# AGILE – Fermi - Pamela

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# Summary

- The on orbit experiments
  - Agile
  - Fermi
  - Pamela
- Gamma-rays and Cosmic-rays science highlights
  - Focus on:
    - new and unexpected results
    - GR-CR connection
  - Many items are completely left out
- Conclusions

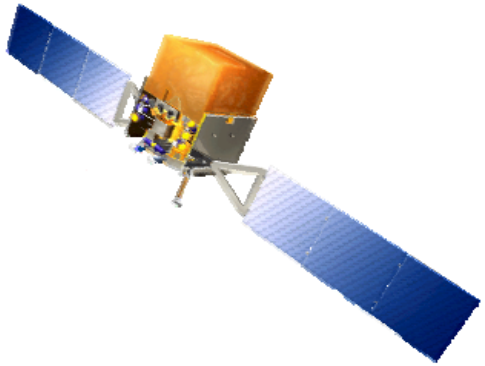
Credits:
→AGILE: C. Pittori (Agile Data Center – ASDC)
→Pamela: R. Sparvoli (Roma Tor Vergata)

# The Space Experments

## AGILE

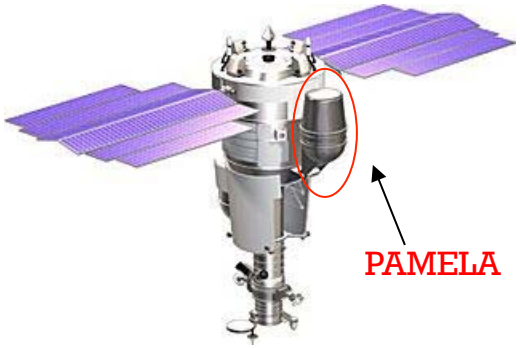
| |
|---|
| γ-ray pair conversion telecope (GRID) 30 MeV - 30 GeV |
| X-ray coded mask (SuperAgile) 18-60 keV |
| 100 kg |
| Pointing → 10/2009 Sky Scanning 11/2009 → |
| Launched: April 2007 |

## Fermi



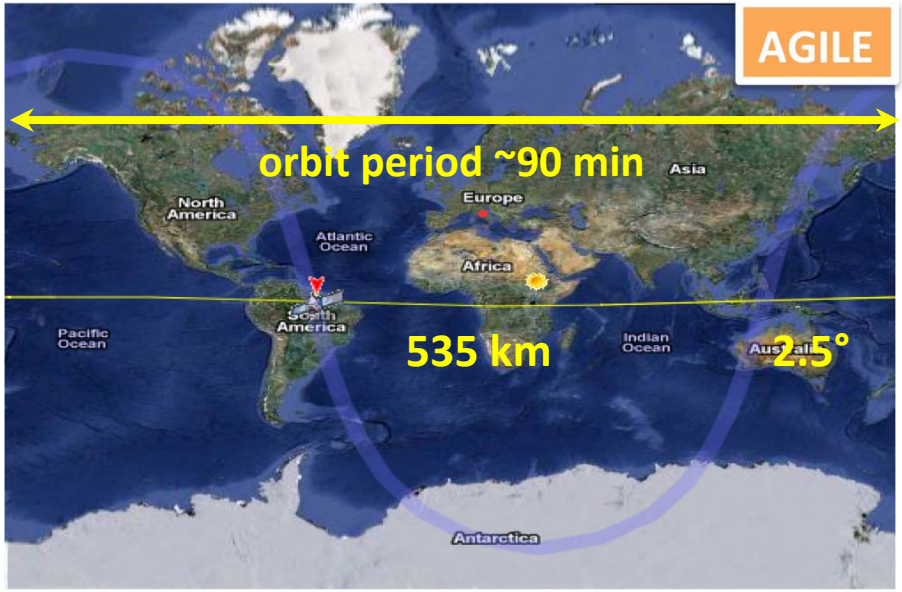
| |
|---|
| γ-ray pair conversion telecope (LAT) 30 MeV - >300 GeV |
| GBM 8 keV – 40 MeV |
| 3000 kg |
| All-sky monitor |
| Launched: June 2008 |

