Astrofisica Nucleare e Subnucleare

Introduzione

Astrofisica Nucleare e Subnucleare

(Fisica Astroparticellare/Astrofisica Particellare)

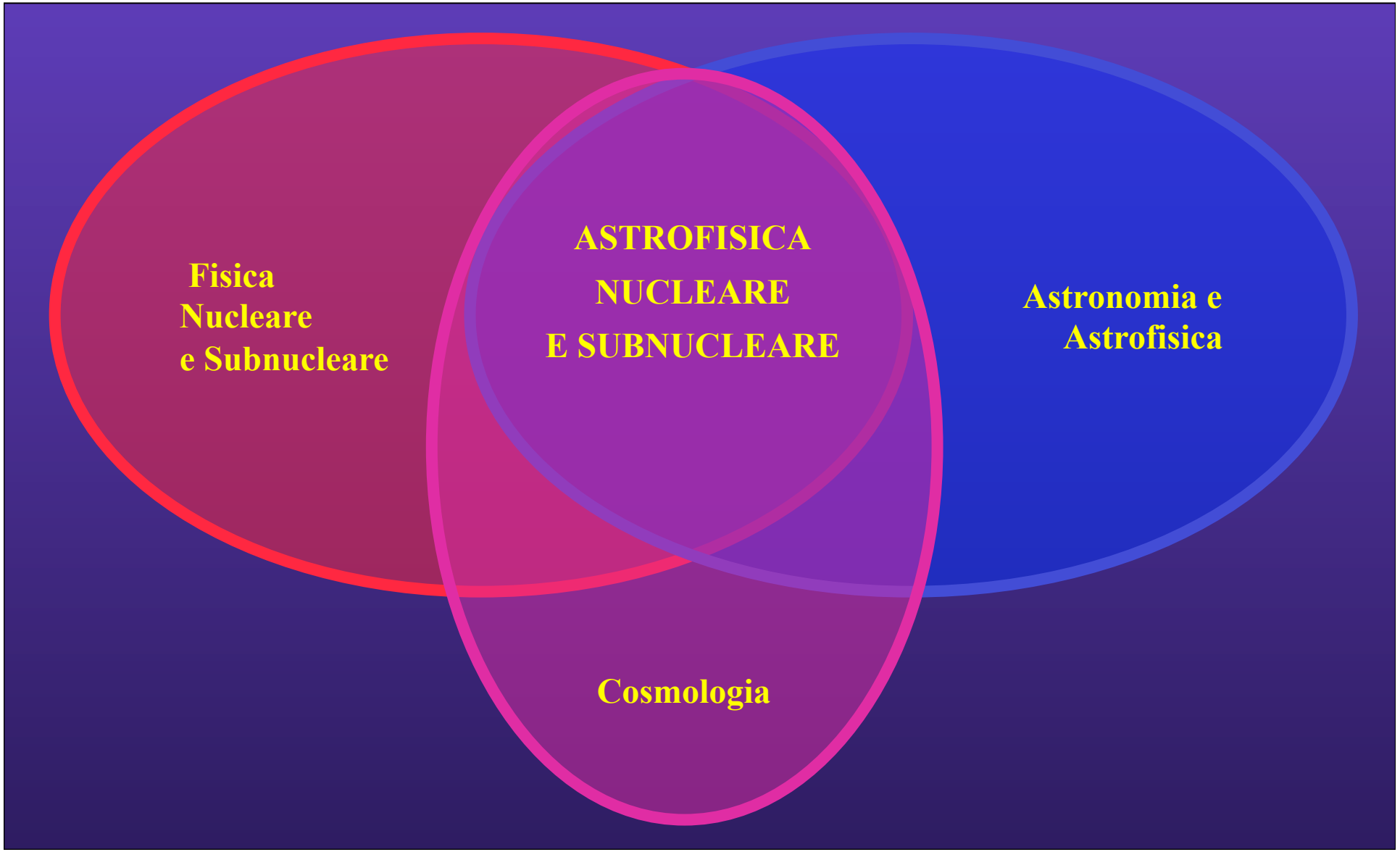
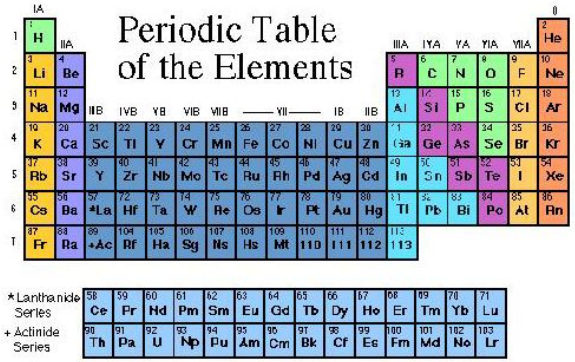
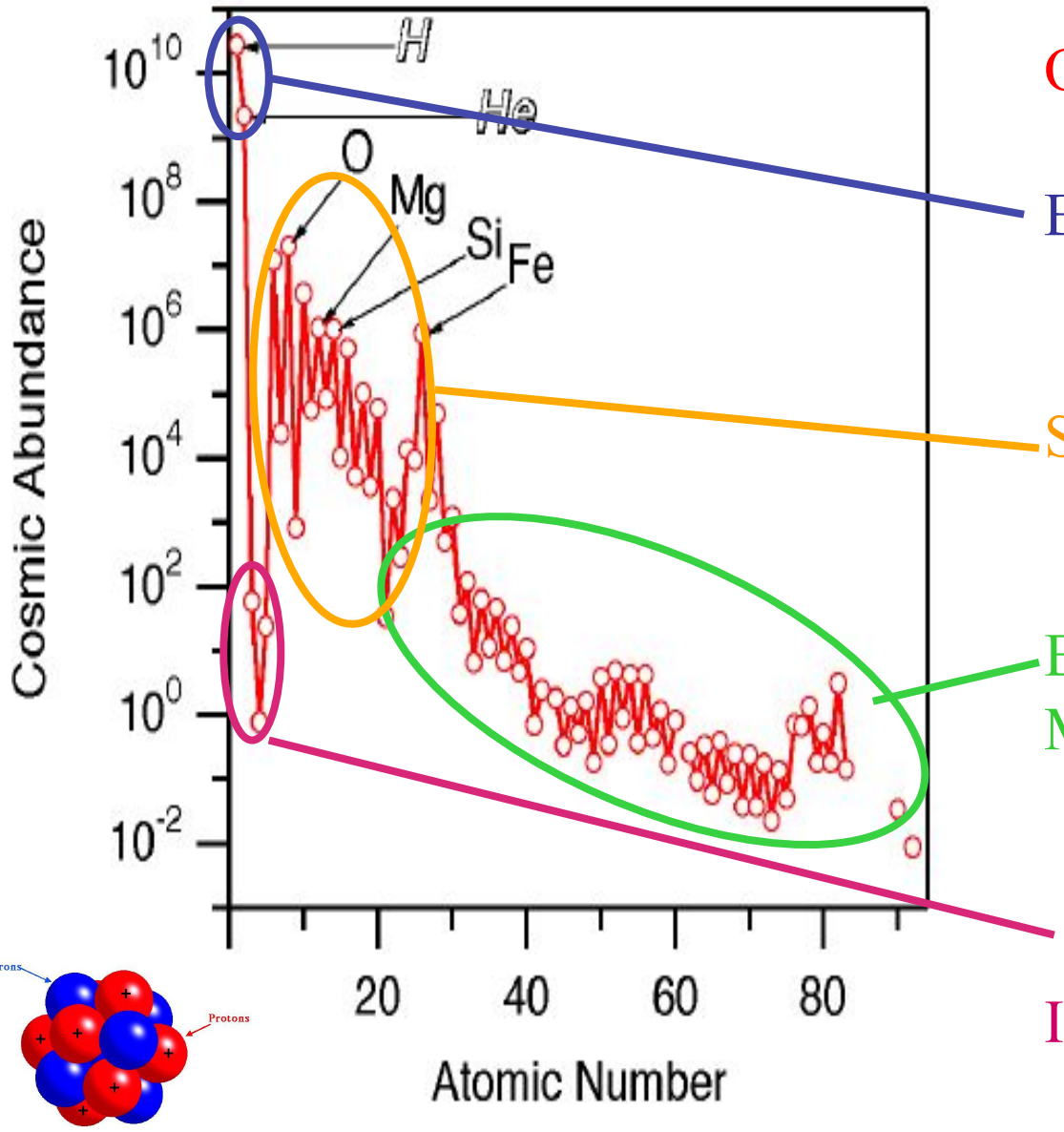


Tavola periodica degli elementi ==========>



Origine:



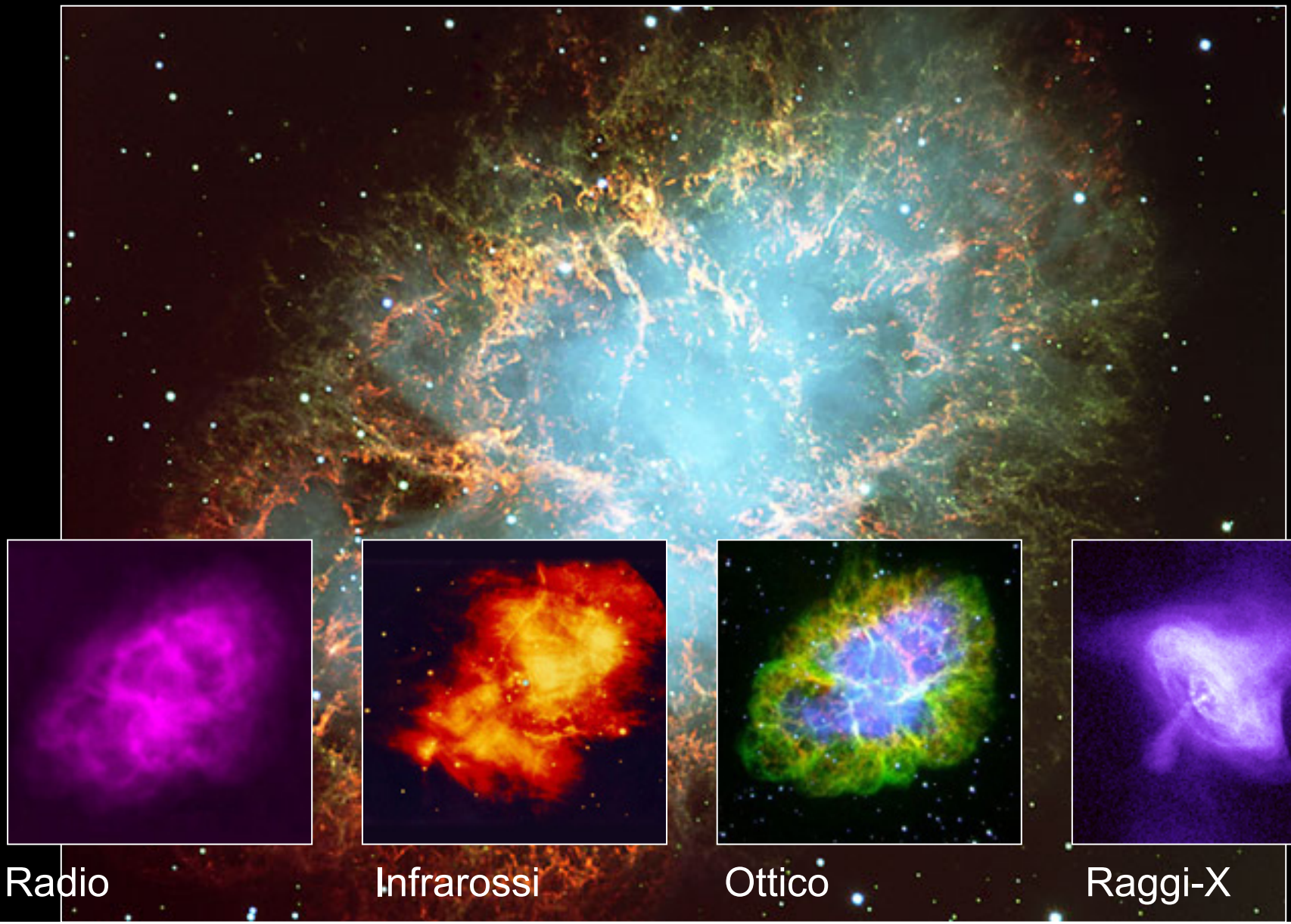
Big Bang Nucleosintesi

Stelle massive

Esplosioni di Supernova /
Merging di Stelle di Neutroni

Interazioni con raggi cosmici

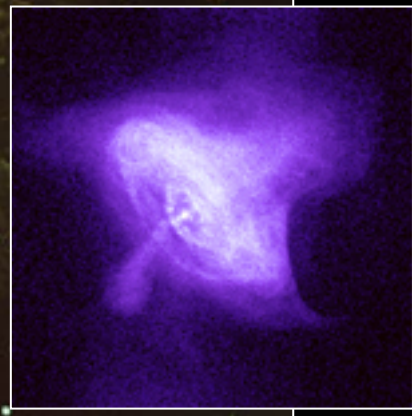
La nebulosa del Granchio (Crab Nebula)
Supernova osservata dalla Cina nel 1054



Radio

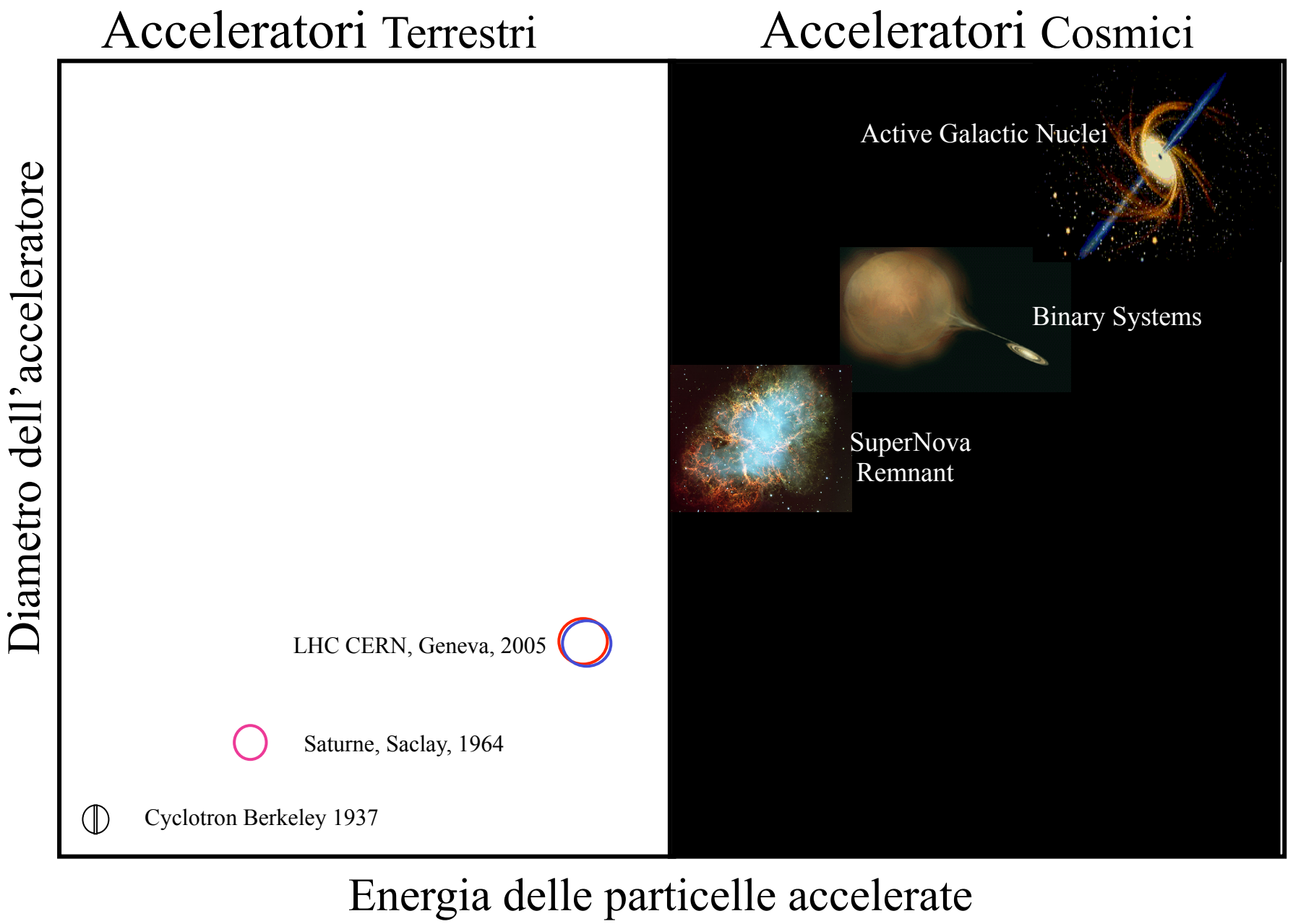
Infrarossi

Ottico

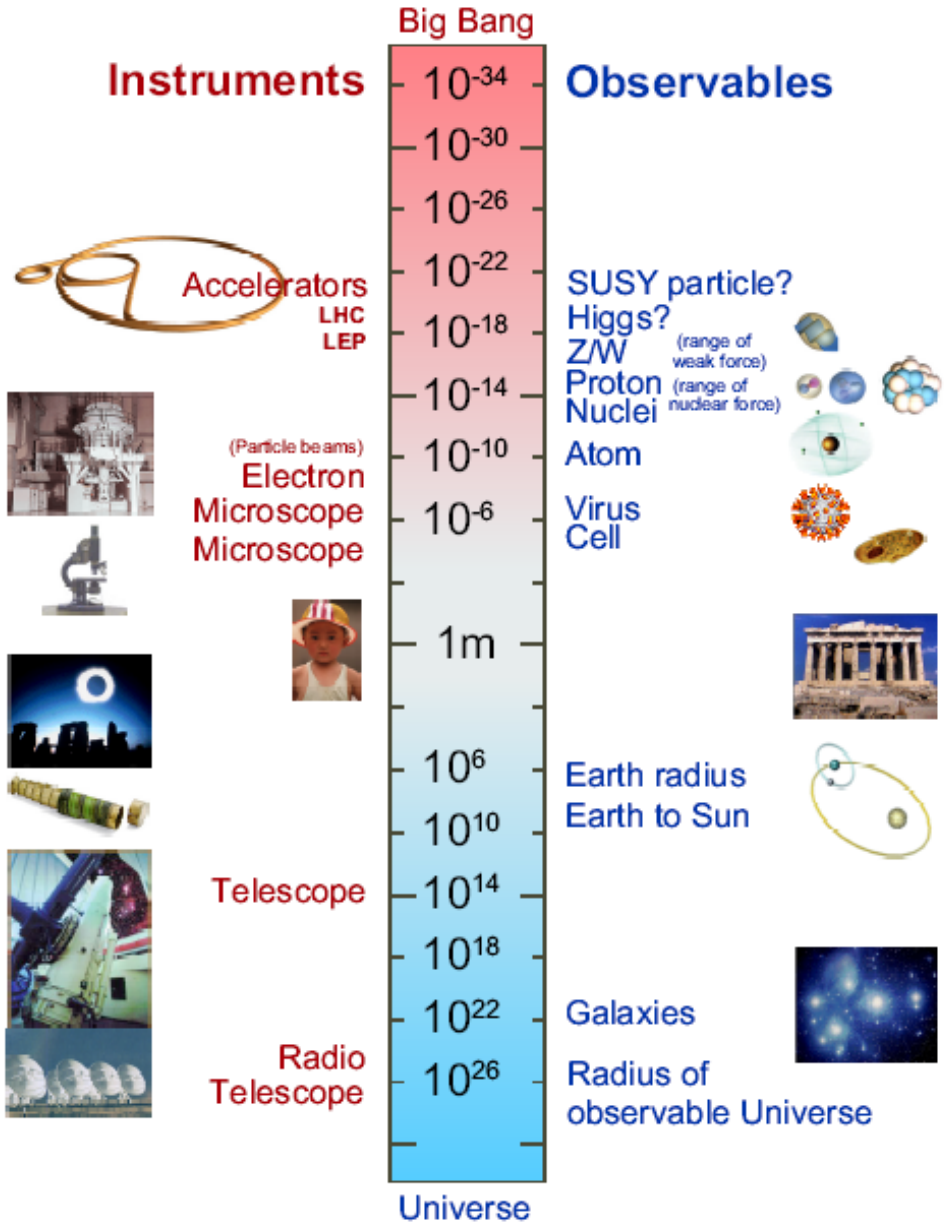


Raggi-X

Fisica Nucl. e S. ⇒ Astrofisica Nucl. e S.

