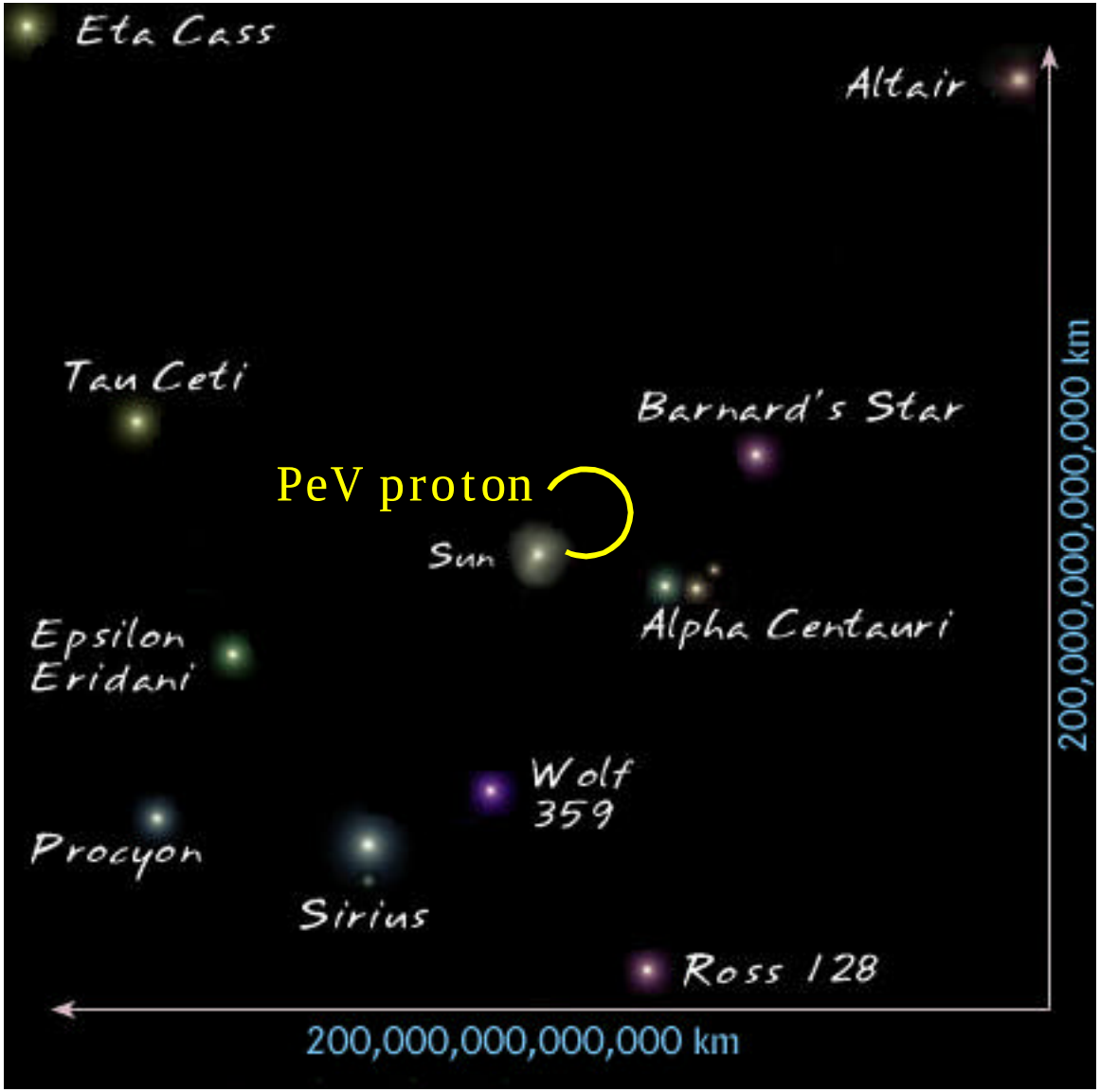
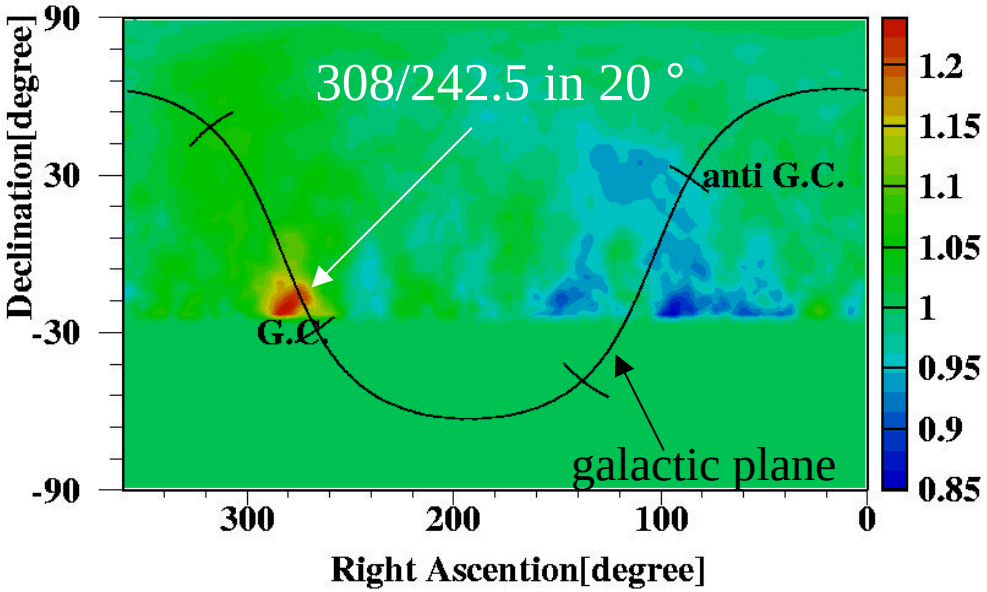
# Cosmic rays cannot be used to image the Universe...



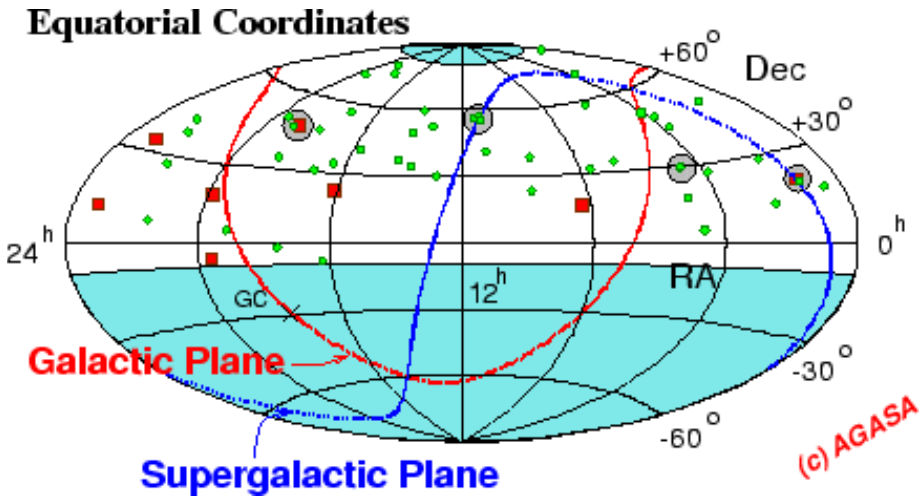

M. Masetti

# But we try anyway...

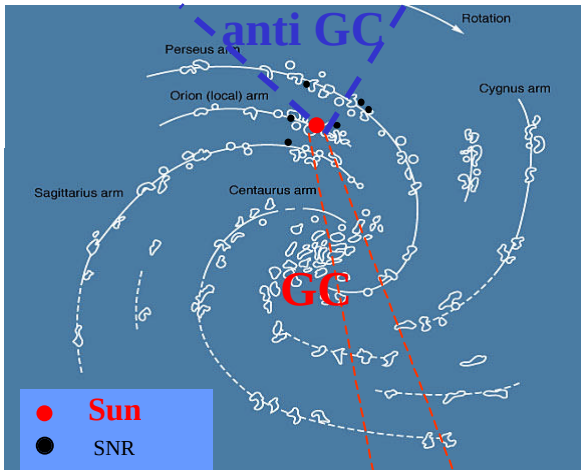
$8 \times 10^{17} < E < 8 \times 10^{18}$ eV




