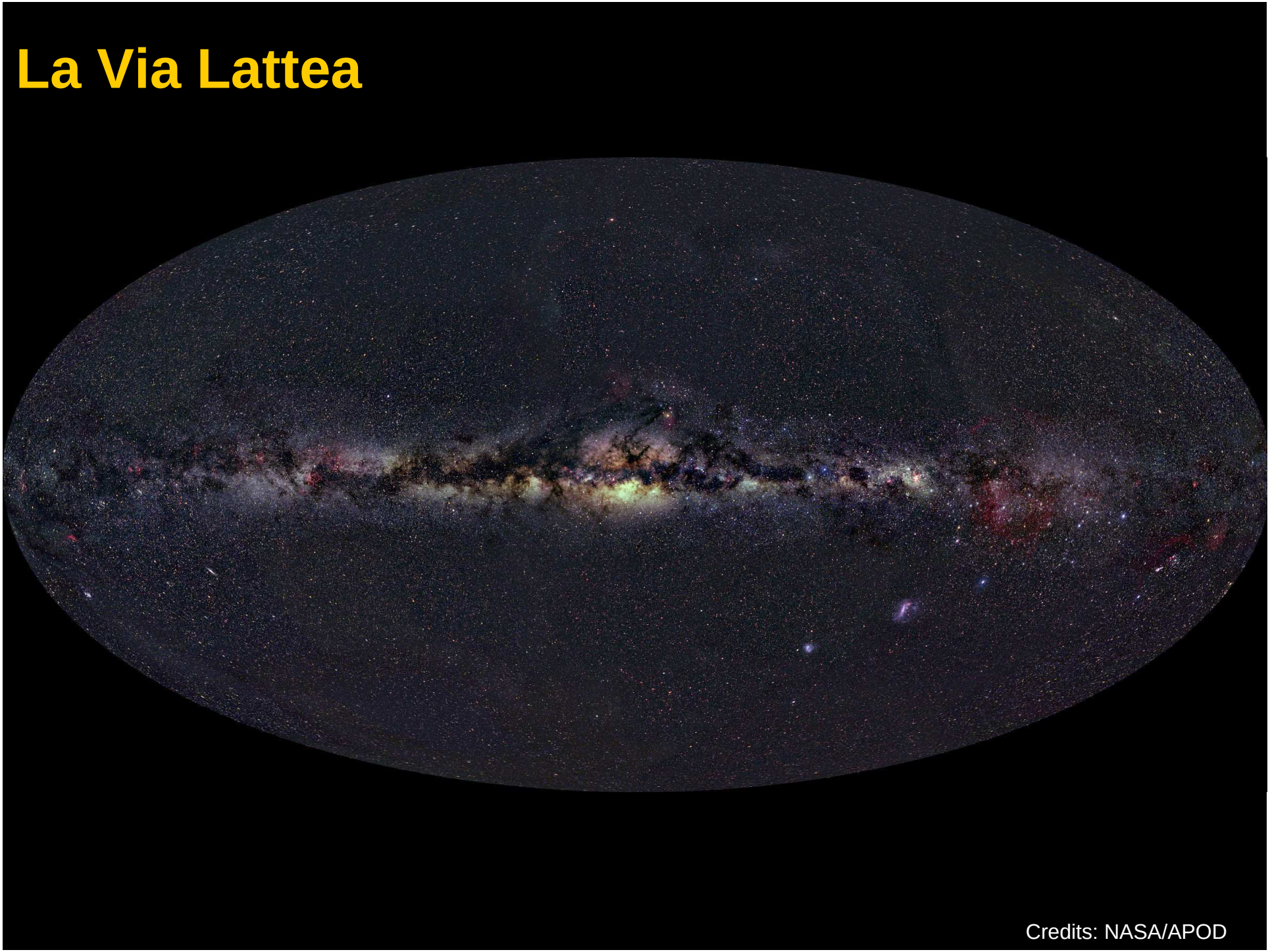
(Università di Pisa & INFN-Pisa)

9 Ottobre 2015
Incontri di Fisica – XV Edizione


Astronomy Picture of the Day (2012 August 1)
WallyPacholka / AstroPics.co

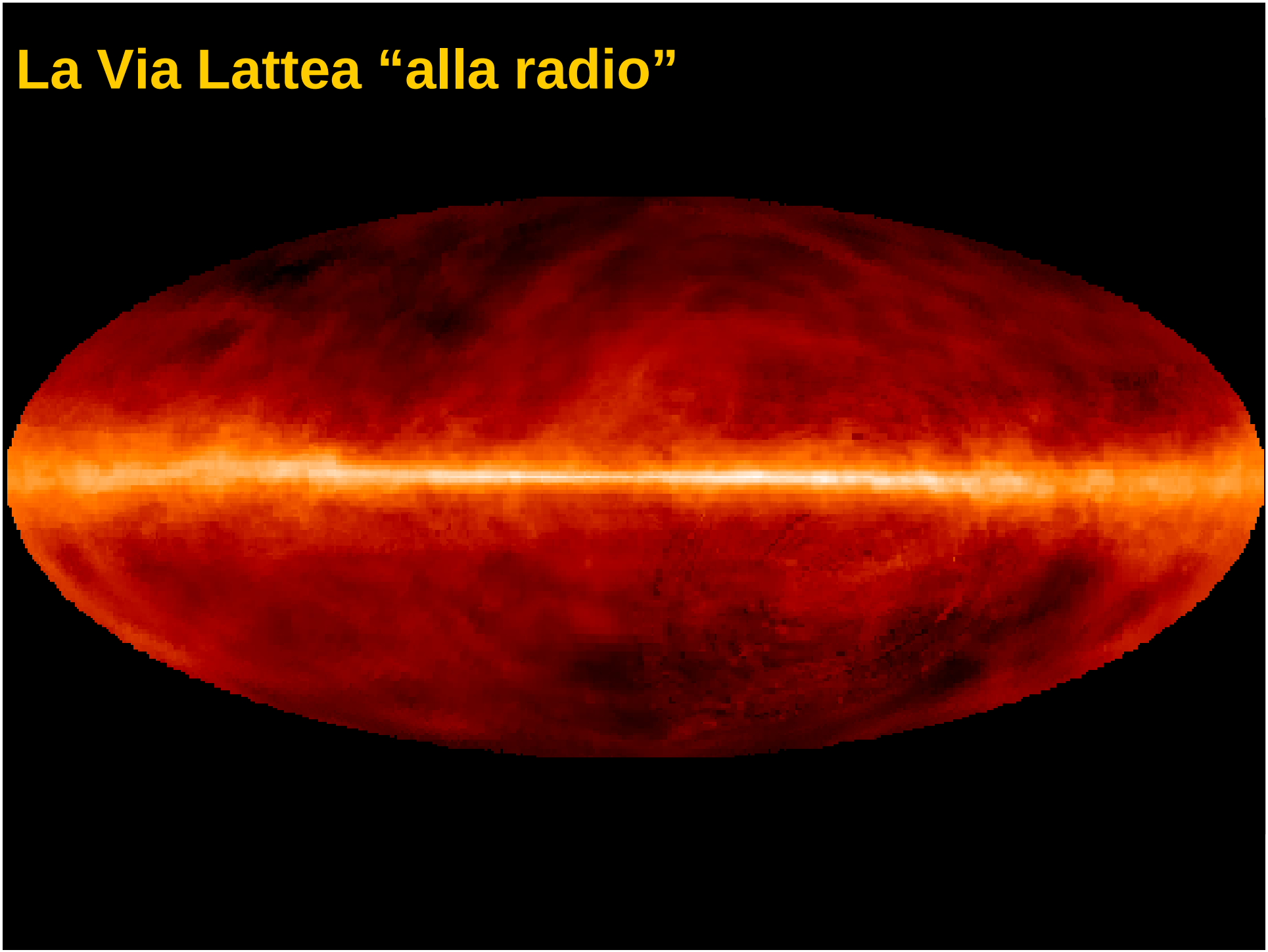
Voi siete qui

La Via Lattea

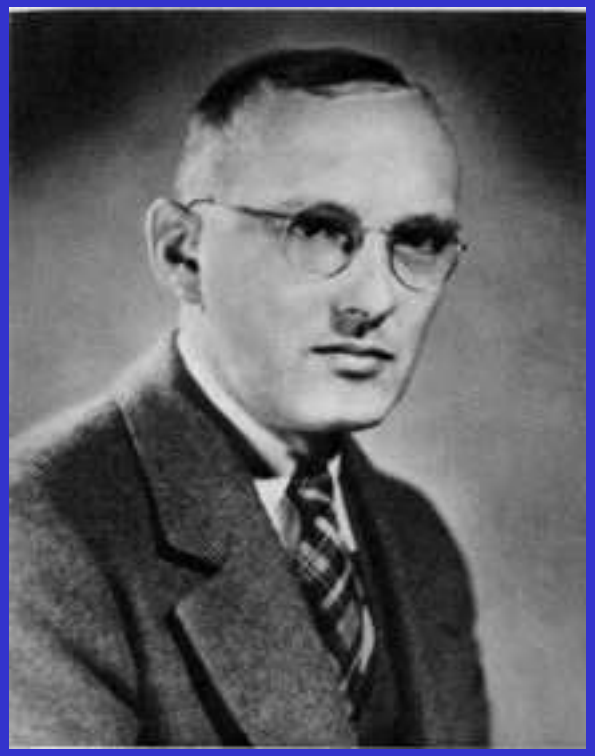


Credits: NASA/APOD

La Via Lattea “alla radio”