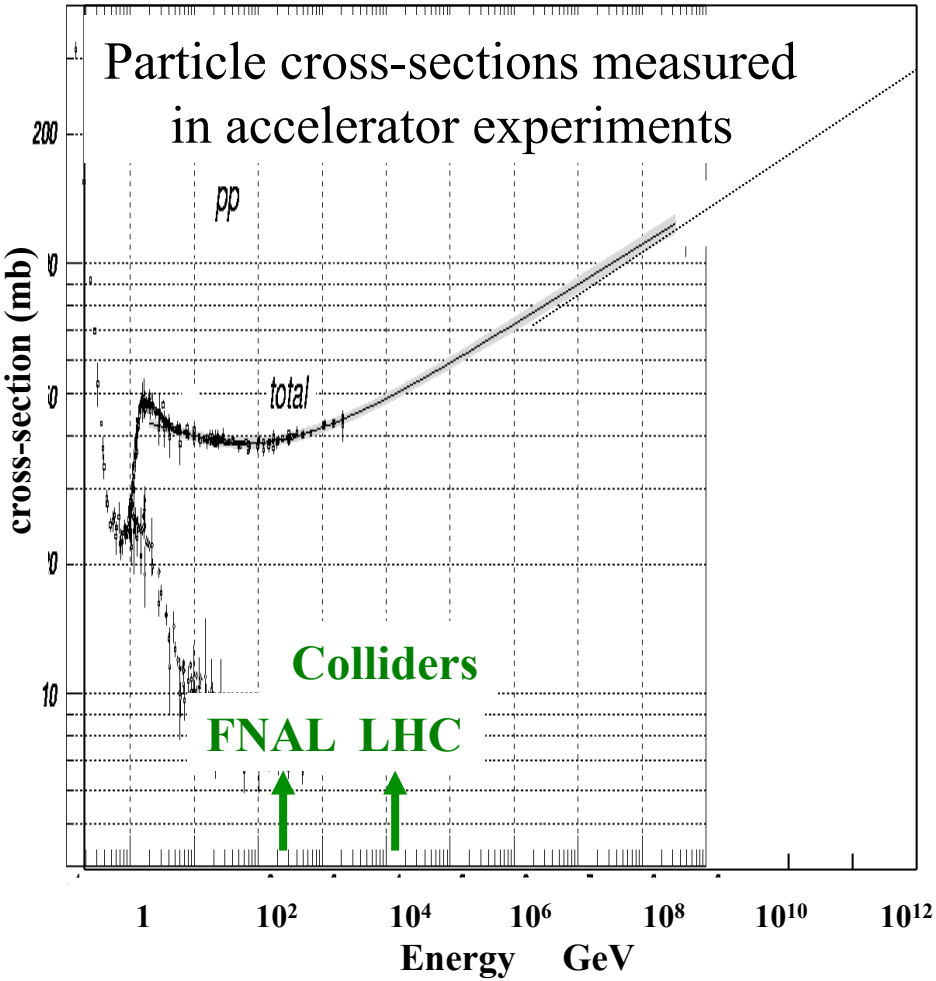


The size of things

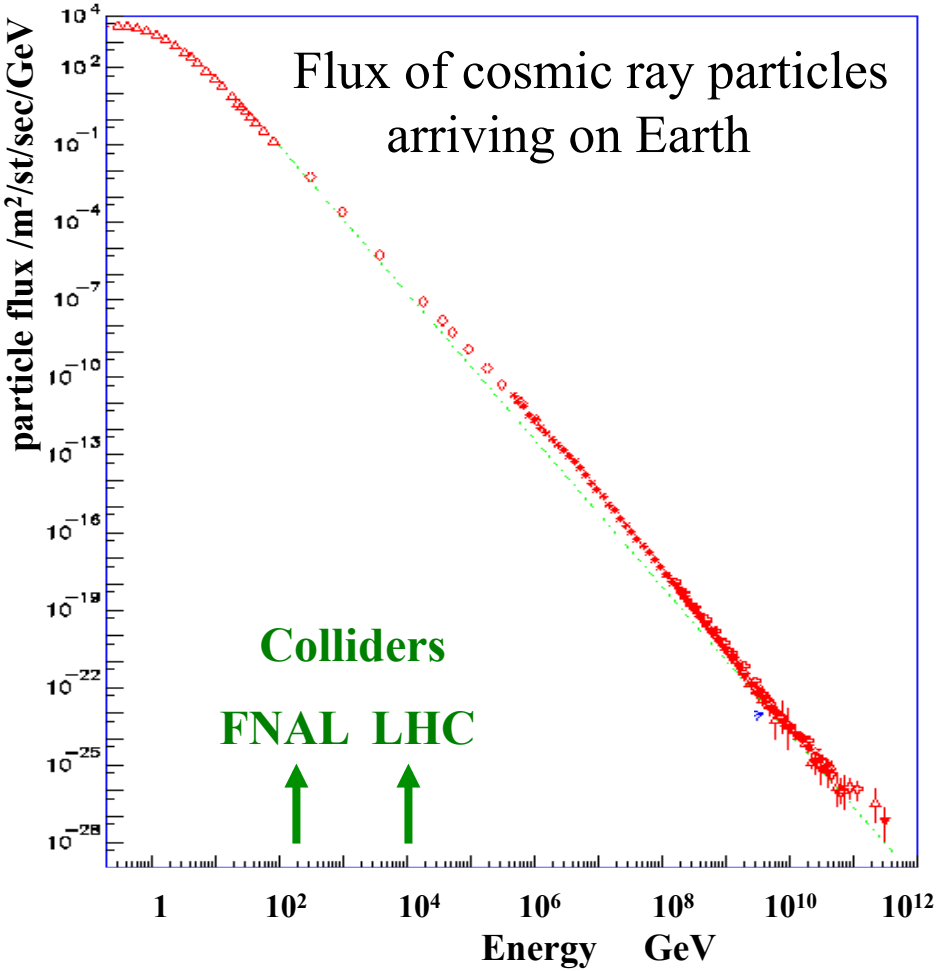


Ultra High Energy from Cosmic Rays

From laboratory accelerators



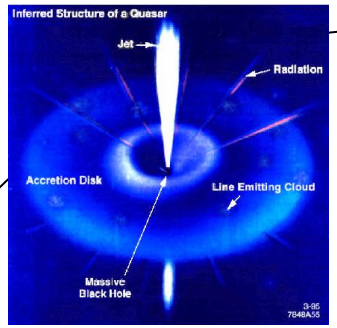
From cosmic accelerators



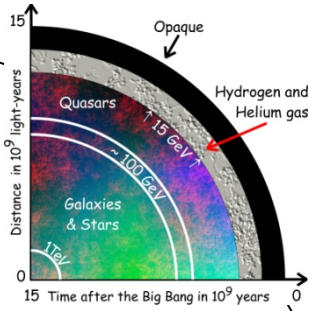
Ultra High Energy Particles arrive from space for free: make use of them