$E > 4 \times 10^{19}$ eV




**Galactic source ?**



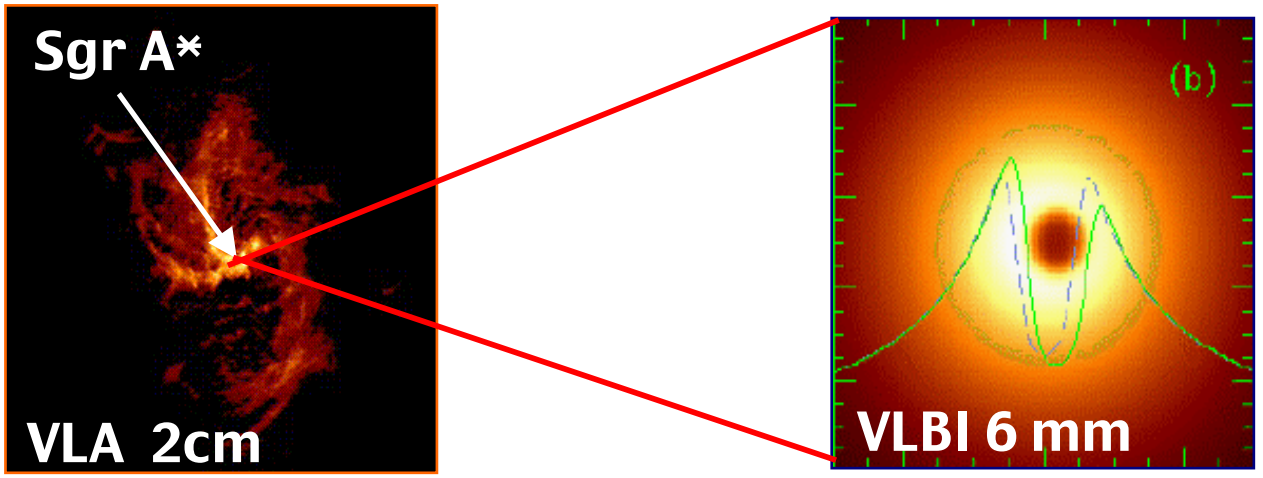

See events from same place in < 2.5° 3 doublets and 1 triplet

Are these sources?

Or random chance coincidences?
Probability < 1% that is chance

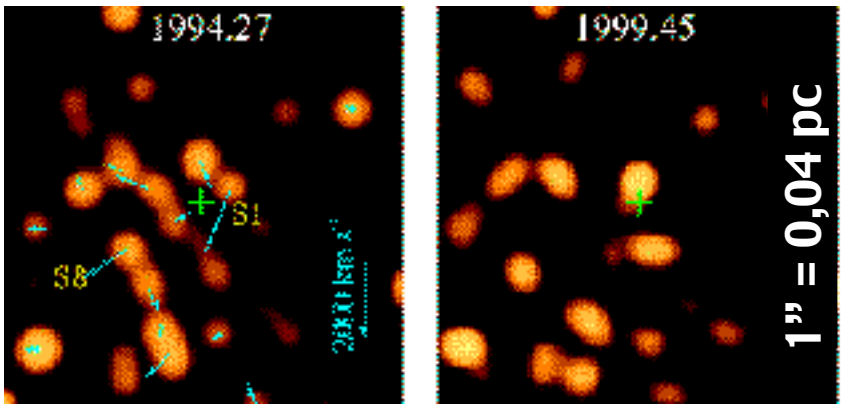
# Black Hole at Galactic Centre

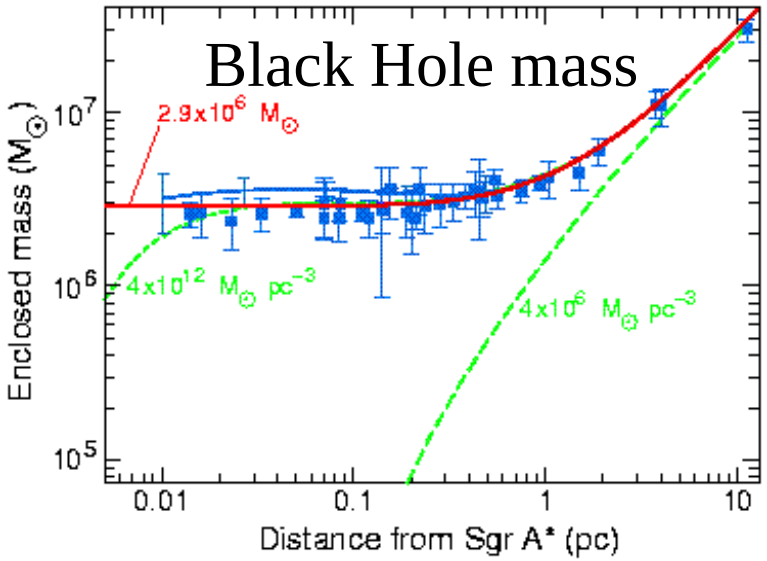
**Radio**




Black Hole horizon ?

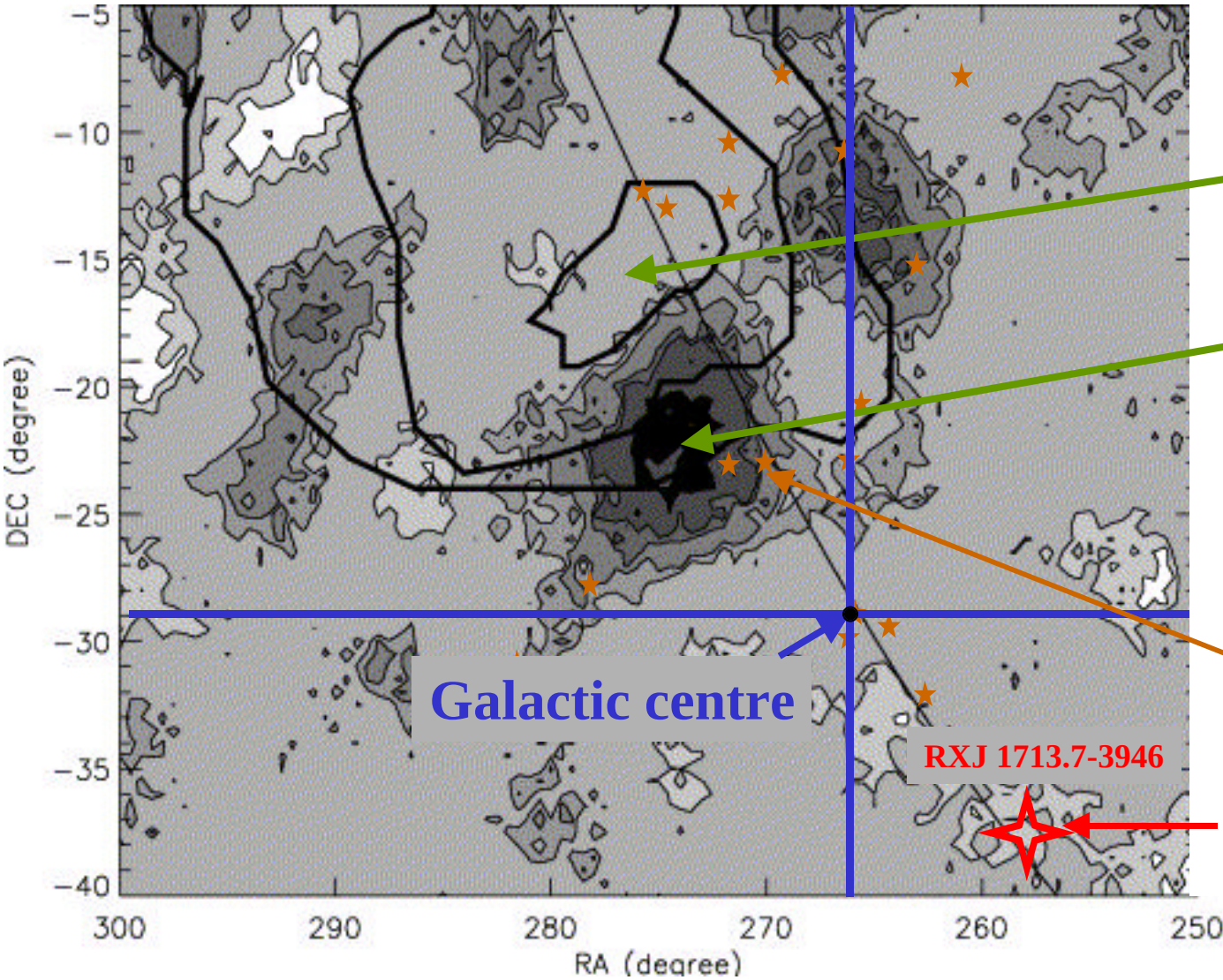
**Infrared**



# Galactic Centre in Multi-Messengers

**Cosmic Rays E ~ $10^{18}$ eV**




**Cosmic Rays**

**AGASA**
**"4.5σ" effect**

**SUGAR**
**"<0.5% fluctuation"**

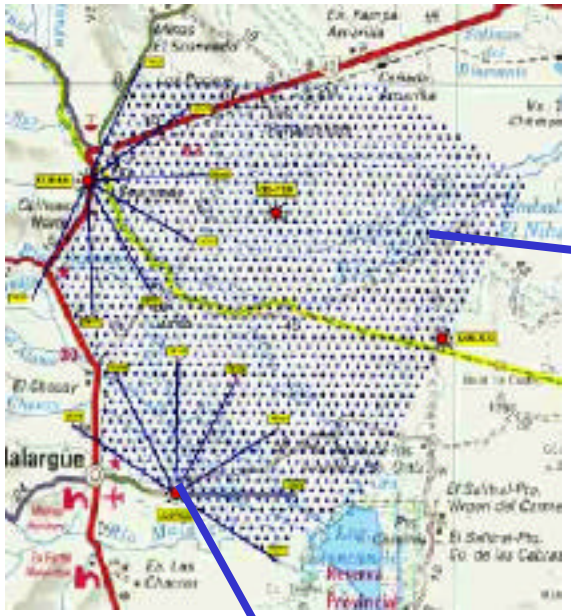
**Cosmic Ray Source**
**~ 7°**
**from Galactic Centre**