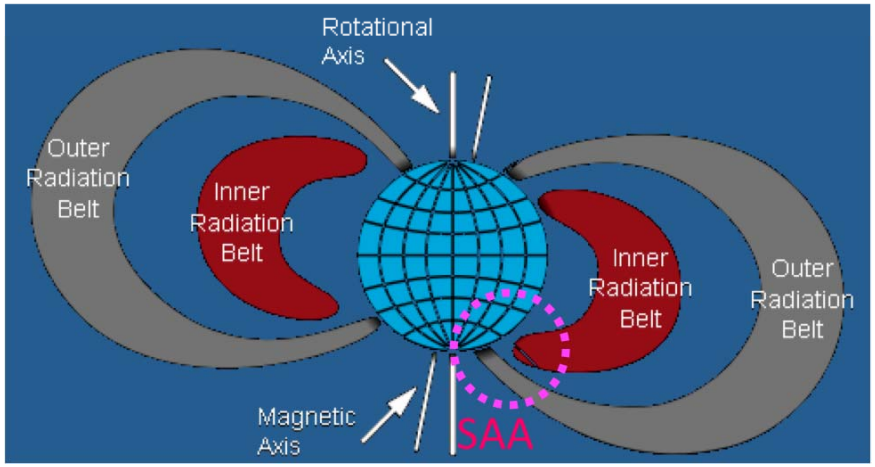
## Pamela

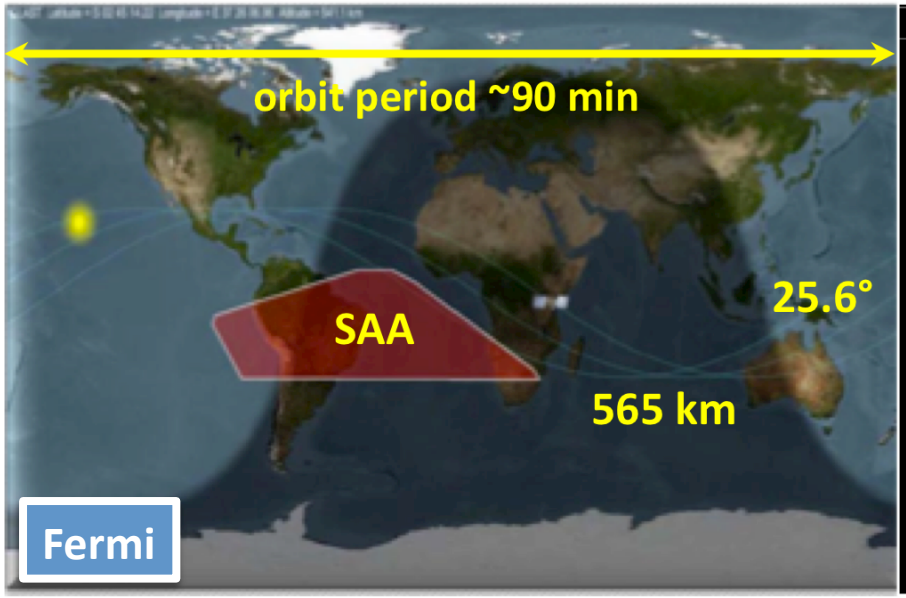


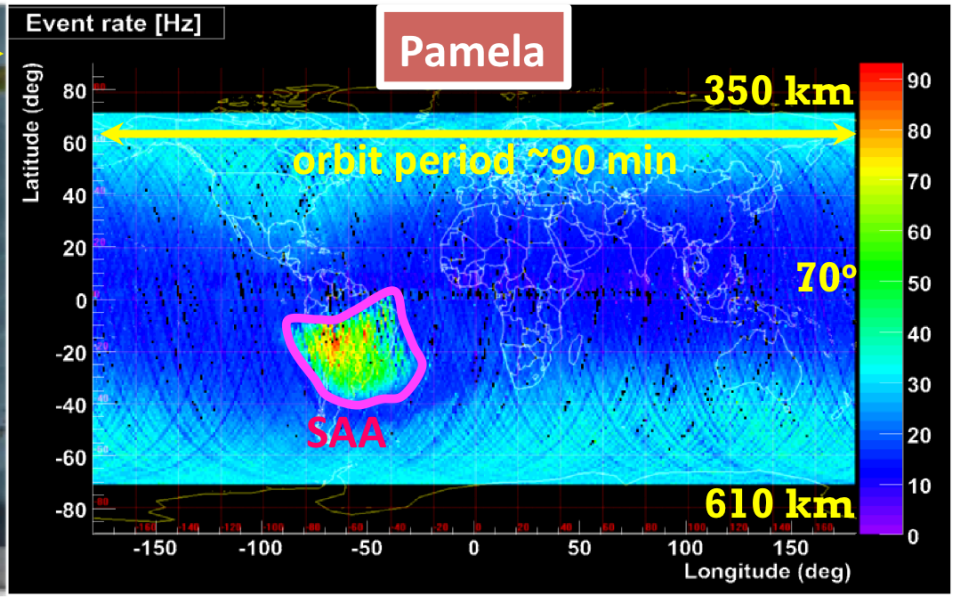

| |
|---|
| Magnetic spectrometer |
| Maximum detectable rigidity ~ 1 TV |
| 470 kg |
| Launched: June 2006 |