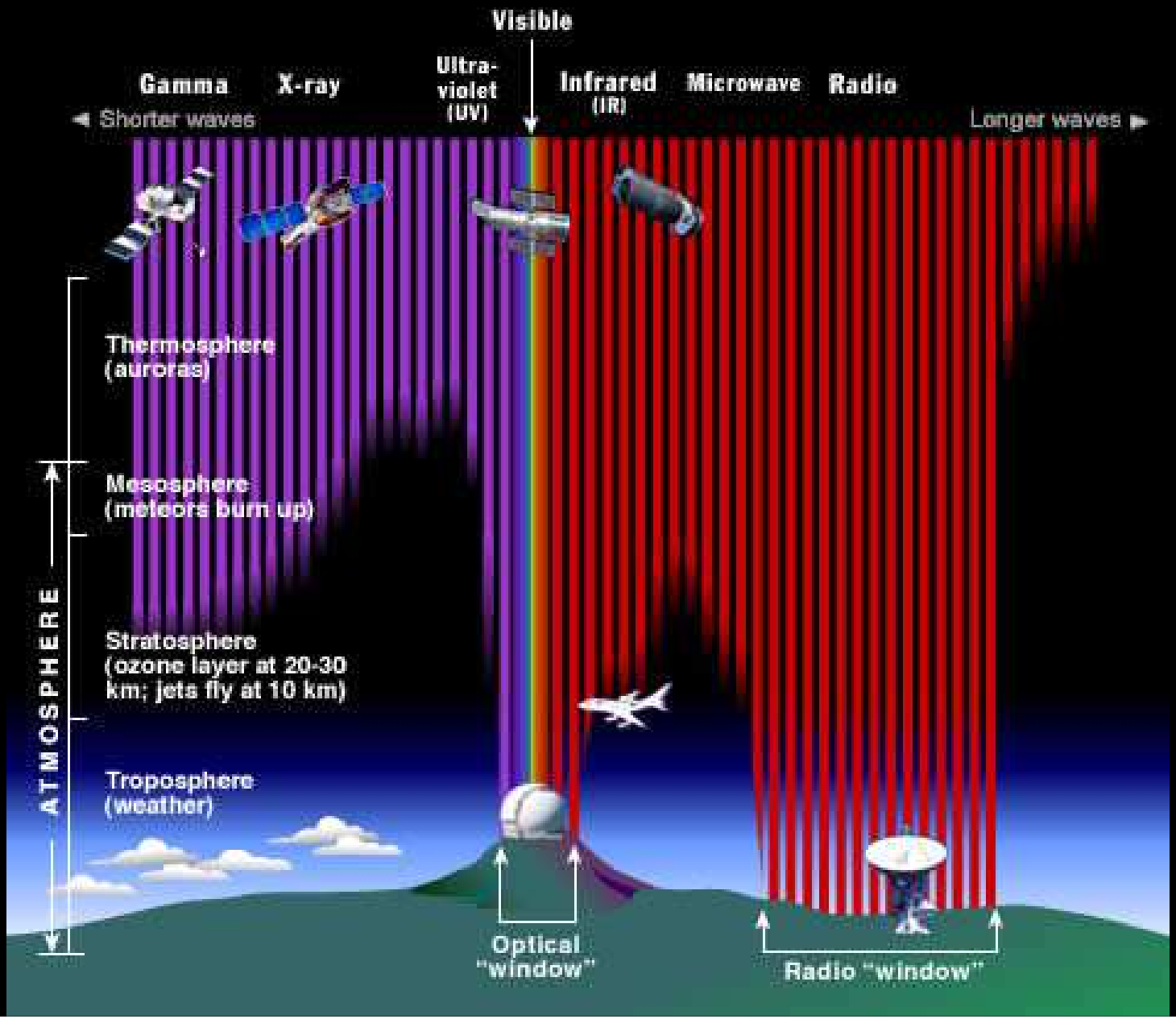


Onde radio dal cielo

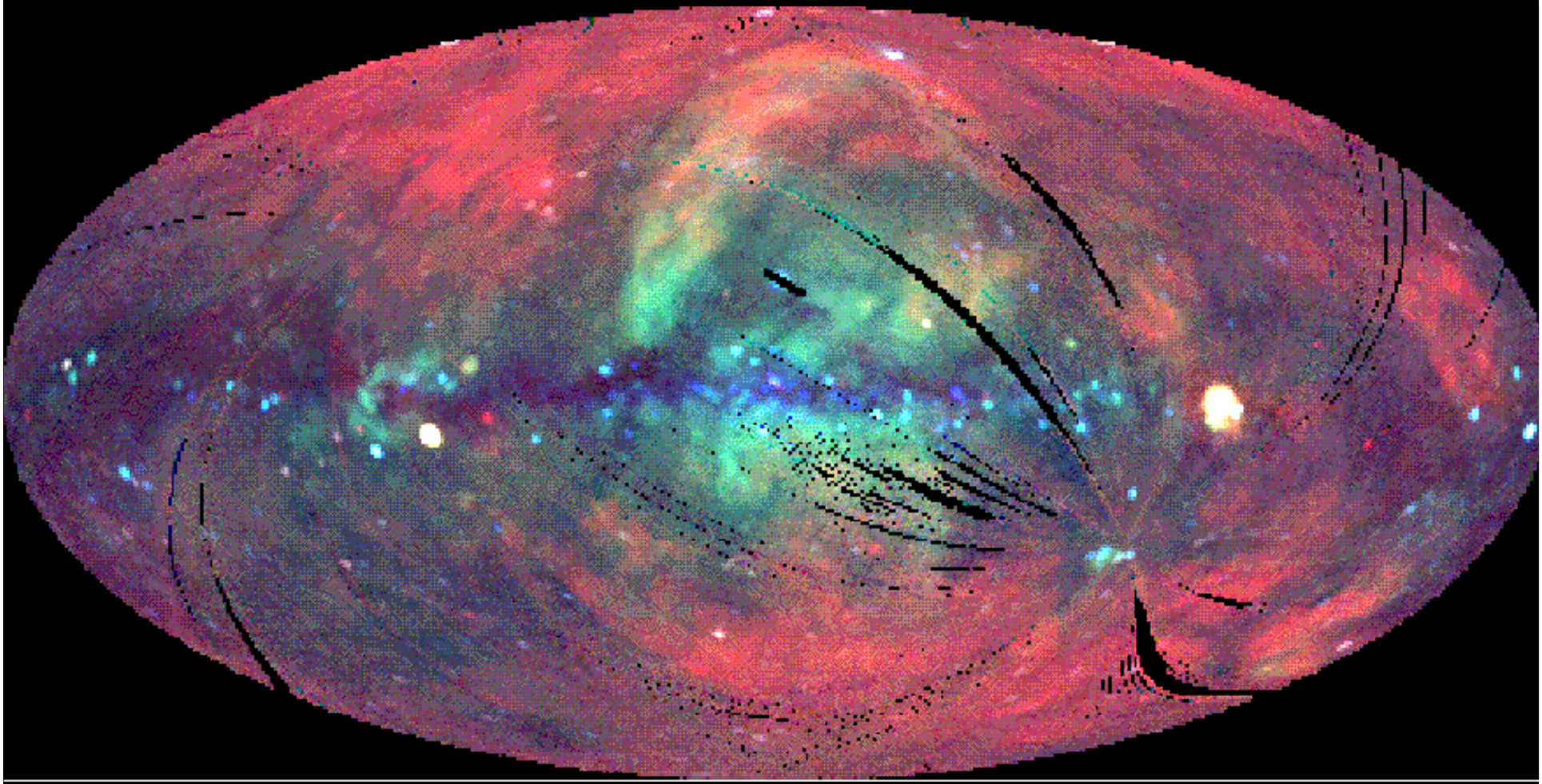


Karl Jansky
1905-1950

Astrofisica spaziale

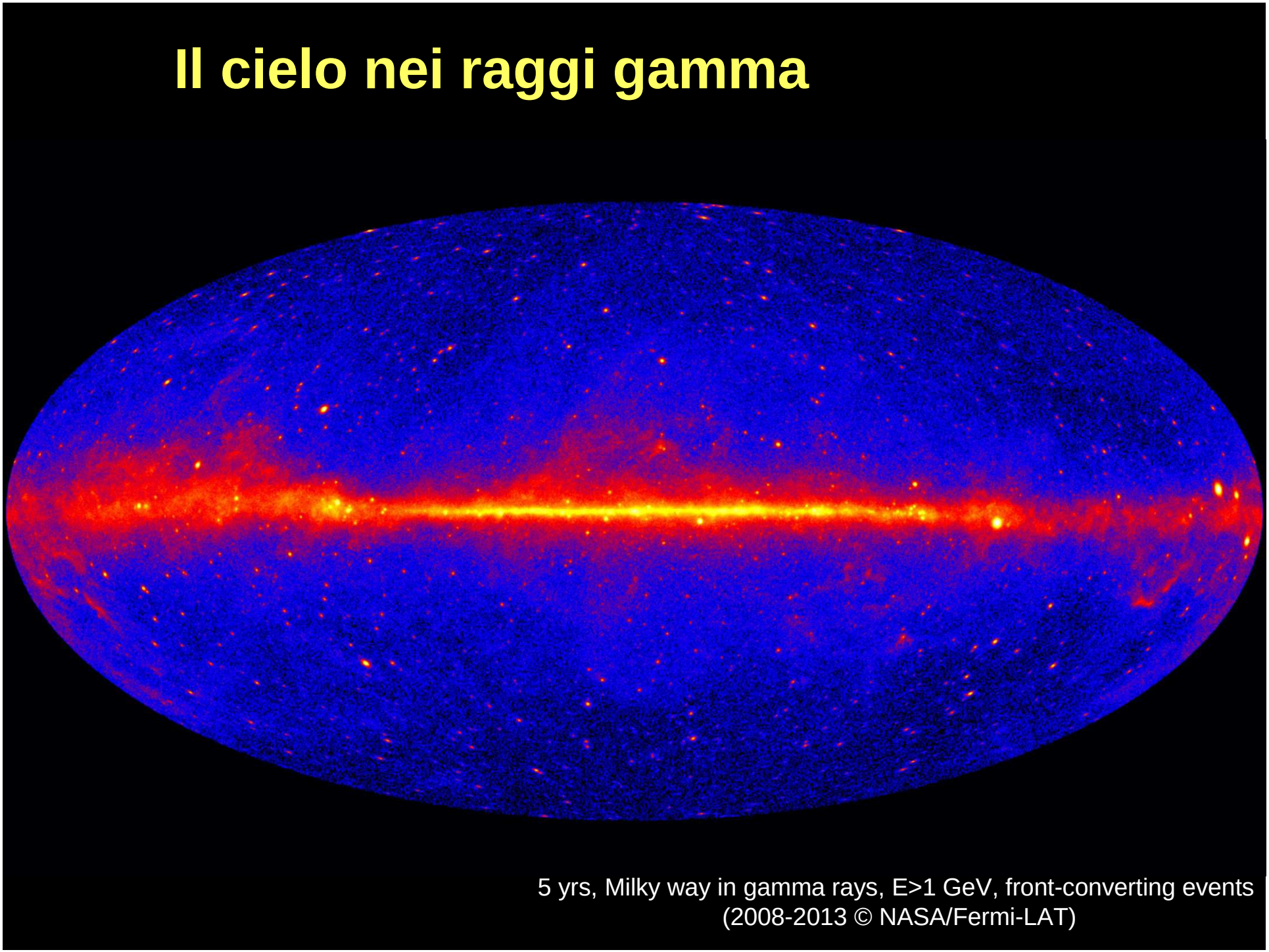


Una radiografia al cielo



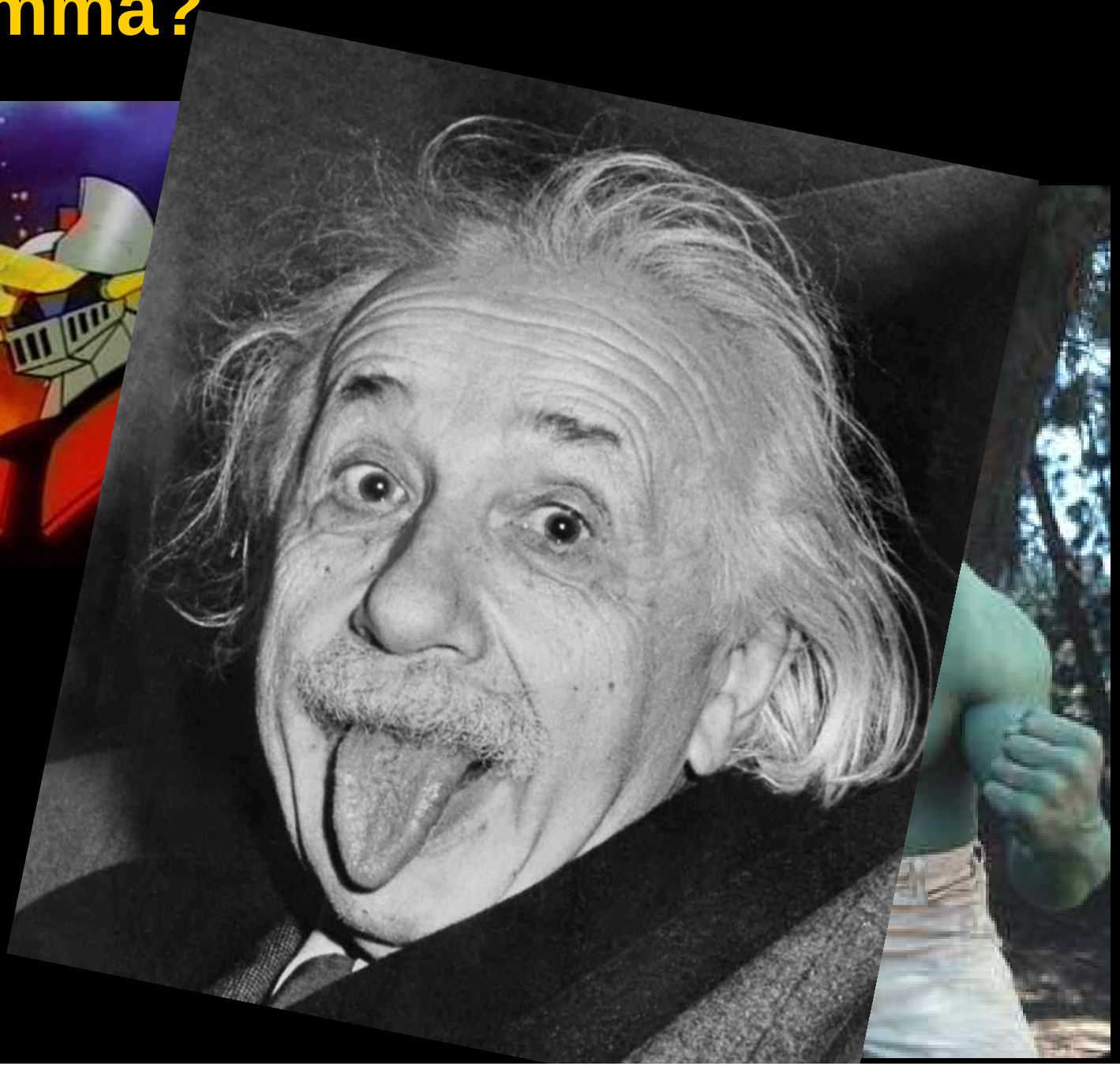
ROSAT (1996)
APOD, 8 Oct 1996

Il cielo nei raggi gamma

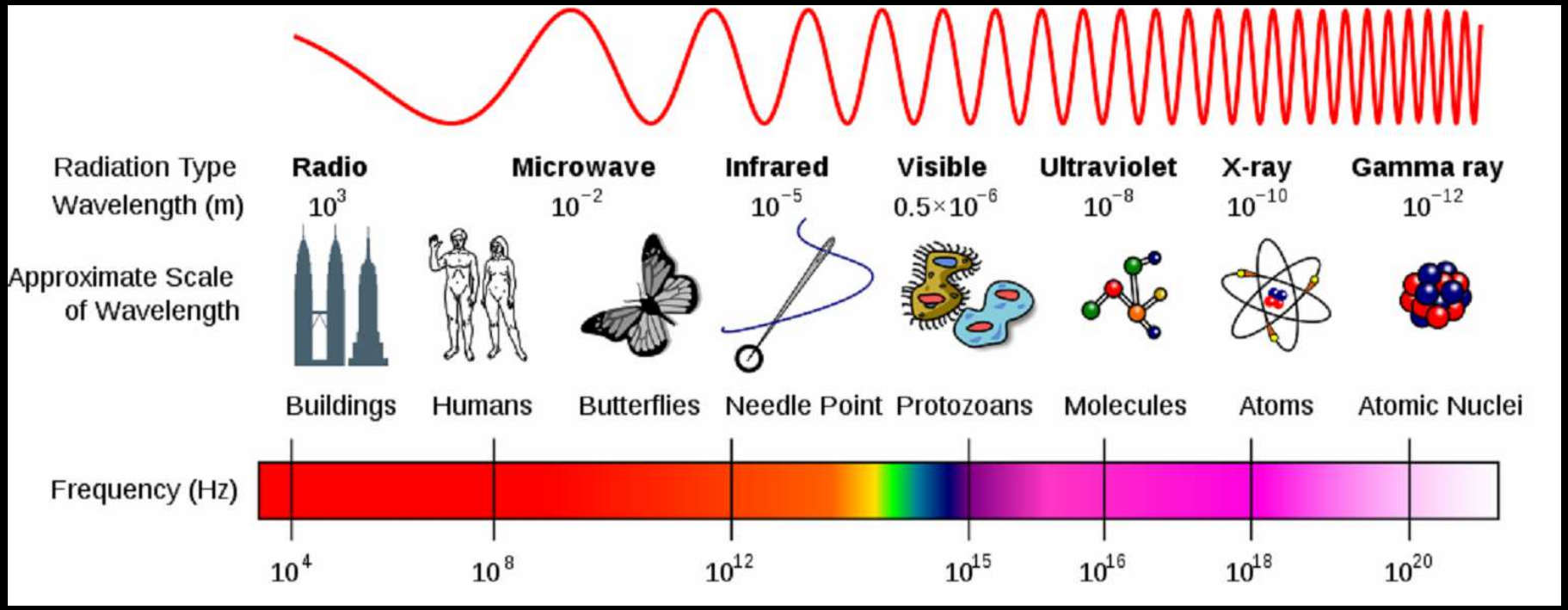


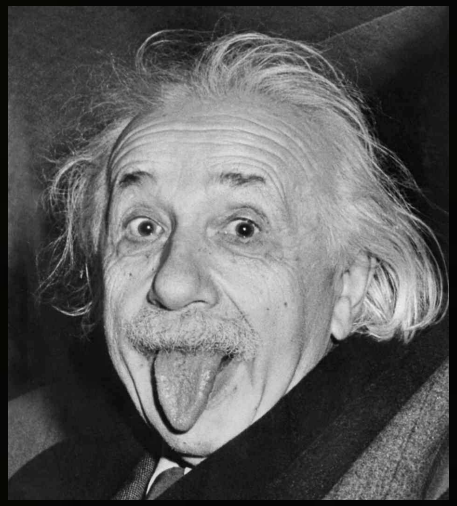
5 yrs, Milky way in gamma rays, E>1 GeV, front-converting events
(2008-2013 © NASA/Fermi-LAT)

Raggi gamma?



Fiat lux


Radiation Type
Wavelength (m)
Approximate Scale of Wavelength
Radio
10^{3}
Microwave
10^{-2}
Infrared
10^{-5}
Visible
0.5×10^{-6}
Ultraviolet
10^{-8}
X-ray
10^{-10}
Gamma ray
10^{-12}
Buildings
Humans
Butterflies
Needle Point
Protozoans
Molecules
Atoms
Atomic Nuclei
Frequency (Hz)
10^{4}
10^{8}
10^{12}
10^{15}
10^{16}
10^{18}
10^{20}



Luce ed energia

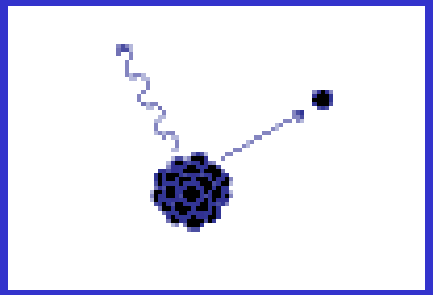
$$E = h\nu$$

Piccole λ = alte energie

1 elettronvolt = 1.6×10^{-19} Joule

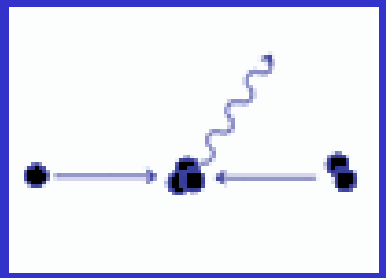
Visible ~ 1 eV
UV ~10 eV
X rays = 0.1 keV-100 keV
Gamma rays= >100 keV

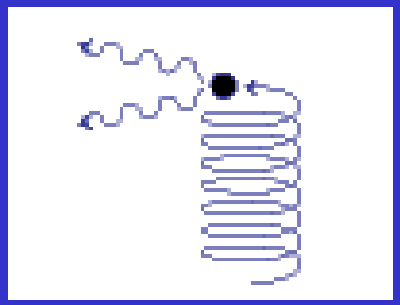
Meccanismi di produzione



Decadimento gamma

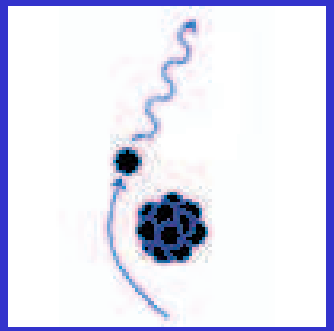
Fusione nucleare

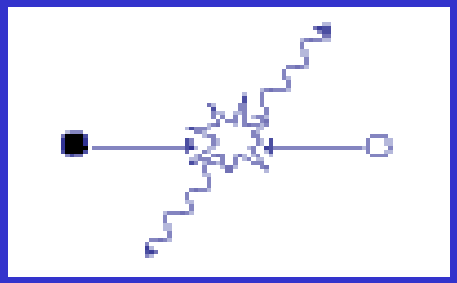




Sincrotrone

Bremsstrahlung





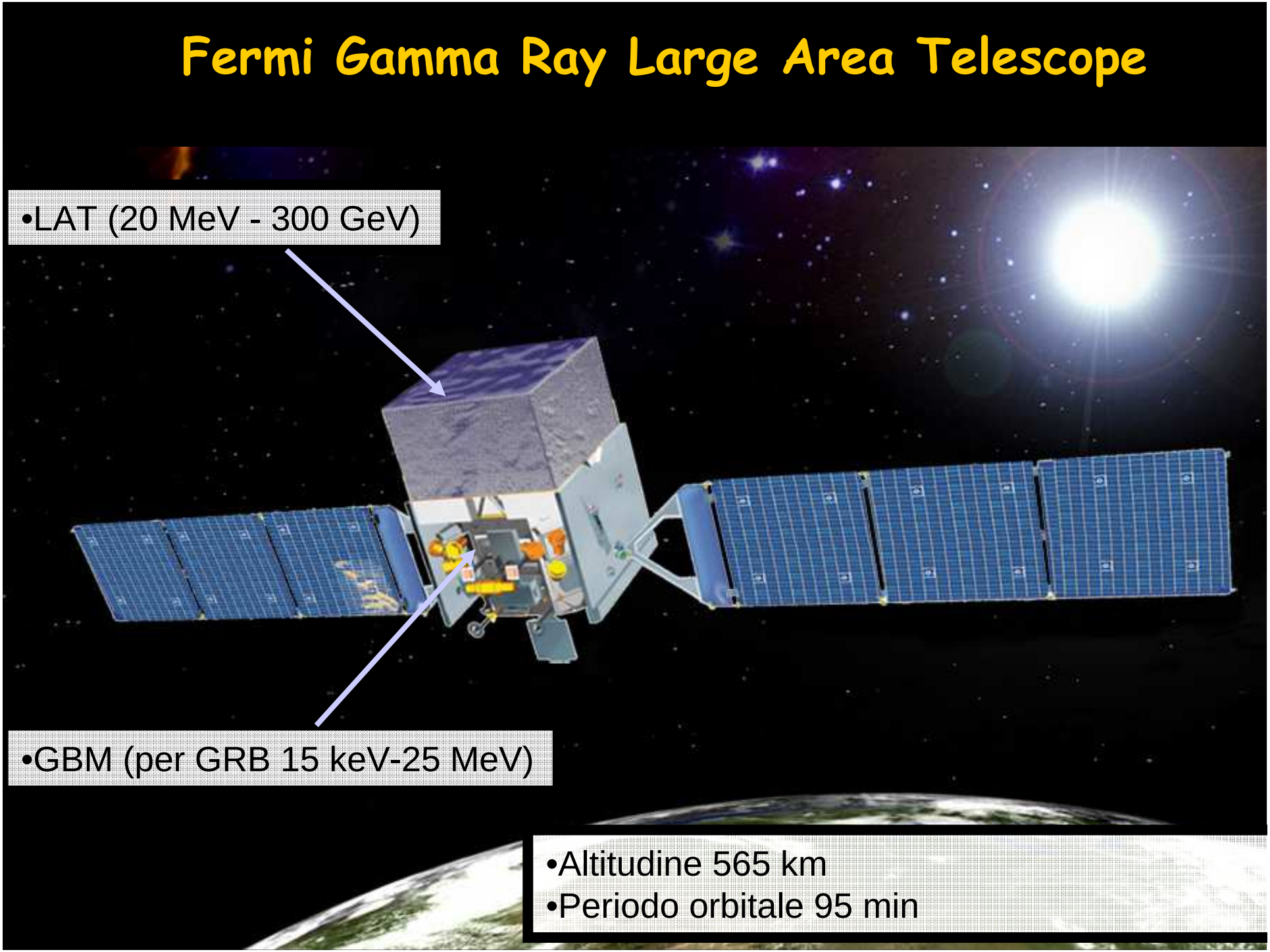
Annichilazione materia - antimateria

Effetto Compton inverso

Non-Thermal, "Non-Traditional" Universe

- **Extreme environments that accelerate particles**
  - **Neutron Stars**
  - **Black Holes (AGNs, etc.)**
  - **Black Hole Birth Announcements: Gamma Ray Bursts (GRBs)**
  - **Supernova Remnants, Pulsar Wind Nebulae, novae…**
- **Particles interaction with Interstellar medium**
  - **Gas and Dust**
  - **Radiation fields – Radio, IR, Optical, …**
  - **Intergalactic Magnetic Fields, …**
- **Produced gamma rays travel to us!**
  - **Probe cosmological distances**
- **Surprises!**
  - **Astrophysics: new source classes, new phenomena**
  - **New Physics (e.g. Dark Matter, QG, …)**

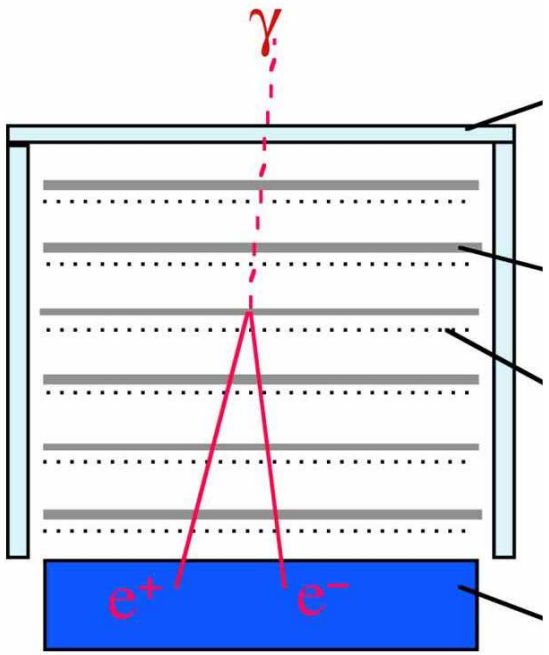
Fermi Gamma Ray Large Area Telescope



~7 anni in orbita

- **Cape Canaveral Air Force Station 11 June 2008 at 12:05PM EDT**
- **Inizio osservazioni 4 agosto, 2008**
- **Rinominato da GLAST to Fermi**
- **Missione iniziale 5 anni, ora estesa**

“Vedere” i raggi gamma



Anticoincidenza → reiezione fondo

Convertitore (W)

Tracciatore → direzione

Calorimetro → Energia

> 20 MeV :

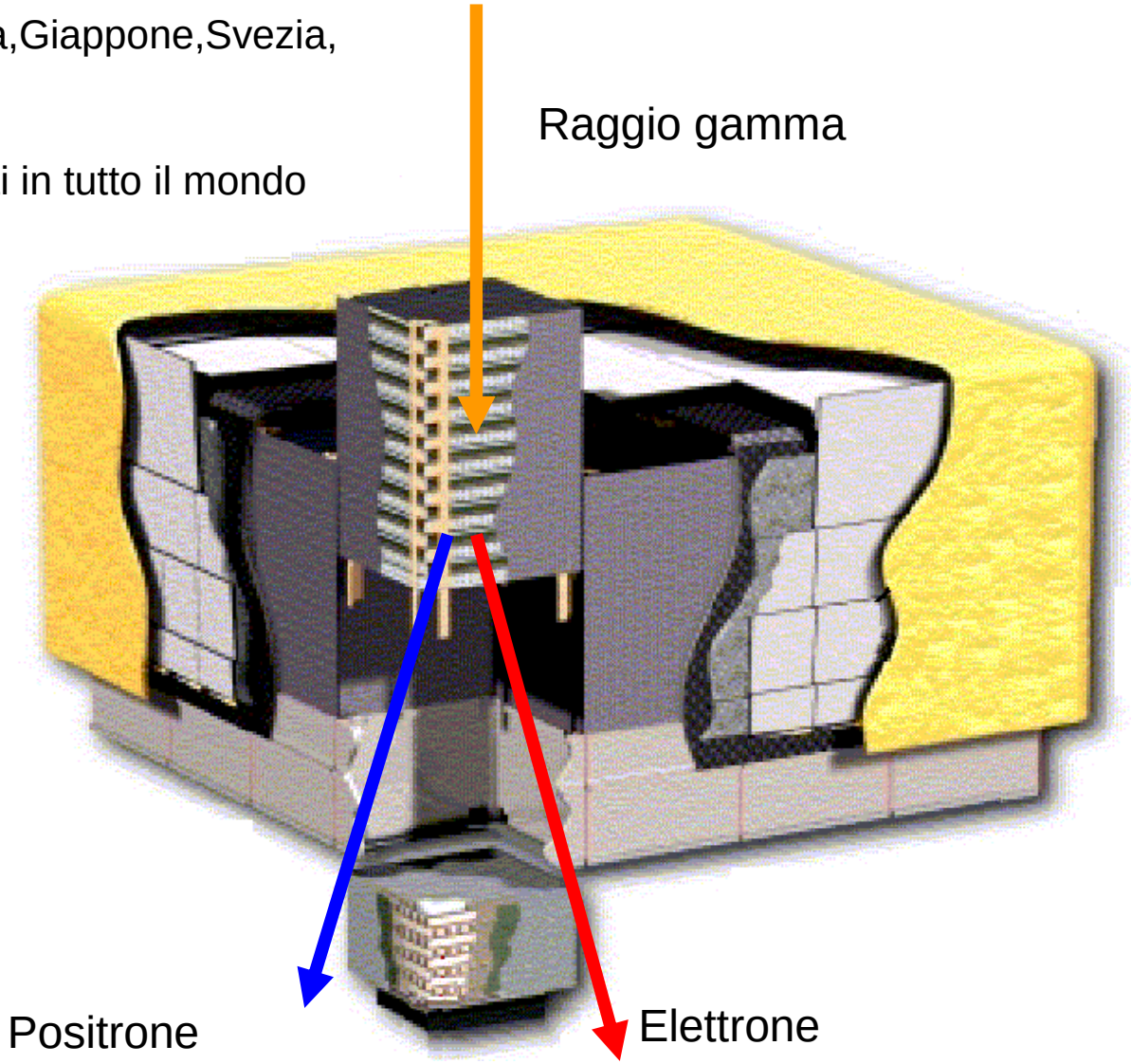
Produzione coppie elettrone - positrone

Large Area Telescope

Atwood, W. B. et al. 2009, ApJ, 697, 1071

USA, Italia, Francia,Giappone,Svezia, Germania

Circa 500 scienziati in tutto il mondo

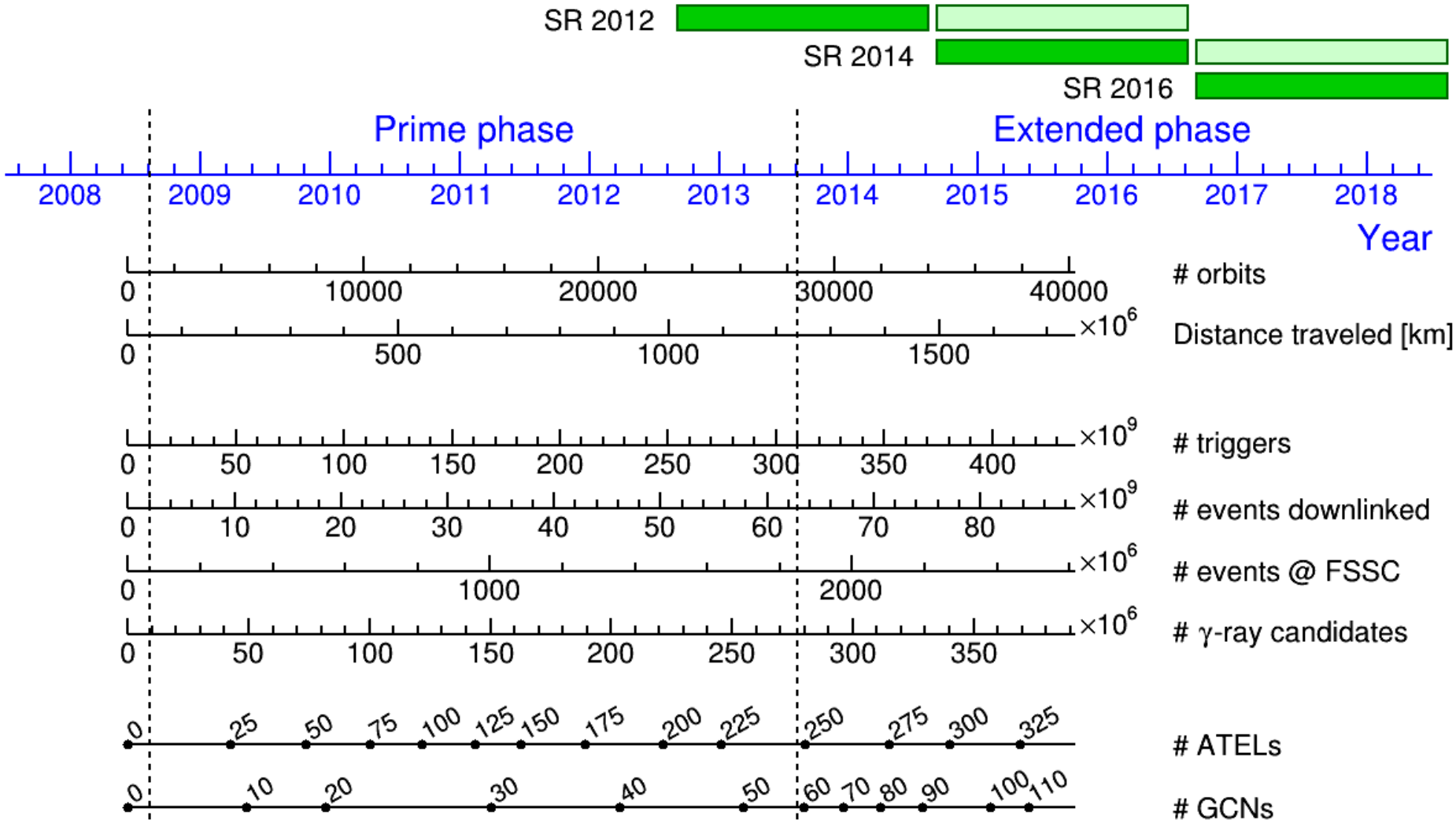


Detecting gamma rays

Un telescopio?