**GeV Gamma rays**
**(EGRET sources)**

**TeV Gamma rays**

# AUGER experiment

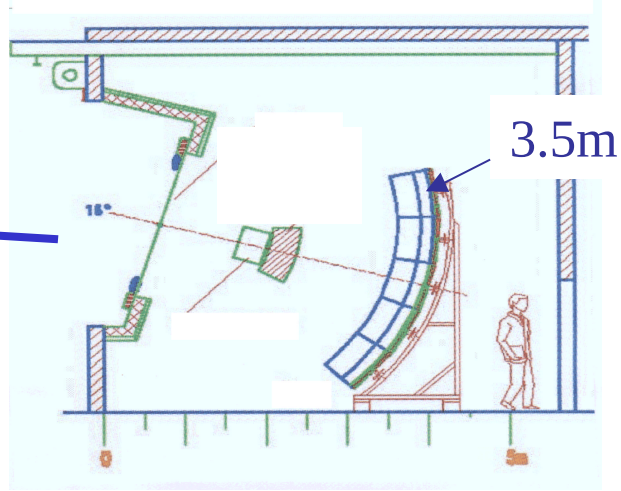
2 sites each 3000km$^2$, E > 5.10$^{18}$eV




Southern site,
Mendoza Province,
Argentina

Water Cherenkov
Tanks
(1600 each 10m$^2$)

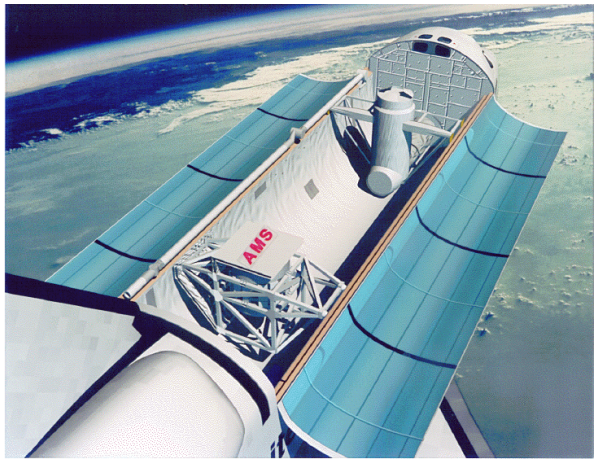
Fluorescence Telescopes (6 telescopes each 30° ×30° at 4 sites)

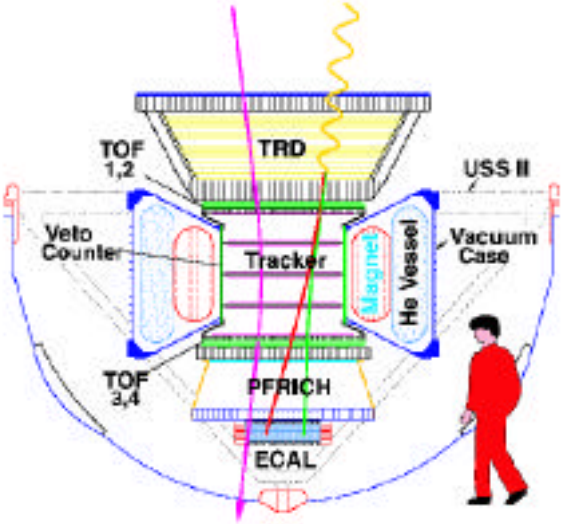


# AMS Experiment

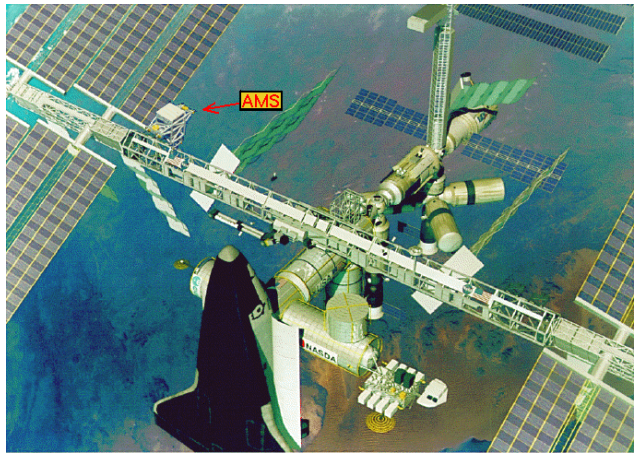
## Detailed measurements on Cosmic Ray composition: anti-matter ?