# Orbits and Operations

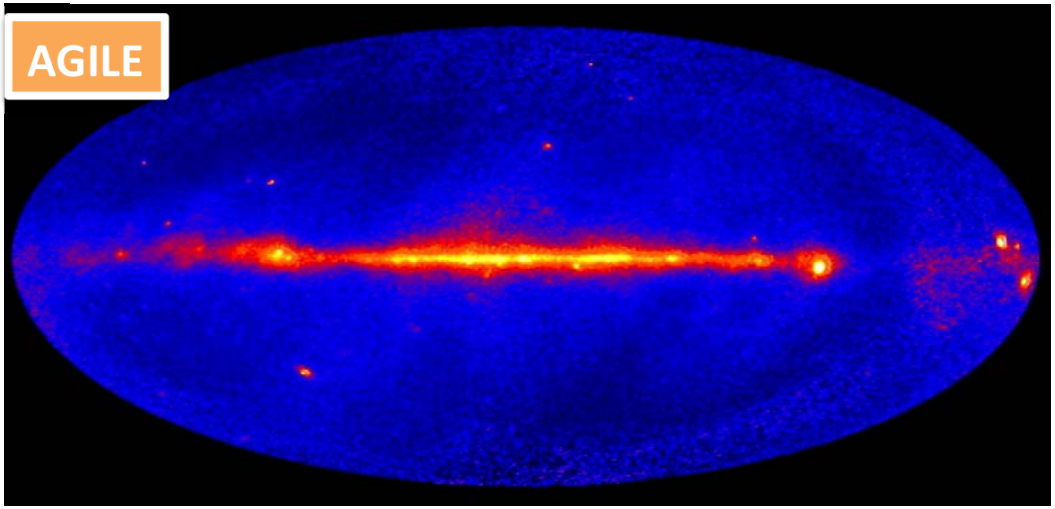


# Gamma-ray Sky



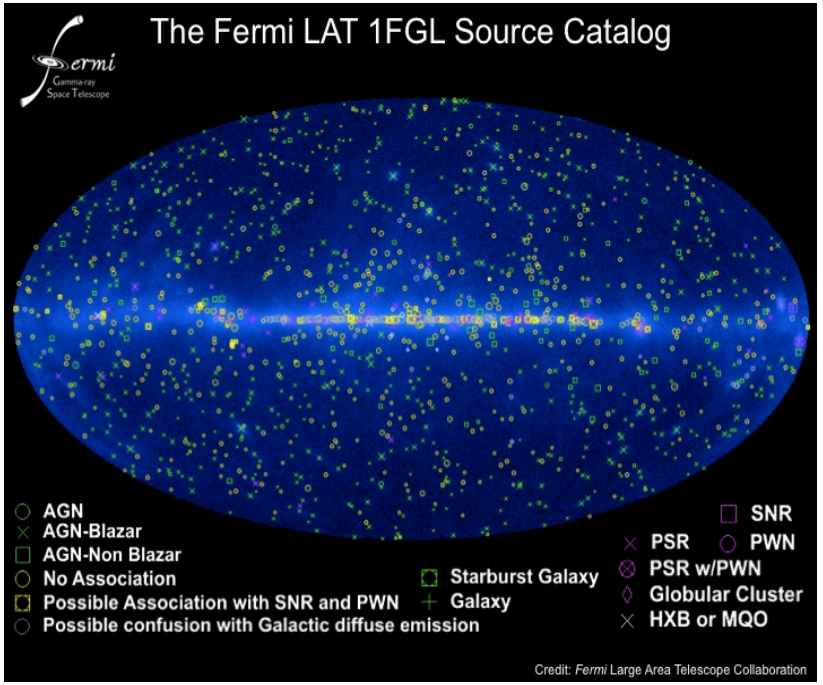

→New gamma-ray telescopes are producing images of the sky with unprecedented details