Astrofisica Nucleare e Subnucleare
Astrofisica Gamma – Overview

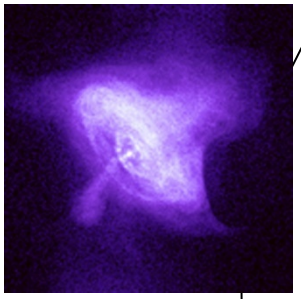
Science Objectives



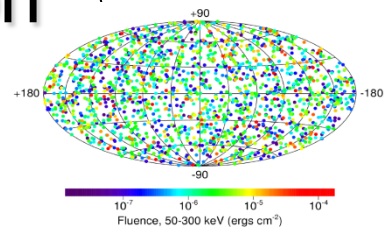
AGNs



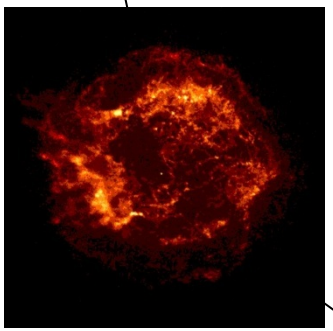
Cosmological γ ray horizon



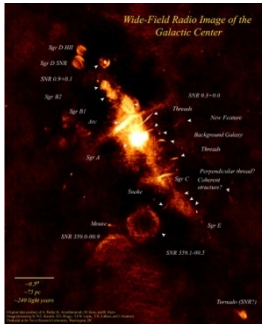
Pulsars



GRBs



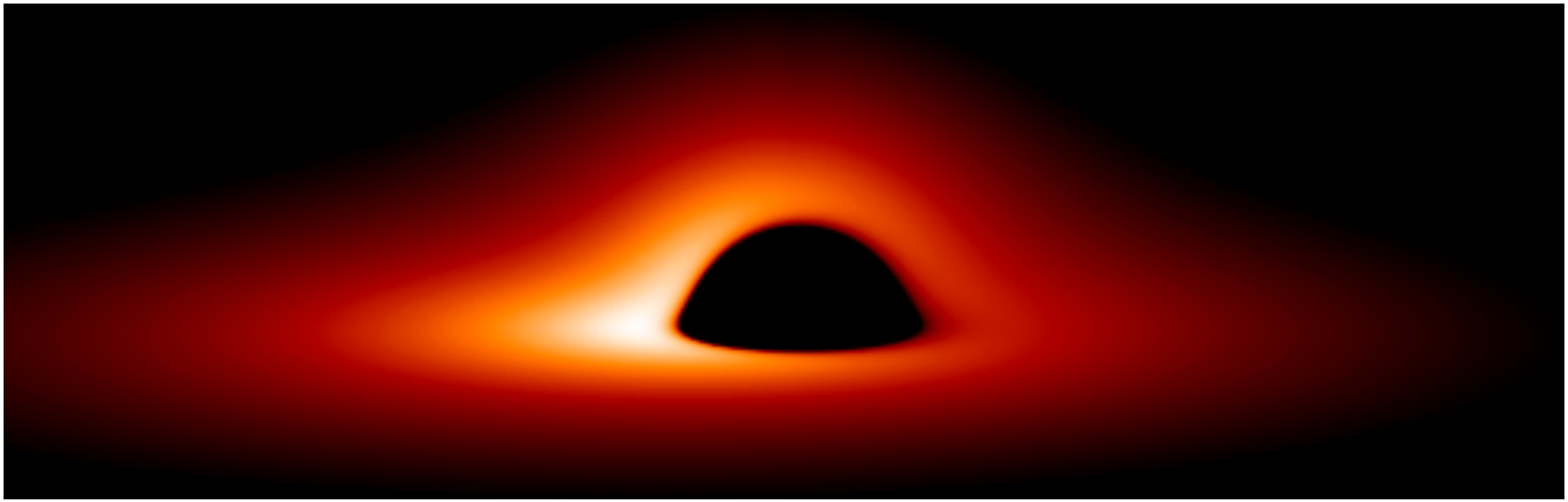
SNRs



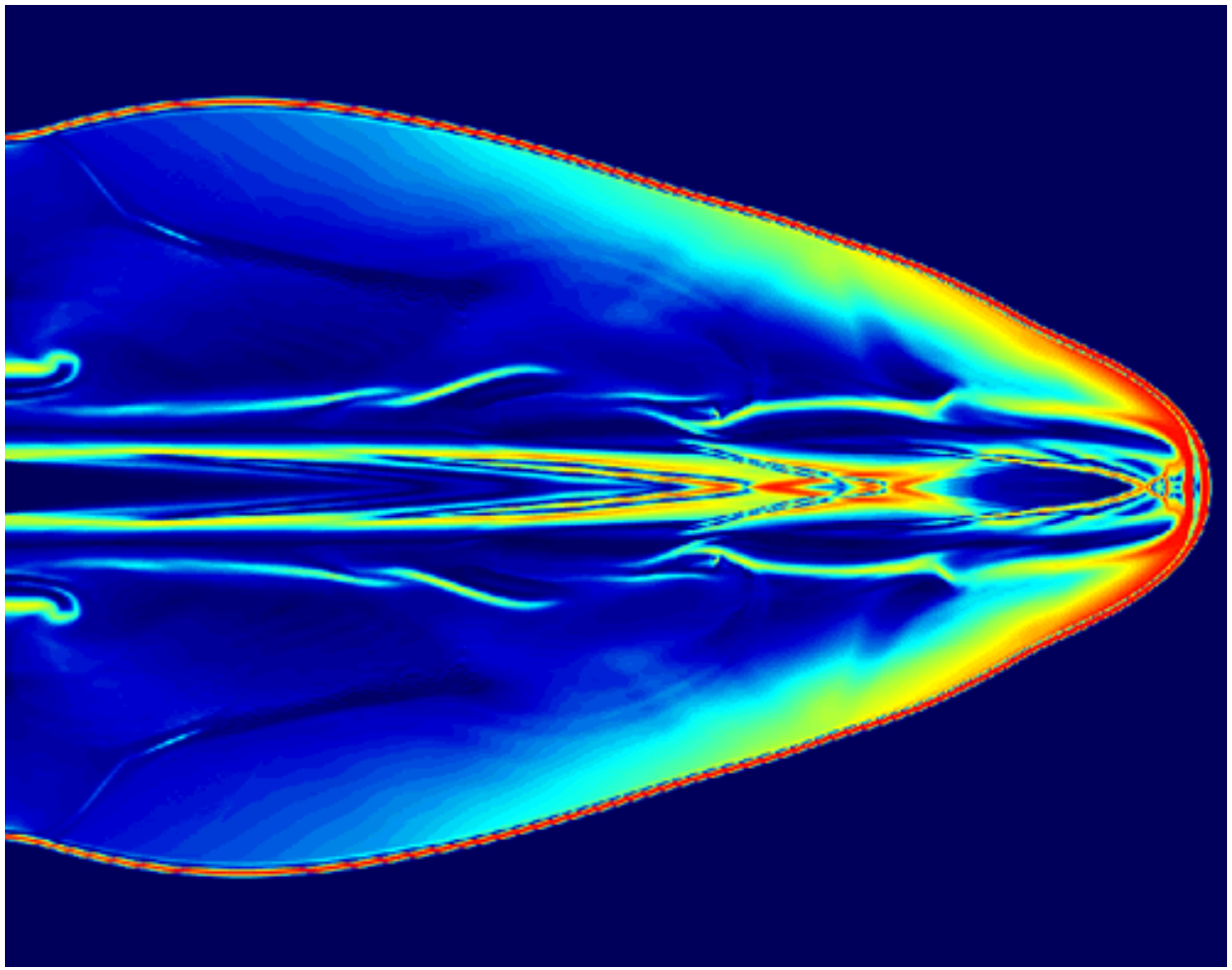
Cold Dark Matter

Tests on Quantum Gravity effects

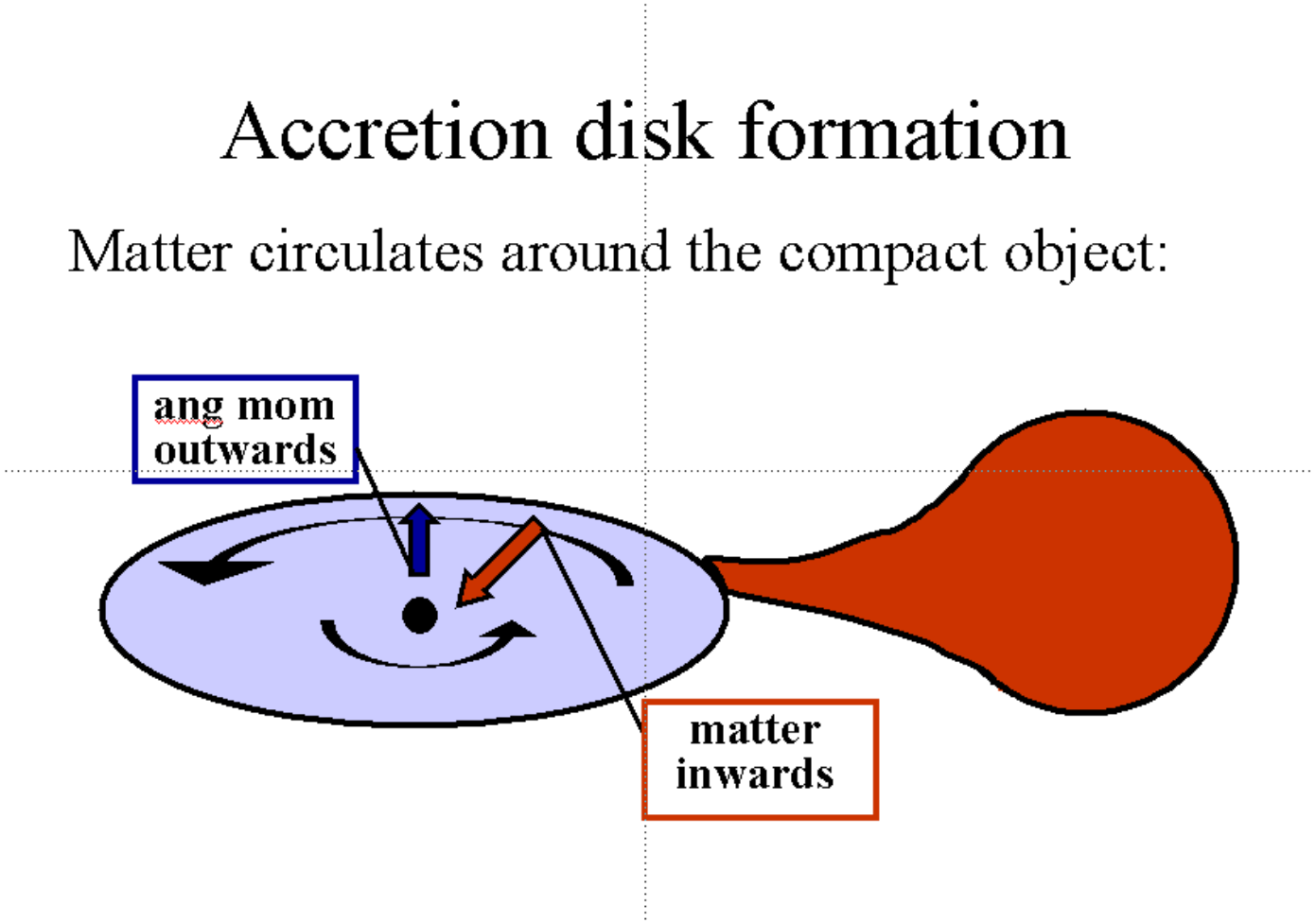
Compact objects



Jets

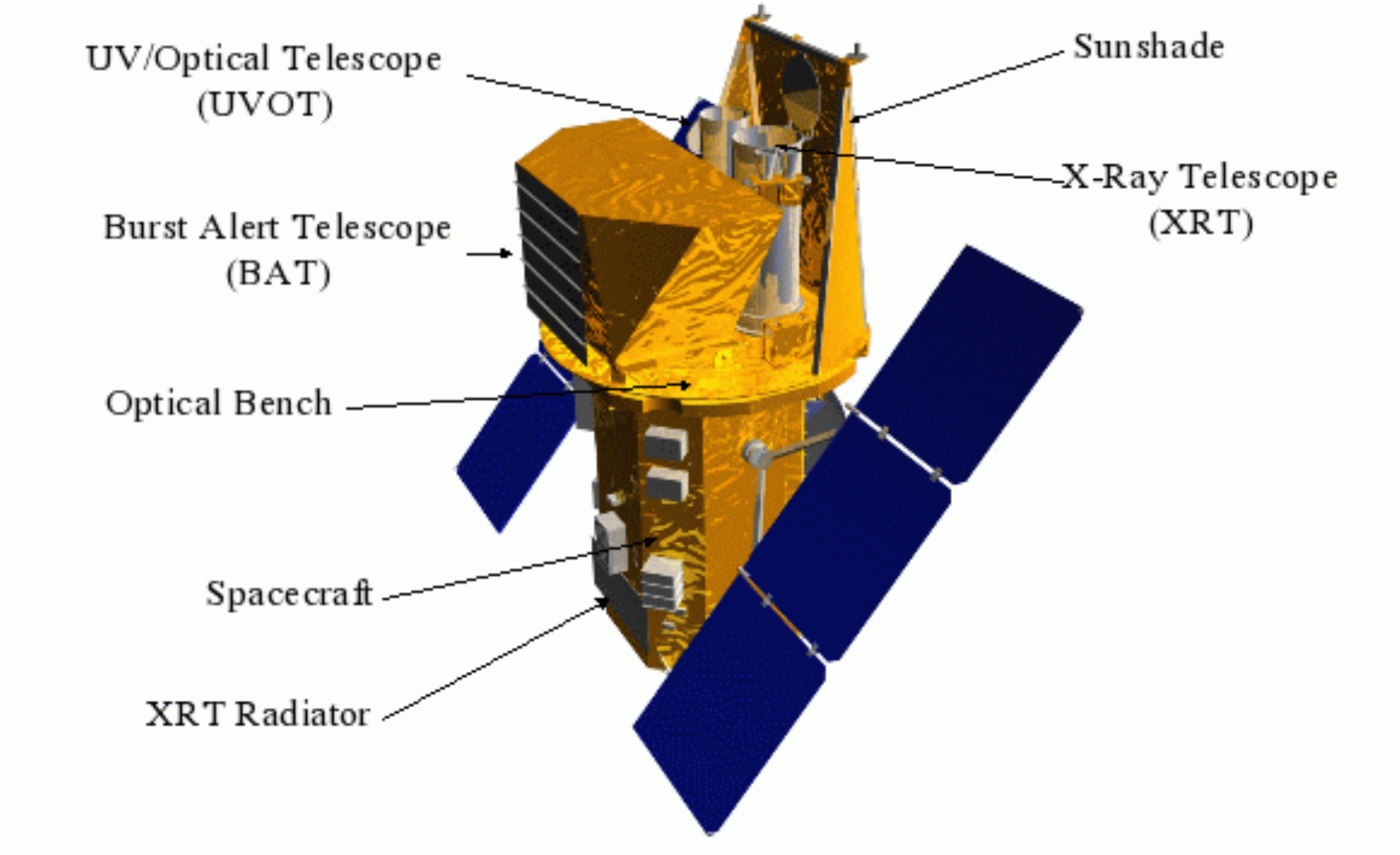


Accretion

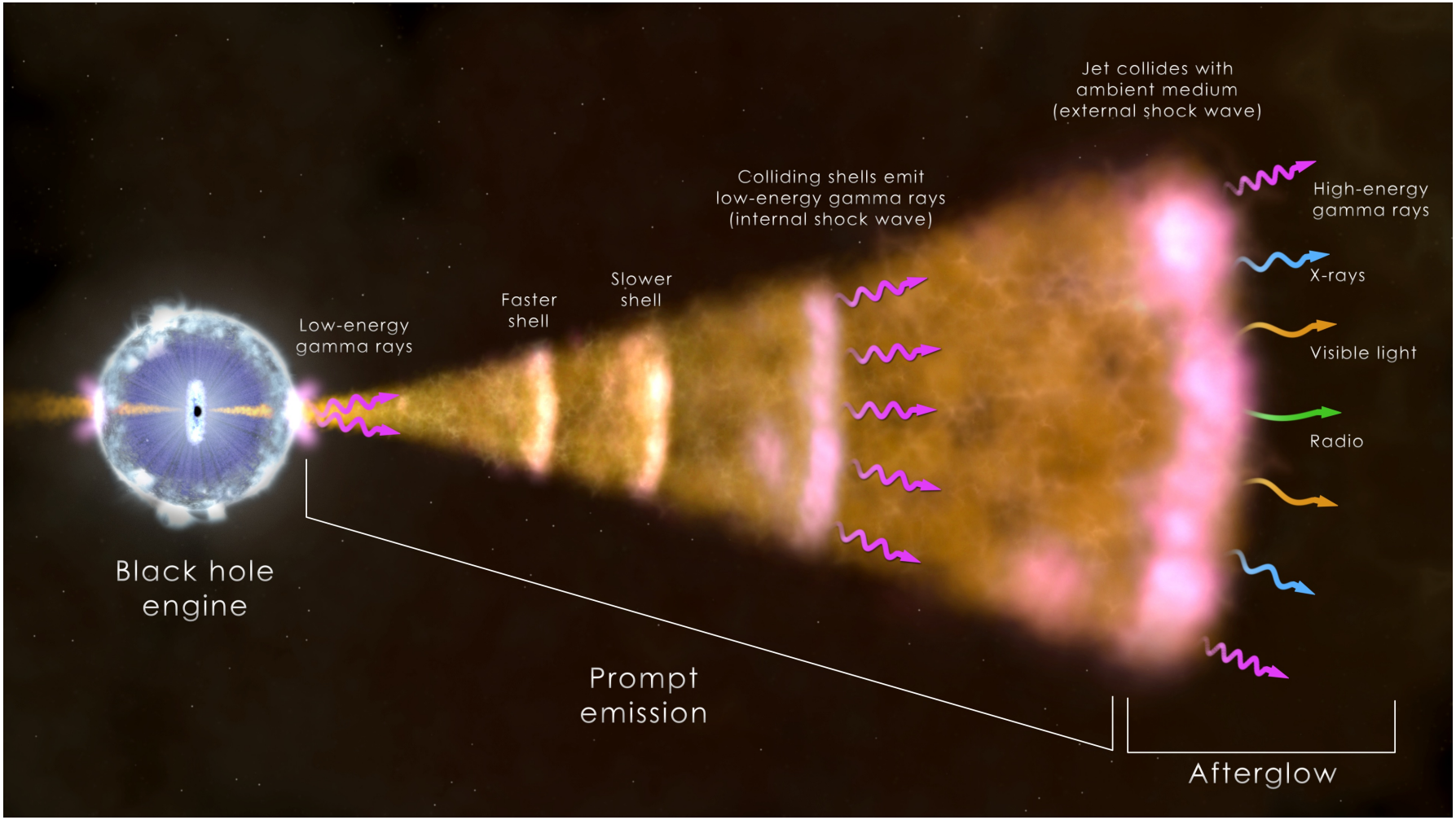

Accretion disk formation
Matter circulates around the compact object:
ang mom outwards
matter inwards

keV-MeV gamma-ray astrophysics

Swift

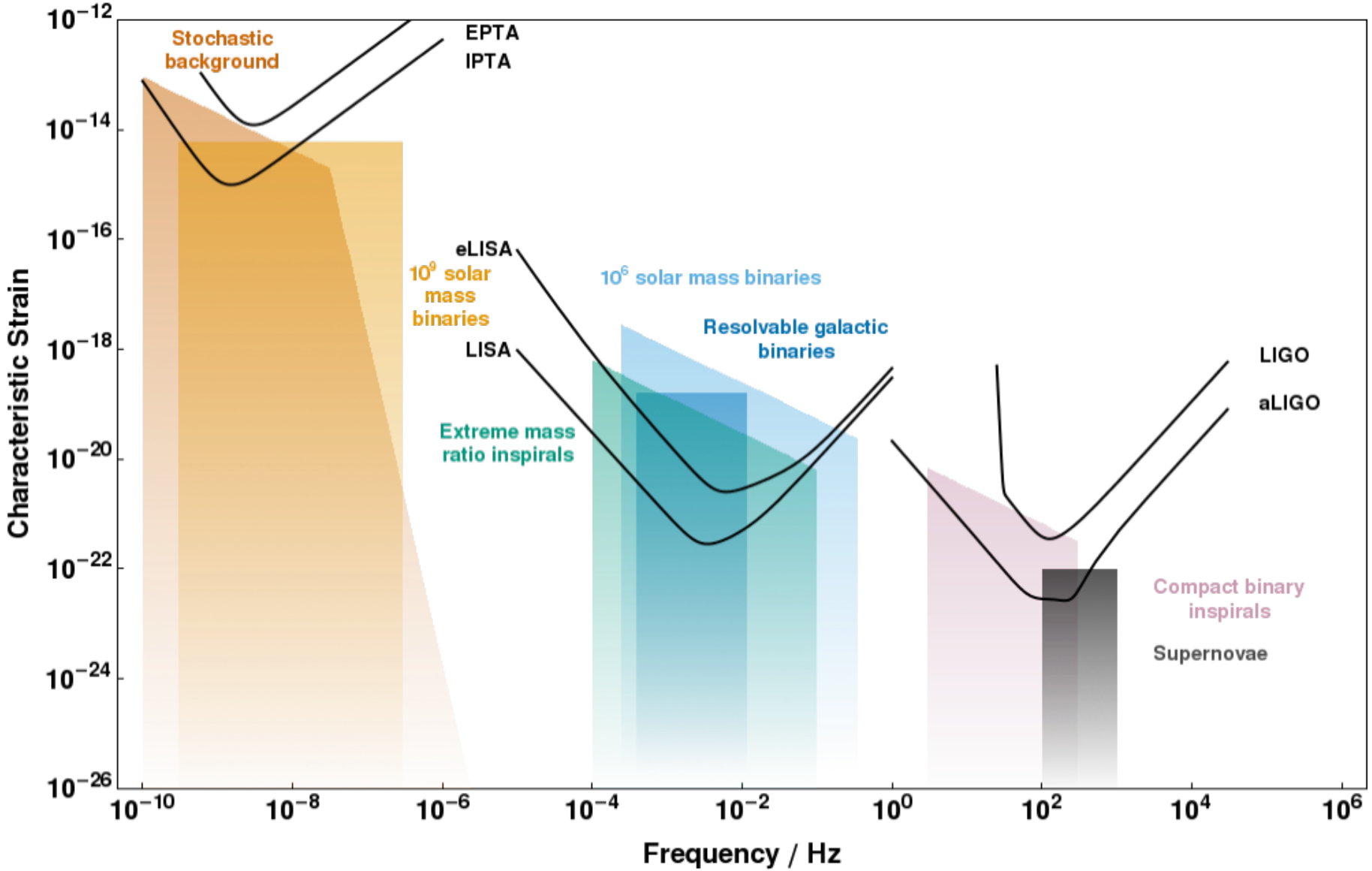

UV/Optical Telescope
(UVOT)
Sunshade
X-Ray Telescope
(XRT)
Burst Alert Telescope
(BAT)
Optical Bench
Spacecraft
XRT Radiator

GRB


Jet collides with
ambient medium
(external shock wave)
Colliding shells emit
low-energy gamma rays
(internal shock wave)
Slower
shell
Faster
shell
Low-energy
gamma rays
High-energy
gamma rays
X-rays
Visible light
Radio
Black hole
engine
Prompt
emission
Afterglow

Gravitational Waves

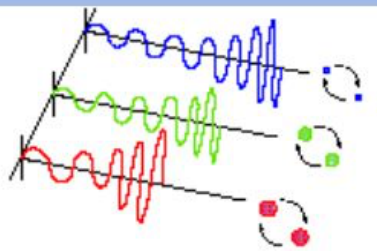
Gravitational Waves

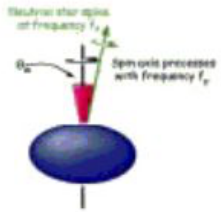


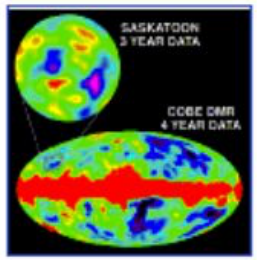
Gravitational Waves

Astrophysical Sources for Terrestrial GW Detectors

- Compact binary inspiral: "chirps"
  - NS-NS, NS-BH, BH-BH
- Supernovas or GRBs: "bursts"
  - GW signals observed in coincidence with EM or neutrino detectors
- Pulsars in our galaxy: "periodic waves"
  - Rapidly rotating neutron stars
  - Modes of NS vibration
- Cosmological: "stochastic background" ?
  - Probe back to the Planck time (10^{-43} s)
  - Probe phase transitions : window to force unification
  - Cosmological distribution of Primordial black holes