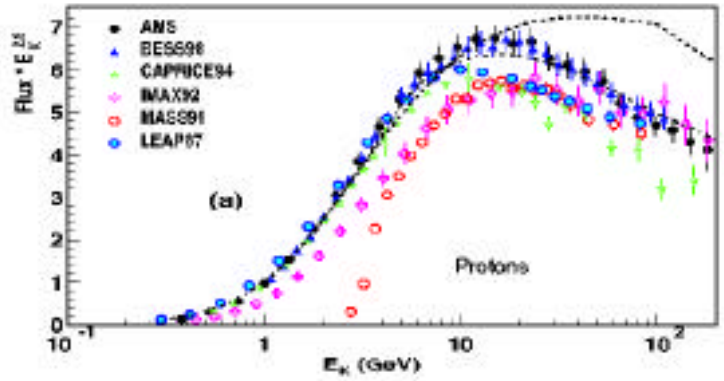
Space Shuttle June 1998

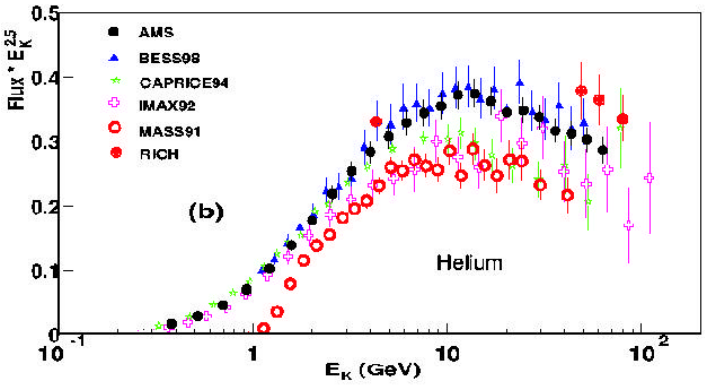



International Space Station 2004



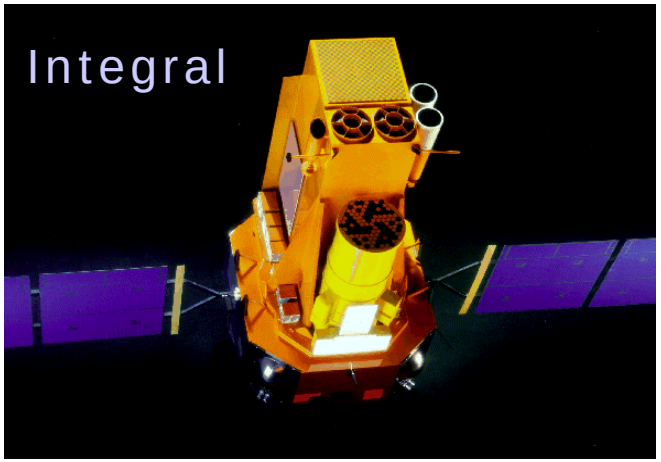



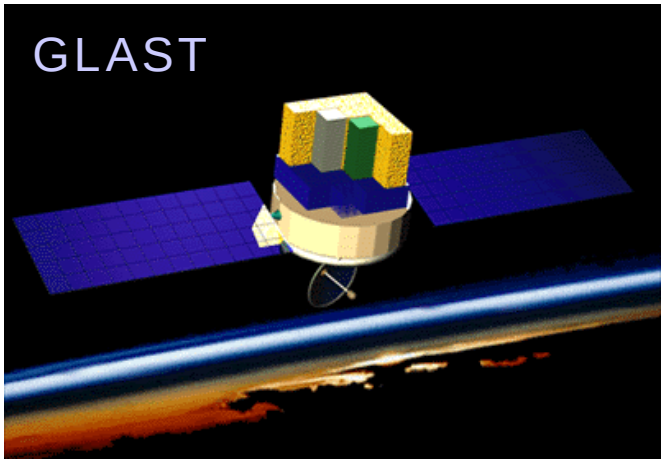




limit on anti-helium/helium ratio < $10^{-6}$

# Gamma Ray Astronomy

## Low Energy Gamma Astronomy from satellites

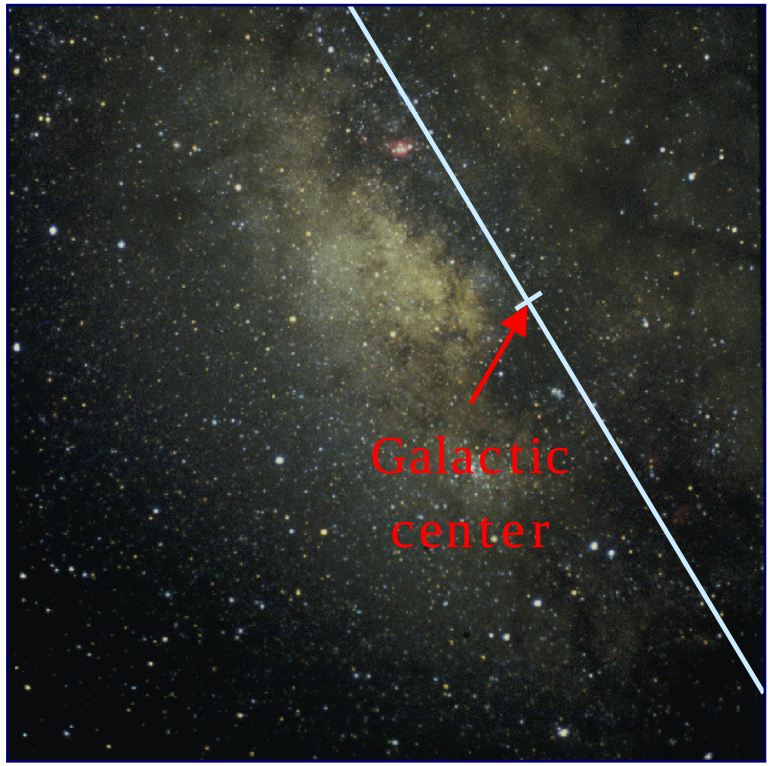



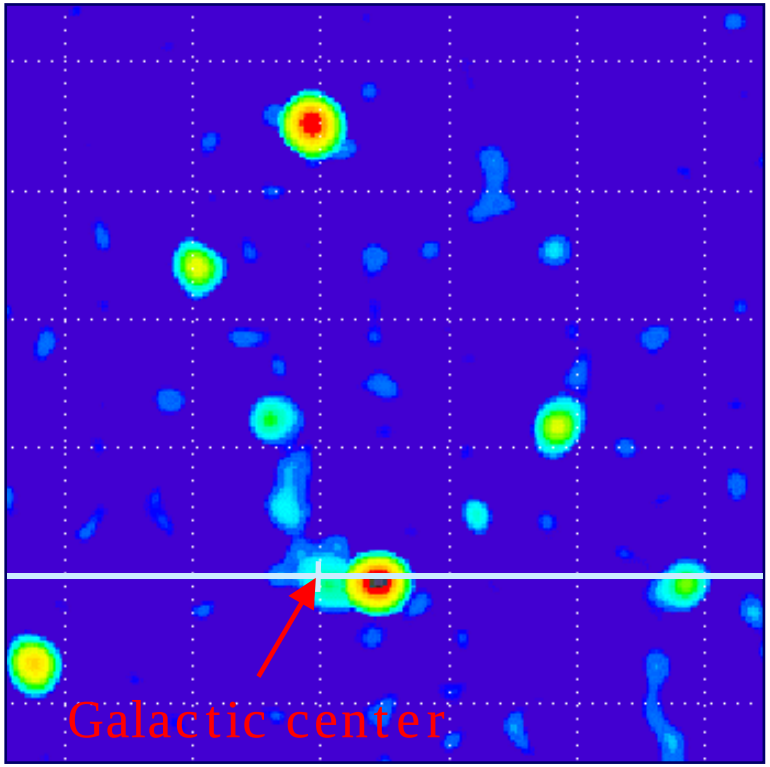

## High Energy Gamma Astronomy from ground

# Advantage of gamma-ray astronomy

- The penetrating power of gamma-ray photons
  - Media optically thick at other _
  - Regions masked at other _, as the Galactic center