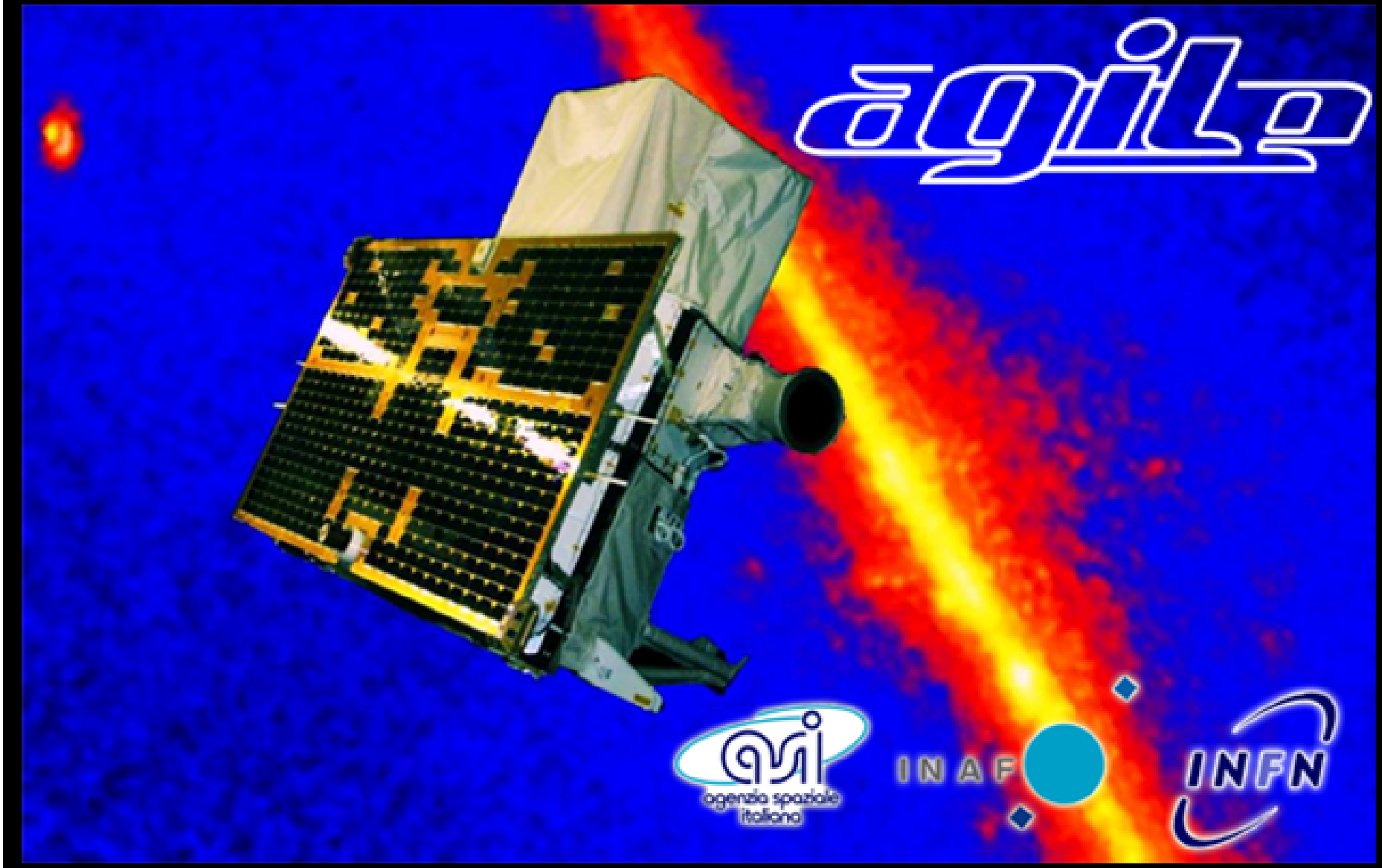
Energia	>20 MeV
Dimensioni	**1.5x1.5 m**
Massa	**<3 tonn**
Consumo	**<650 W**
Campo vista	**¼ sky**
Risoluzione angolare	**3.5° (0.1° @10 GeV)**

Cronache dallo spazio

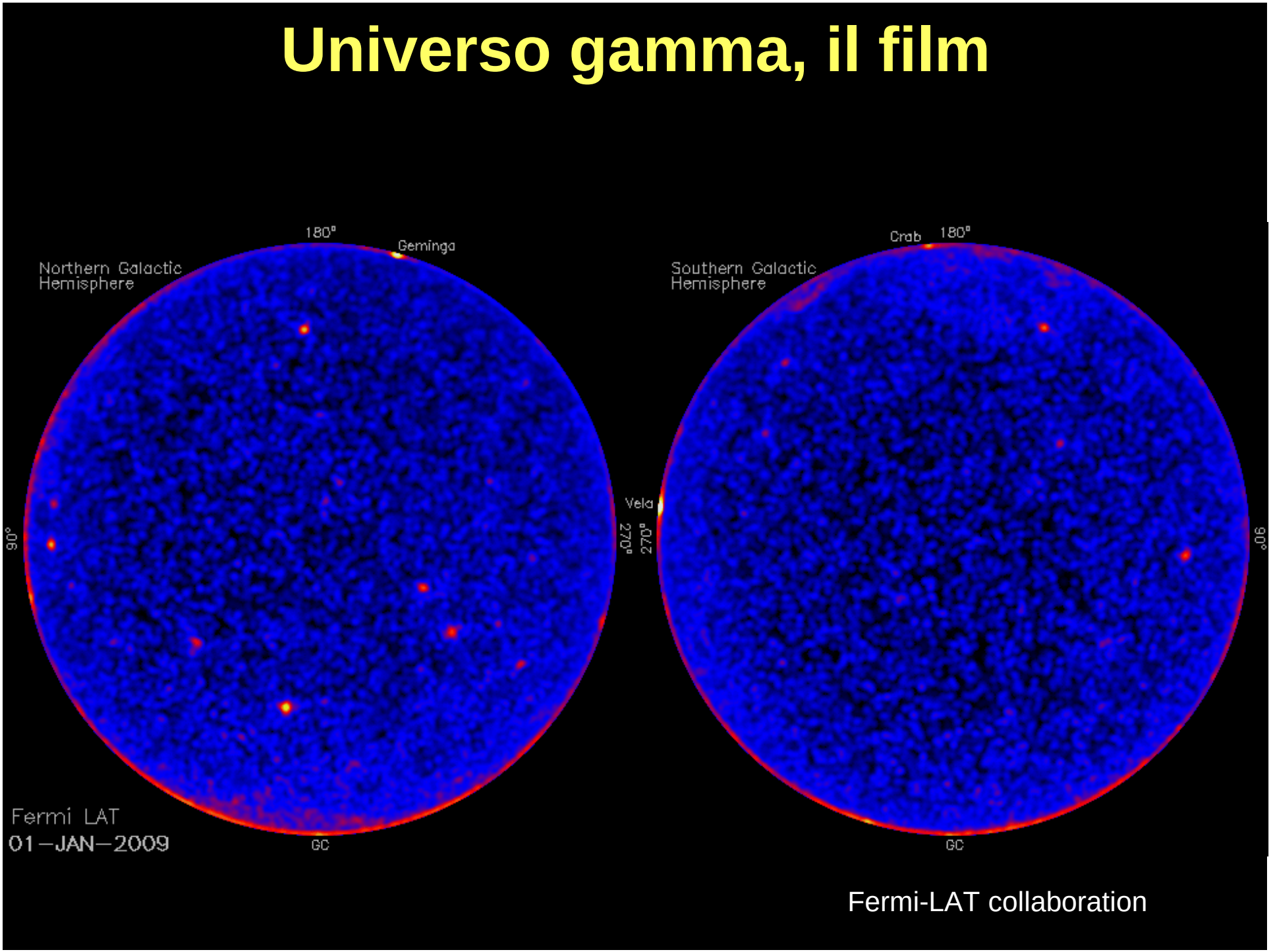


Credits: L. Baldini

AGILE, made in Italy

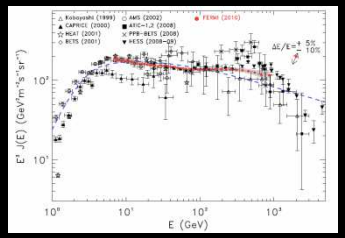


Universo gamma, il film

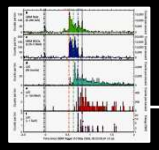


Fermi-LAT collaboration

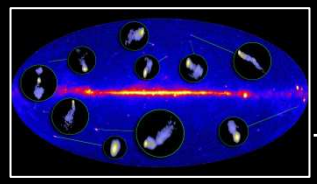
Un ricco menu



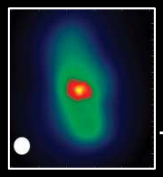
e^+e^- spectrum



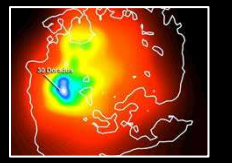
GRBs

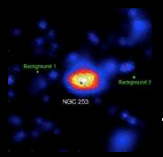


Blazars (782)



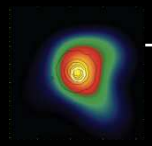
Radio Galaxies (12)





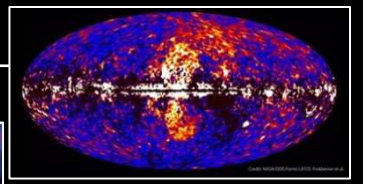
Starburst Galaxies (4)

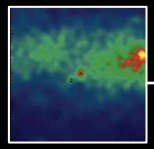
M31, LMC & ~~SMC~~



Globular Clusters (11)

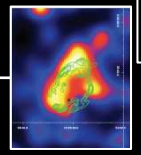
Fermi Bubbles

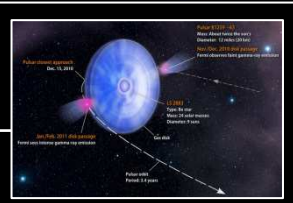




Nova (1)

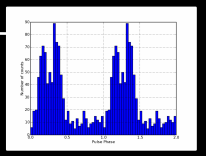
SNR & PWN (68)



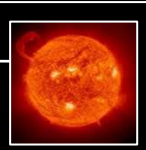


γ-ray binaries (6)

Pulsars: young & millisecond (MSP) (132)



Sun: flares & CR interactions



Terrestrial Gamma-ray Flashes

Nolan+12,ApJS (2FGL catalog)

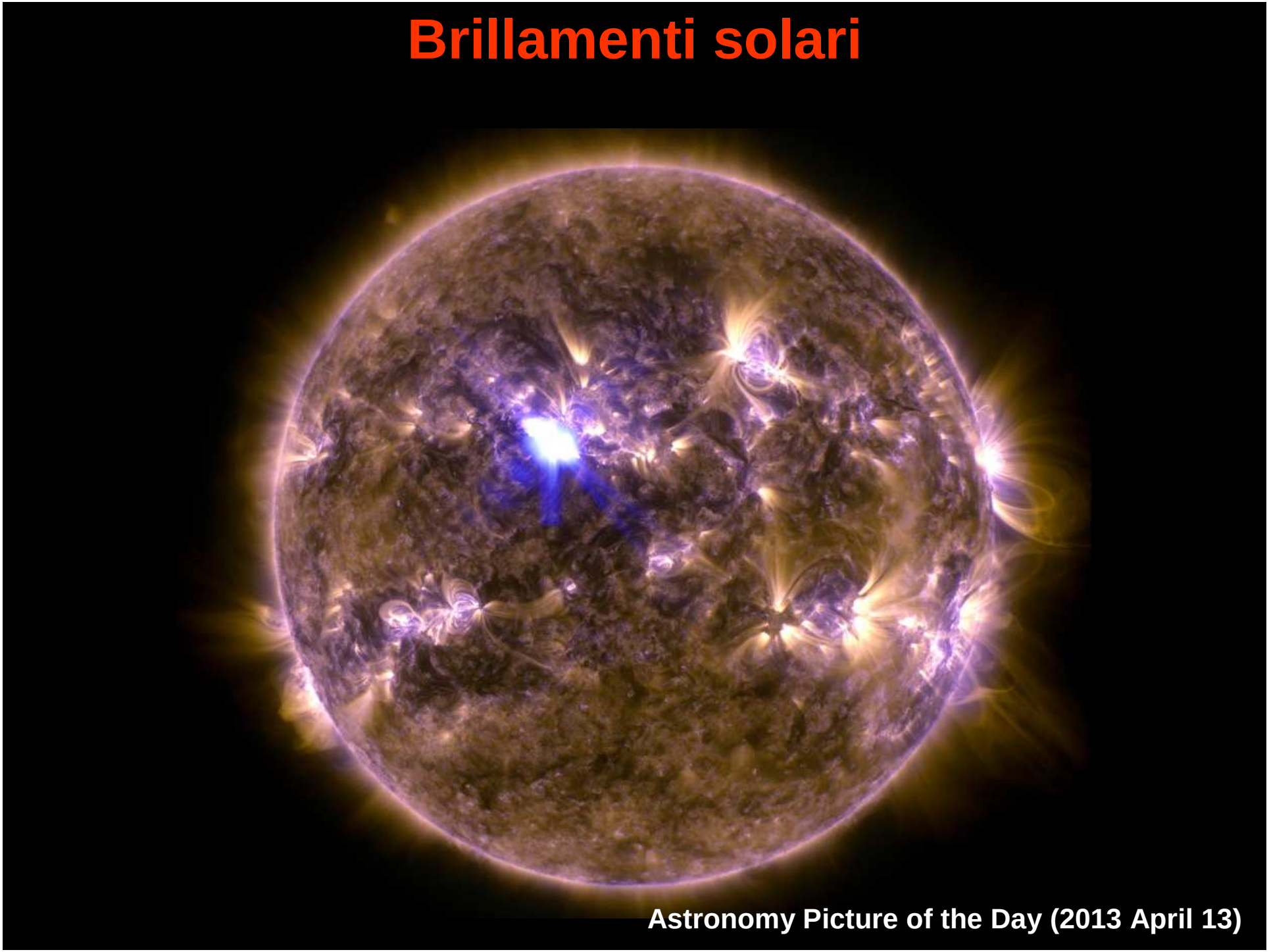
Unidentified Sources (~1/3 total)