→The energy range at tens GeV energy was completely unexplored

→ Increasing the number and details for known gamma-ray emitting sources

→Finding uexpected features for already known sources

→Unveiling new types of gamma-ray emitters

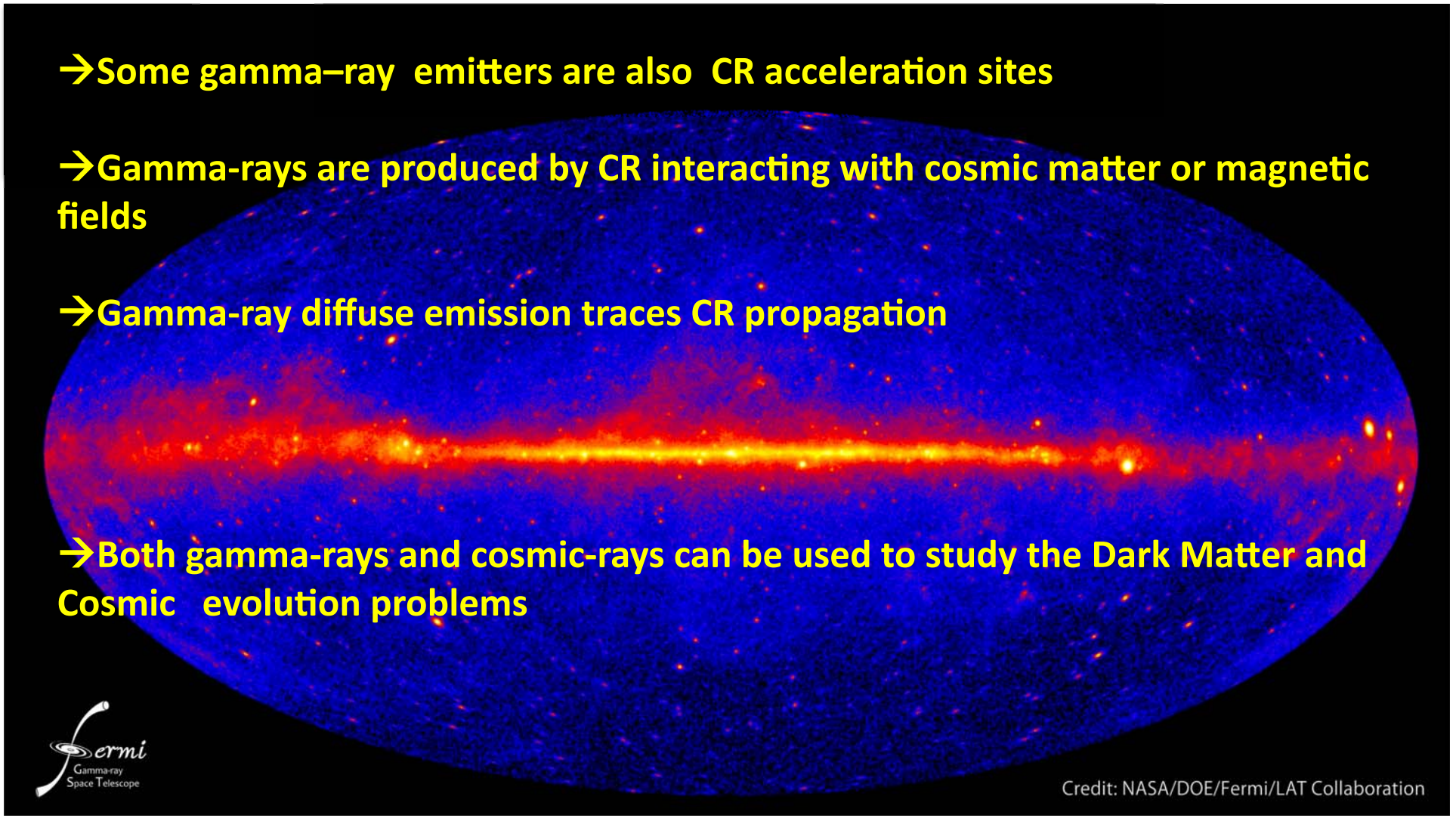