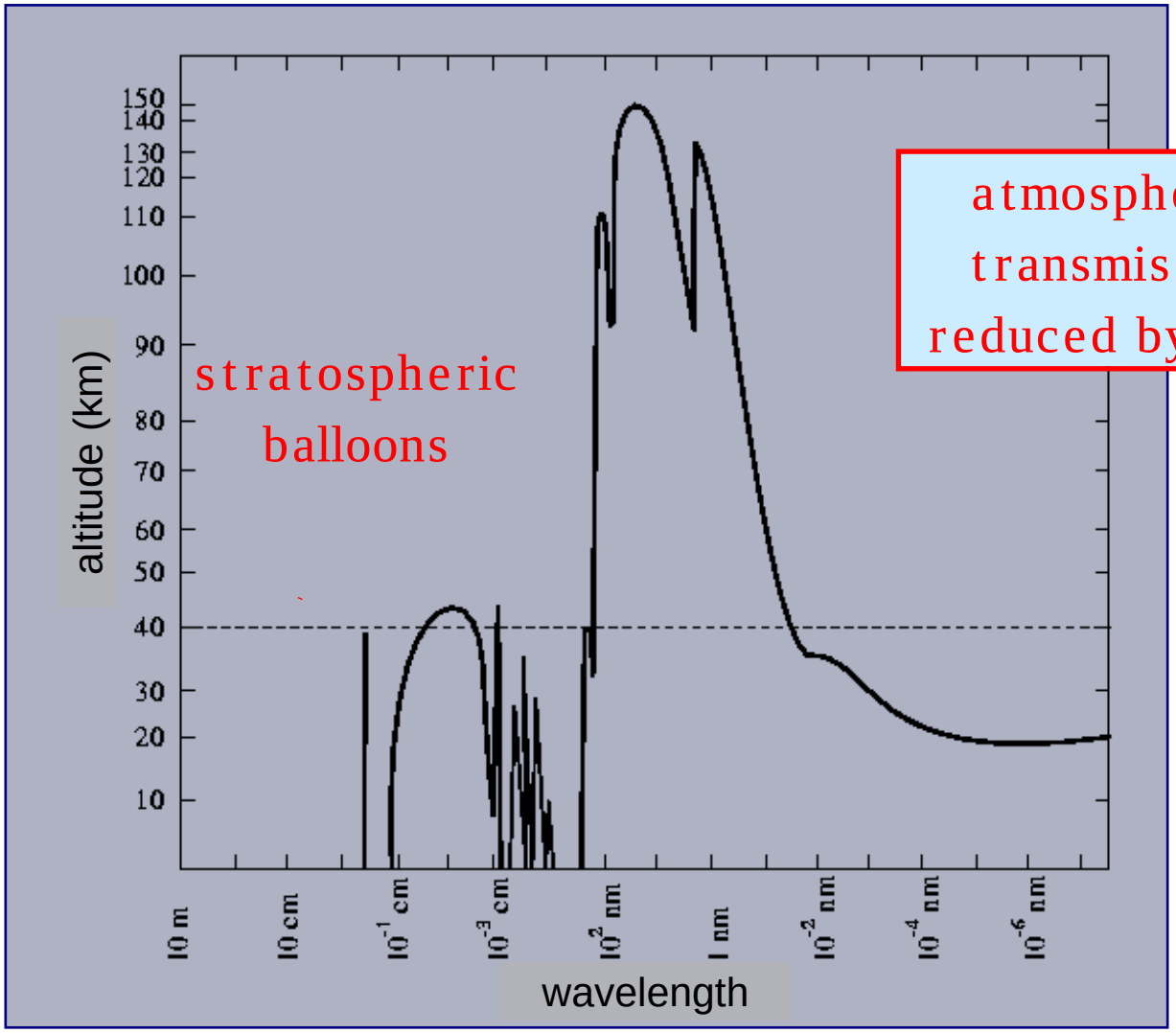



Visible band

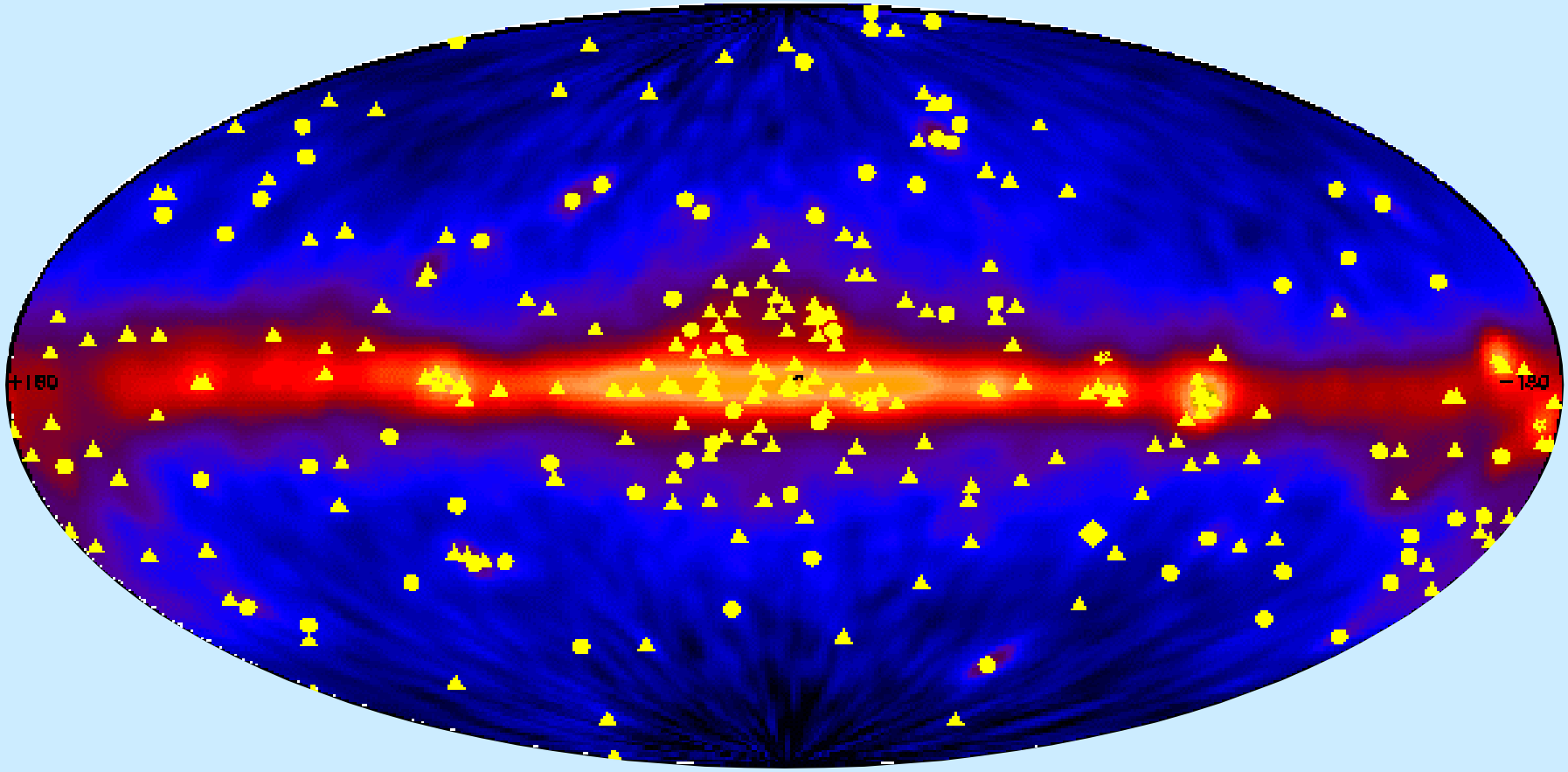



Soft gamma rays (40-80 keV)

# Why in Space ?


altitude (km)
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
stratospheric balloons
atmospheric transmission reduced by 50%
10 m
10 cm
$10^{-1}$ cm
$10^{-3}$ cm
$10^{2}$ nm
1 nm
$10^{-2}$ nm
$10^{-4}$ nm
$10^{-6}$ nm
wavelength

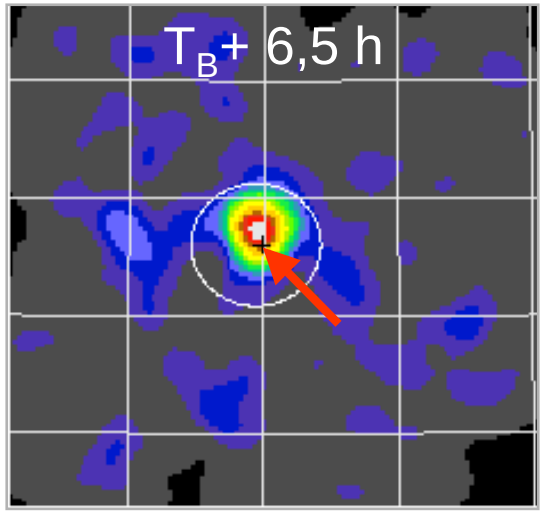
# Gamma Ray Sky Map

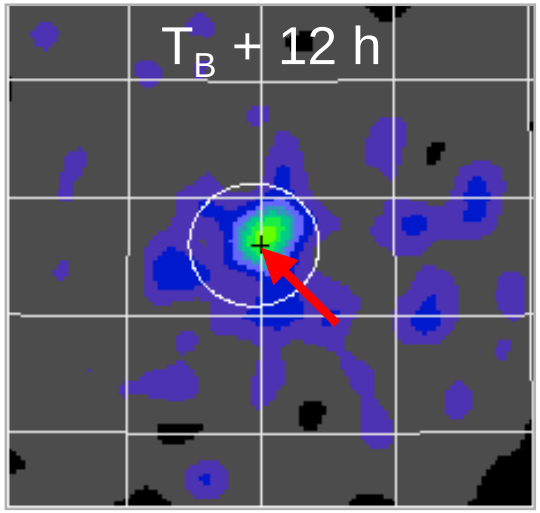


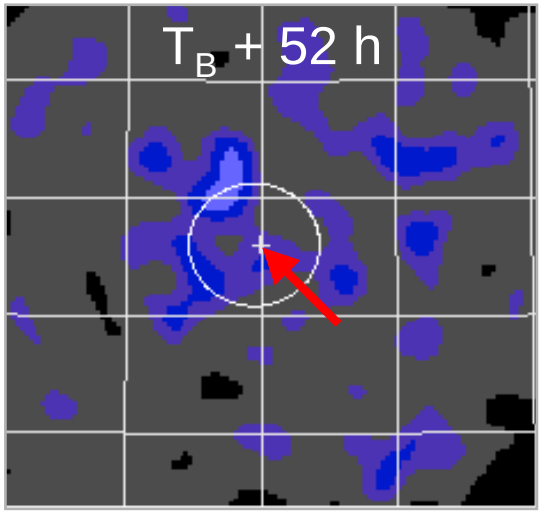

EGRET catalog of high-energy gamma-ray sources
including tens of blazars

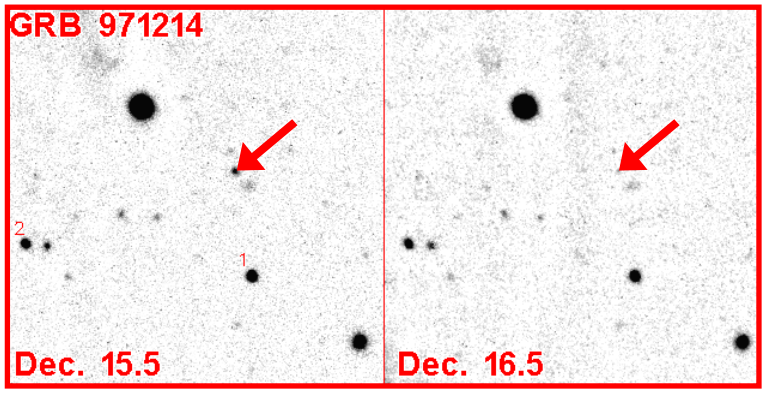
# Gamma Ray Burst

Beppo-SAX



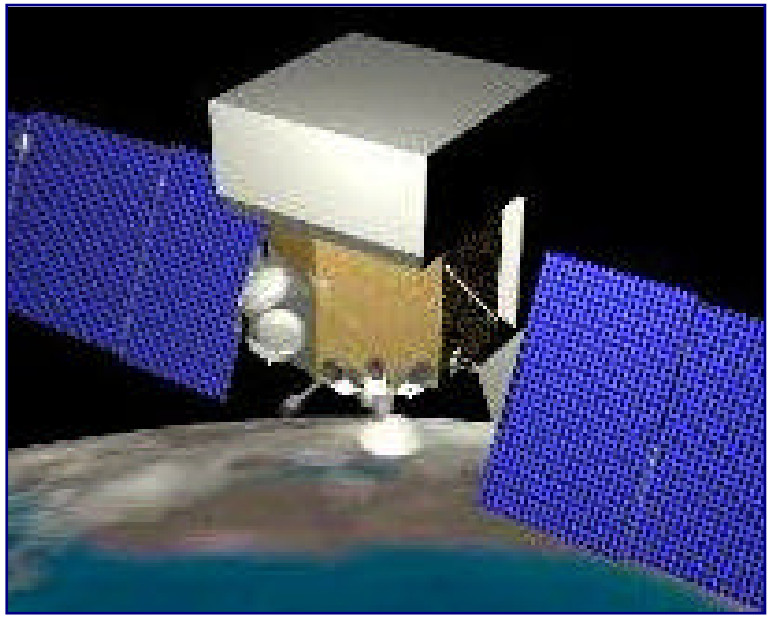




Afterglow in the visible

Afterglow of GRB 971214

Fading X-ray source detected in the 1.3-10 keV band within the gamma-ray burst error box by the focusing telescope aboard BeppoSAX satellite