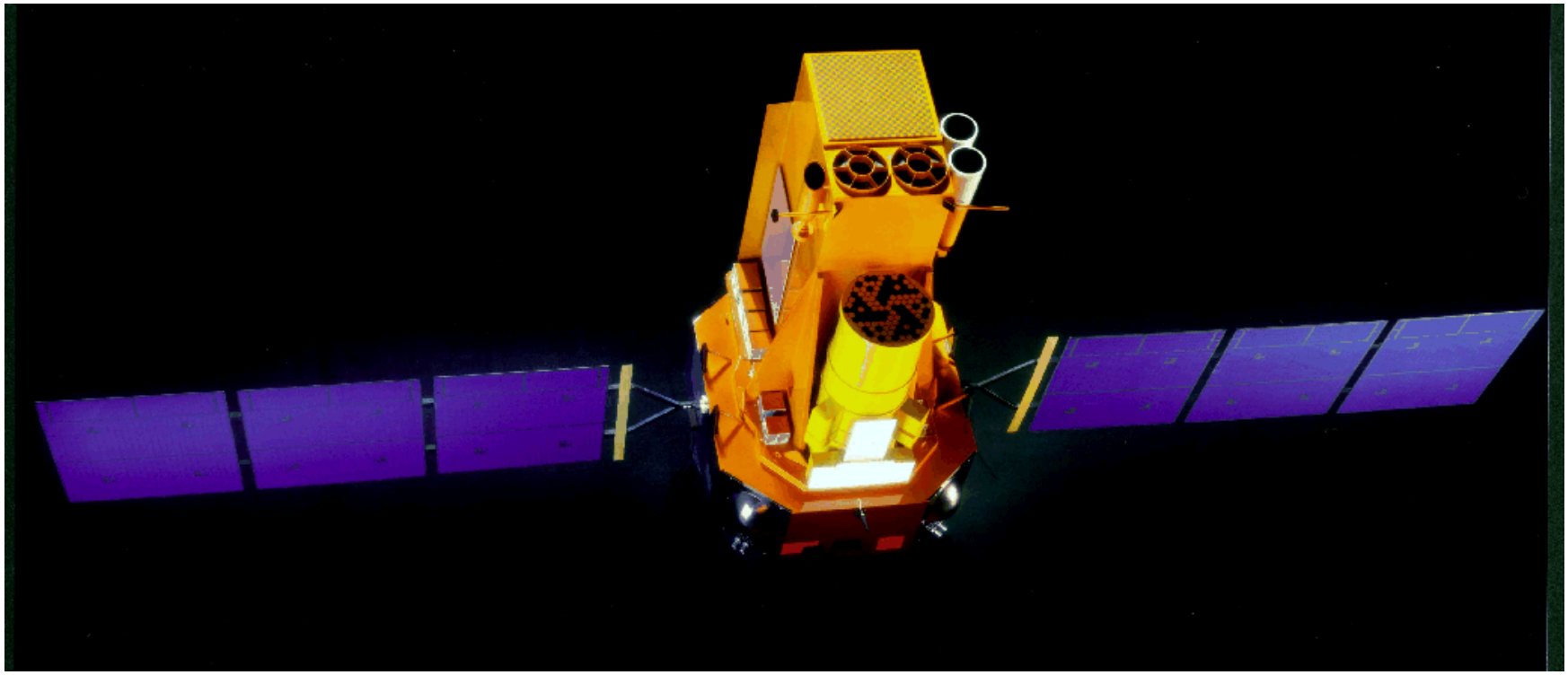




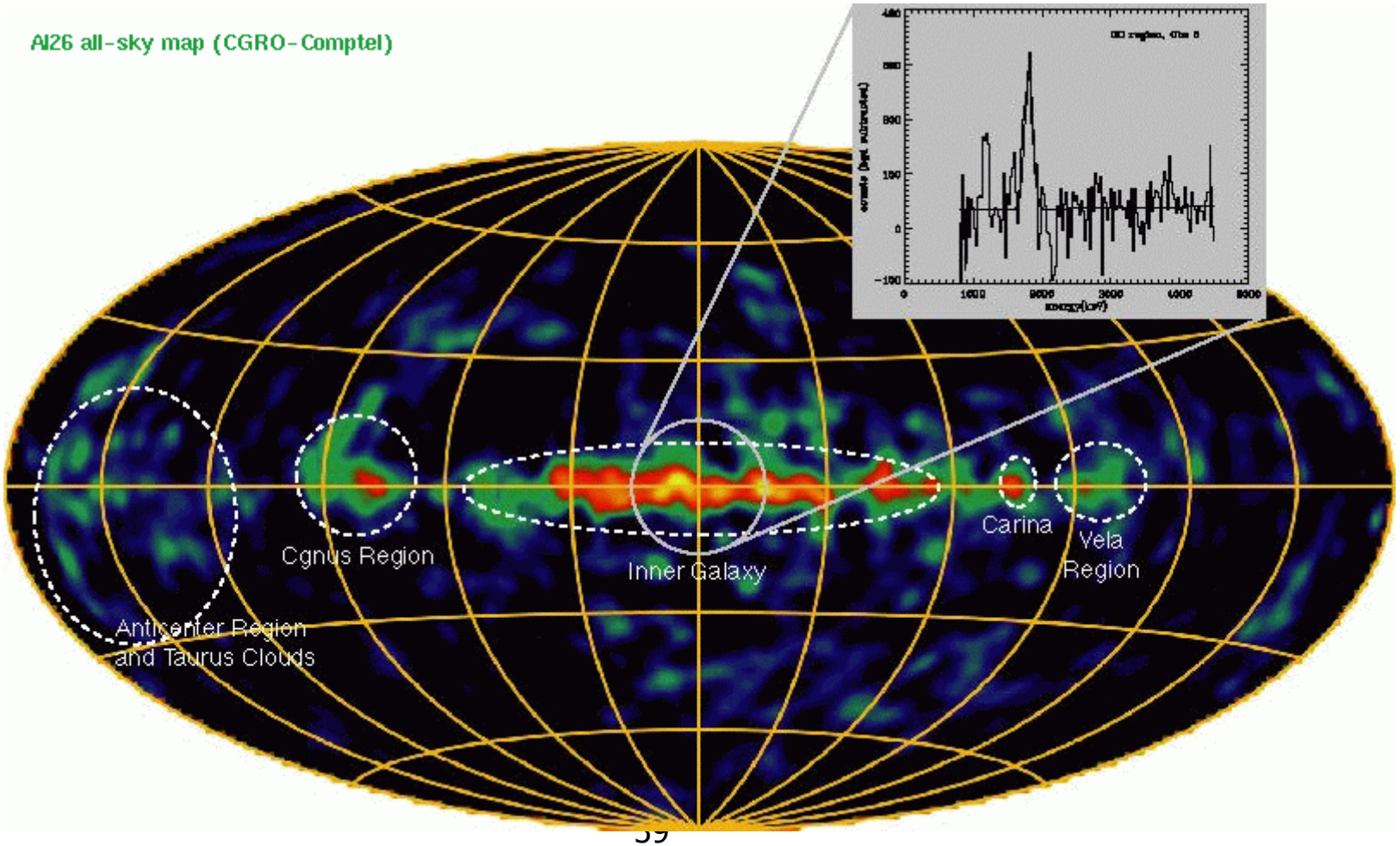


Courtesy;: Stan Whitcomb

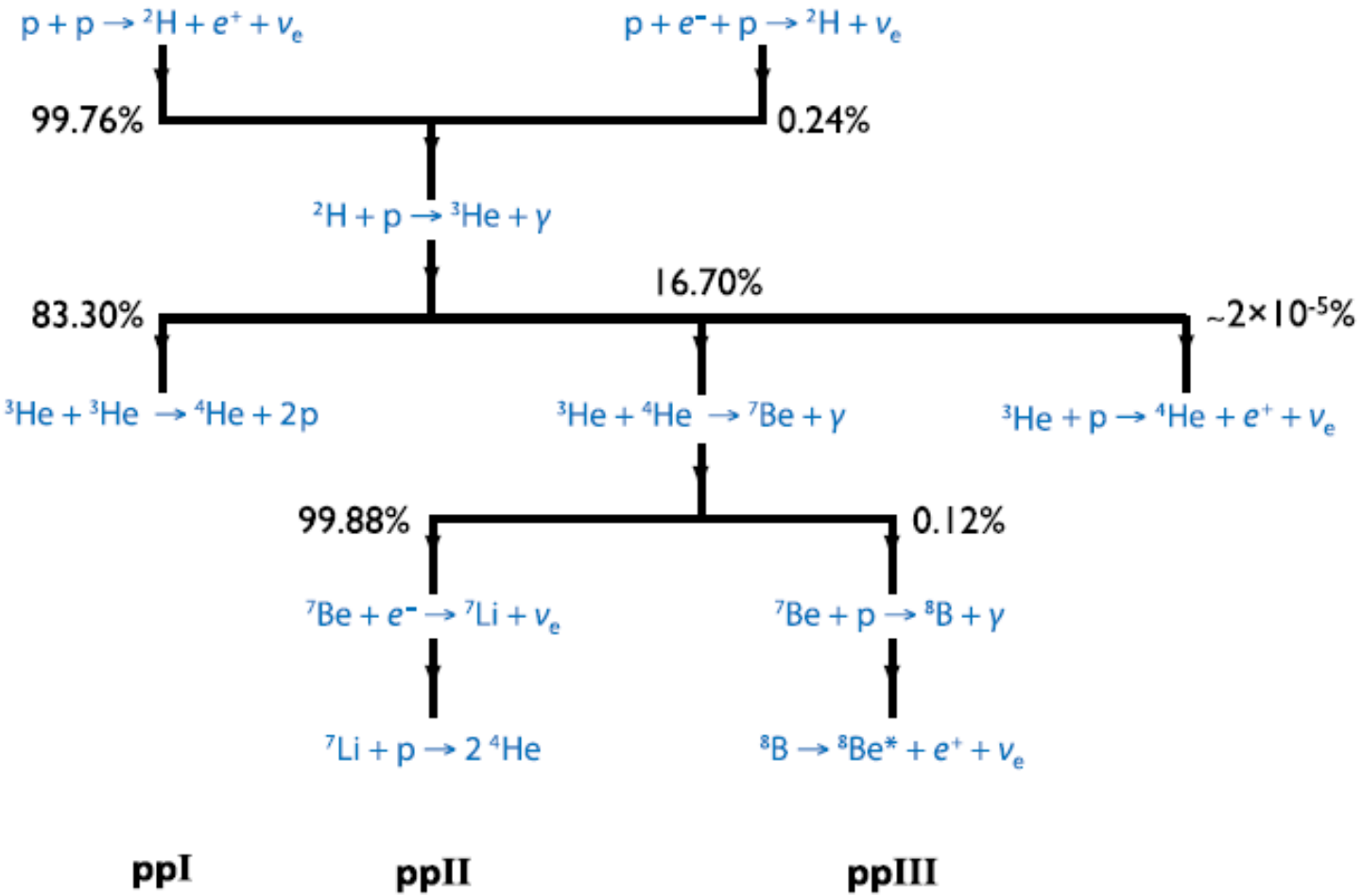
INTEGRAL



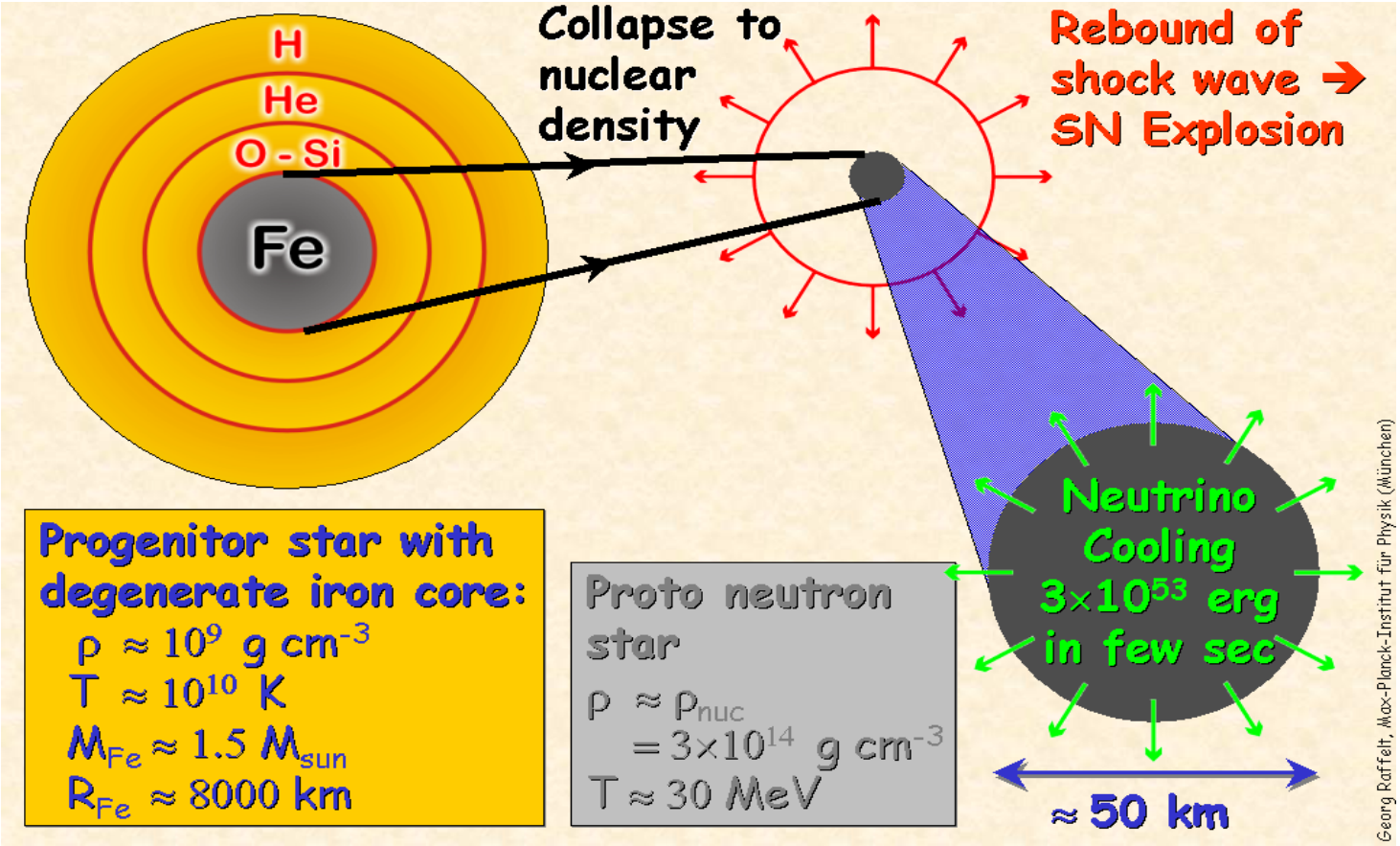
INTEGRAL

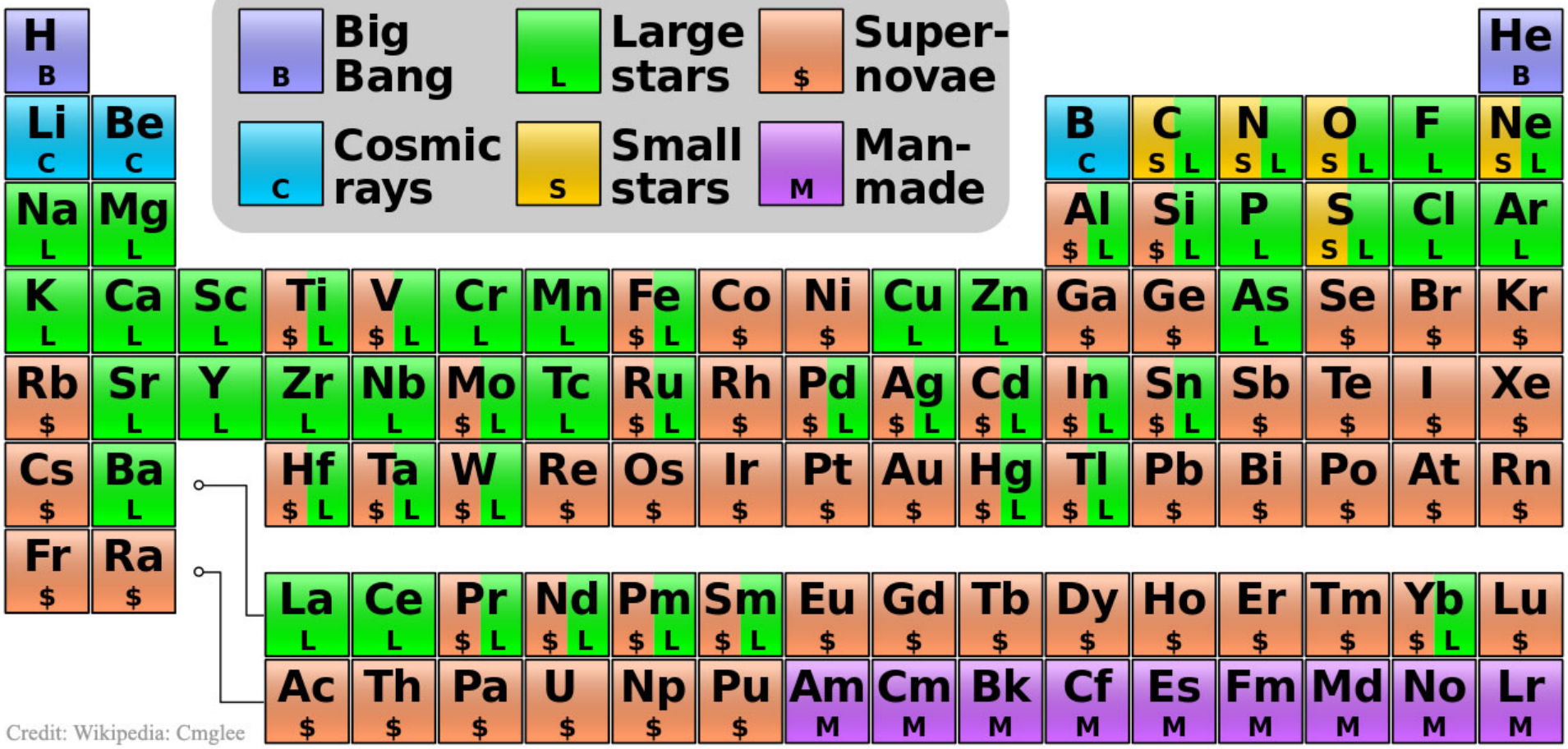

Al26 all-sky map (CGRO-Comptel)
Cygnus Region
Inner Galaxy
Carina
Vela
Region
Anticenter Region
and Taurus Clouds

Solar Thermonuclear Cycles

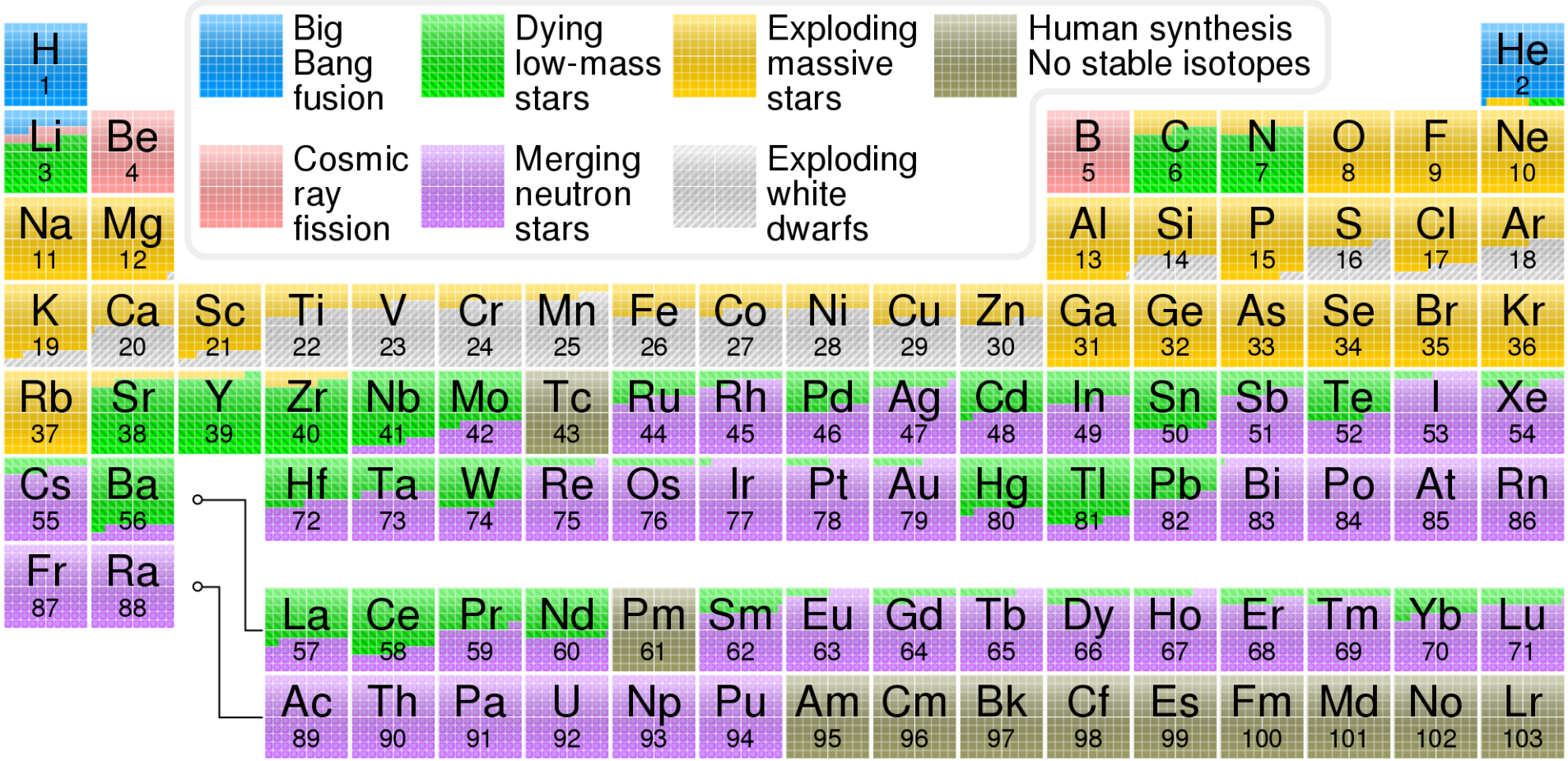


Stellar collapse and neutrinos





Credit: Wikipedia: Cmglee

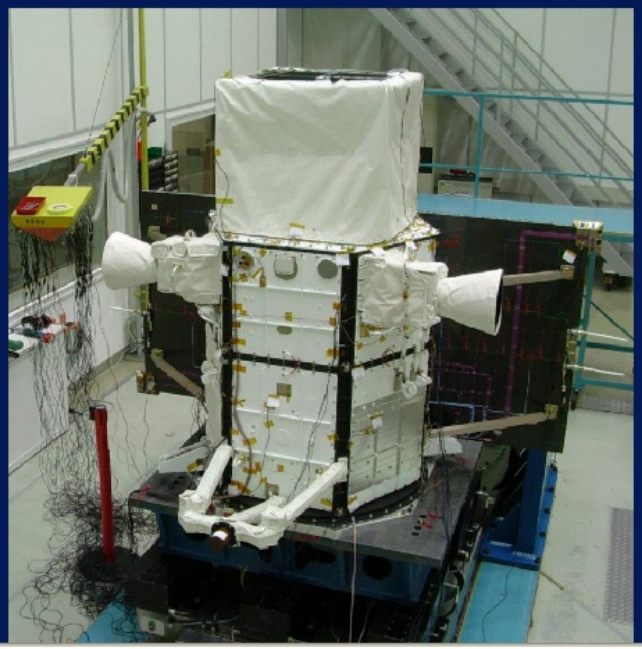


Dopo GW 170817

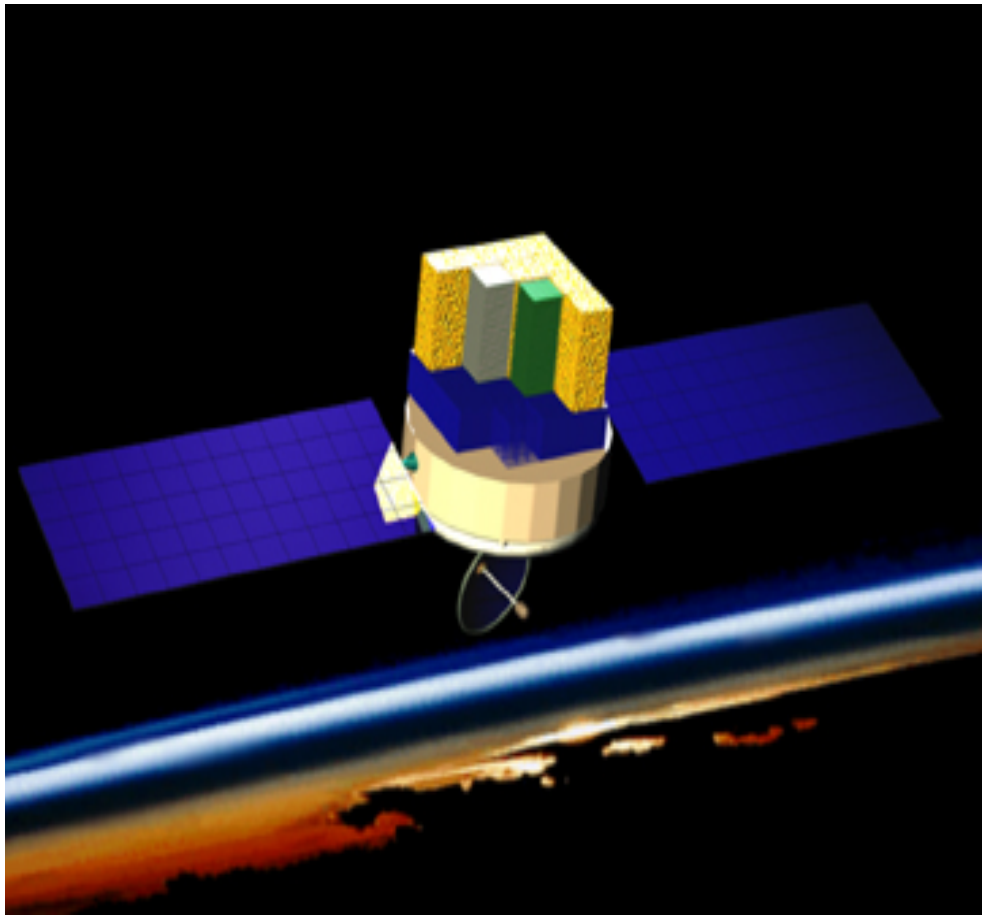
GeV gamma-ray astrophysics

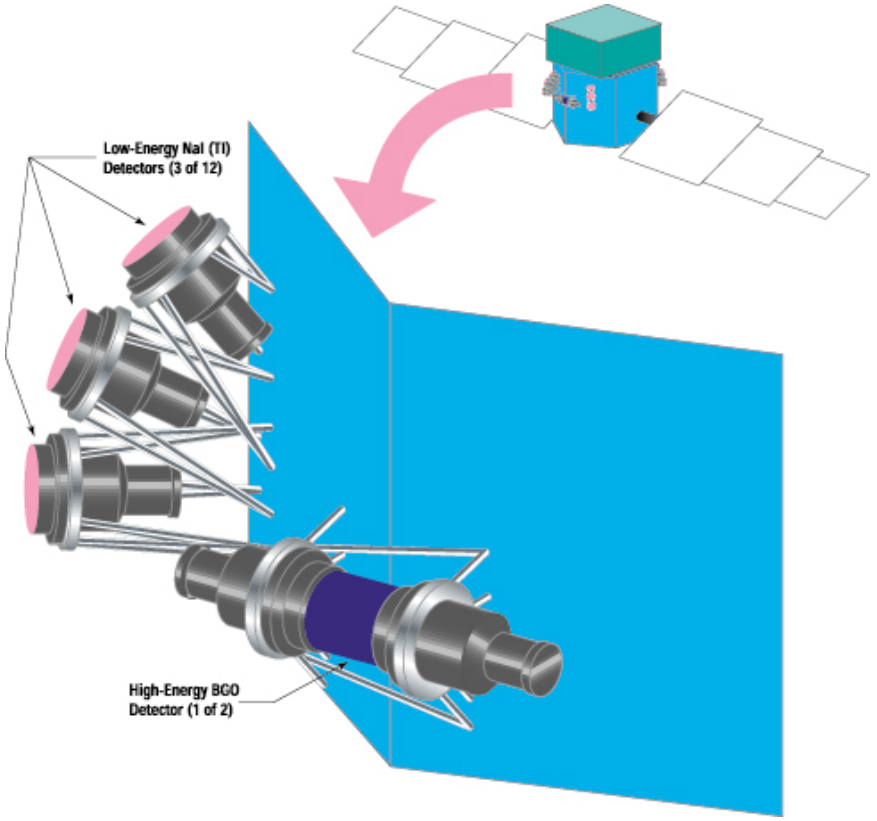
AGILE

- Home
- AGILE Team
- AGILE System Team
- AGILE in ASI
- AGILE Industrial Partners
- AGILE Progress Status
- Science with AGILE
- AGILE Sensitivity
- AGILE Selected Publications
- AGILE latest review paper
- Highlights
- Education & Public Outreach
- Public Information
- AGILE Site

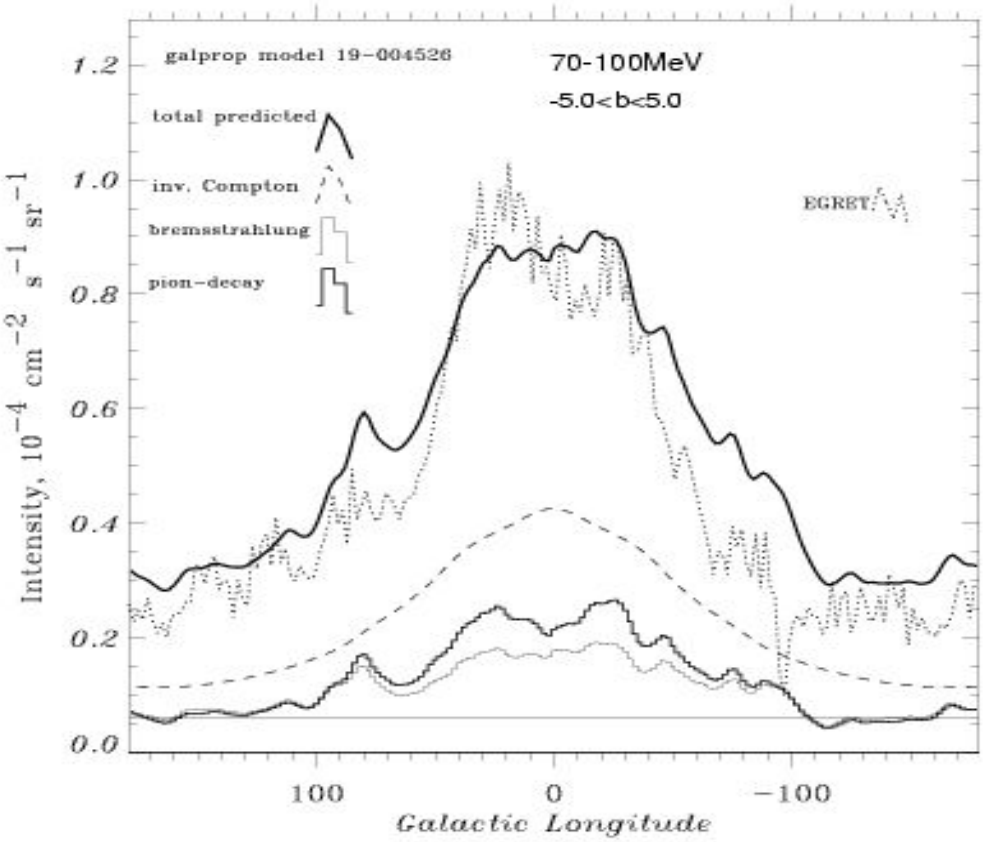


Fermi/GLAST

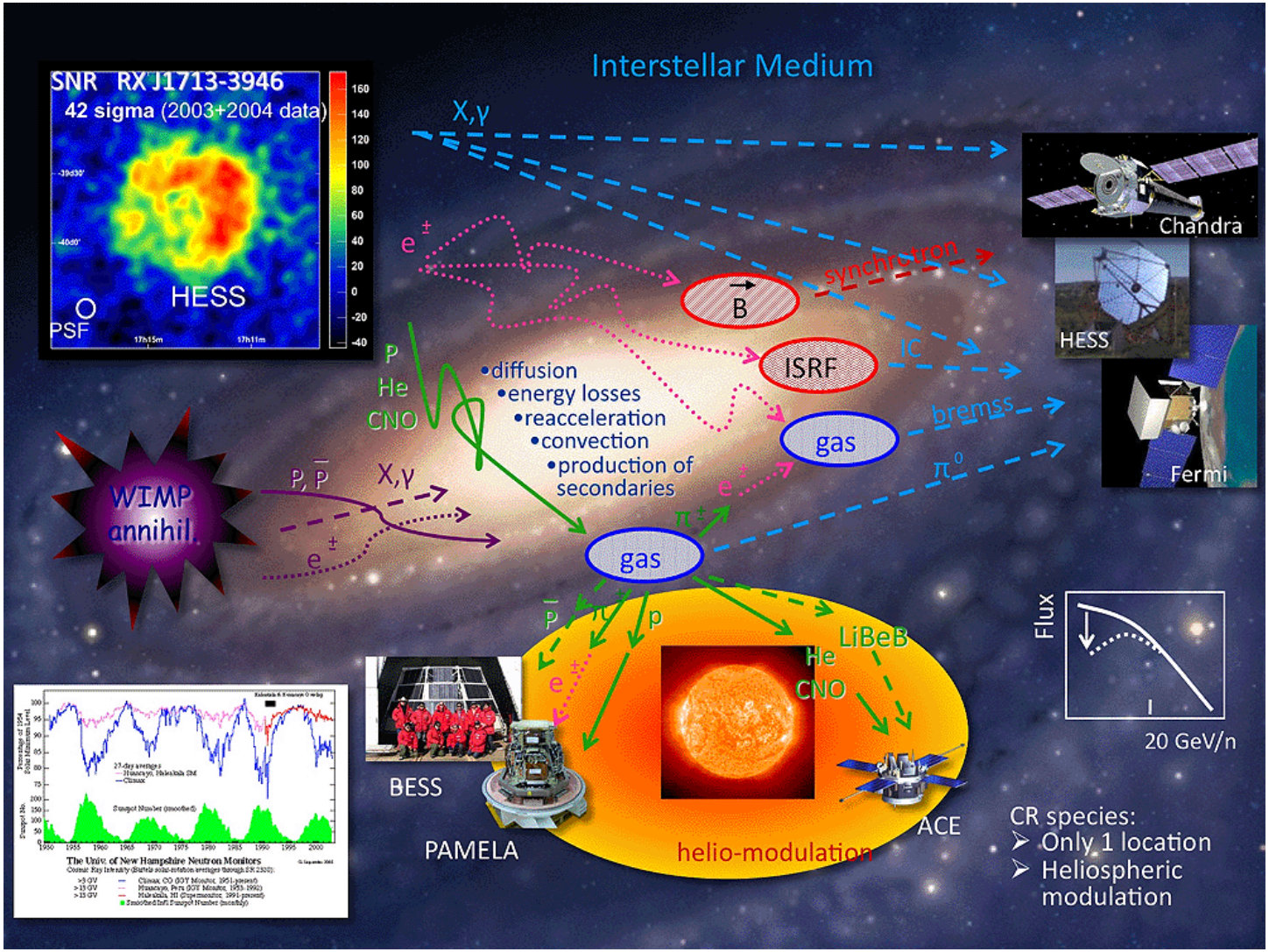



Low-Energy NaI (Tl)
Detectors (3 of 12)
High-Energy BGO
Detector (1 of 2)