Extragalactic

Galactic

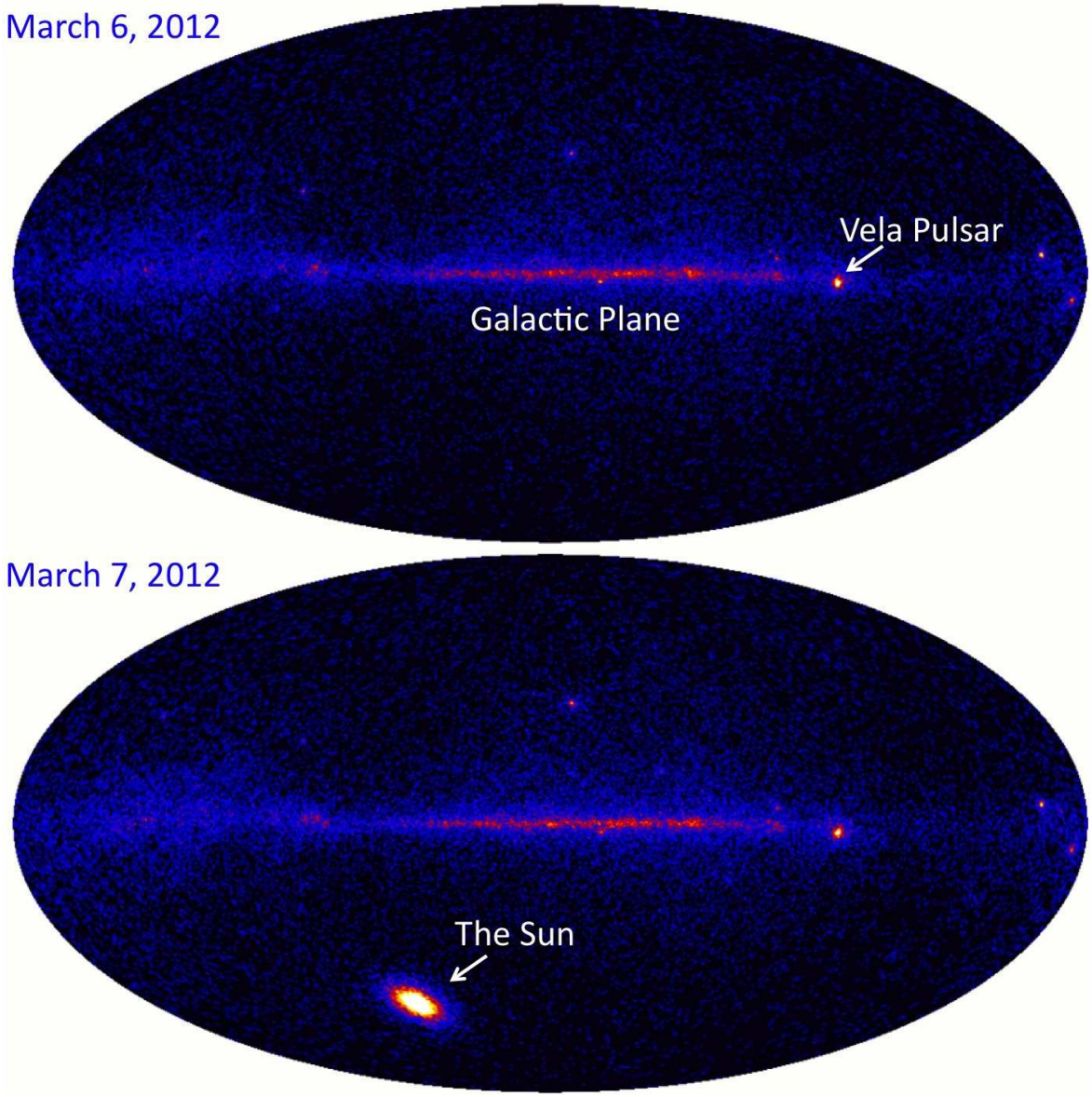
Local

Brillamenti solari



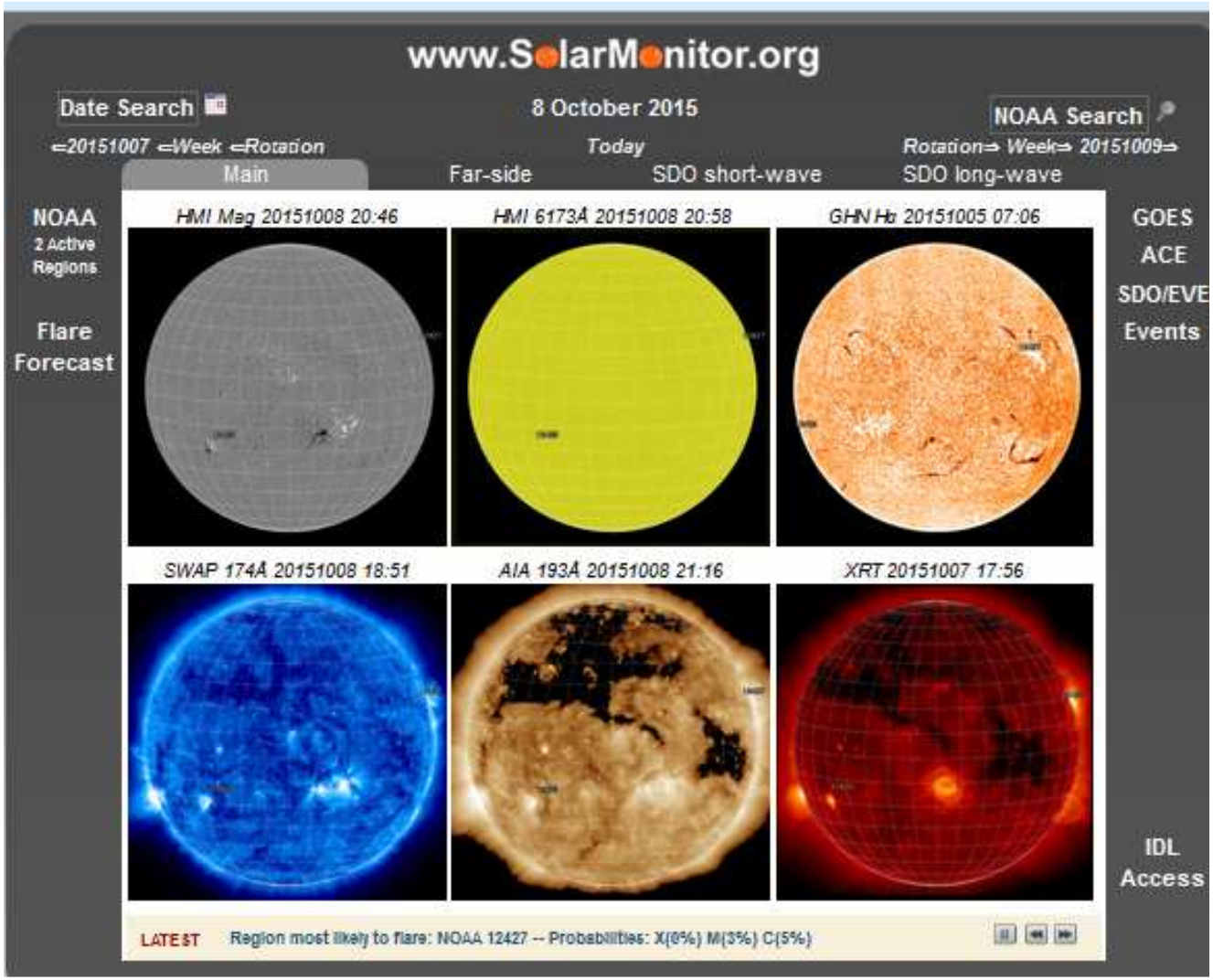
Astronomy Picture of the Day (2013 April 13)

Fermi e il Sole

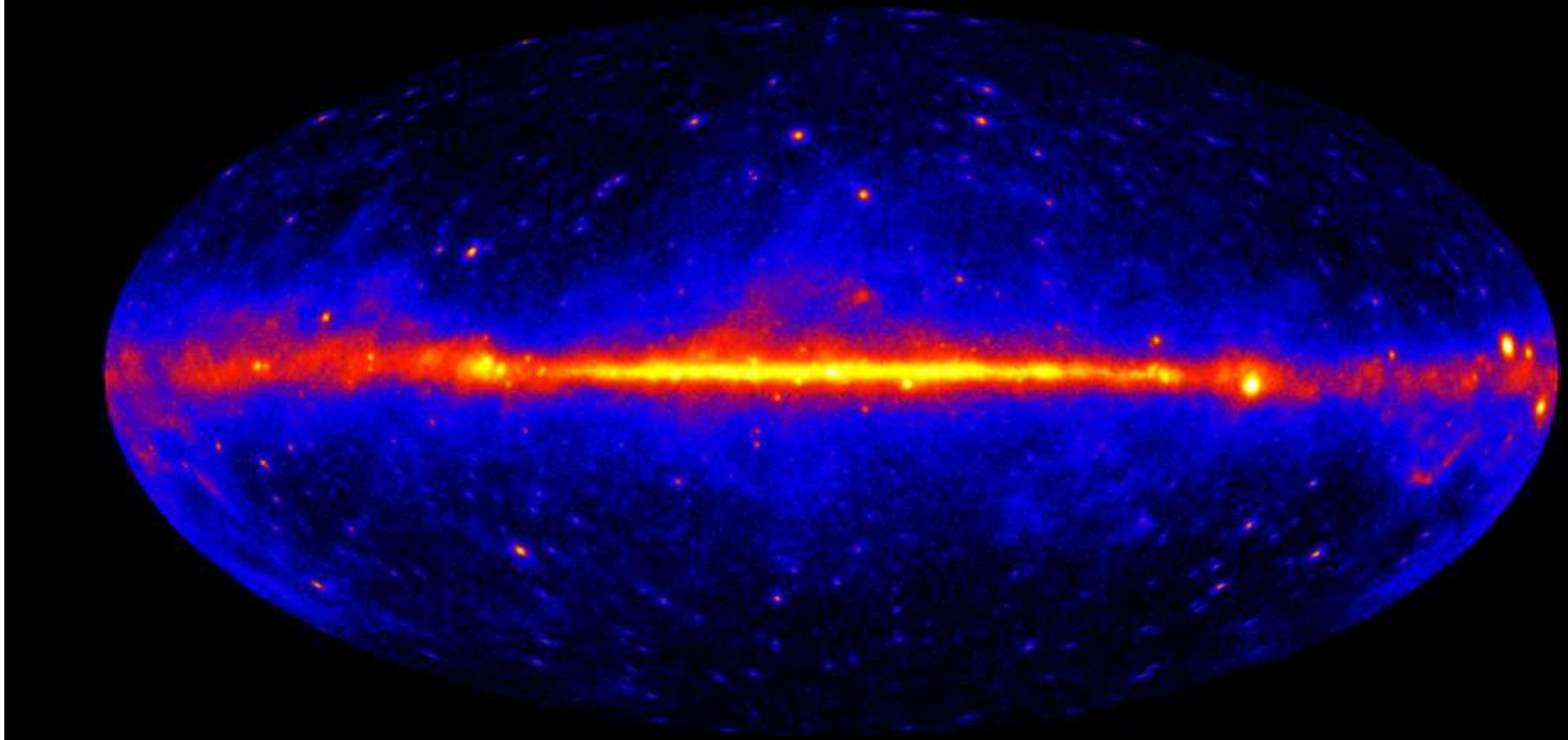


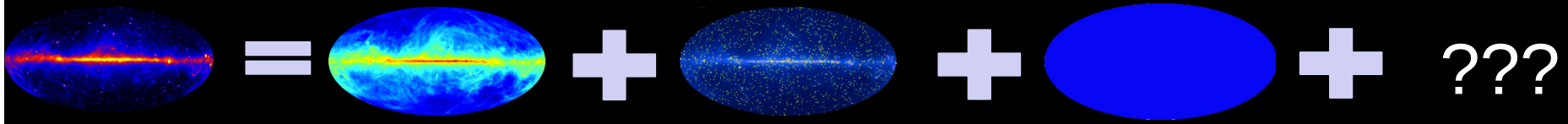
Meteo spaziale

www.solarmonitor.org



Il cielo gamma sotto esame

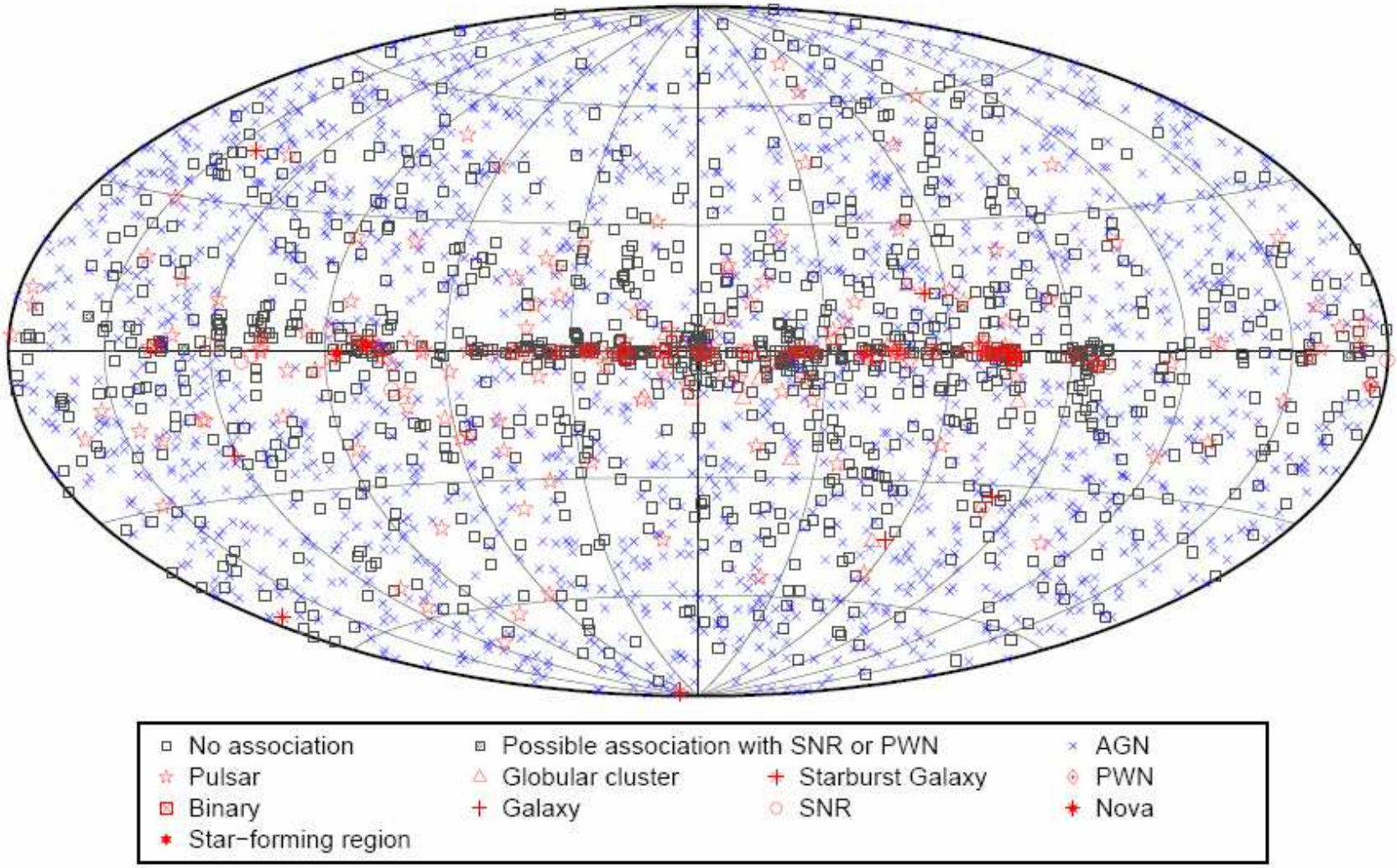




GeV Sky Galactic Point Sources Isotropic

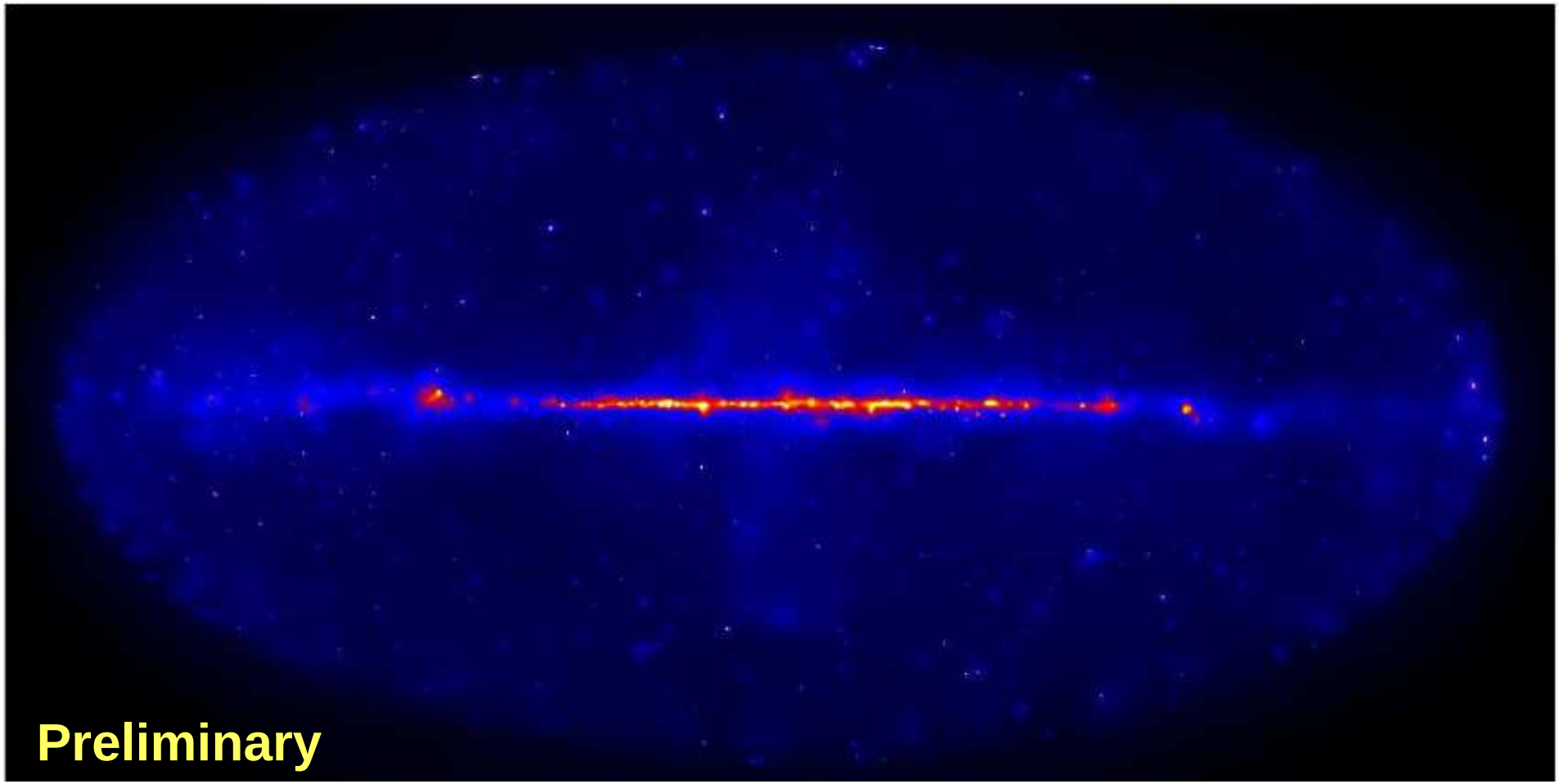
Fermi-LAT Third Source Catalog (3FGL)

Acero et al., ApJS 218, 2012)



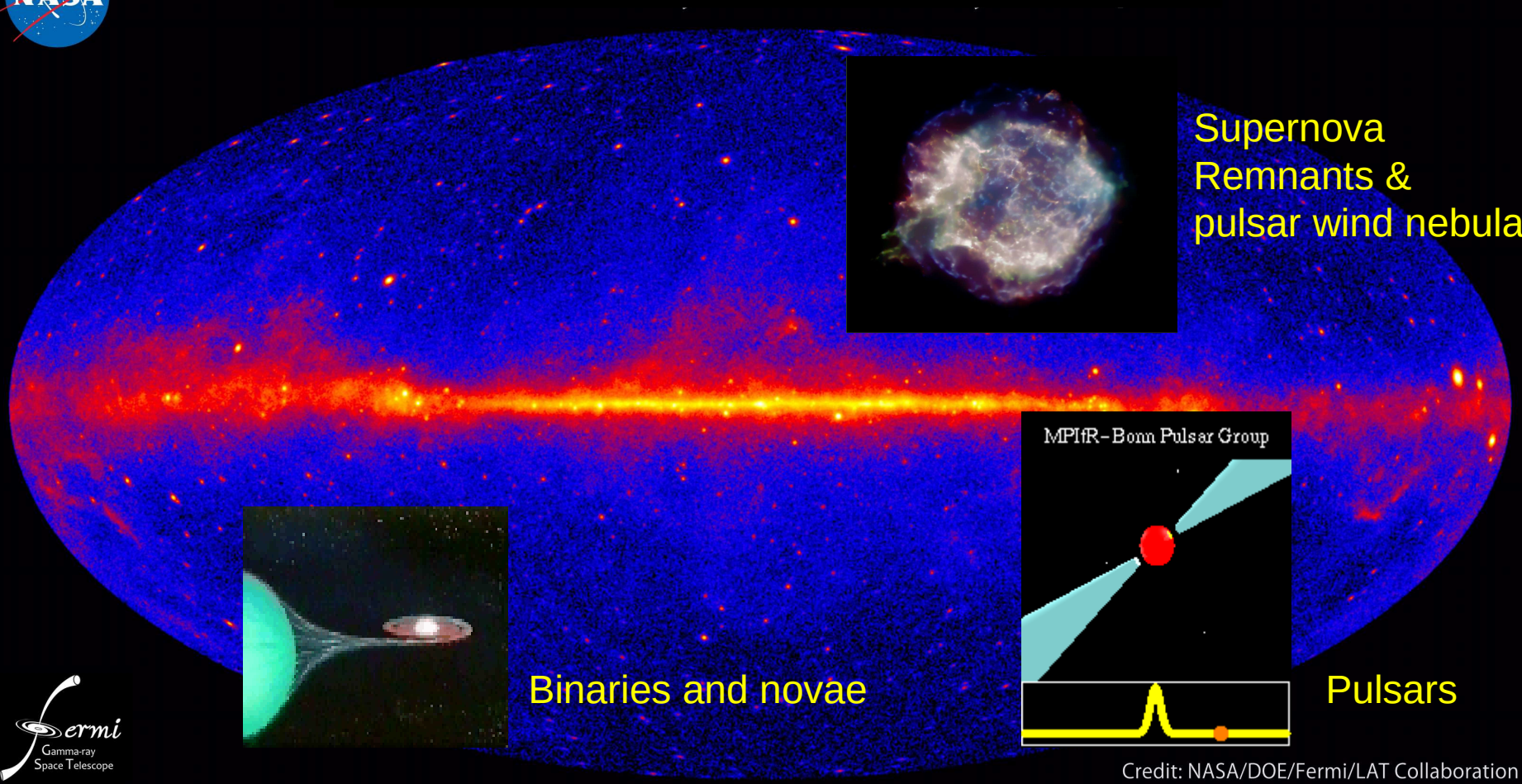
- 4 anni
- 3033 sorgenti, 1010 non identificate

Il cielo sopra 50 GeV



- 2nd Fermi Hard Source List (2FHL), in prep.
- 6 years of data, Pass 8
- ~55k photons, ~350 sources

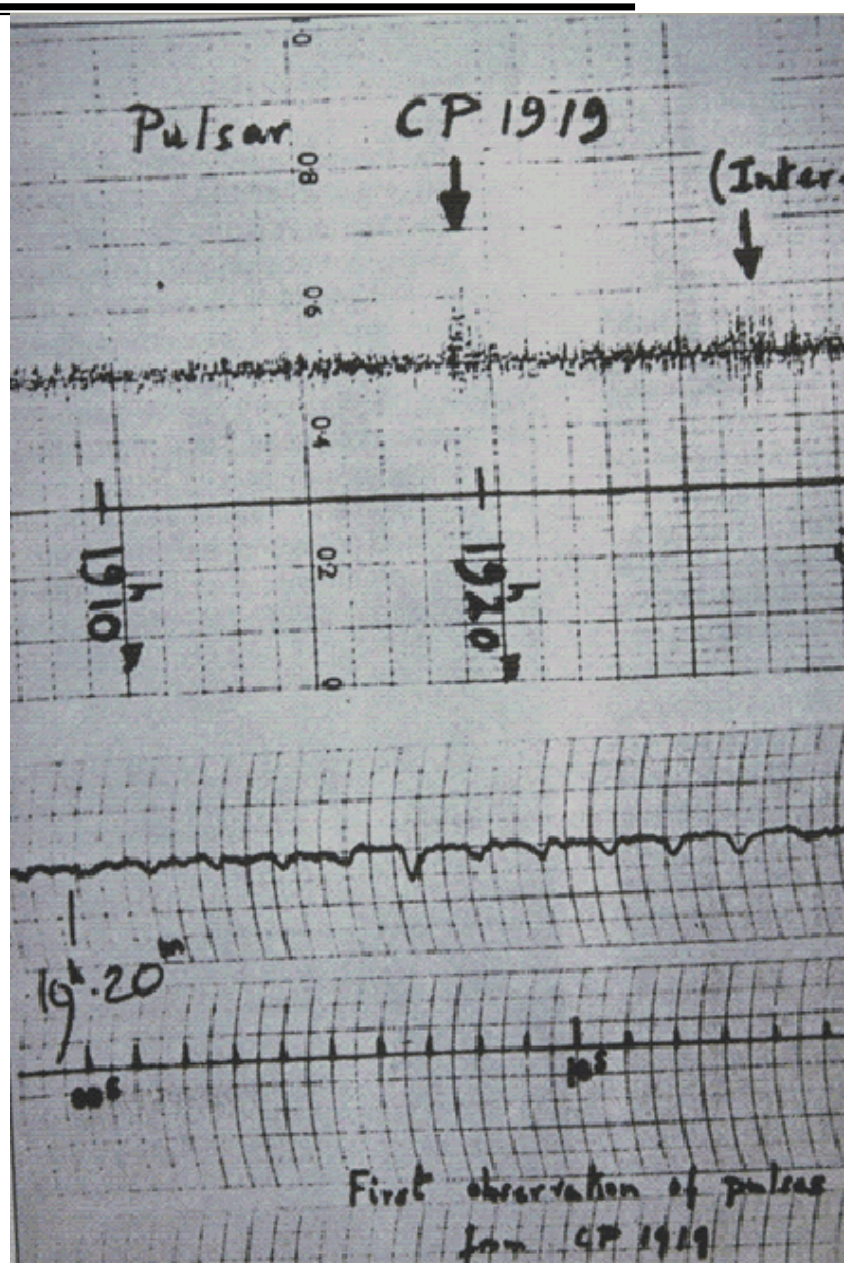
La Via Lattea nei raggi gamma



Credit: NASA/DOE/Fermi/LAT Collaboration

Pulsar

Jocelyn Bell
&
Anthony Hewish
(1967)



Reprinted from *Nature*, February 24, 1968

Observation of a Rapidly Pulsating Radio Source

by

A. HEWISH
S. J. BELL
J. D. H. PILKINGTON
P. F. SCOTT
R. A. COLLINS

Mullard Radio Astronomy Observatory,
Cavendish Laboratory,
University of Cambridge

Unusual signals from pulsating radio sources have been recorded at the Mullard Radio Astronomy Observatory. The radiation seems to come from local objects within the galaxy, and may be associated with oscillations of white dwarf or neutron stars.