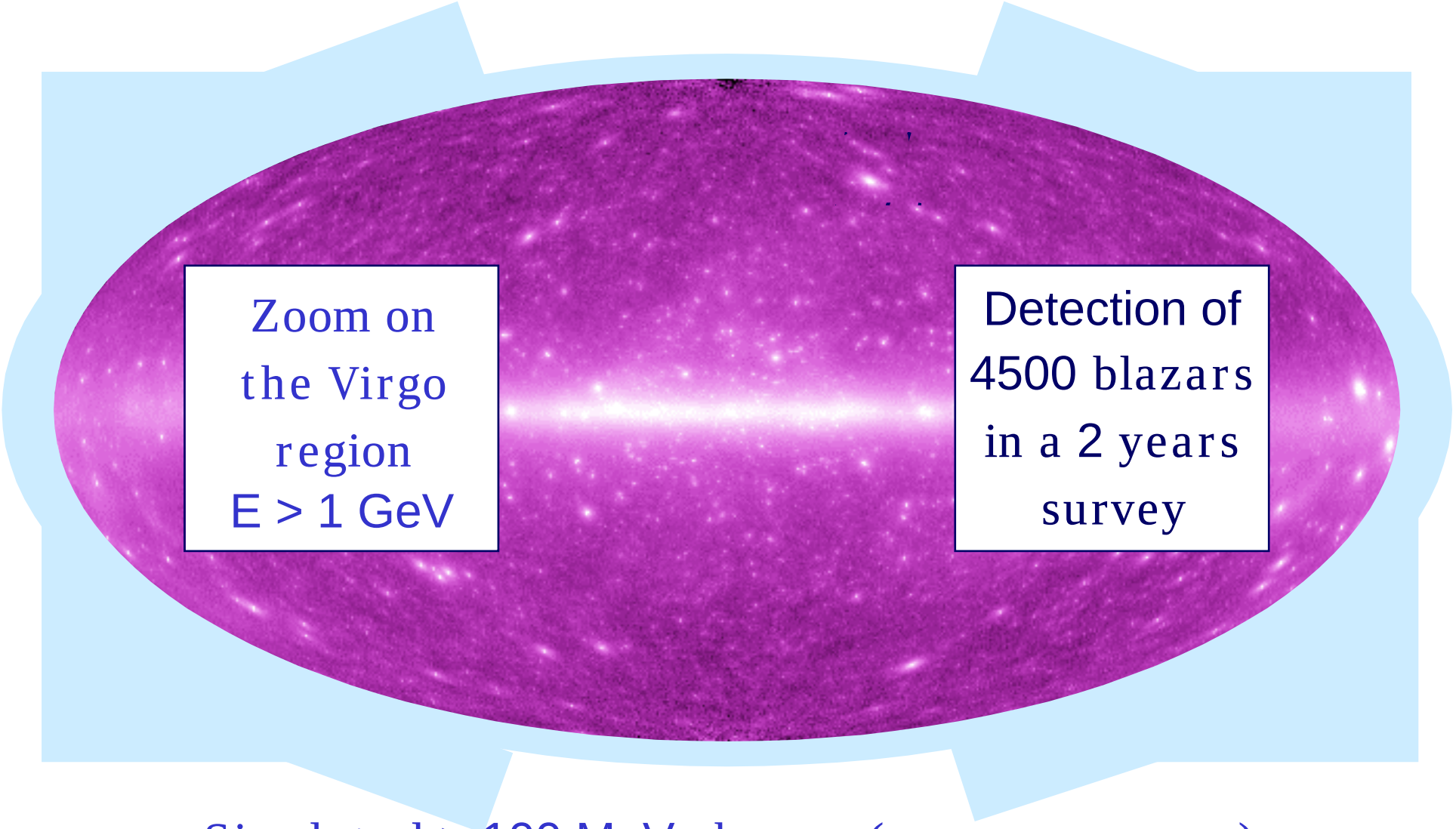
# Future of satellite gammas: GLAST



- Launched in 2005
  Lifetime: 5 y (goal 10 y)
- Payload to be built by a wide collaboration of Astrophysics and Particle Physics institutes in USA, France, Italy, Germany, Sweden and Japan

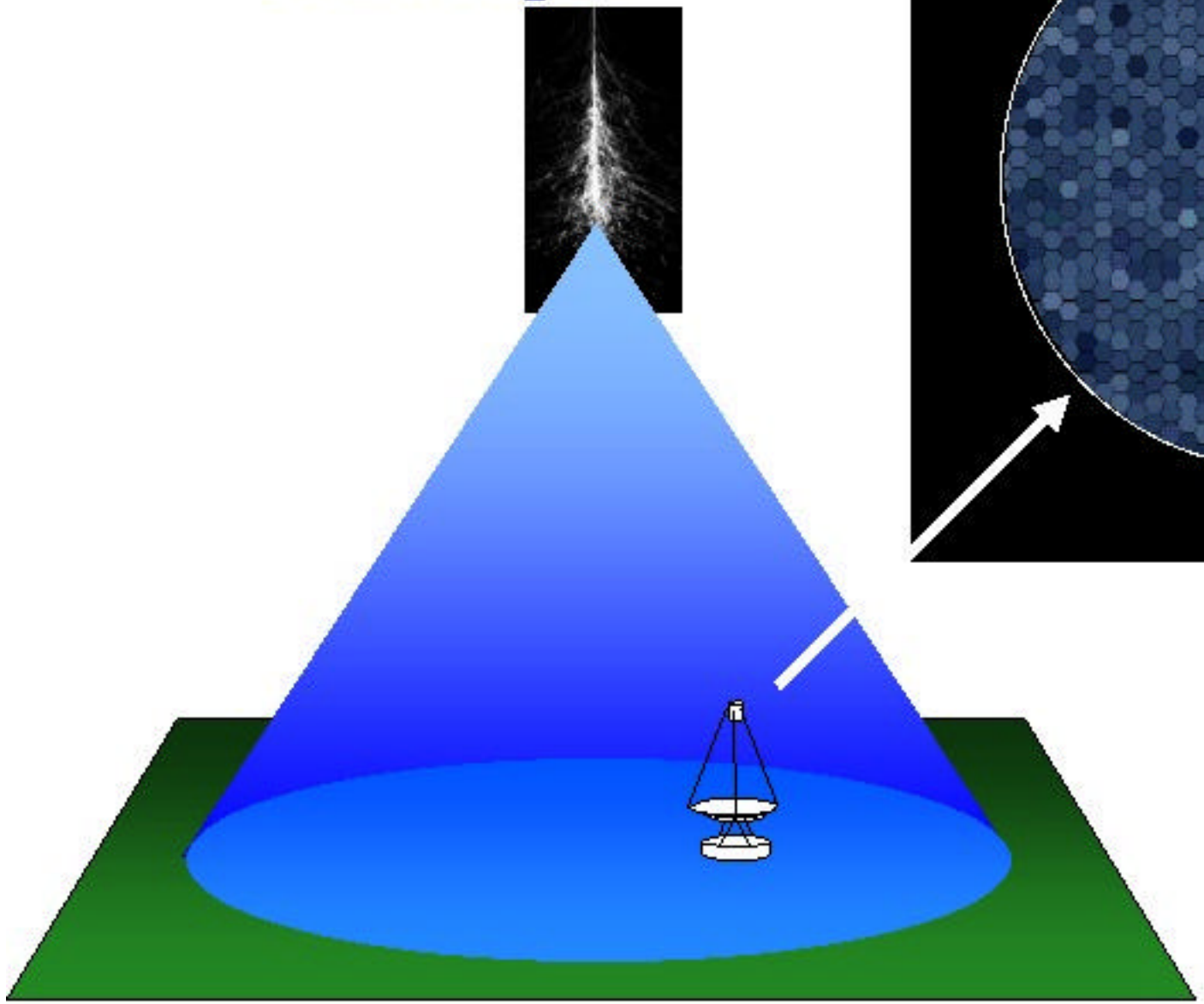
| | |
|---|---|
| Energy range: | 10 MeV to > 300 GeV |
| Field of view: | > 3 sr |
| Source location accuracy: | 30” - 1’ |
| Energy resolution (1 _): | 2% (> 10 GeV) |
| Sensitivity (2-y survey): | $2\ 10^{-9}$ cm$^{-2}$ s$^{-1}$ (> 100 MeV) |