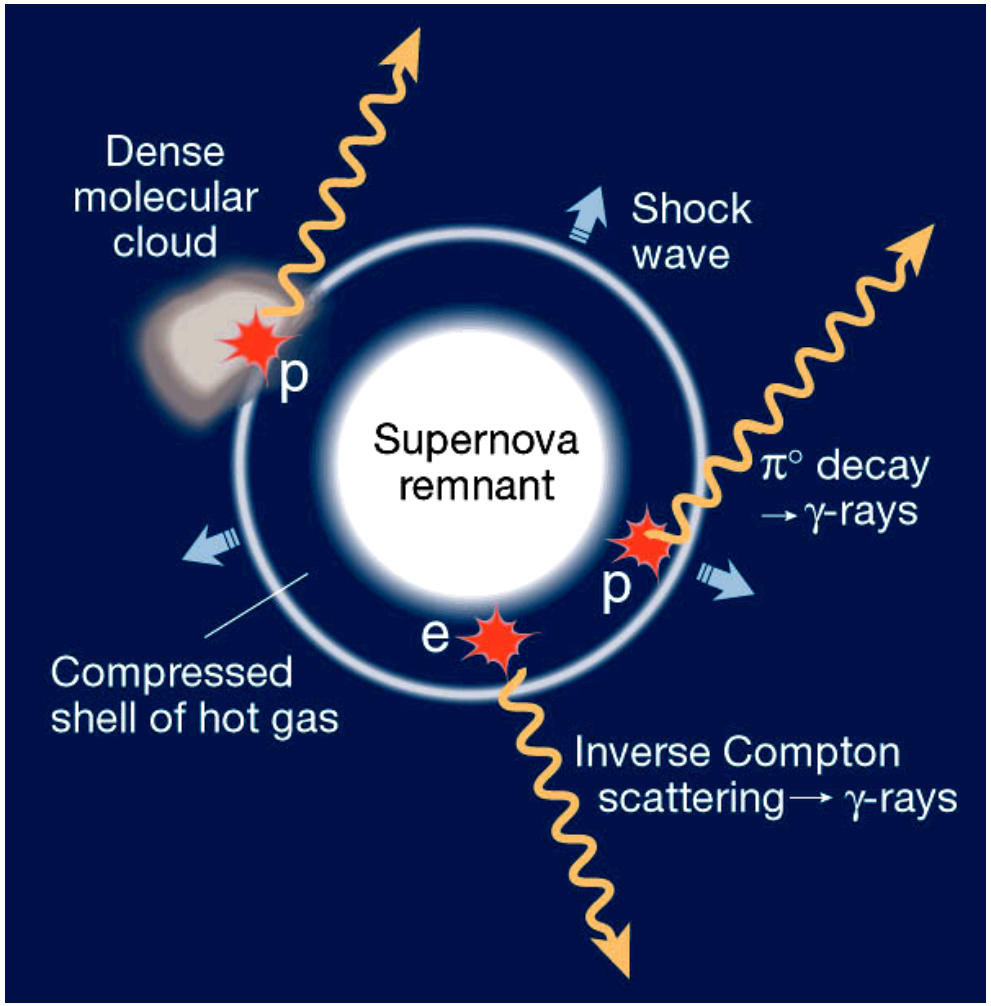
The galactic plane



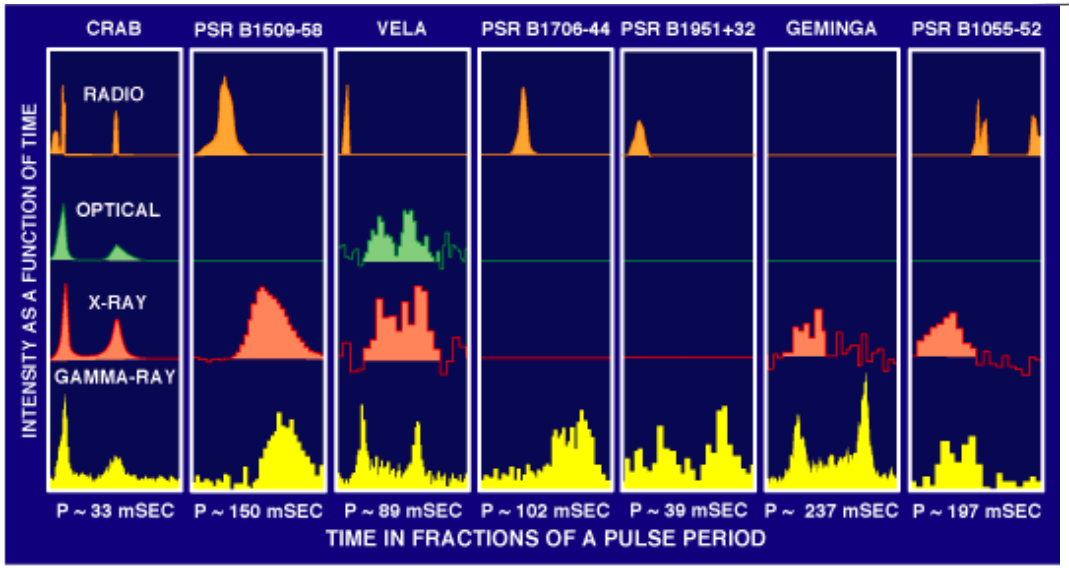
Cosmic Rays Propagation

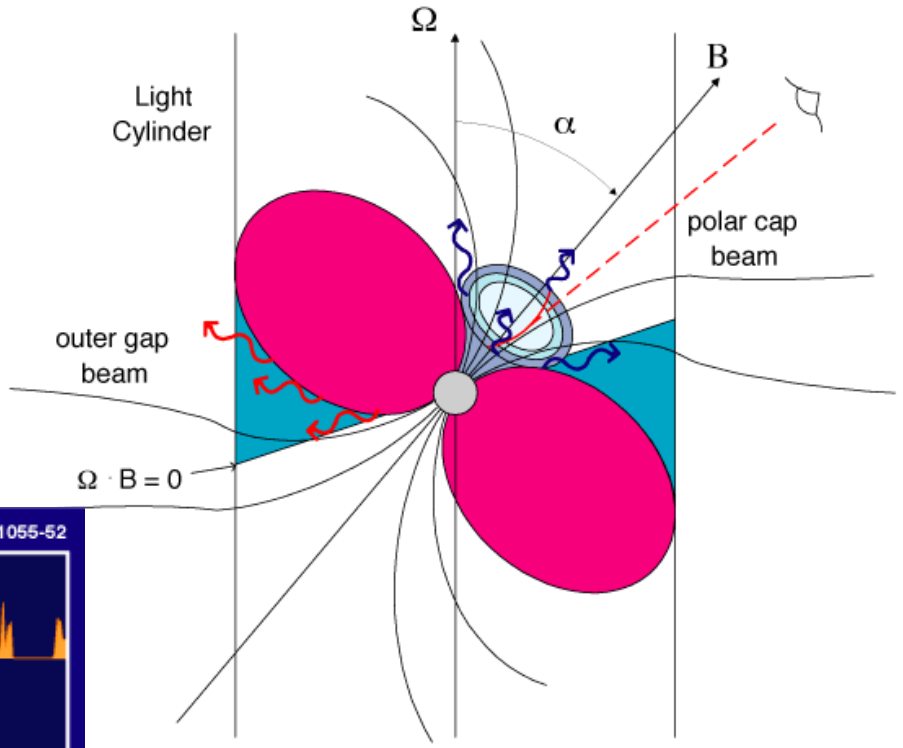


Supernova Remnants

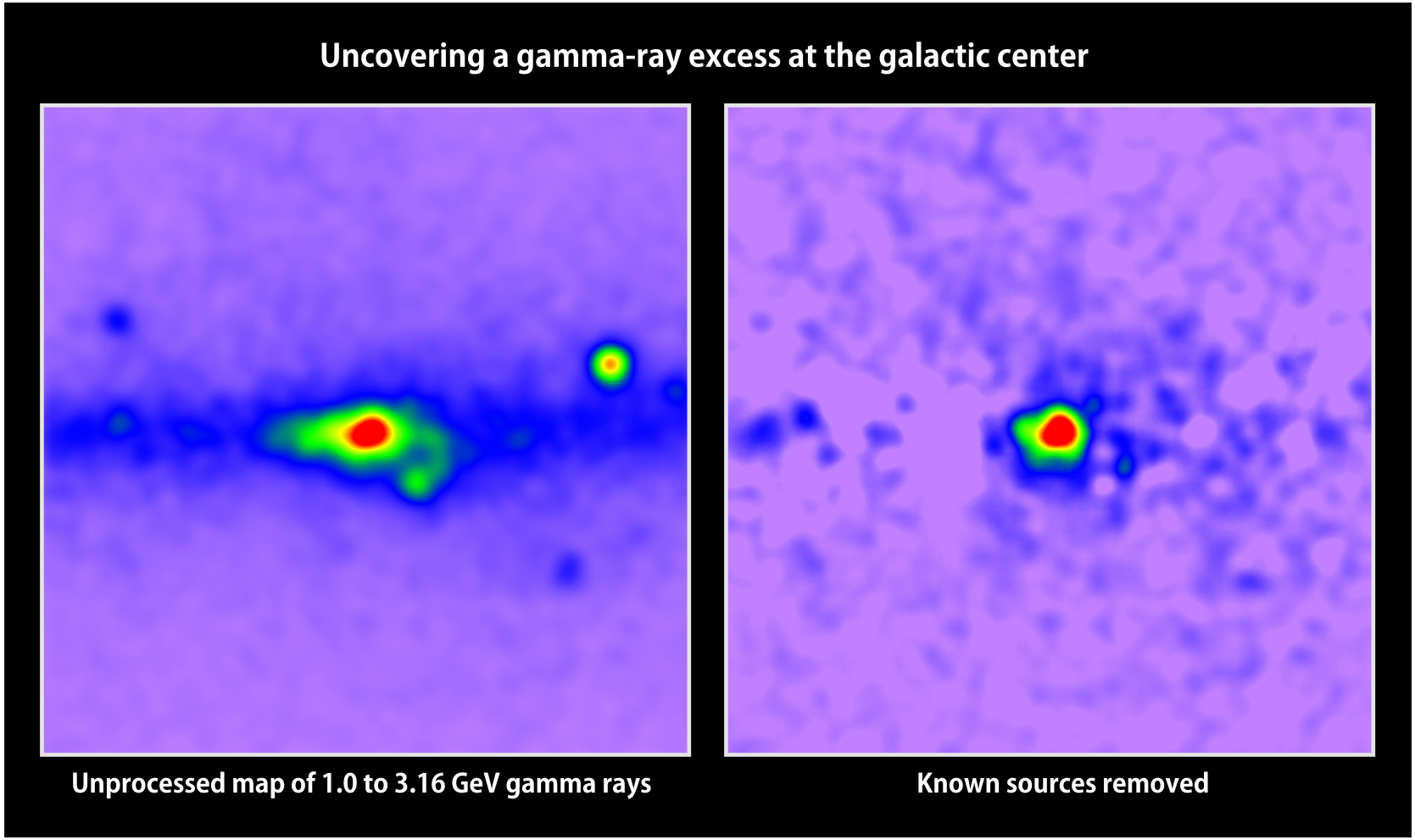


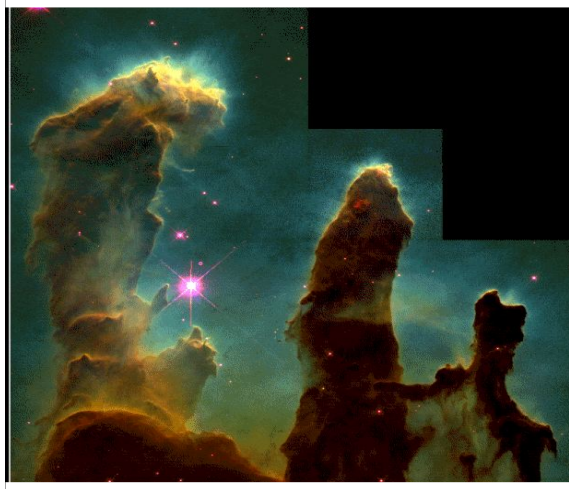
Pulsars

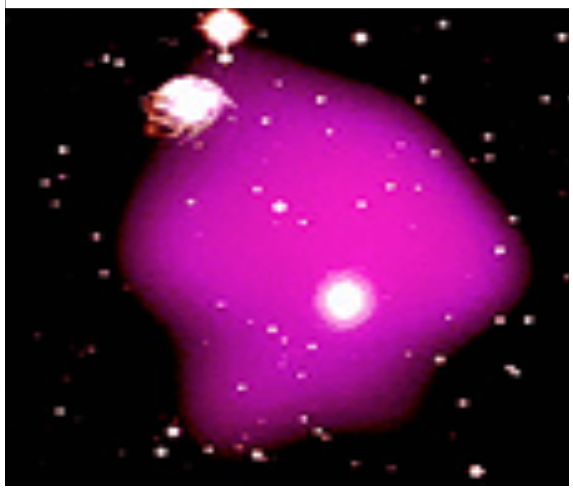

CRAB
PSR B1509-58
VELA
PSR B1706-44
PSR B1951+32
GEMINGA
PSR B1055-52
RADIO
OPTICAL
X-RAY
GAMMA-RAY
INTENSITY AS A FUNCTION OF TIME
P ~ 33 mSEC
P ~ 150 mSEC
P ~ 89 mSEC
P ~ 102 mSEC
P ~ 39 mSEC
P ~ 237 mSEC
P ~ 197 mSEC
TIME IN FRACTIONS OF A PULSE PERIOD


Ω
B
Light
Cylinder
α
polar cap
beam
outer gap
beam
Ω · B = 0

Dark Matter


Uncovering a gamma-ray excess at the galactic center
Unprocessed map of 1.0 to 3.16 GeV gamma rays
Known sources removed





Dark Matter

Evidence :

Need to hold together Galaxy Clusters

Explain Galaxy Rotation velocities

Astronomy object candidates :

Brown Dwarfs (stars mass <0.1 M_{sun} no fusion)

- some but not enough

White Dwarfs (final states of small stars)

- some but not enough

Neutron Stars/Black Holes (final states of big stars.)

- expected to be rarer than white dwarfs

Gas clouds

- ~75% visible matter in the universe, but observable

Particle Physics candidates:

Neutrinos

- Evidence for mass from oscillation, not enough

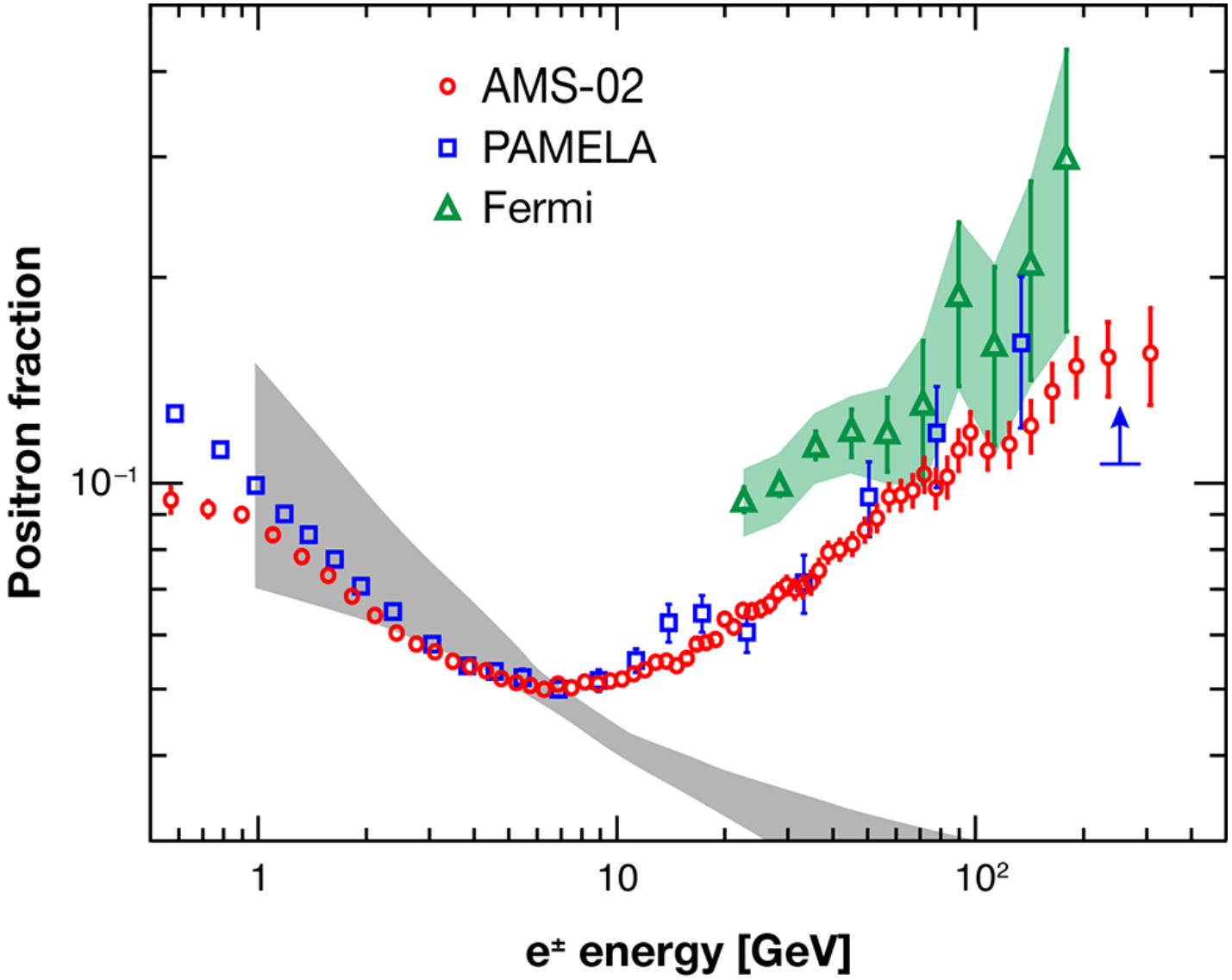
Axions

- Difficult to detect ….