In July 1967, a large radio telescope operating at a frequency of 81·5 MHz was brought into use at the Mullard Radio Astronomy Observatory. This instrument was designed to investigate the angular structure of compact radio sources by observing the scintillation caused by the irregular structure of the interplanetary medium[1]. The initial survey includes the whole sky in the declination range $-08° < \delta < 44°$ and this area is scanned once a week. A large fraction of the sky is thus under regular surveillance. Soon after the instrument was brought into operation it was noticed that signals which appeared at first to be weak sporadic interference were repeatedly observed at a fixed declination and right ascension; this result showed that the source could not be terrestrial in origin.

Systematic investigations were started in November and high speed records showed that the signals, when present, consisted of a series of pulses each lasting ~0·3 s and with a repetition period of about 1·337 s which was soon found to be maintained with extreme accuracy. Further observations have shown that the true period is constant to better than 1 part in 10^7 although there is a systematic variation which can be ascribed to the orbital motion of the Earth. The impulsive nature of the recorded signals is caused by the periodic passage of a signal of descending frequency through the 1 MHz pass band of the receiver.

The remarkable nature of these signals at first suggested an origin in terms of man-made transmissions which might arise from deep space probes, planetary radar or the reflexion of terrestrial signals from the Moon. None of these interpretations can, however, be accepted because the absence of any parallax shows that the source lies far outside the solar system. A preliminary search for further pulsating sources has already revealed the presence of three others having remarkably similar properties which suggests that this type of source may be relatively common at a low flux density. A tentative explanation of these unusual sources in terms of the stable oscillations of white dwarf or neutron stars is proposed.

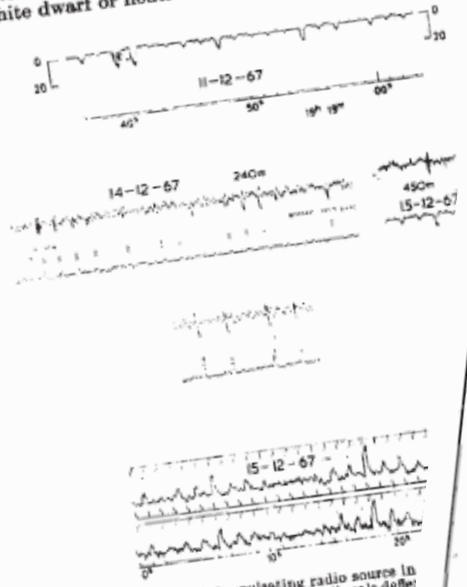


Fig. 1. *a*, A record of the pulsating radio source in ditions (receiver time constant 0·1 s). Full scale defle 20×10^{-26} W m^{-2} Hz^{-1}. *b*, Upper trace: records obtai paths (240 m and 450 m) in one side of the interferor normal interferometer records. (The pulses are because they occurred near a null in the interferenc fies the phase but not the amplitude of the oscilla upper trace.) *c*, Simulated pulses obtained usin *d*, Simultaneous reception of pulses obtained identi different frequencies. Pulses at the lower freq about 0·2 s.

SPACE 'SIGNALS' MAY BE FROM INTELLIGENT BEING

PULSATING STAR TRACED

By Dr. ANTHONY MICHAELIS
Science Correspondent

AN entirely novel kind of star, or the first signal from other intelligent beings in space, has been discovered by radio astronomers in Cambridge. It came to light on Aug. 6 last year and, at first, the extremely regular pulsations of the new radio source could only be explained by intelligent signalling.

The star was referred to by astronomers as LGM (Little Green Men).

Now, with further tests under way, their opinion has changed and it is thought to be a novel type between a white dwarf star and a neutron.

The name Pulsar (Pulsating Star) is likely to be given to it. Since last August four others have been discovered.

"Natural explanation"

Dr. A. Hewish of the Cavendish laboratory, Cambridge, told me yesterday: "We think there is a natural explanation. We have eliminated any source within our own solar system and have found it to lie within our own galaxy.

"It pulsates every 1.337 seconds with extreme accuracy, better than one part in 10 million. Since we published the results last week I have had several telephone calls from America. I am sure that today every radio telescope is looking at the Pulsars. It is the greatest thing in radio astronomy for a long time."

Sir Martin Ryle, director of the Mullard Radio Astronomy Observatory, Cambridge, where they were discovered, described them as "the funniest stars I have ever come across."

The accurate pulsations were noticed first by Miss S. Jocelyn Bell, a Ph.D. student from Ireland working under Dr. Hewish. At the observatory at Barton, near Cambridge, I saw the interplanetary scintillation aerial, the telescope with which they were discovered.

Mr. B Elsmore, of the observatory, said that the telescope made of thin cedar wood supports, 12ft high, containing 50 miles of wire, cost less than £1,000.

Daily Telegraph
March '68

What is a pulsar?

Stelle di neutroni altamente magnetizzate, super-dense, in forte rotazione,e che emettono particelle e radiazione

Qualche numero…

Massa: ~1.4 M_{sol} (from X-rays binaries, e.g. see Stairs 2004)

Raggio ~ 10 Km;

Periodo: ~0.0015 s – ~8.5 s;

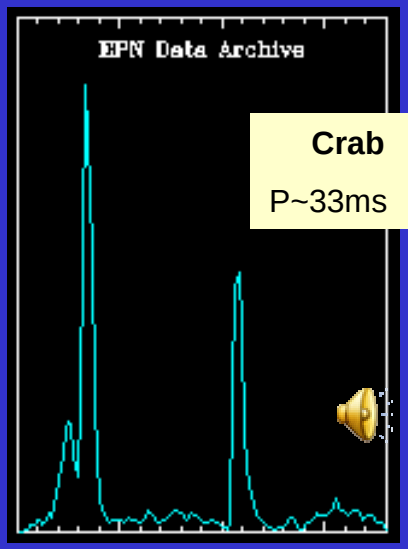
Momento di inertia: 10^{45} g cm^2;

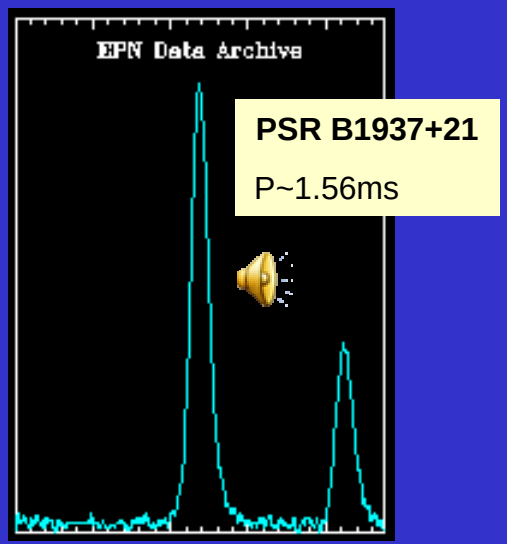
Densità: 10^{15} g/cm^3 at the center;

Campo magnetico: ~ 10^8G-10^{14}G

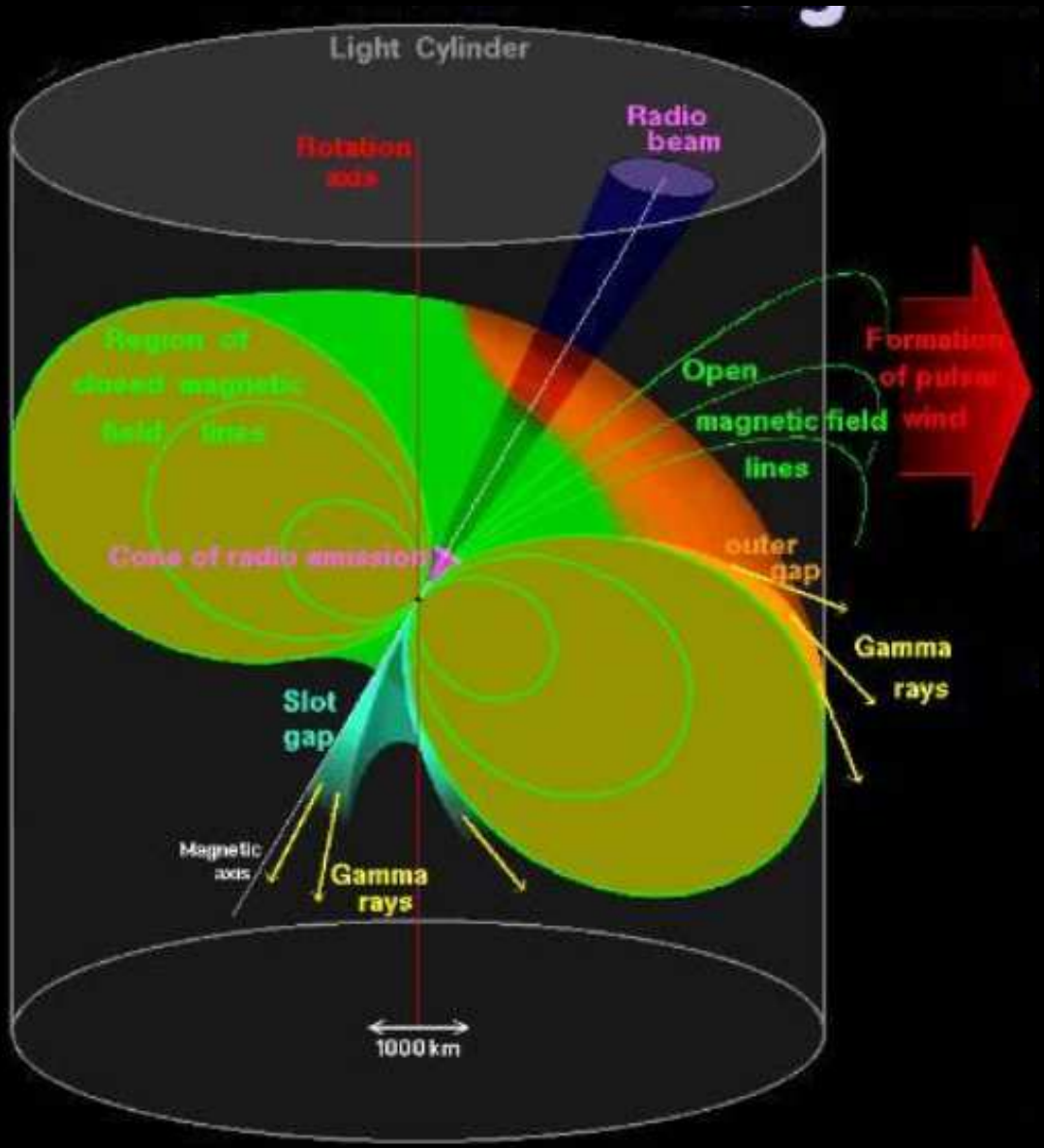
Il "suono" delle pulsar

Jodrell bank:
http://www.jb.man.ac.uk/~pulsar/Education/Sounds/sounds.html
Princeton group:
http://pulsar.princeton.edu/pulsar/multimedia.shtml



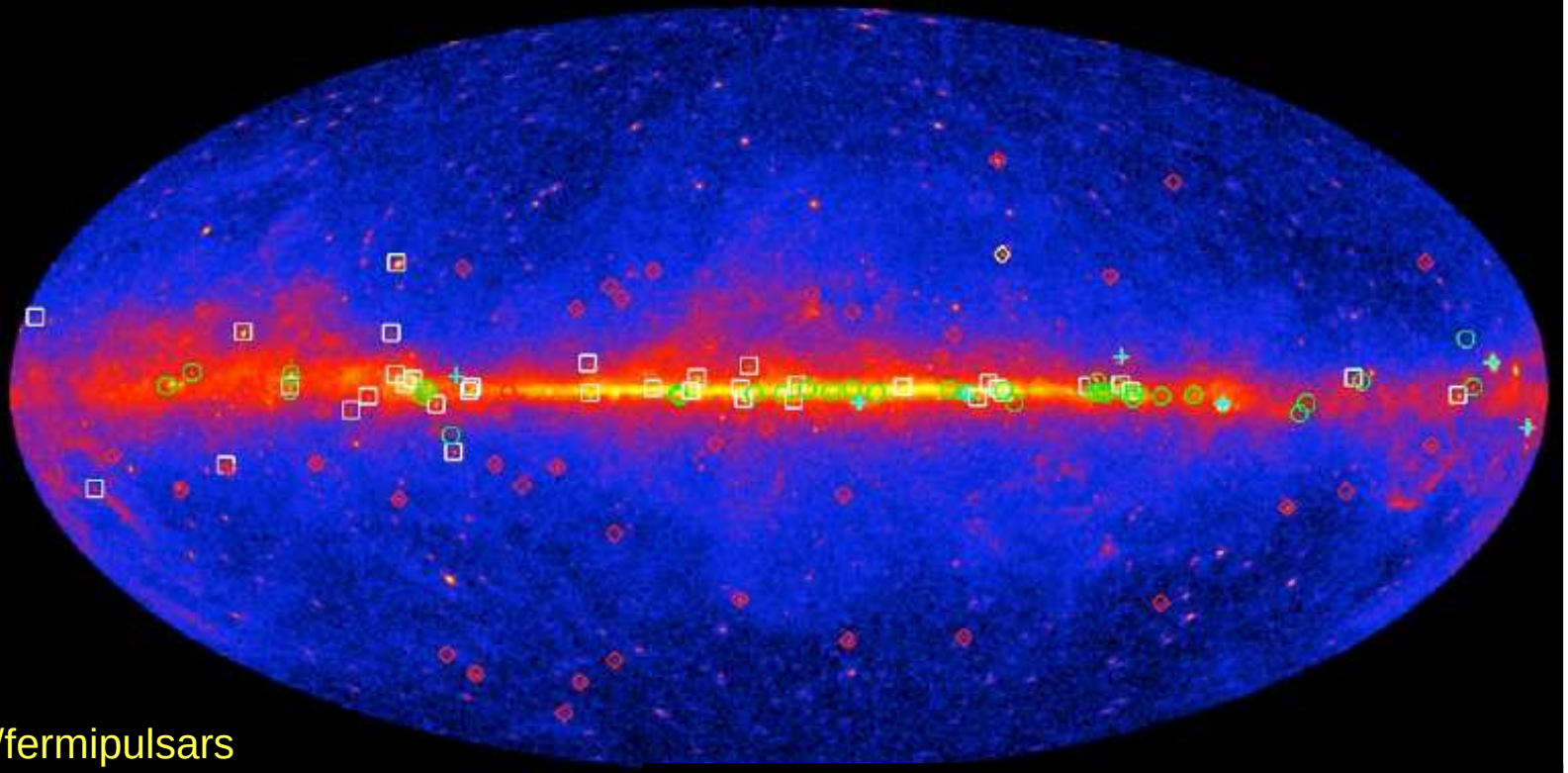


Pulsars


Light Cylinder
Radio beam
Rotation axis
Region of closed magnetic field lines
Open magnetic field lines
Formation of pulsar wind
Cone of radio emission
outer gap
Gamma rays
Slot gap
Magnetic axis
Gamma rays
1000 km

Pulsars

7 anni di pulsar



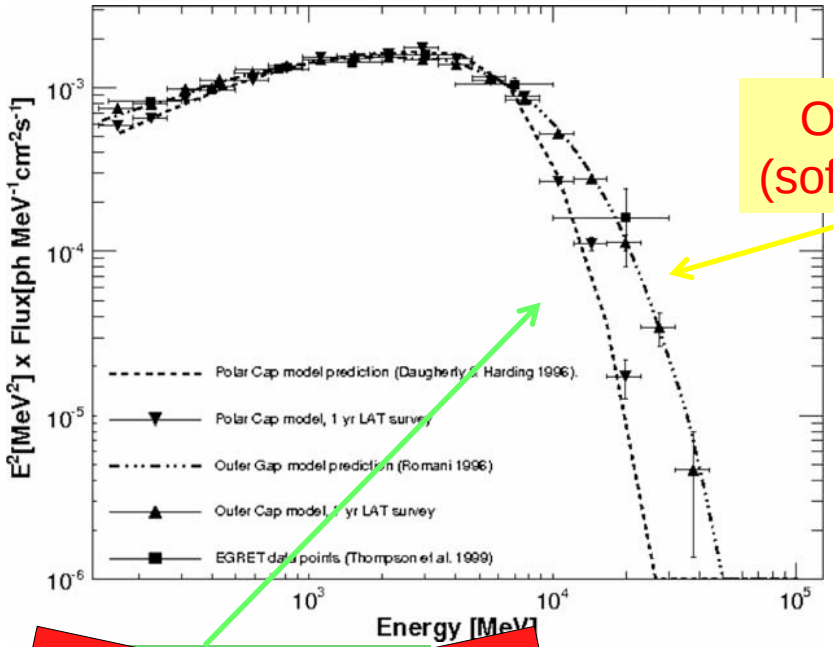
Public list
http://tinyurl.com/fermipulsars

42 young radio- and X-ray-selected (green circles, cyan crosses)
36 young γ-ray-selected (white squares)
46 radio-selected MSPs (red diamonds) + 1 γ-ray-selected MSP (yellow diamond)
(+20 to be published!)

Last Updated	29 September 2014
Young or middle-aged, radio/X selected	50
Young or middle-aged, gamma selected	41
Millisecond, radio selected	68
Millisecond, gamma selected	1
Total number of pulsars	**160**
Total publicly announced (link to list)	**147**
LAT Papers with Pub Board page (published)	135

2PC includes 117 pulsars: 41 young radio (38) or X (3) loud; 36 young radio quiet ; 40 MSPs (20 discovered in Unld sources).