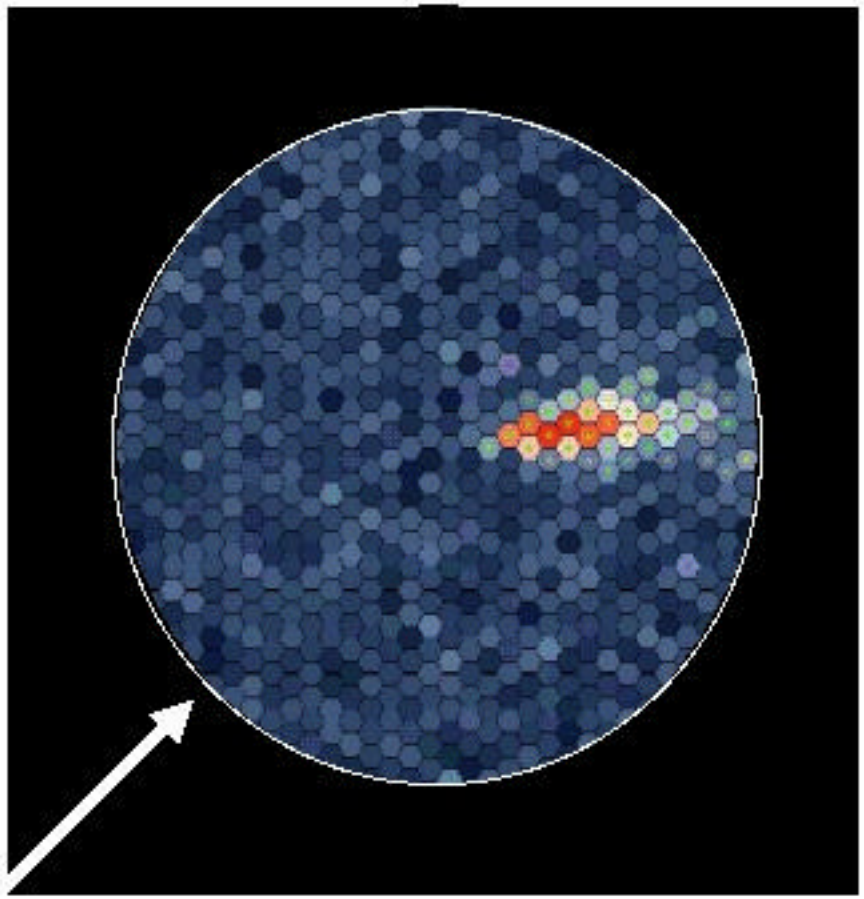
# GLAST: Thousands of blazars



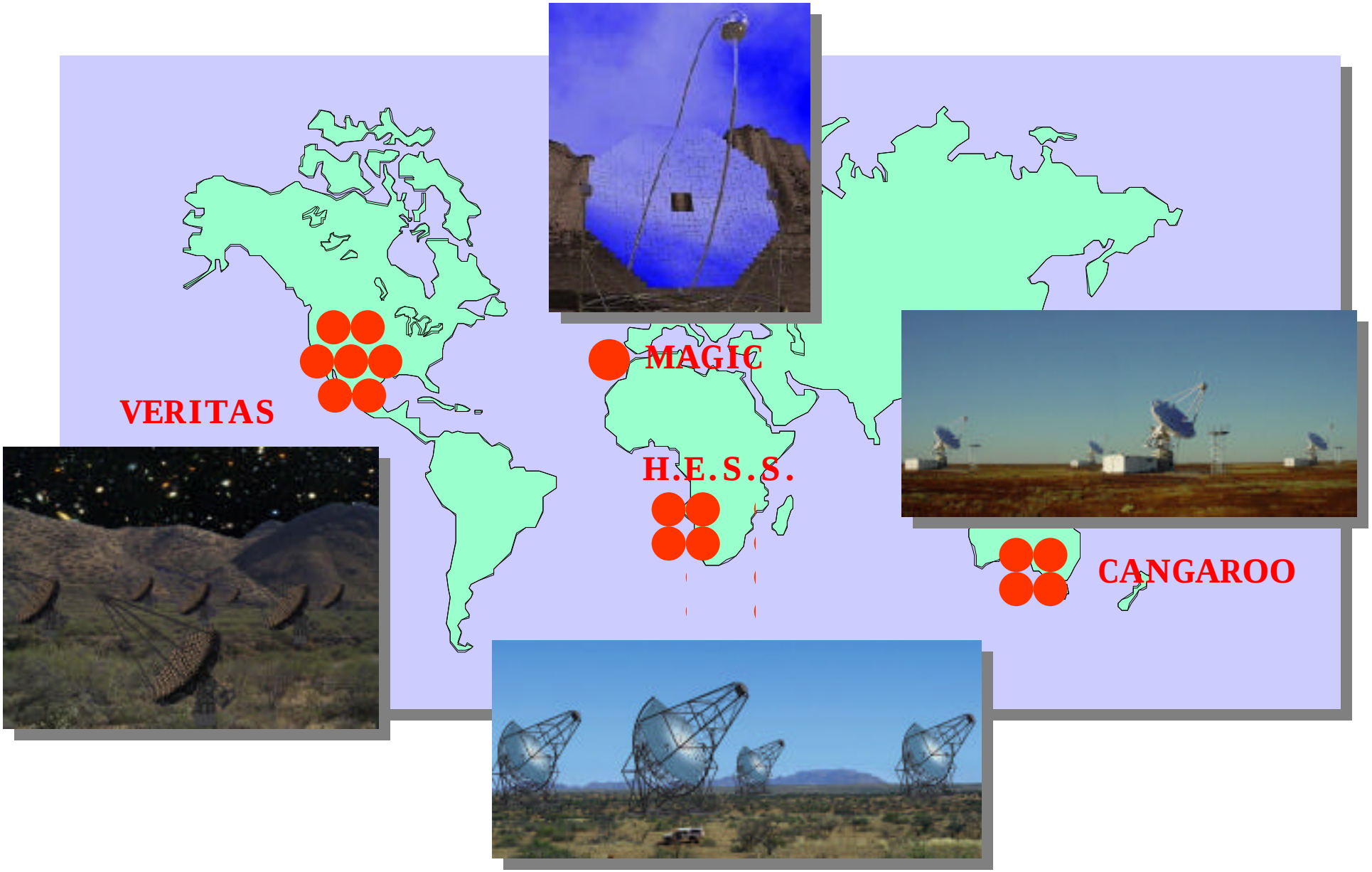

Simulated > 100 MeV skymap (one year survey)