Neutralinos

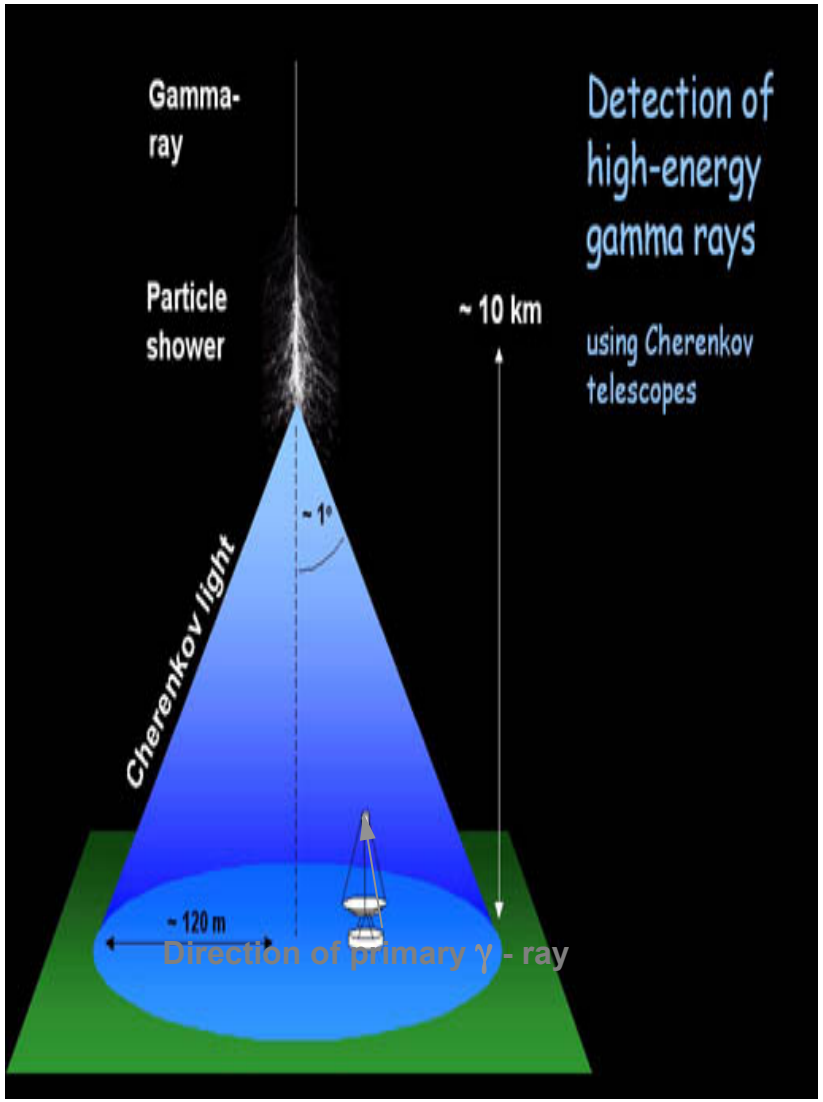
- Particle Physicist Favourite !

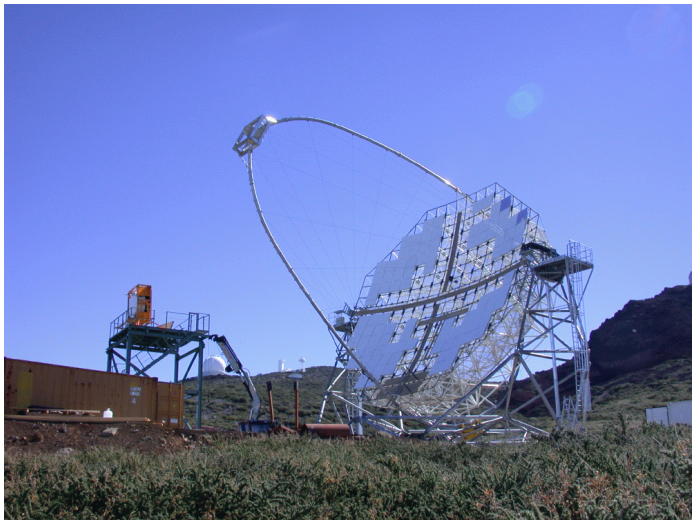
AntiMatter


AMS-02
PAMELA
Fermi
Positron fraction
10^{-1}
1
10
10^2
e± energy [GeV]

TeV astrophysics

Imaging Atmospheric Cherenkov Telescopes

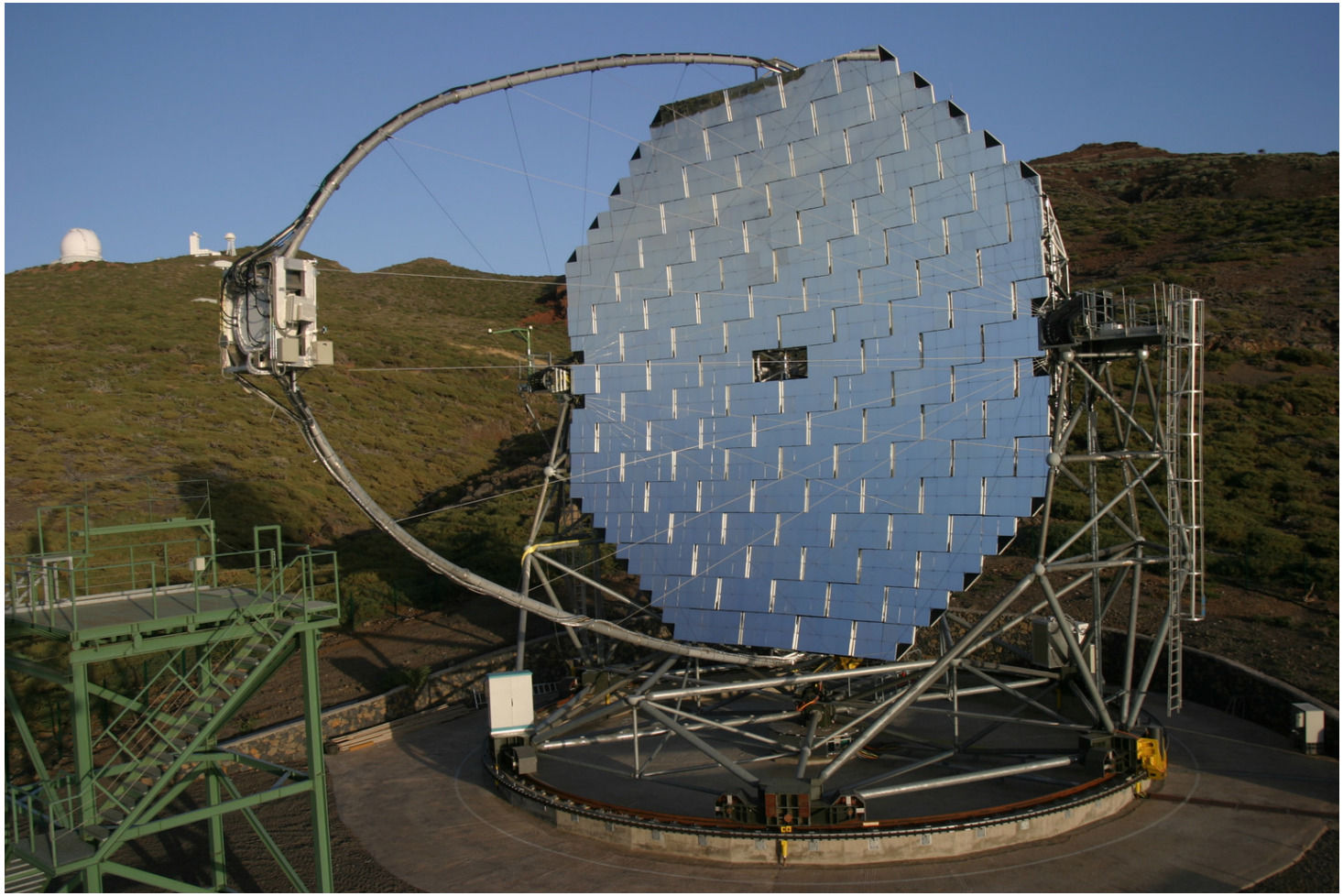


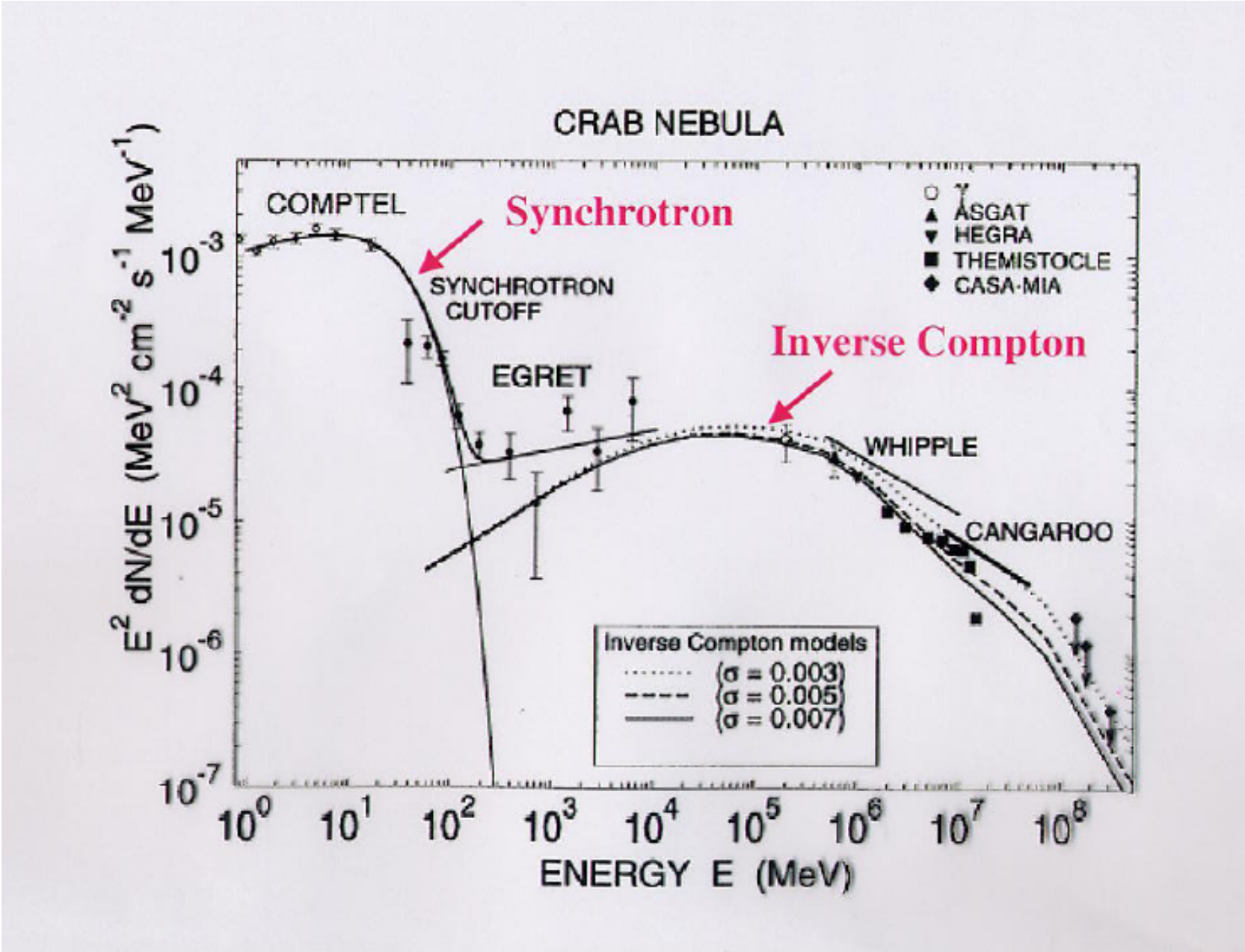


The principle:

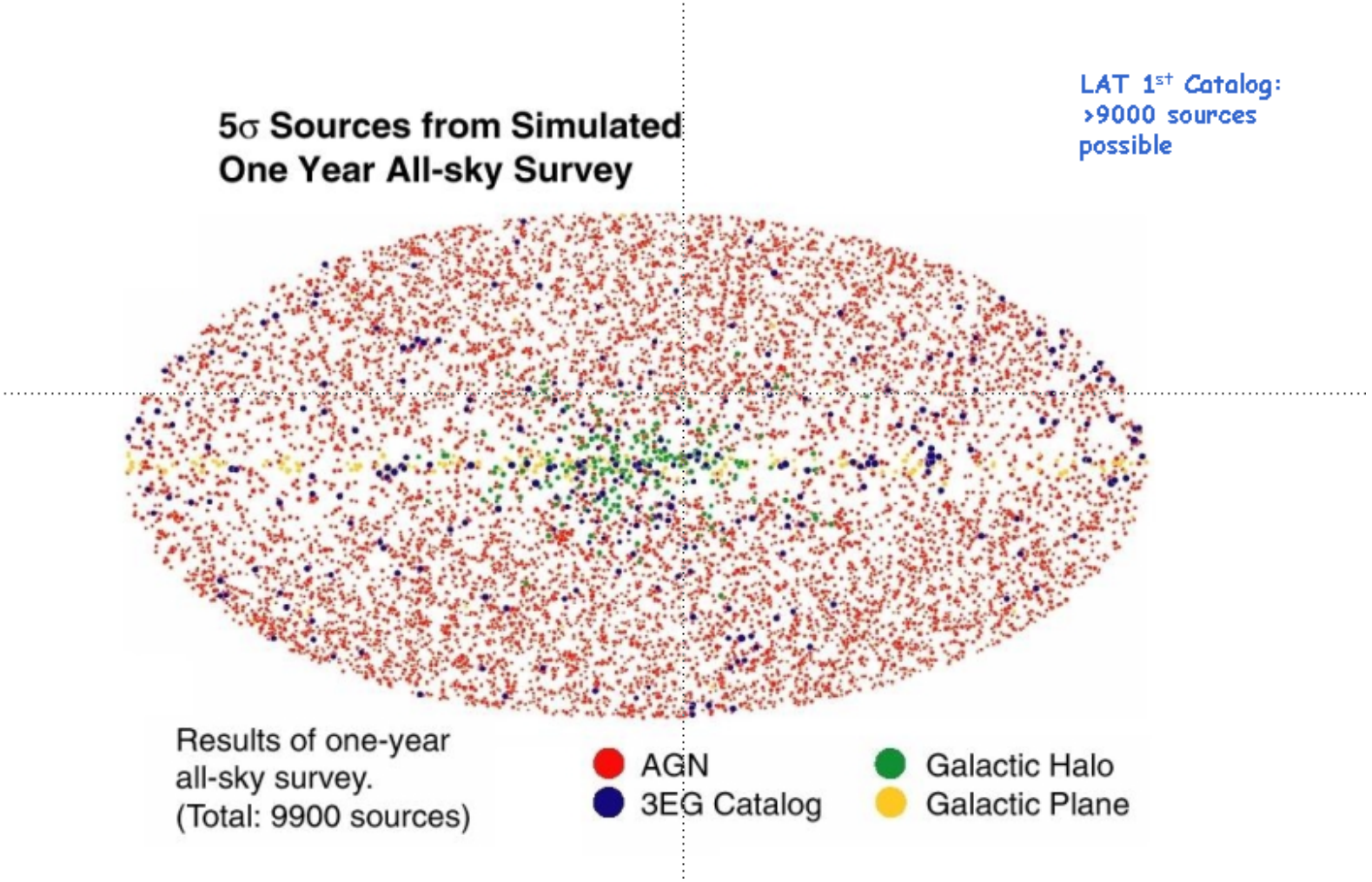
A telescope placed inside the (huge) Cherenkov light pool can obtain an image of the development of the shower above the LONS fluctuations

MAGIC

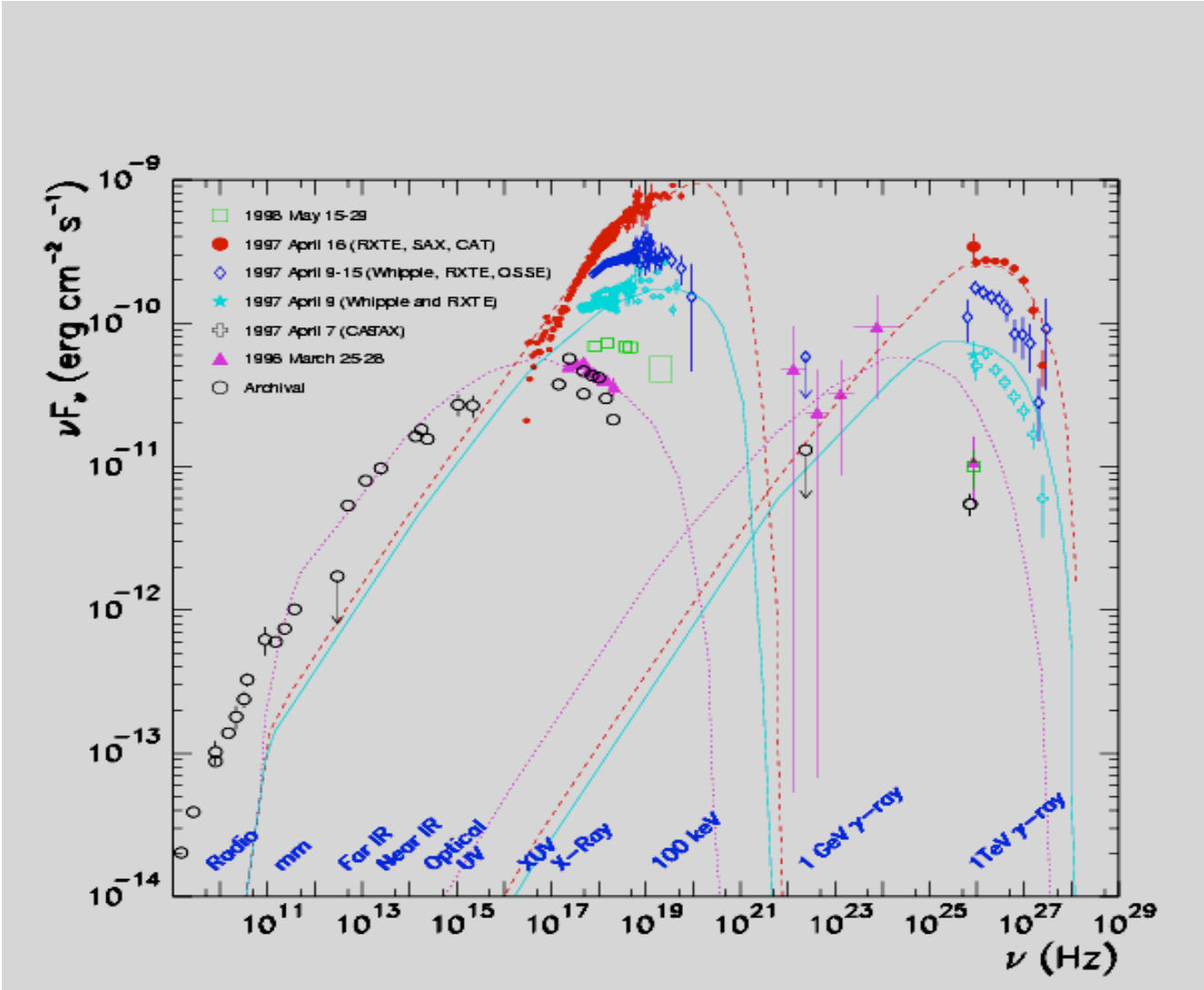



CRAB NEBULA
COMPTEL
Synchrotron
SYNCHROTRON CUTOFF
EGRET
Inverse Compton
WHIPPLE
CANGAROO
ASGAT
HEGRA
THEMISTOCLE
CASA-MIA
Inverse Compton models
(σ = 0.003)
(σ = 0.005)
(σ = 0.007)
E² dN/dE (MeV² cm⁻² s⁻¹ MeV⁻¹)
ENERGY E (MeV)