Dati e modelli



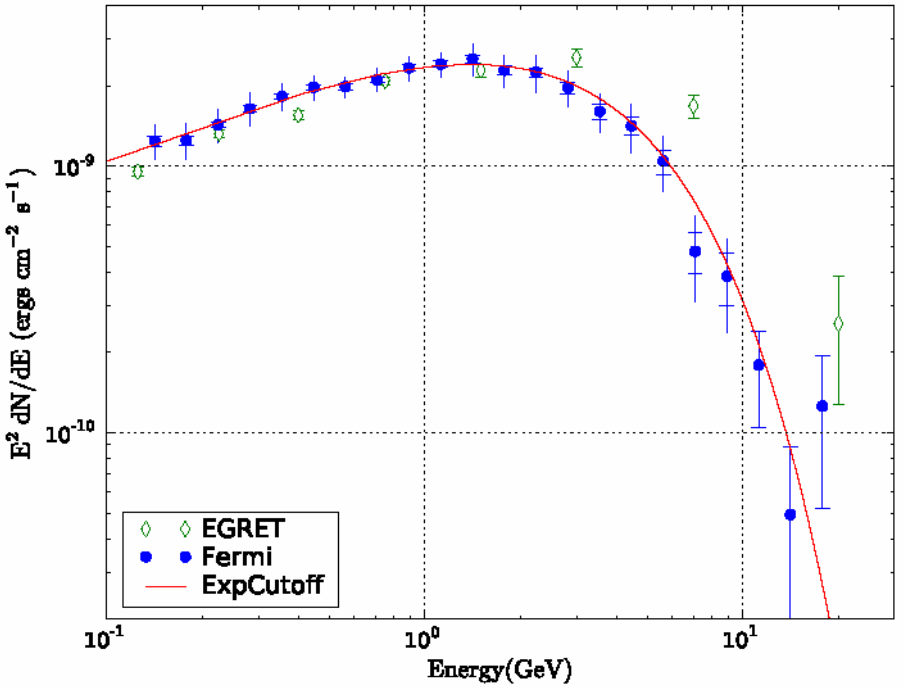
OG/SG
(soft cutoff)

Razzano+09

$$N(E) = N_0 E^{-\Gamma} e^{-(E/E_c)^b}$$

$$\Gamma = 1.51^{+0.04}_{-0.05}$$

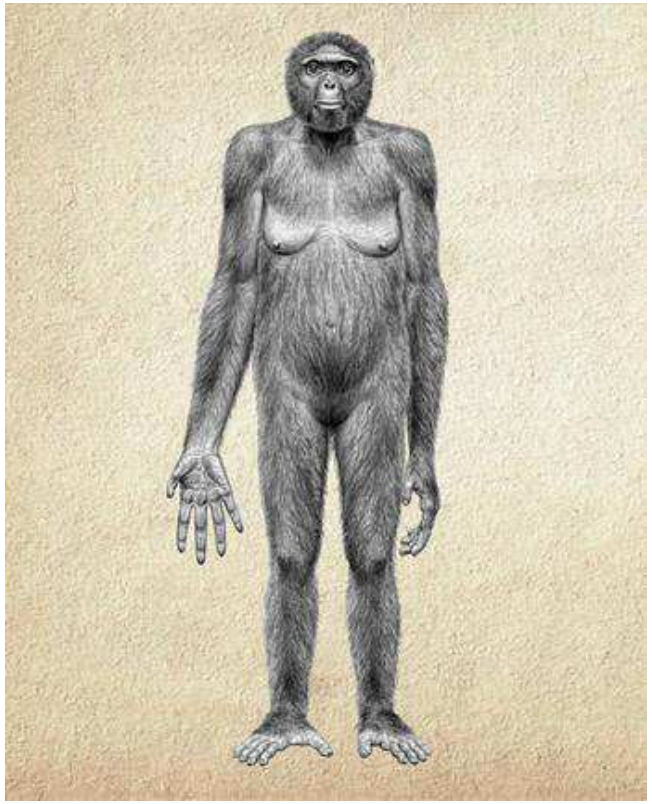
$$E_c = 2.9 \pm 0.1 \text{ GeV}$$



Abdo+08,09

«2nd most relevant discovery in 2009»
(Science)

Il vincitore…



(Arditpitecus)

Volete aiutarci?

About Einstein@Home

Einstein@Home is a World Year of Physics 2005 and an International Year of Astronomy 2009 project. It is supported by the American Physical Society (APS), the US National Science Foundation (NSF), the Max Planck Society (MPG), and a number of international organizations.

Einstein@Home uses your computer's idle time to search for weak astrophysical signals from spinning neutron stars (often called pulsars) using data from the LIGO gravitational-wave detectors, the Arecibo radio telescope, and the Fermi gamma-ray satellite. Einstein@Home volunteers have already discovered about fifty new neutron stars, and we hope to find many more.

Our long-term goal is to make the first direct detections of gravitational-wave emission from spinning neutron stars. Gravitational waves were predicted by Albert Einstein almost a century ago, but have never been directly detected. Such observations would open up a new window on the universe, and usher in a new era in astronomy.

The year 2015 is an exciting one. Five years after the first-generation LIGO detectors were shut down, the upgraded advanced LIGO instruments came

Utente del giorno

Trevor [Freaky]
Just doing my part to make the world a better place. I really like this construct of sharing computer power to help with all sciences.

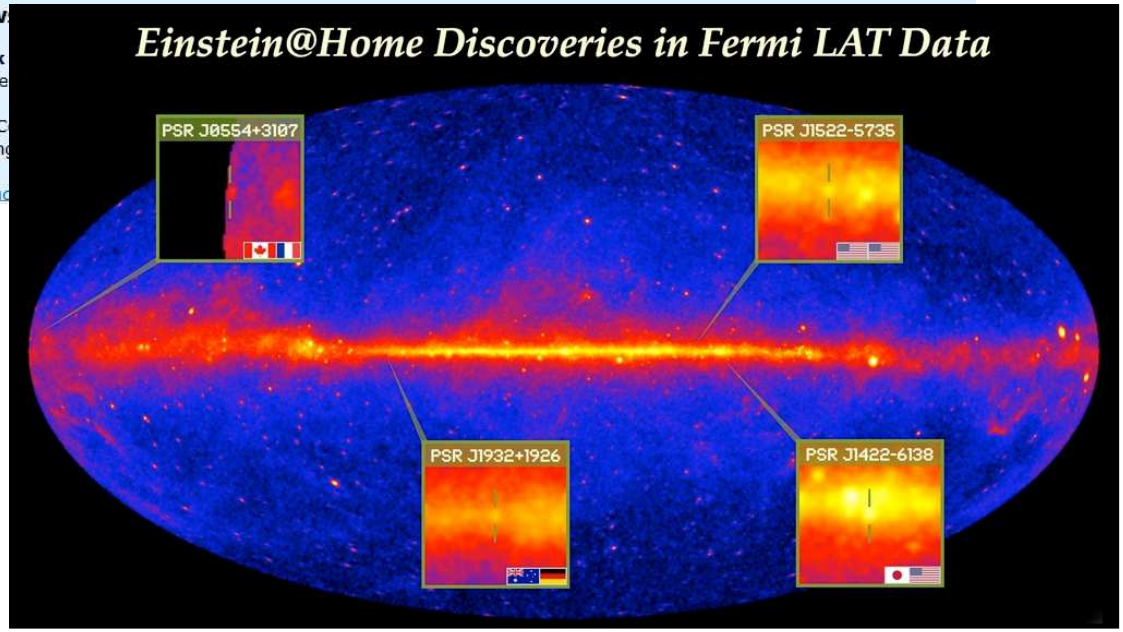
I...

New

Work
Einste

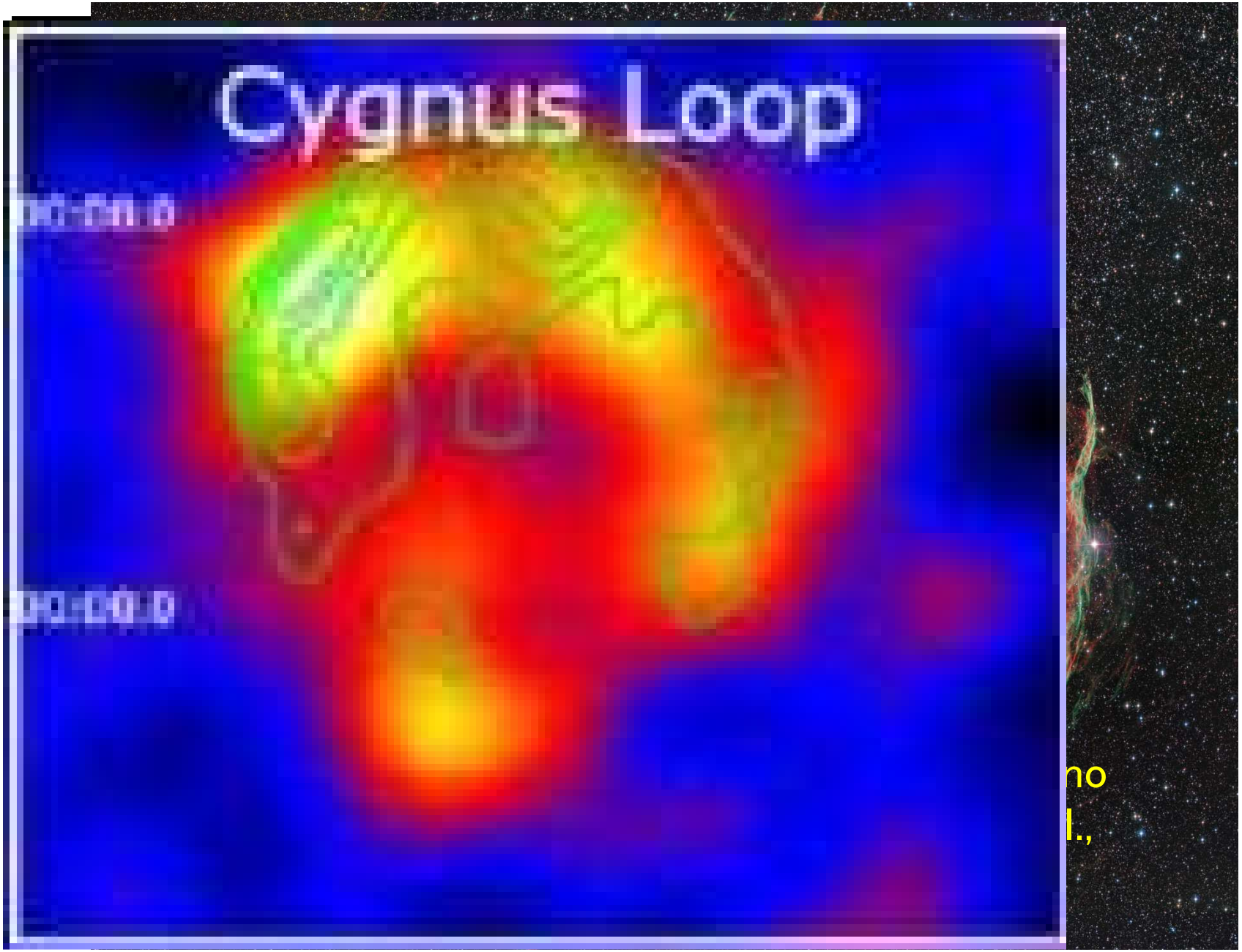
The C
lookin

Job ac

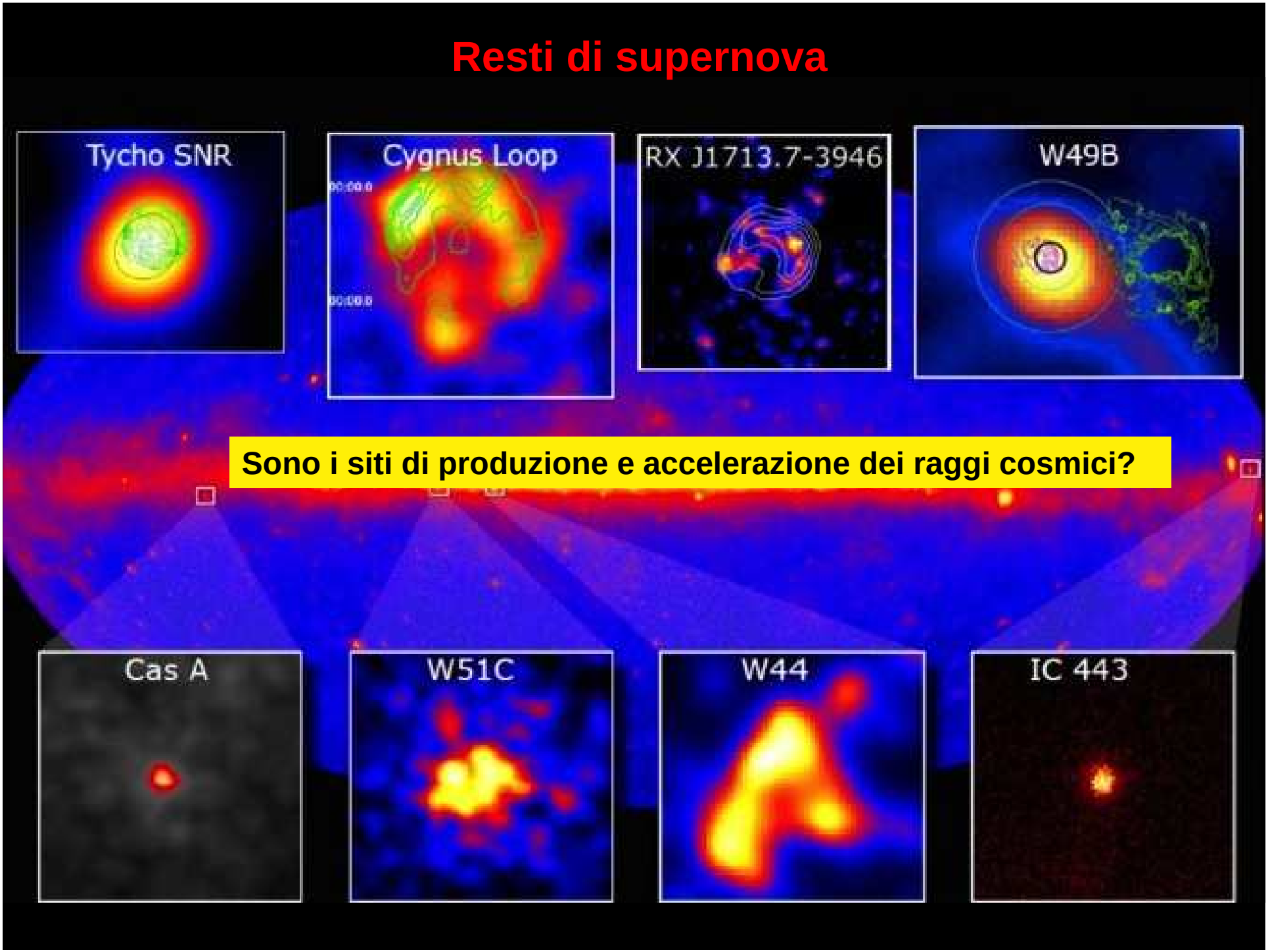


Resti di supernova

Resti di supernova

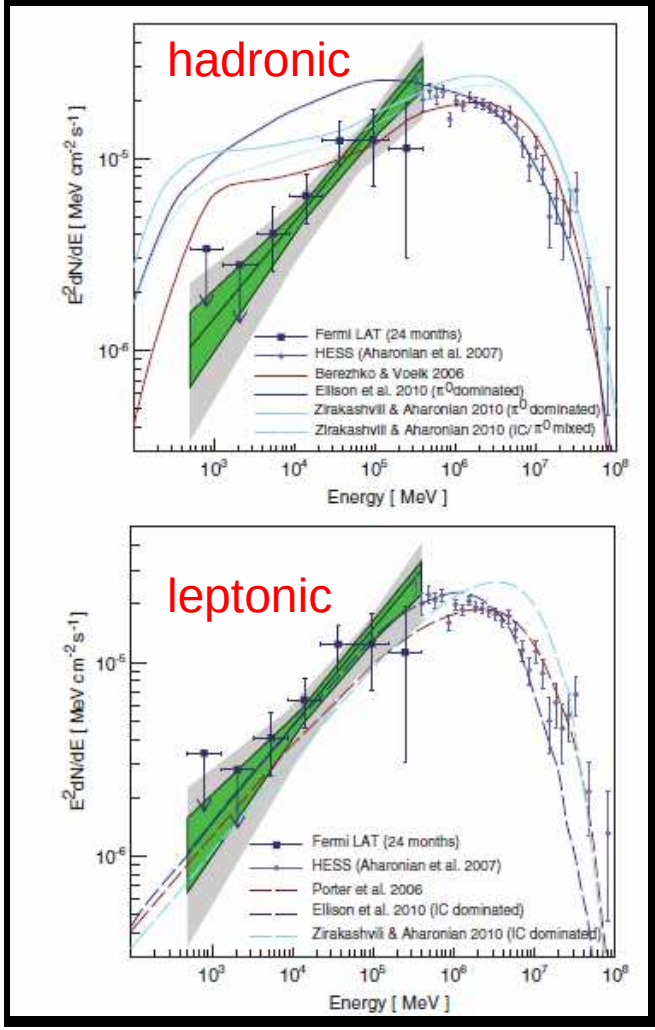


Resti di supernova



Modelli di resti di supernova

Come si sceglie il modello giusto?



RX 1713.7-3946

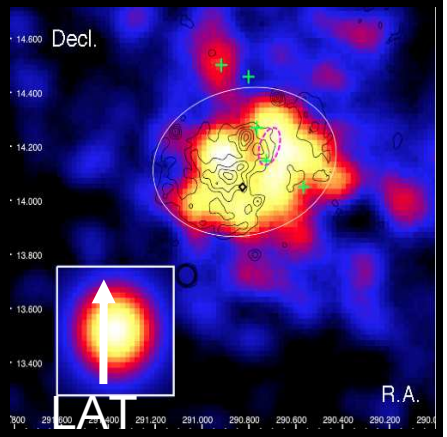
Leptonic model favored

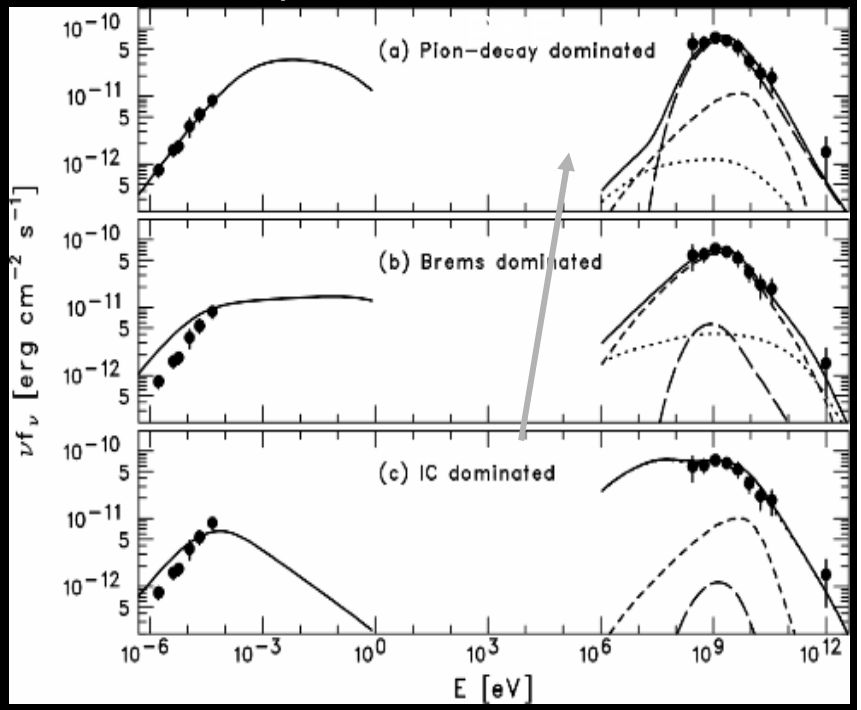
(Abdo et al.ApJ 734,28,2011)

W51C

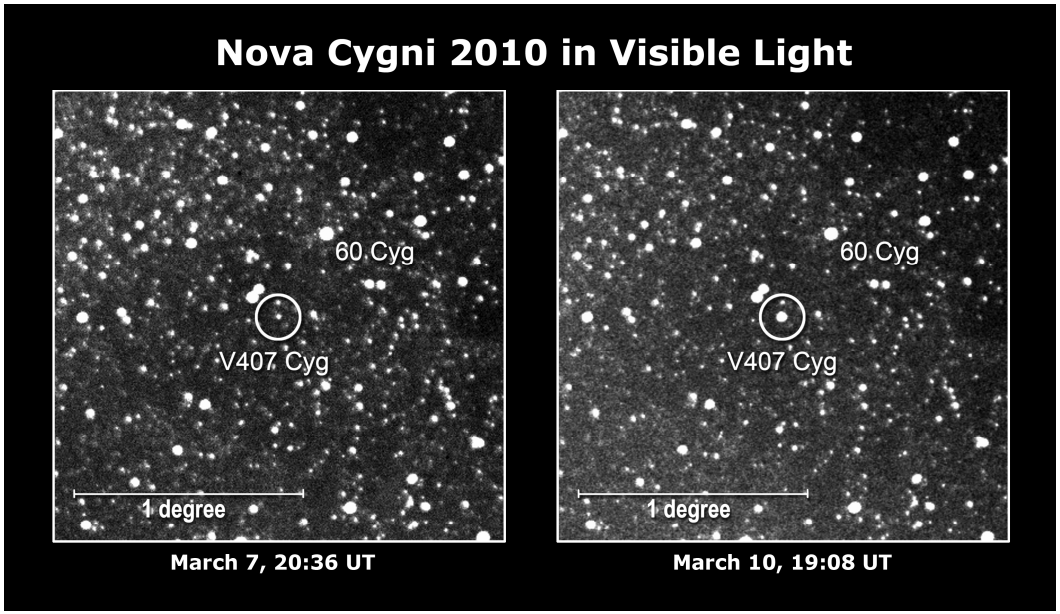
Hadronic model favored

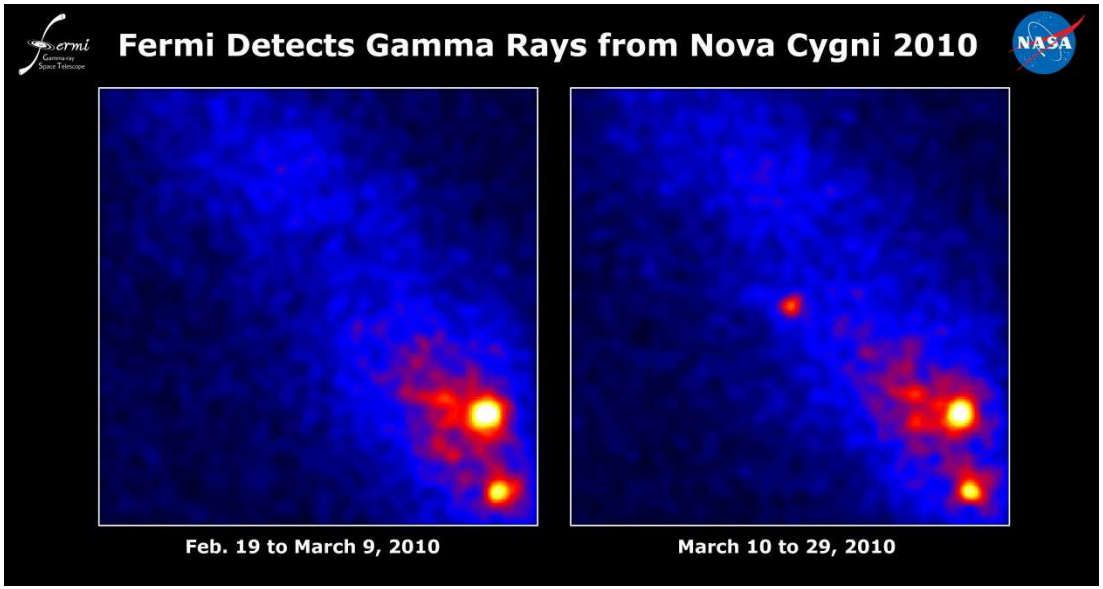
(Abdo et al.2009, 706,1)