# Imaging Gamma Ray Telescopes

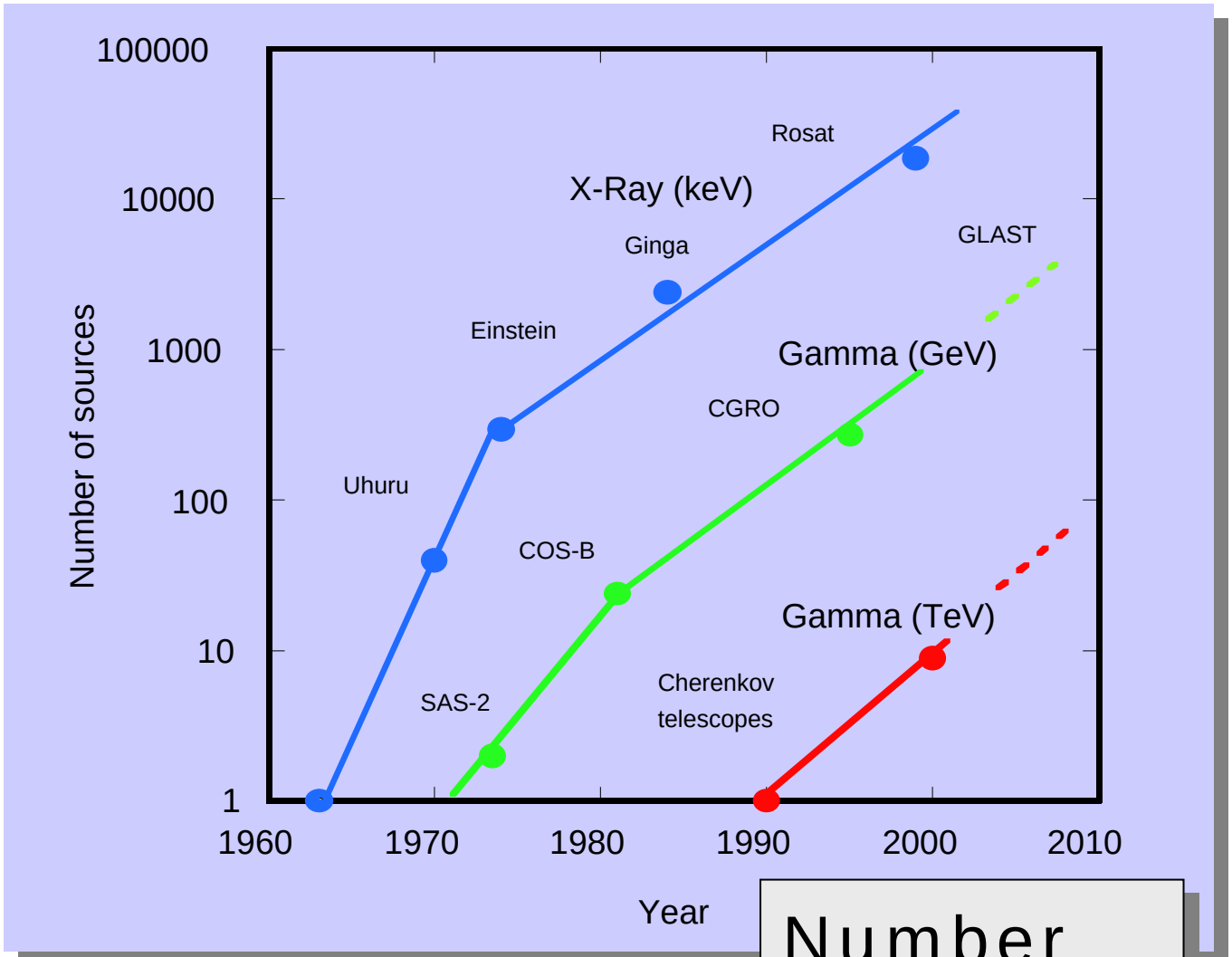




# Large projects in high-energy gamma-ray astronomy

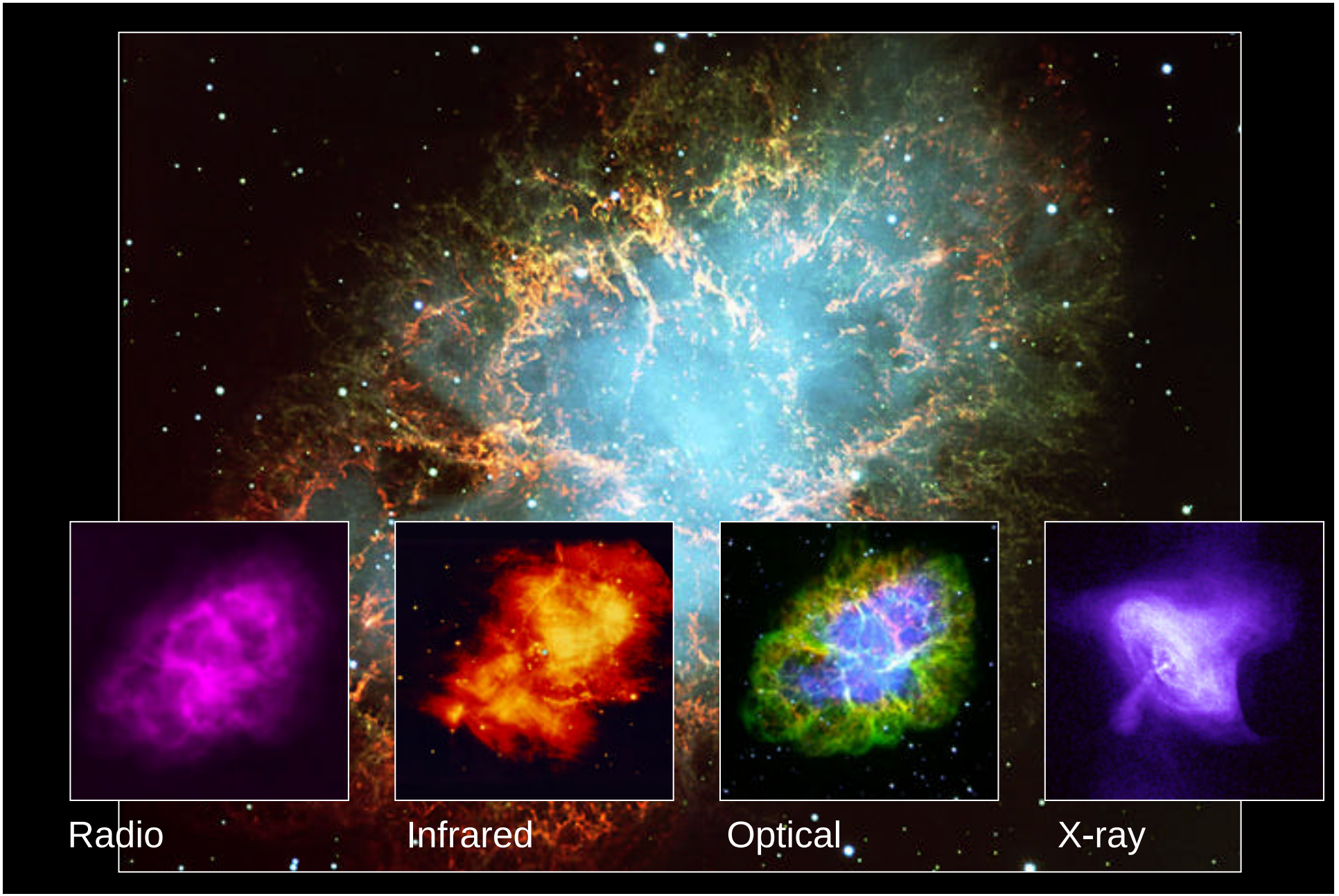


# State of the field of Tev Gamma

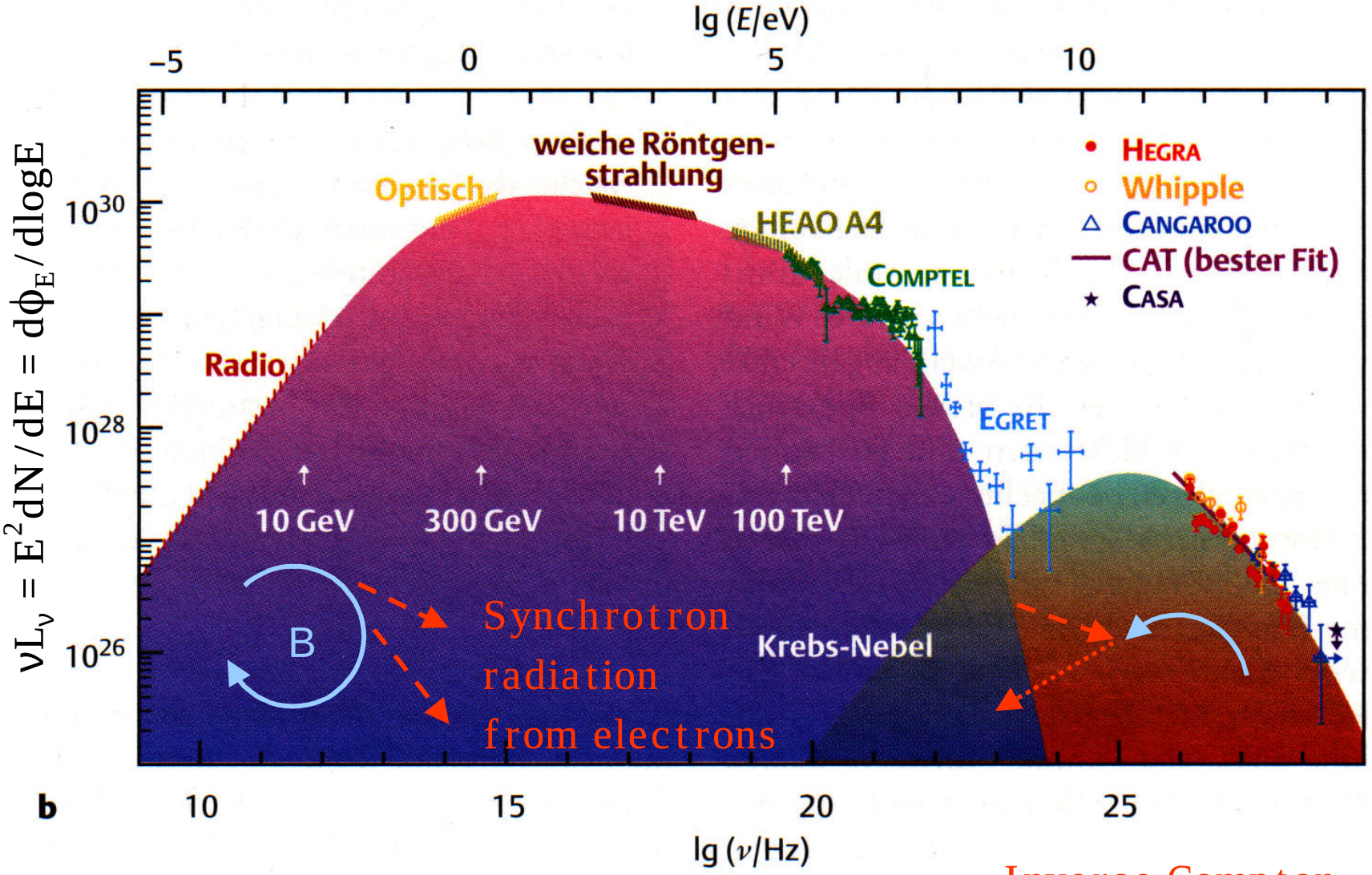



Number of sources

# The Crab in Multi-Wavelengths



# The Crab: Gammas from electrons




Inverse Compton scattering