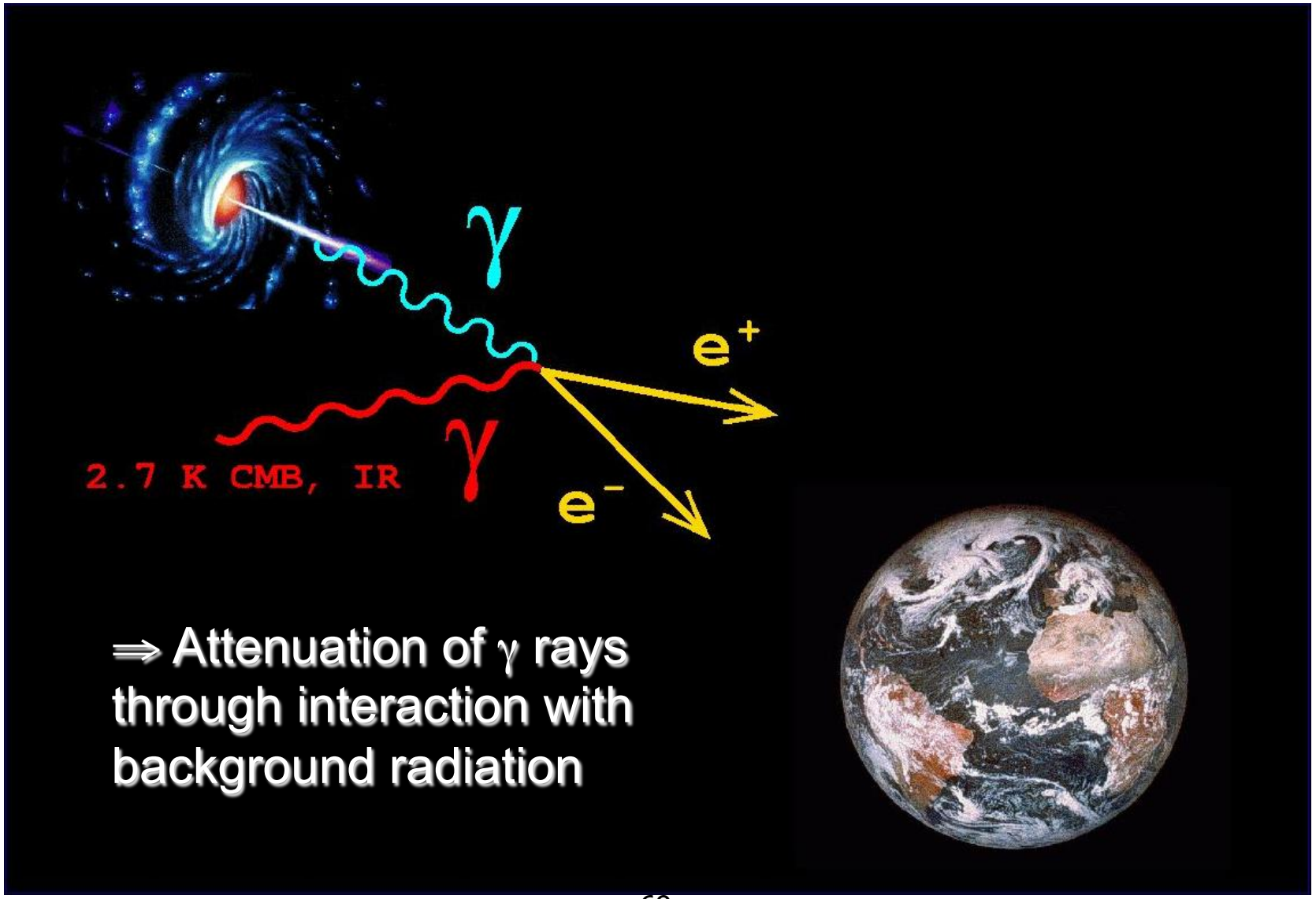
Active Galactic Nuclei



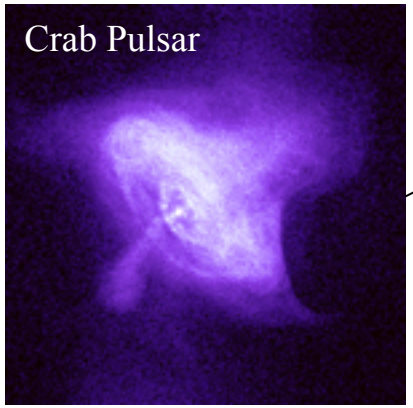
Active Galactic Nuclei

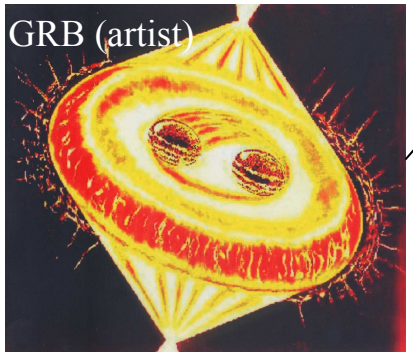


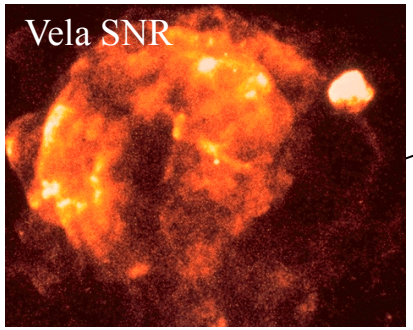
$$\gamma\,\gamma \longrightarrow e^+\,e^-$$

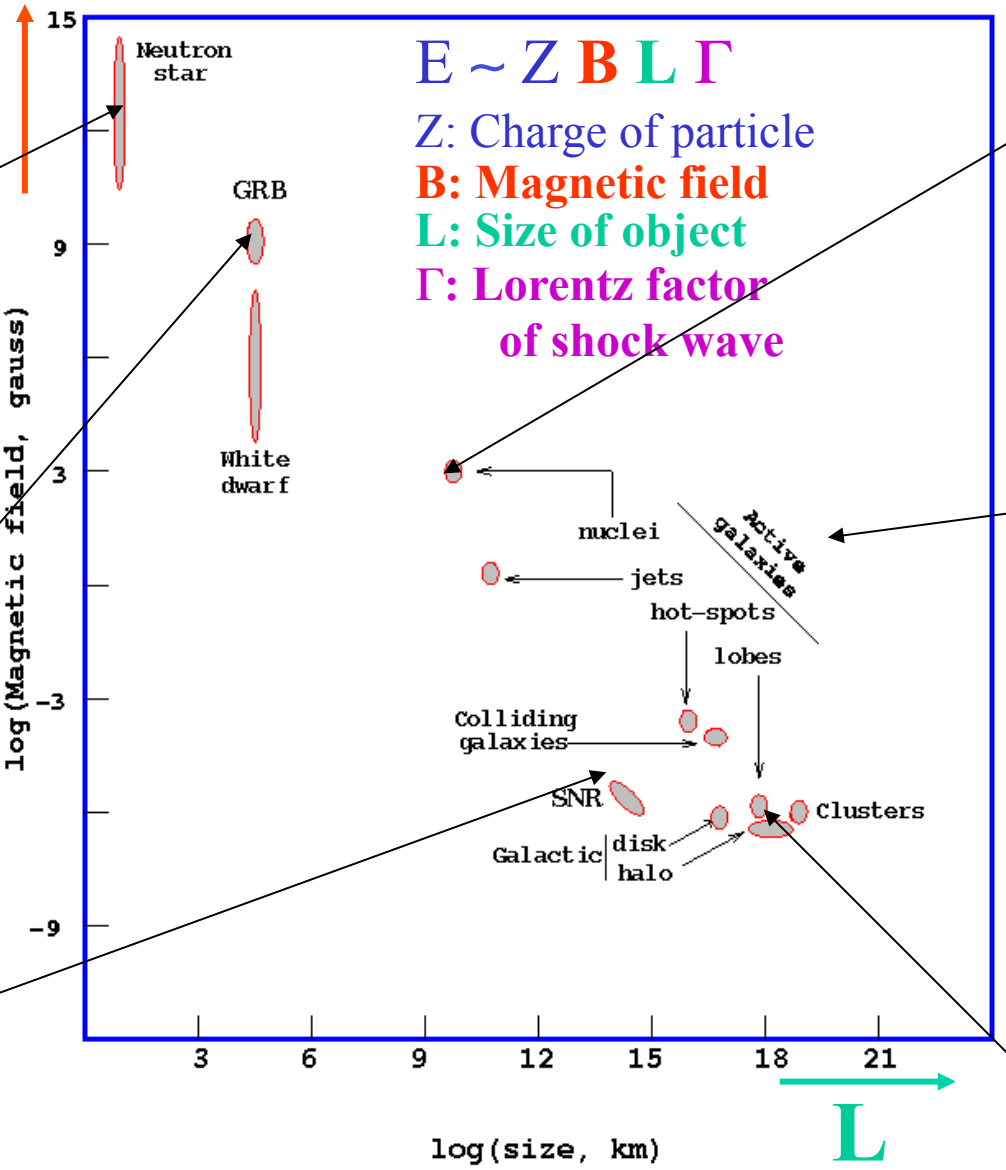


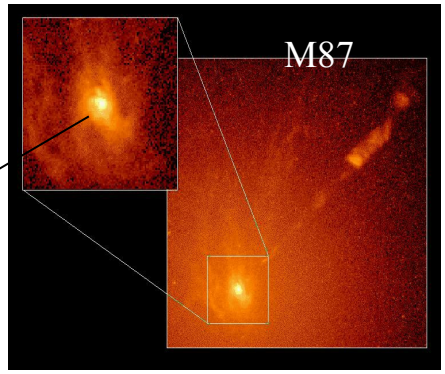
Acceleratori Cosmici: (Hillas Plot)

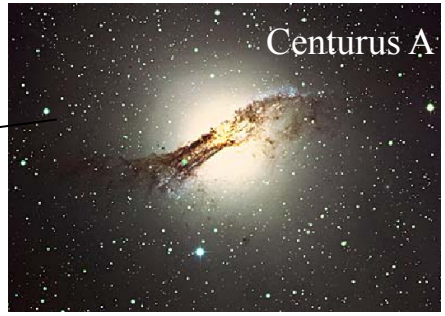


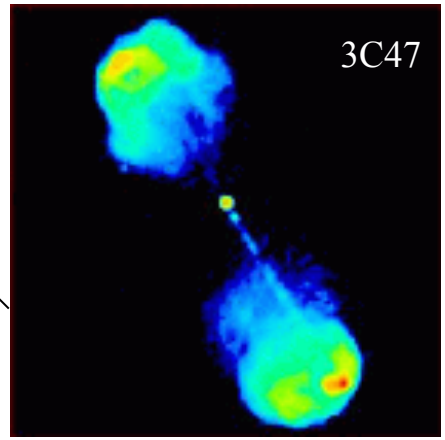




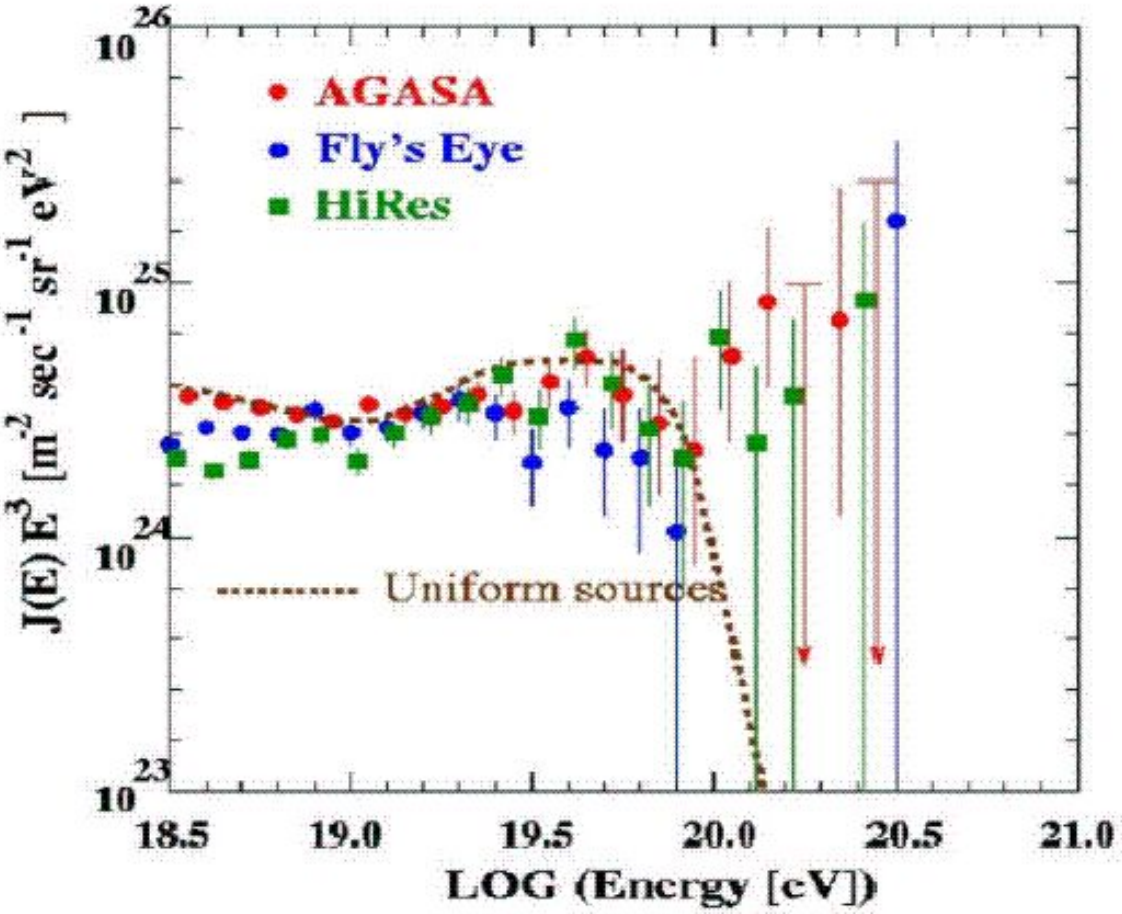




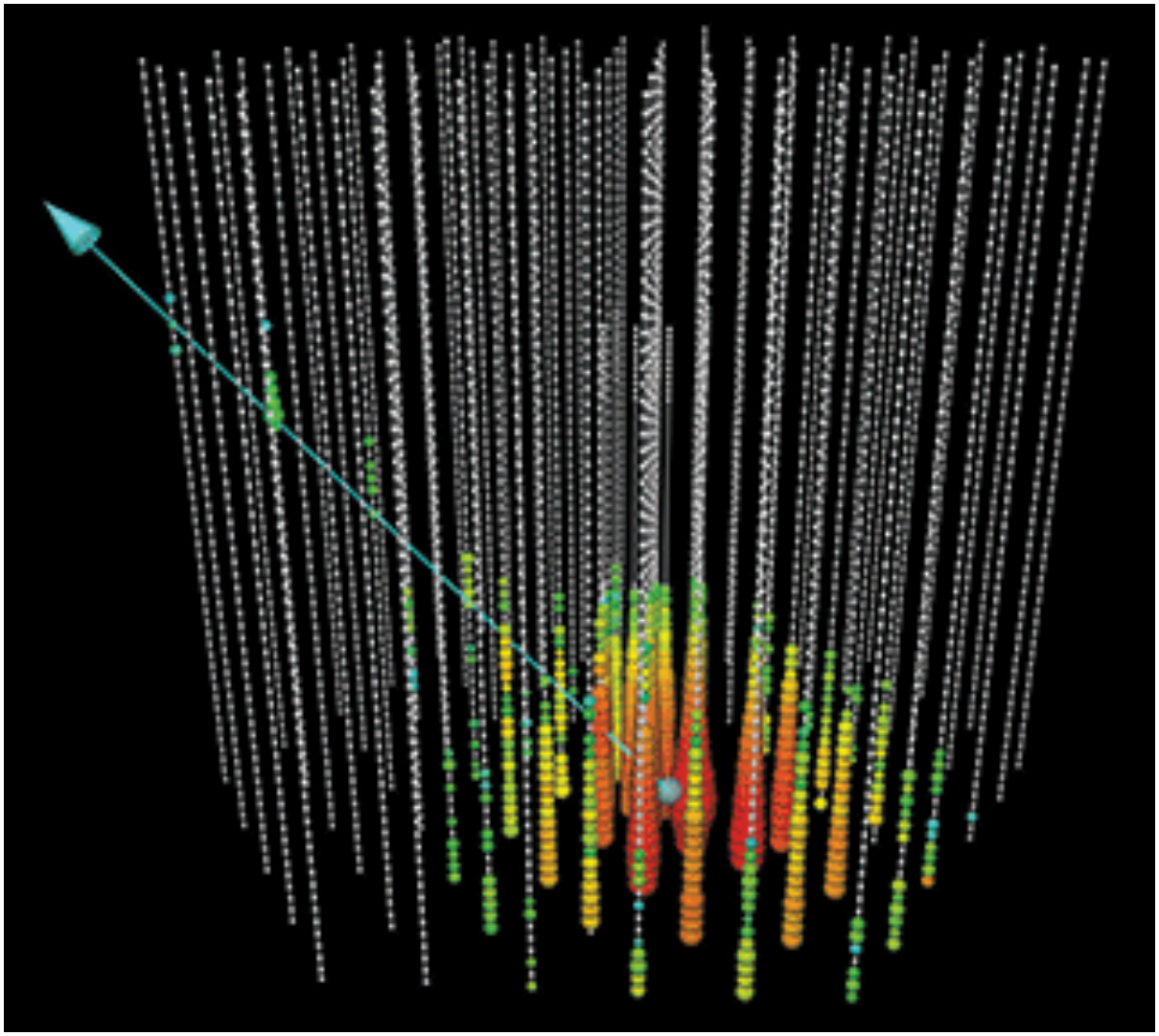




UHECR physics



HE neutrinos



Astrofisica Nucleare e Subnucleare
Introduzione - 2

Organizzazione del corso

- Lezioni frontali
  - Introduzione agli argomenti di Astroparticelle e Astrofisica Nucleare

- Journal Club
  - Lettura di articoli di riferimento del settore
  - Discussione a lezione

- Seminari
  - Invito di esperti del settore (presso UniTs / INFN Ts / INAF Ts)

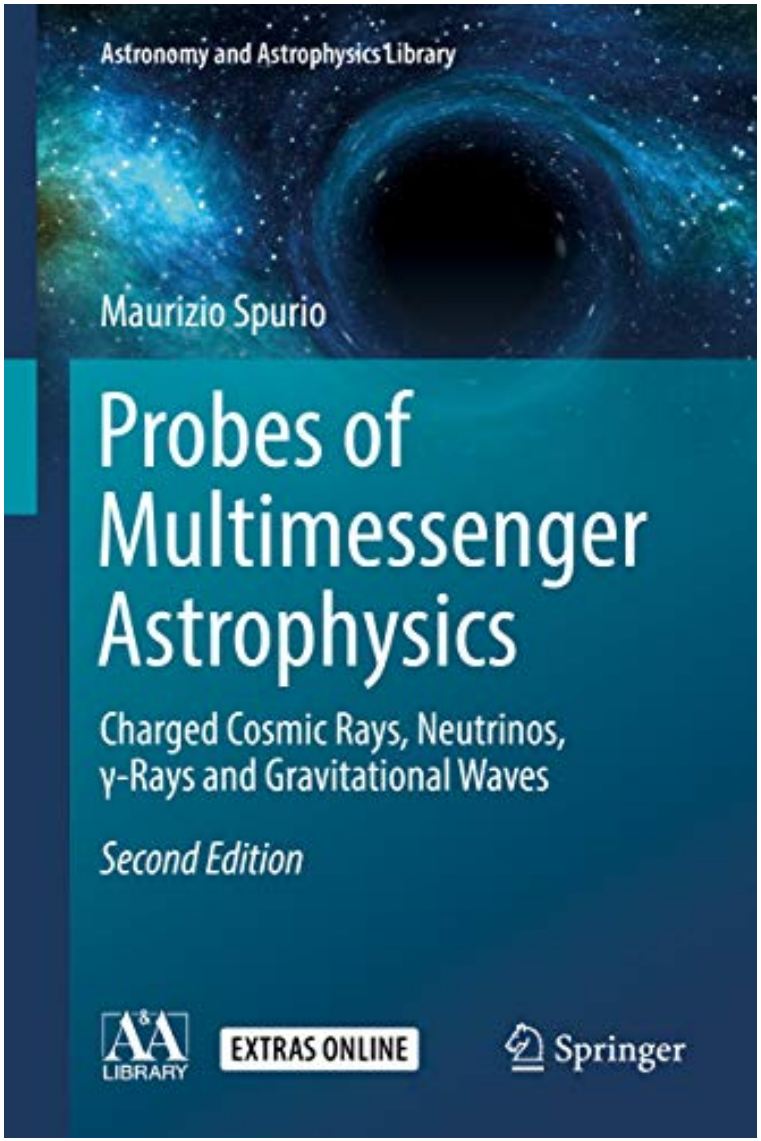
Data Analysis

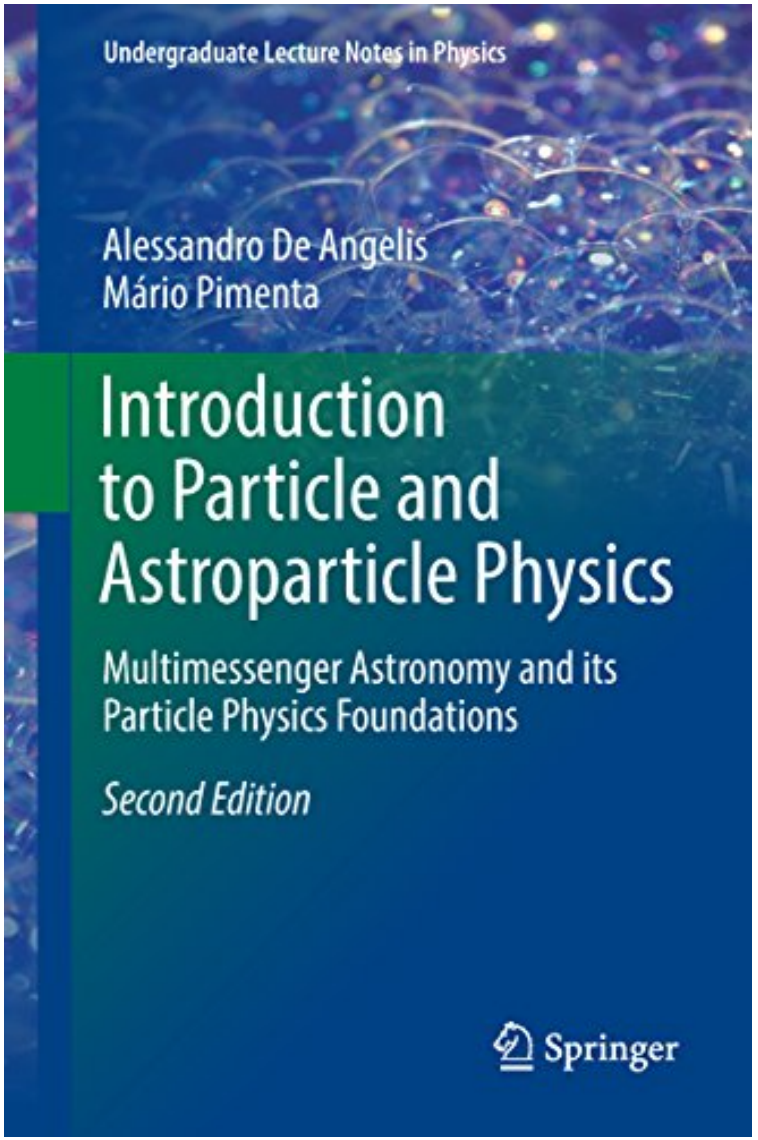
- Gamma Ray data analysis
  - Analysis of MeV GRB data
  - Analysis of GeV Gamma ray data
  - Analysis of TeV Gamma ray simulated data