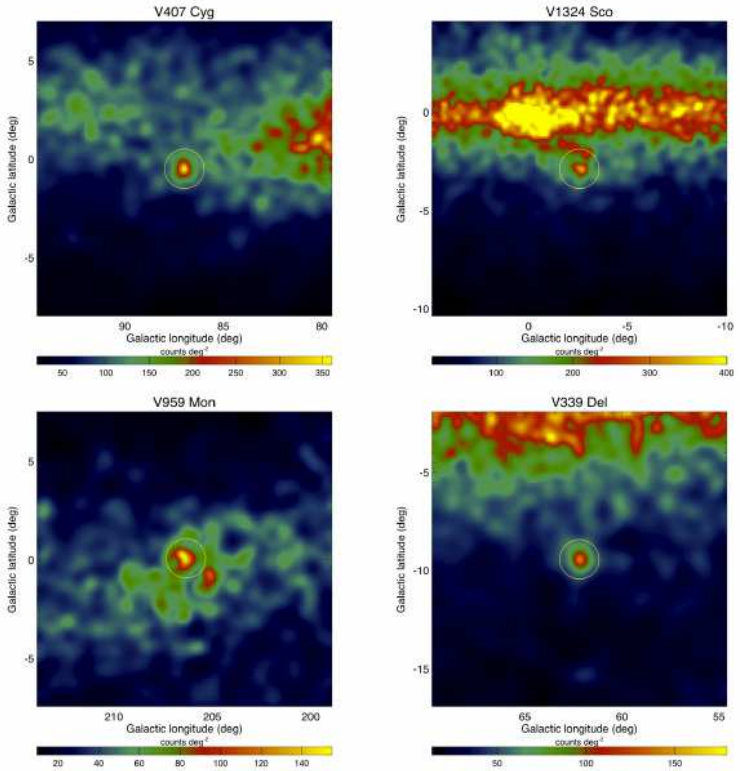
Novae a raggi gamma





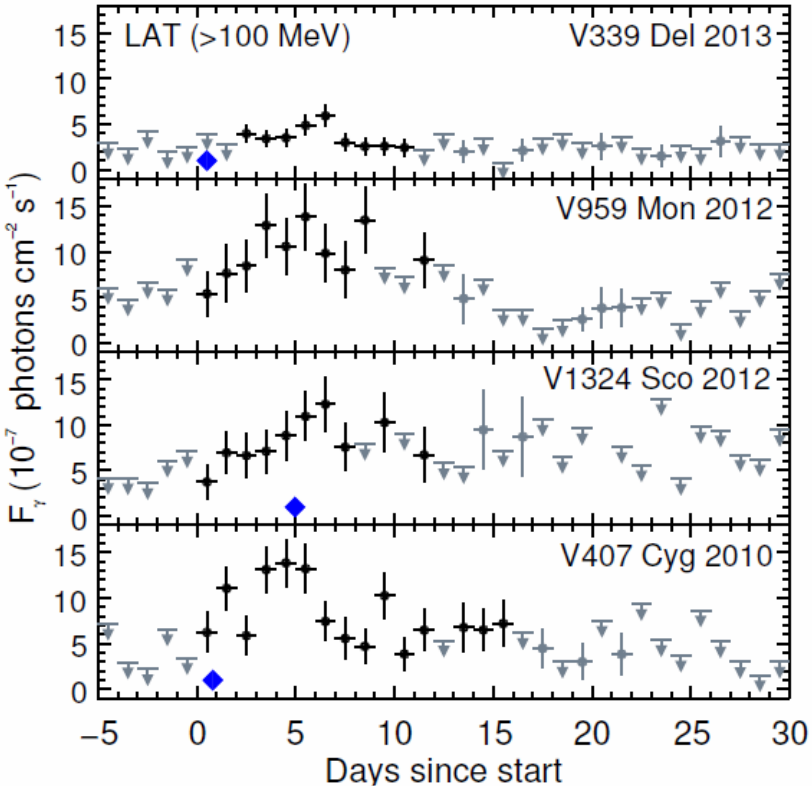
Novae a raggi gamma

Fermi e le novae

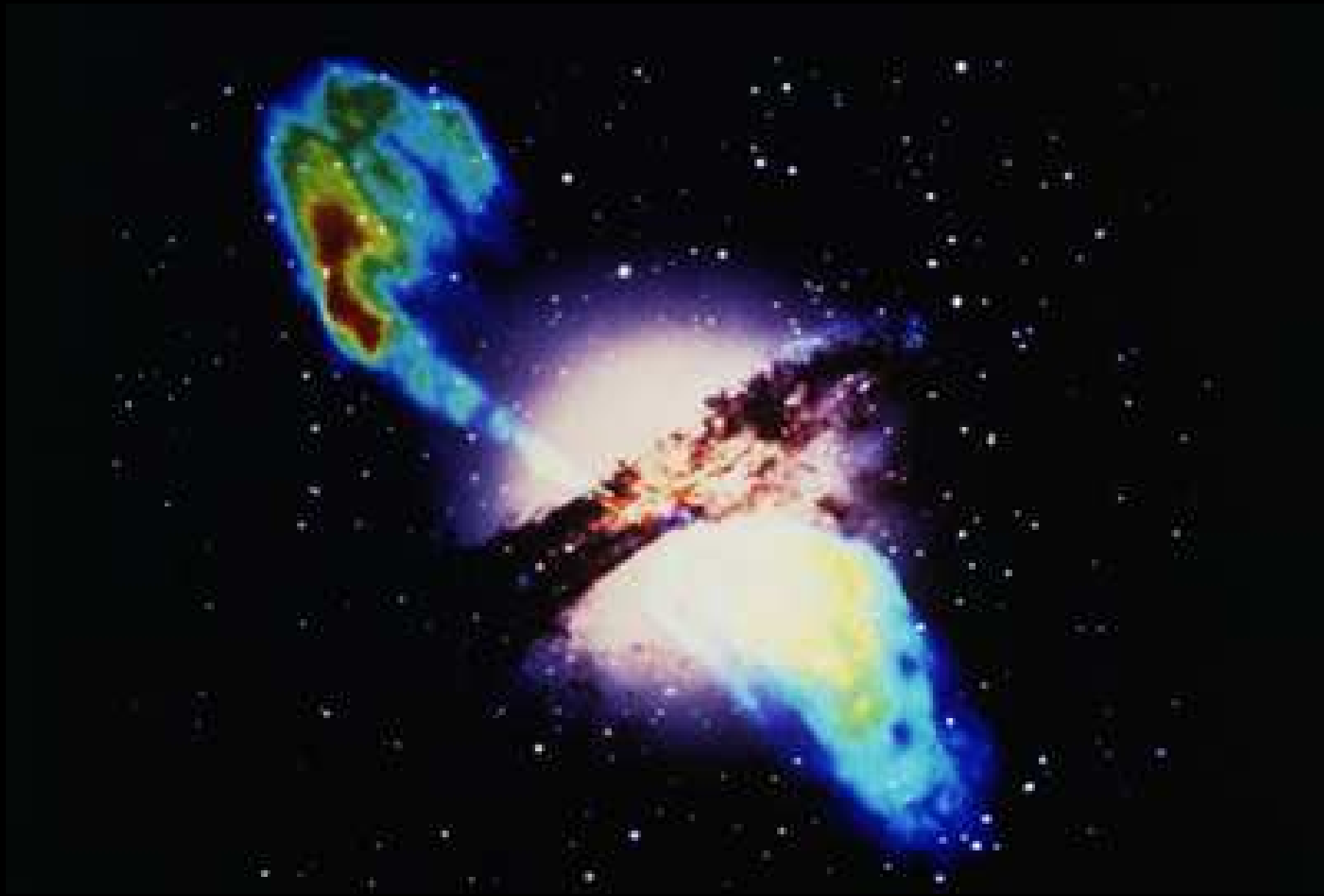


Ackermann+14, Science

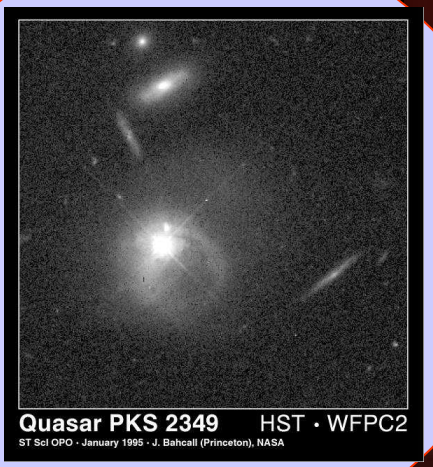
- Nuova classe di sorgenti
- Accelerazione particelle
  - Urti interni
  - Urti con altre stelle?
- Leptonico o adronico

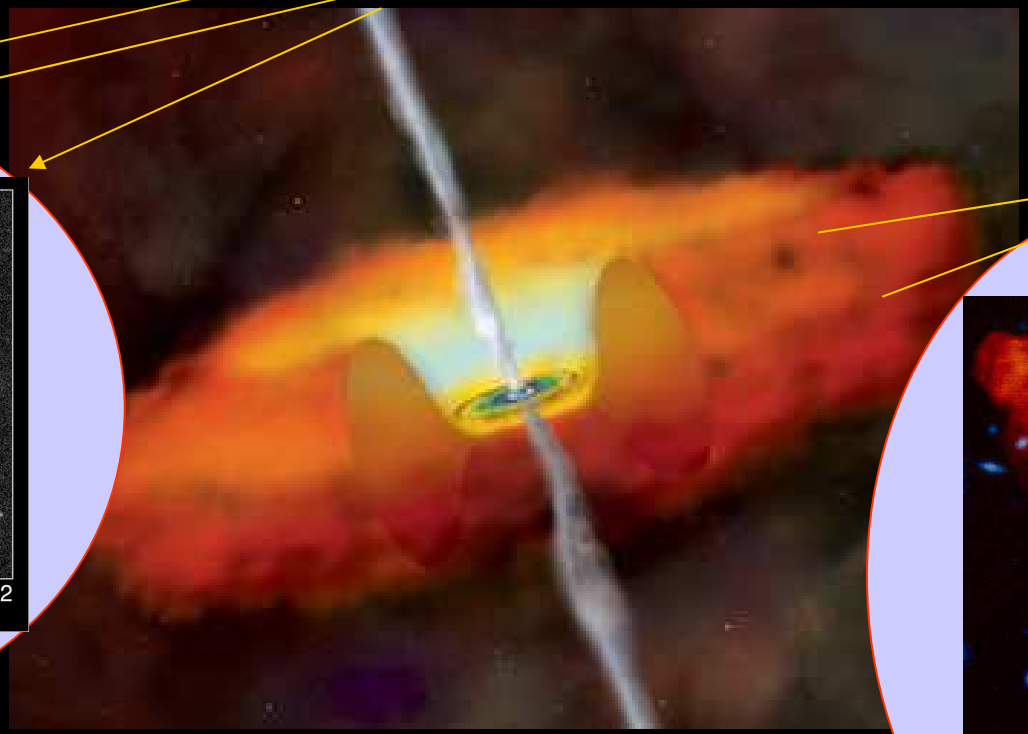


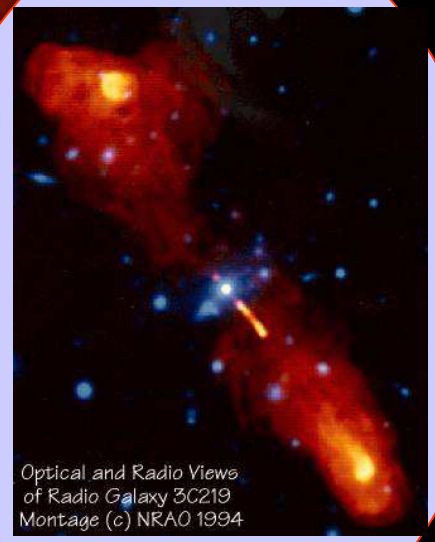
Verso altre galassie



Questione di prospettiva

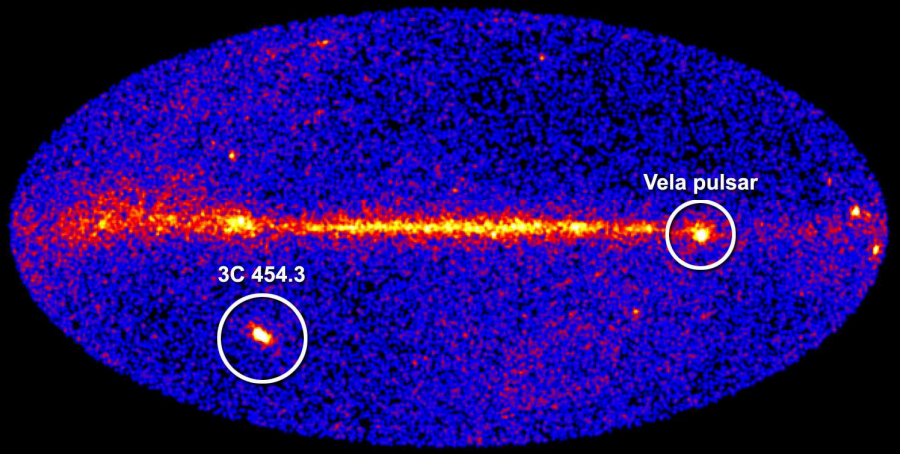




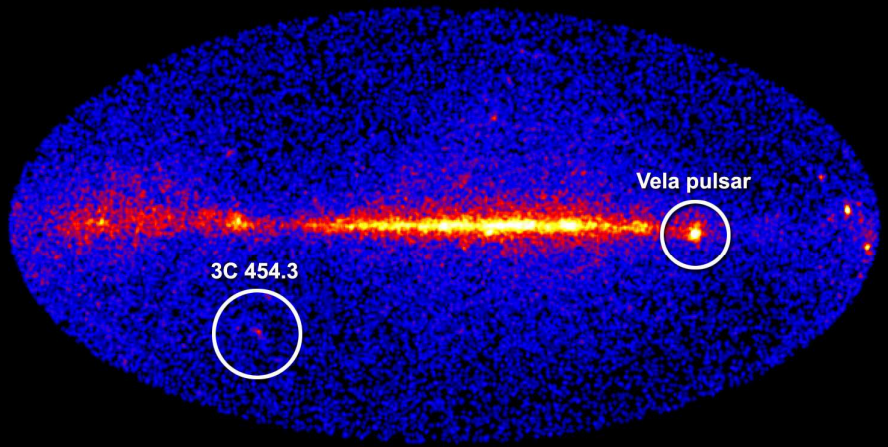


Fermi e i Nuclei Galattici Attivi

Blazar 3C 454.3's Record Flare



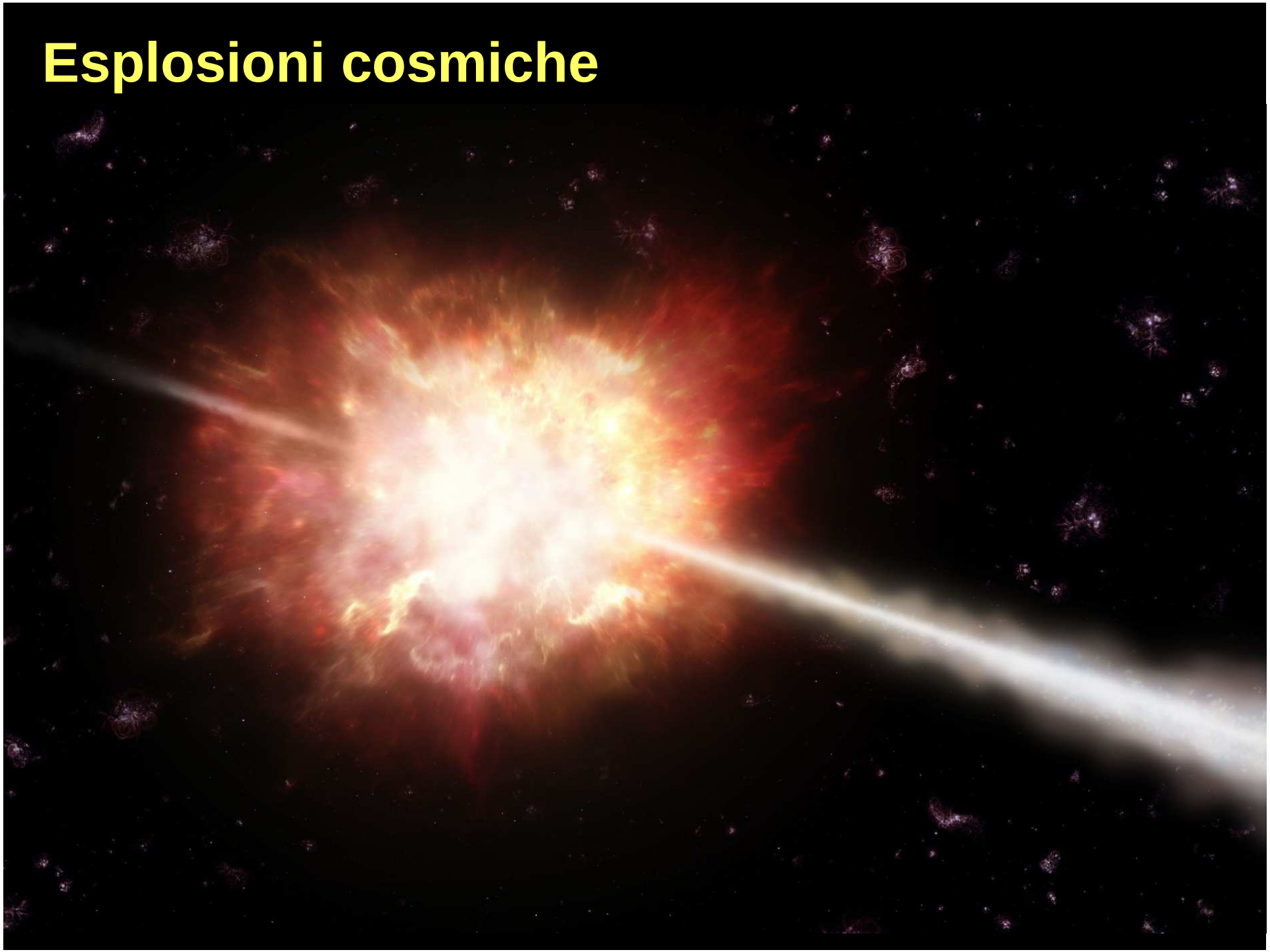
December 2, 2009



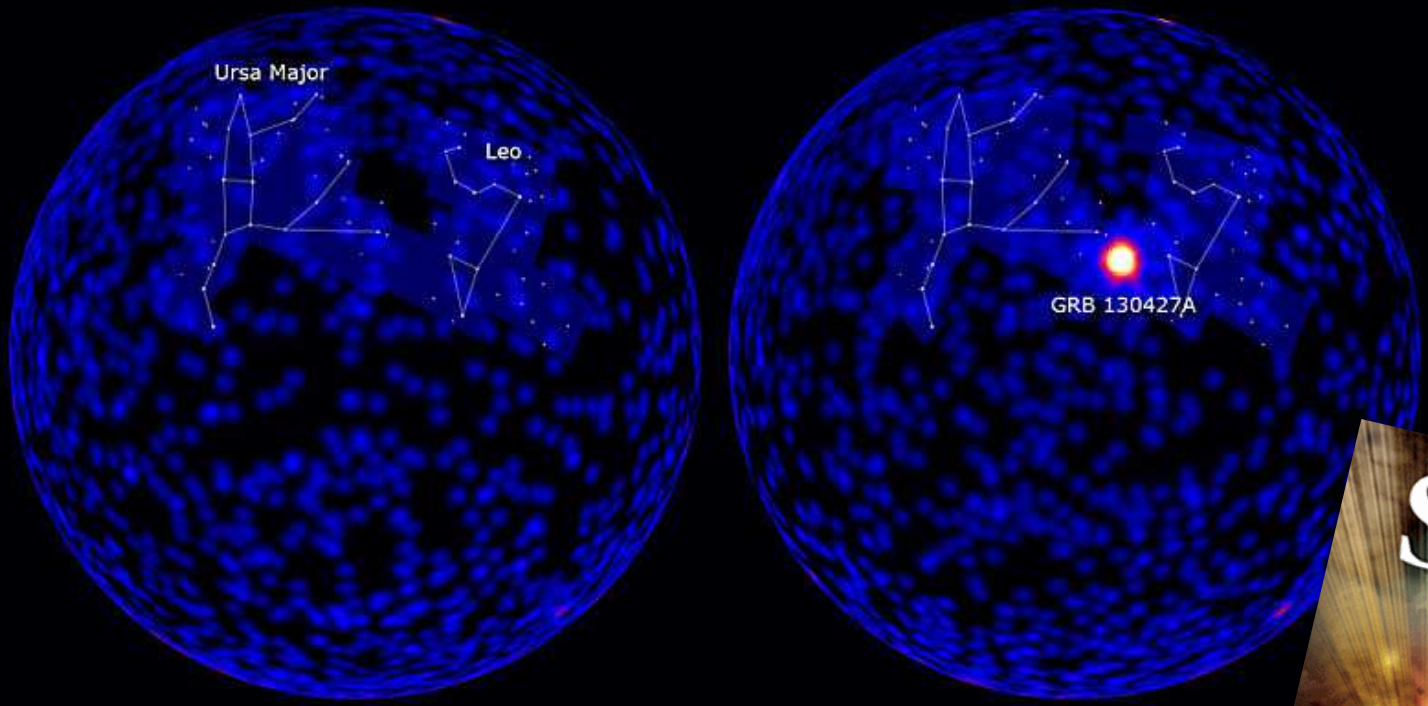
November 3, 2009

Fermi
Gamma-ray
Space Telescope

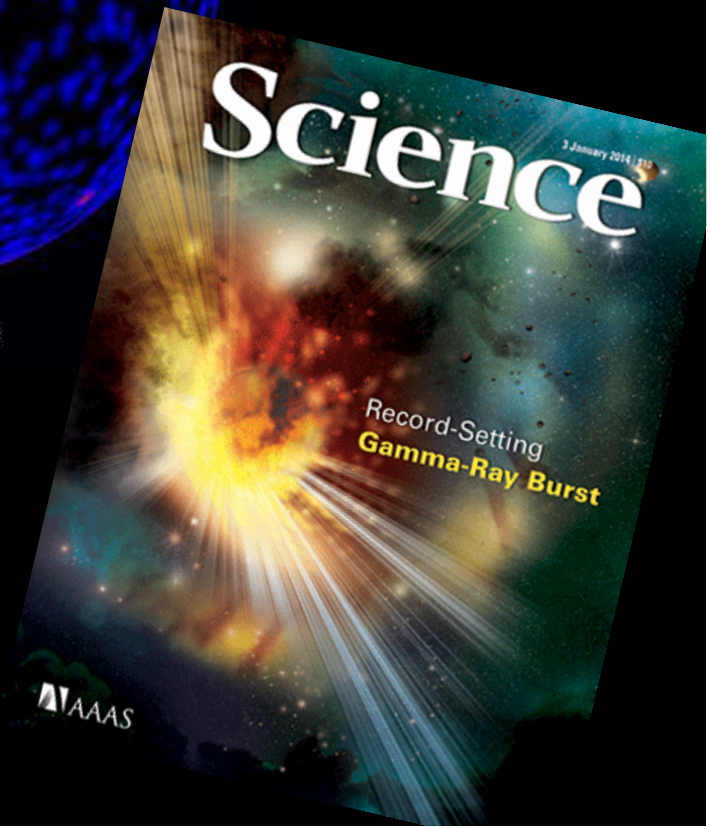
Esplosioni cosmiche



27 aprile 2013



Before and after Fermi LAT views of GRB 130427A, centered on the north galactic pole

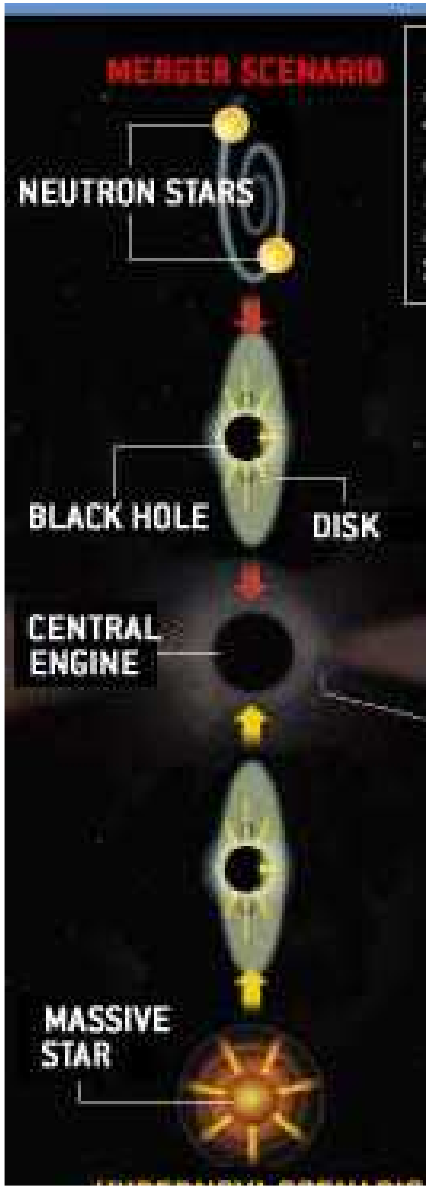


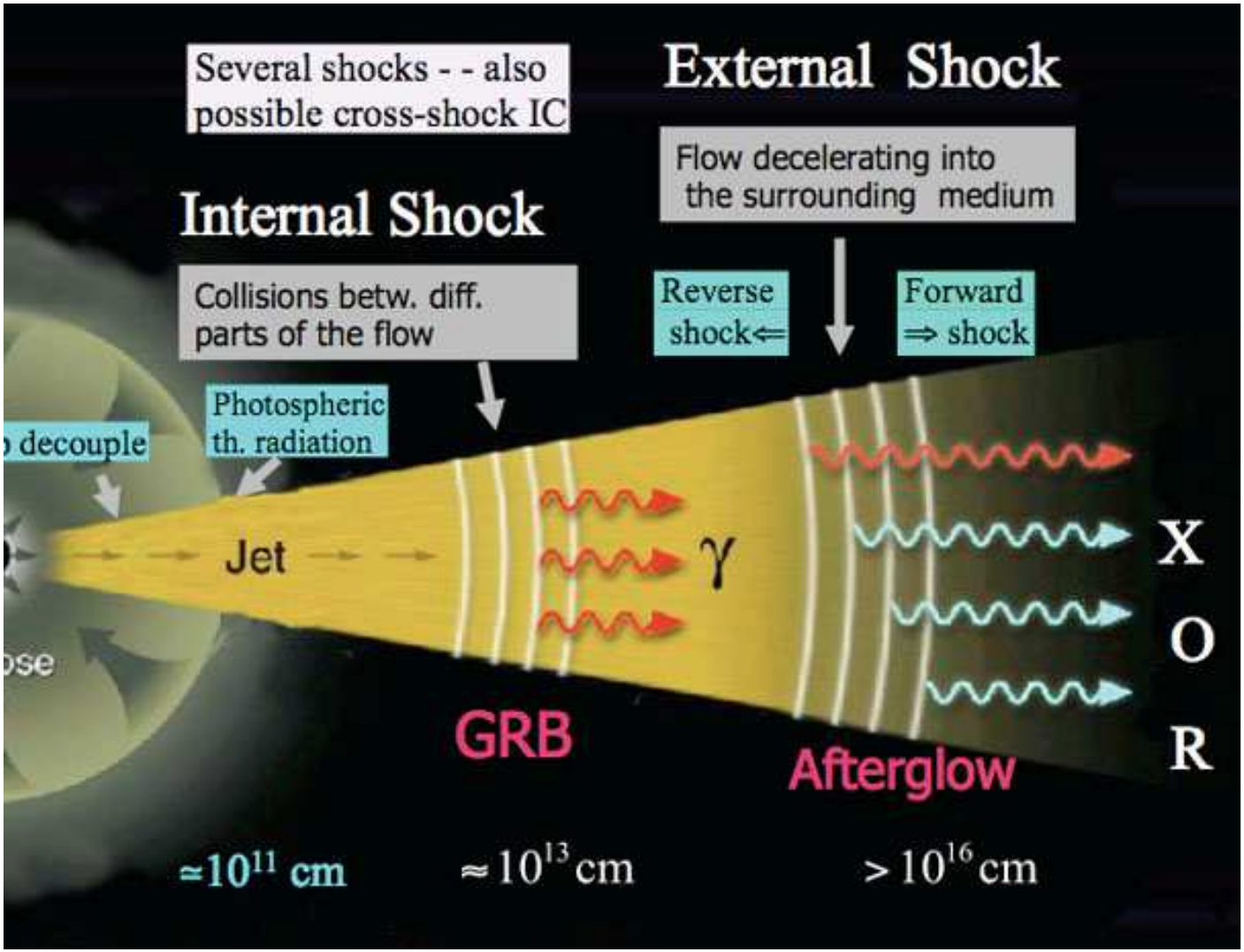
3.6 miliardi di anni luce

+

94 GeV

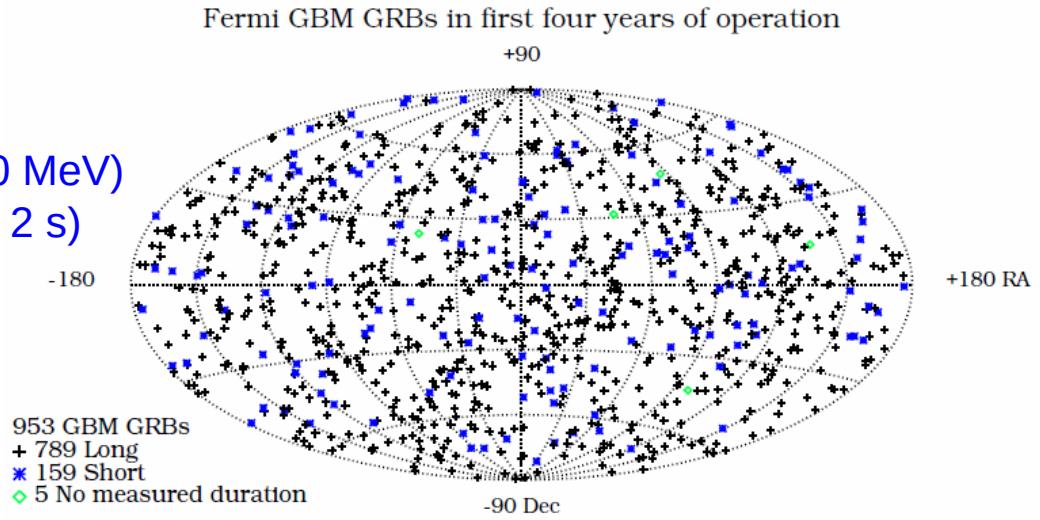
Palle di fuoco?





Esplosioni cosmiche

- First LAT GRB Catalog (Ackermann+13, ApJS)
  - 35 GRBs detected by LAT (28 >100 MeV)
  - 5 of them are short GRBs ($T_{90,GBM} < 2$ s)
- 2° GBM Catalog (Von Kienlin+14)
  - 963 GRBs



Alcuni risultati

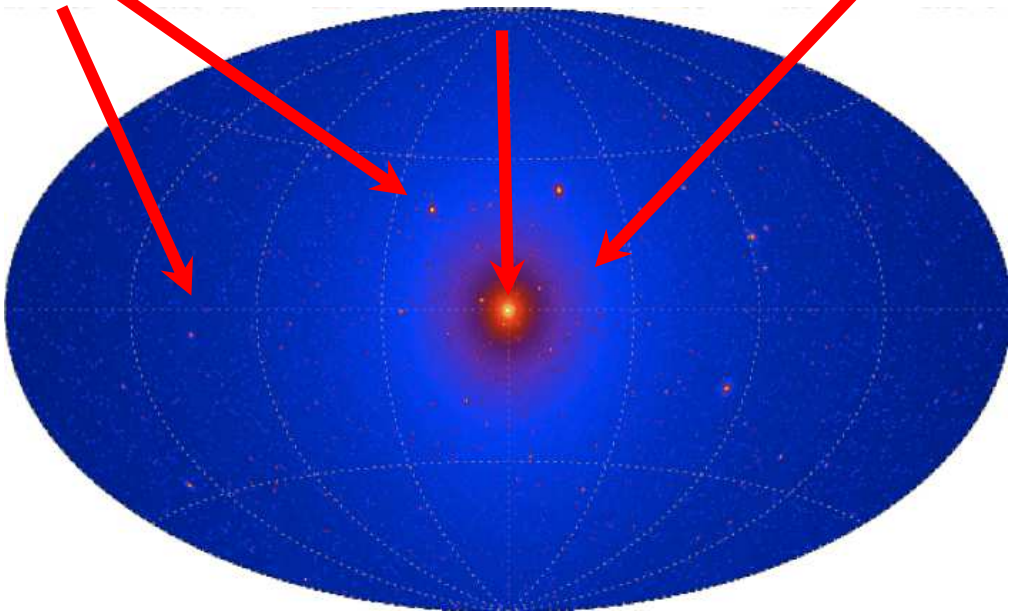
- Spettri e curve di luce:
  - Fotoni di altissima energia
  - Gravità Quantistica
  - Emissioni prolungate

Non solo gamma: Materia Oscura dal cielo

Satelliti della Via Lattea

Centro Galattico

Alone della Via Lattea



Il Sole

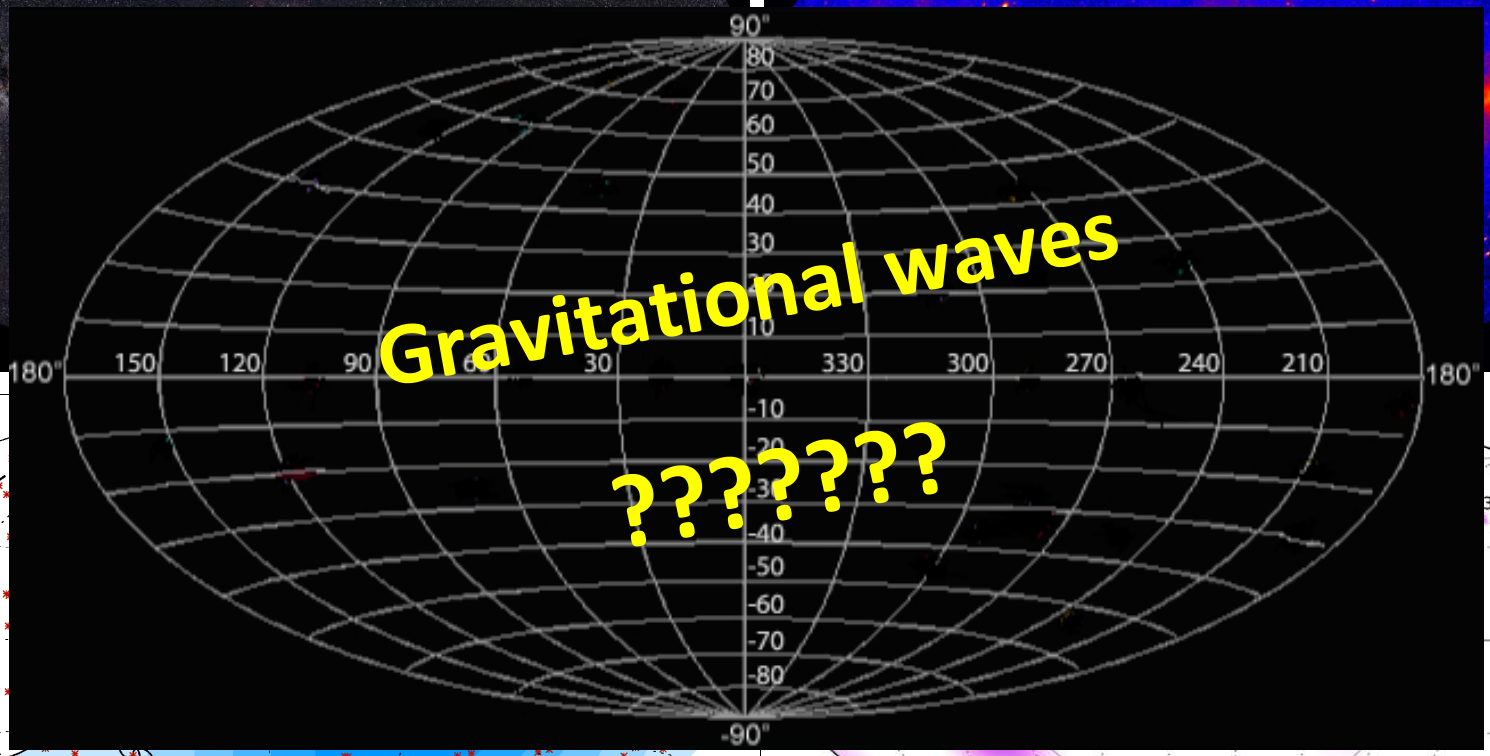
Righe spettrali

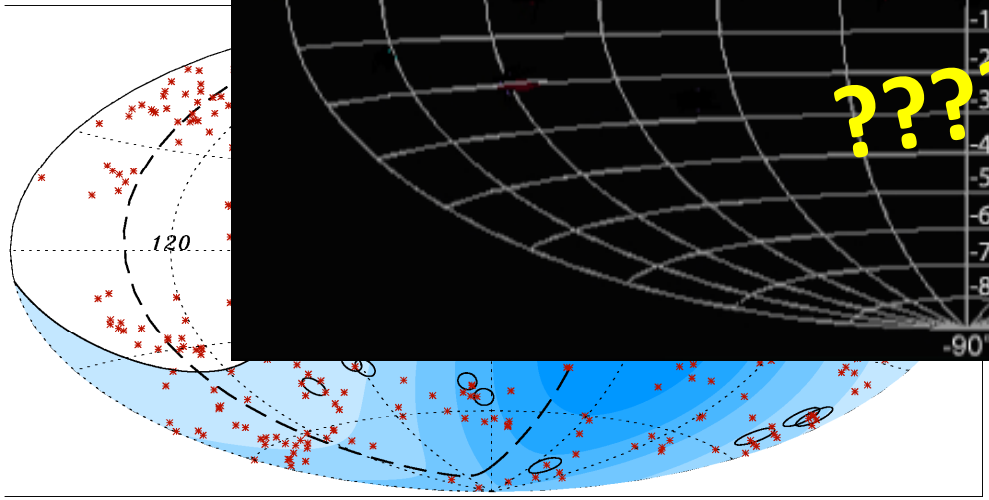
Ammassi di galassie

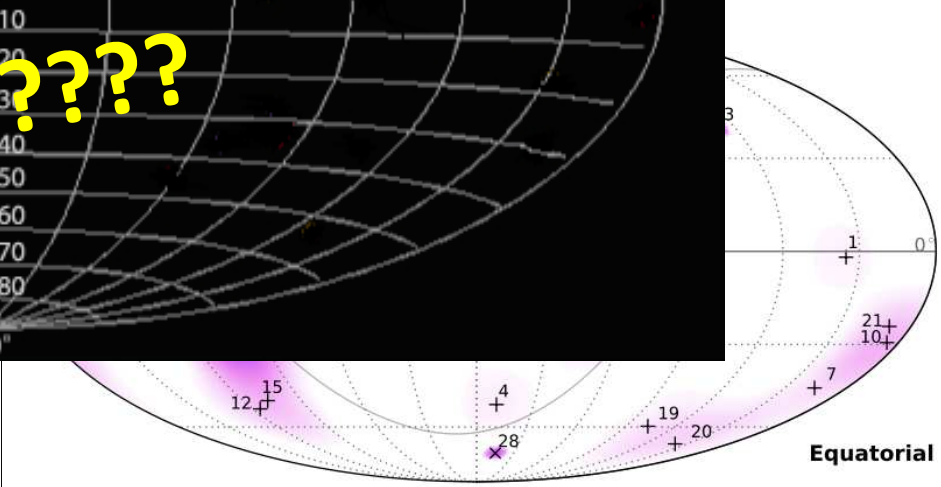
Non solo gamma : messaggeri cosmici

Optical (APOD)

Gamma rays > 0.1 GeV (Fermi-LAT, 2013)







Cosmic rays > 57 Eev (Auger, 2007)

Neutrinos > 30 Tev (Icecube, 2013)

*

M. Razzano

The Science of Fermi (su You Tube)

Fermi in classe

- **Fermi è un ottimo esempio dell'astrofisica "non convenzionale" dallo spazio**
- **Moltissimo materiale educativo, anche in italiano**

- **Video e immagini su sito NASA**
  - ***fermi.gsfc.nasa.gov***

- **Materiale educativo**
  - ***fermi.sonoma.edu***
  - ***glast****.pi.infn.it/****divulgazione****.htm***

- **Progetto Einstein @home**
  - ***https://einstein.phys.uwm.edu***

- **Dati di Fermi pubblici: spunti per tesine**

Grazie per l’attenzione !

Email: massimiliano.razzano@unipi.it