- Analysis of Multiwavelenght data
  - Look for CR open data

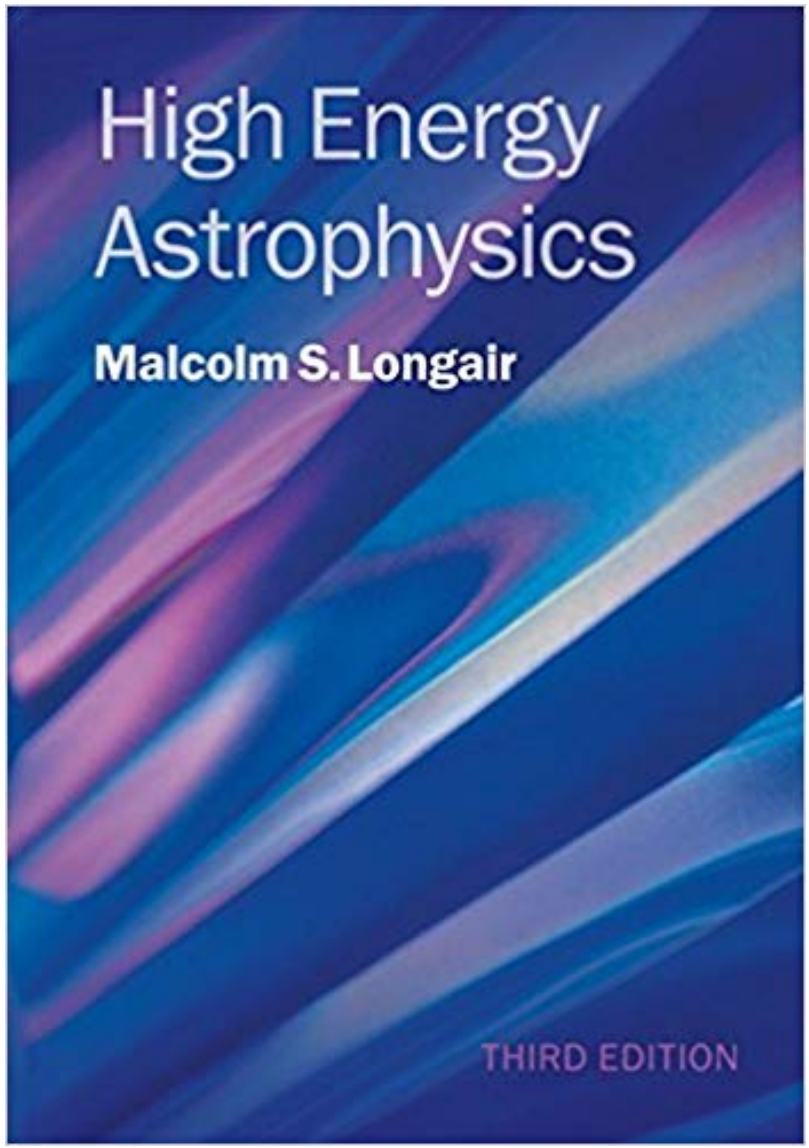
- Simulations of Astroparticle experiments
  - G4 simulation toolkit introduction

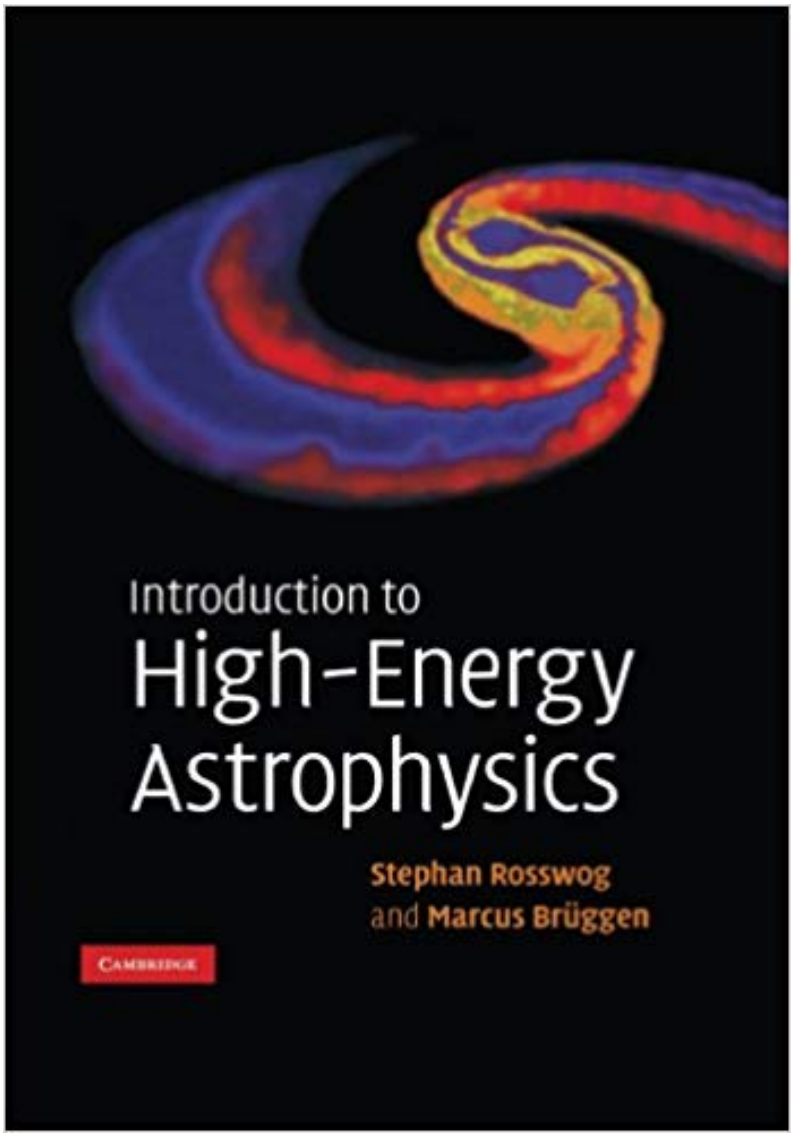
Testi


Astronomy and Astrophysics Library
Maurizio Spurio
Probes of Multimessenger Astrophysics
Charged Cosmic Rays, Neutrinos, γ-Rays and Gravitational Waves
Second Edition
A&A LIBRARY
EXTRAS ONLINE
Springer


Undergraduate Lecture Notes in Physics
Alessandro De Angelis
Mário Pimenta
Introduction to Particle and Astroparticle Physics
Multimessenger Astronomy and its Particle Physics Foundations
Second Edition
Springer

Testi


High Energy
Astrophysics
Malcolm S. Longair
THIRD EDITION


Introduction to
High-Energy
Astrophysics
Stephan Rosswog
and Marcus Brüggen
CAMBRIDGE

Astrofisica Nucleare e Subnucleare
Introduzione - 3

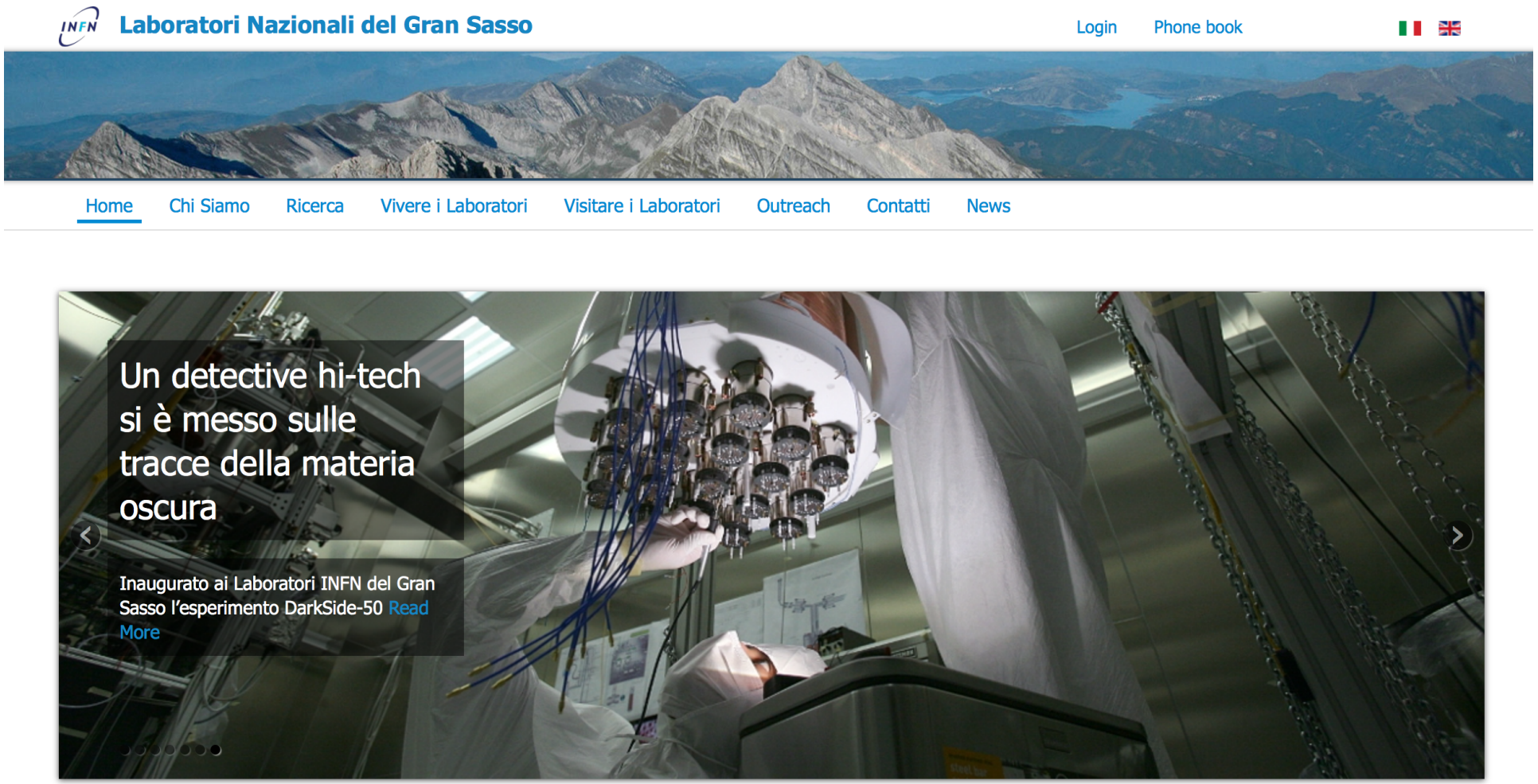
L'INFN

La fisica delle Astroparticelle

L'INFN

www.infn.it

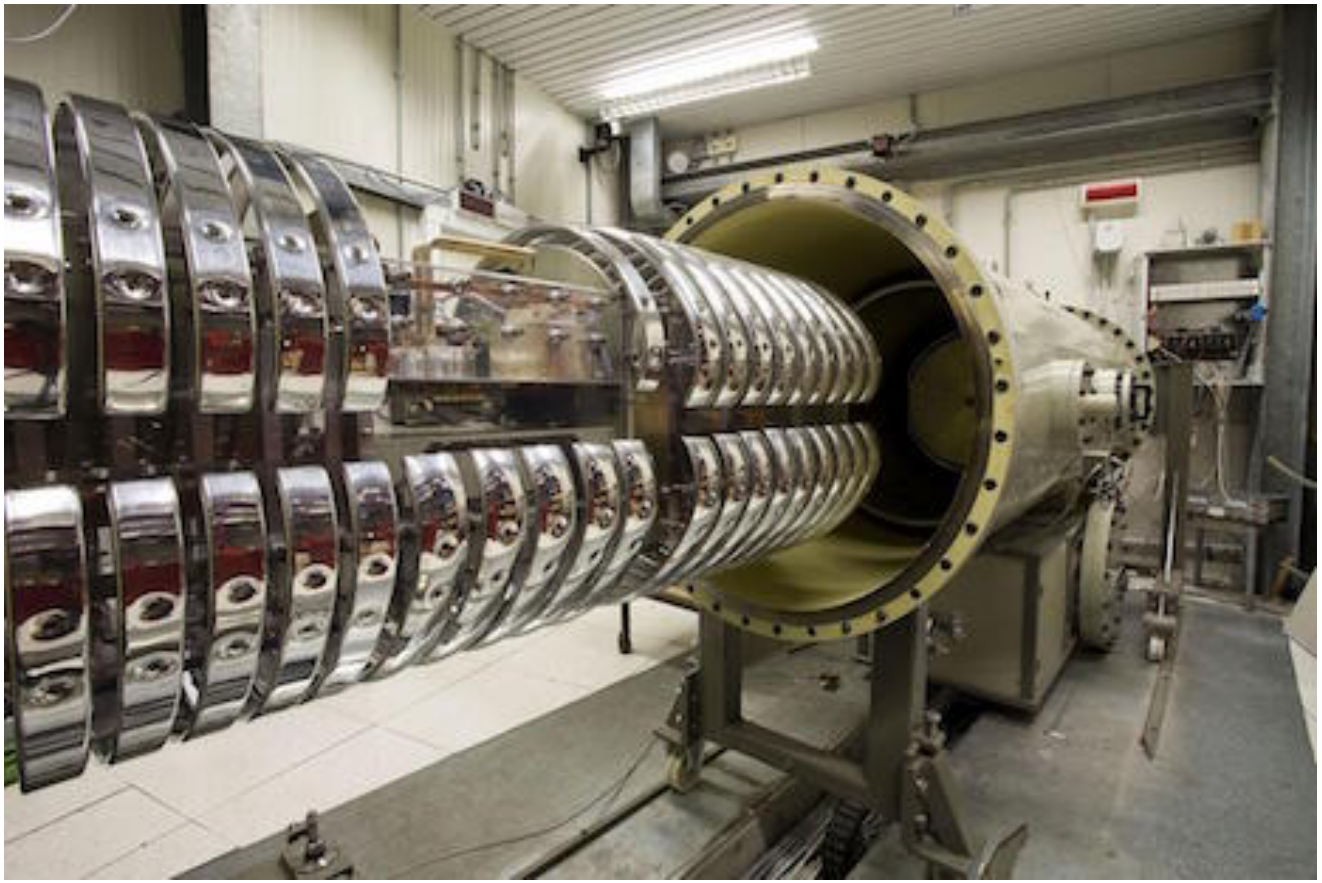
I laboratori dell'INFN



www.lngs.infn.it

I laboratori del Gran Sasso

I meccanismi delle Stelle



L’esperimento LUNA

La Materia Oscura

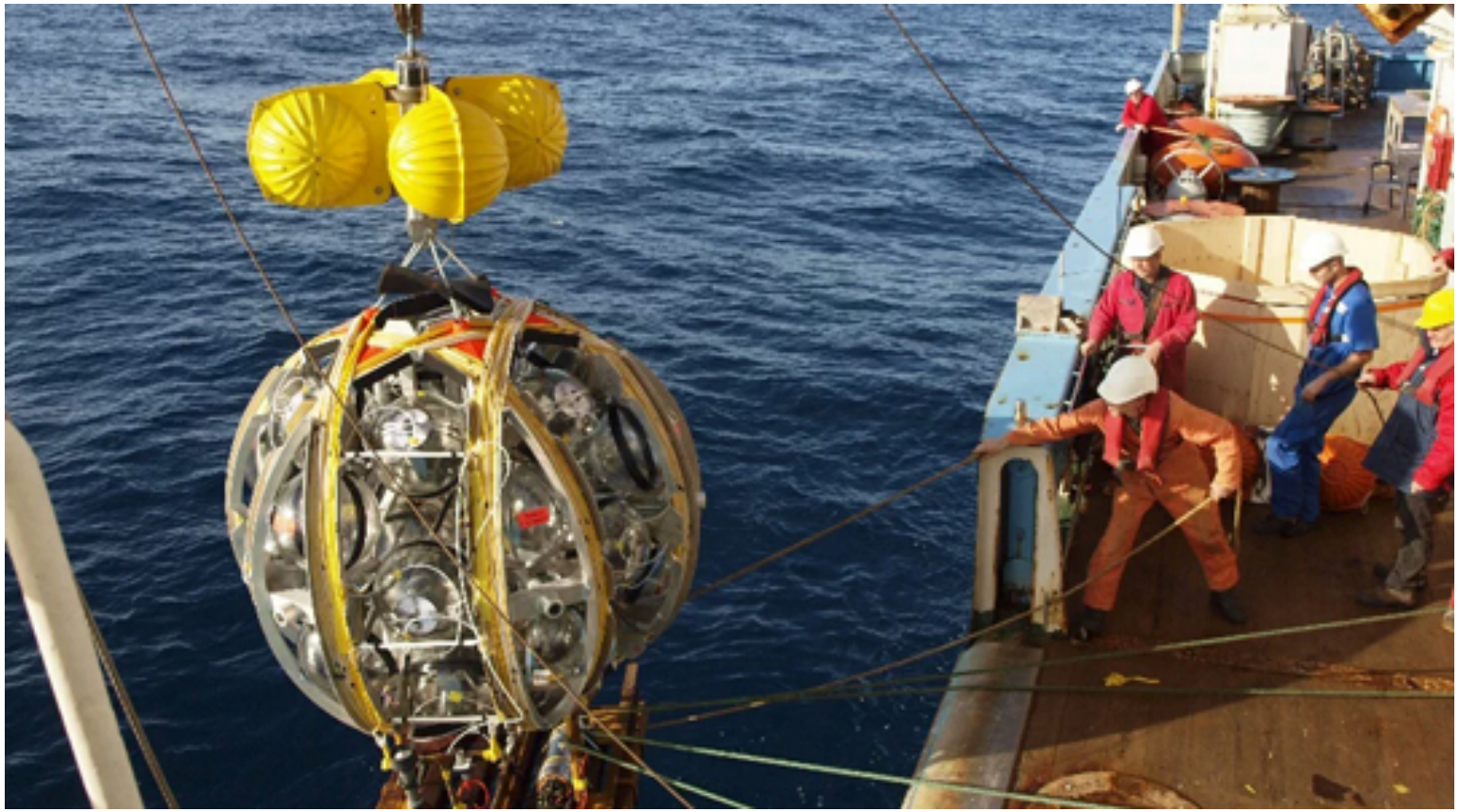
L’esperimento DAMA

I laboratori Nazionali del Sud

www.lns.infn.it

I neutrini astrofisici

I neutrini astrofisici



I laboratori Nazionali di Legnaro

www.lnl.infn.it

Le onde gravitazionali

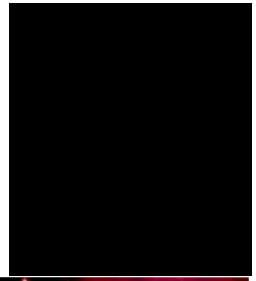
Il progetto SPES

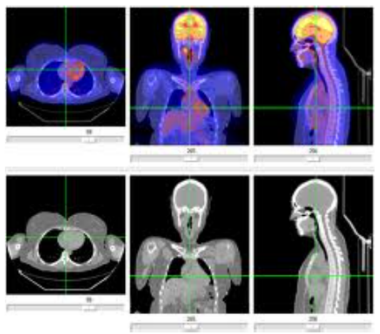
SPES: il progetto principale del laboratorio

- **SPES= Selective Production of Exotic Species**

- **studio di nuclei atomici prodotti nelle fasi avanzate dell'evoluzione stellare**
- **produzione di radioisotopi di interesse sanitario**

-In breve , dalle stelle alla società

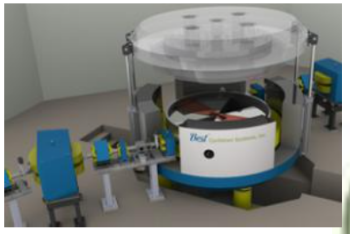




Il progetto SPES

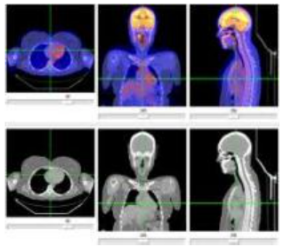
Le quattro fasi del progetto SPES

INFN Istituto Nazionale di Fisica Nucleare



Ciclotrone e infrastruttura

Facility per fasci di ioni radioattivi



Radioisotopi per la salute

Sorgenti di neutroni basate su acceleratori

6