# Gamma-rays - Cosmic-rays Connection

→Some gamma–ray emitters are also CR acceleration sites

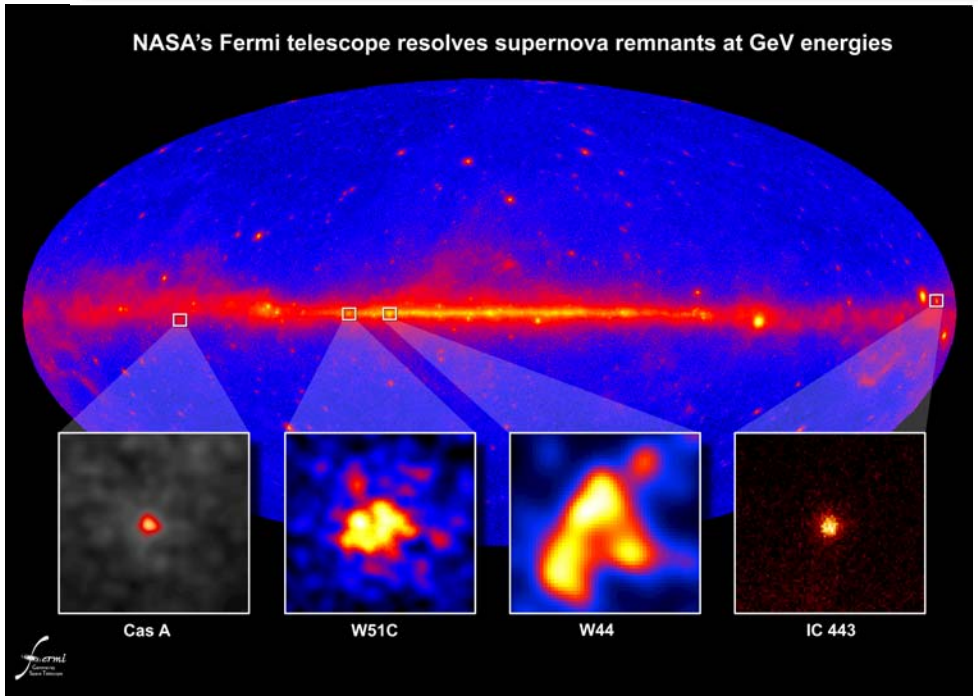
→Gamma-rays are produced by CR interacting with cosmic matter or magnetic fields

→Gamma-ray diffuse emission traces CR propagation

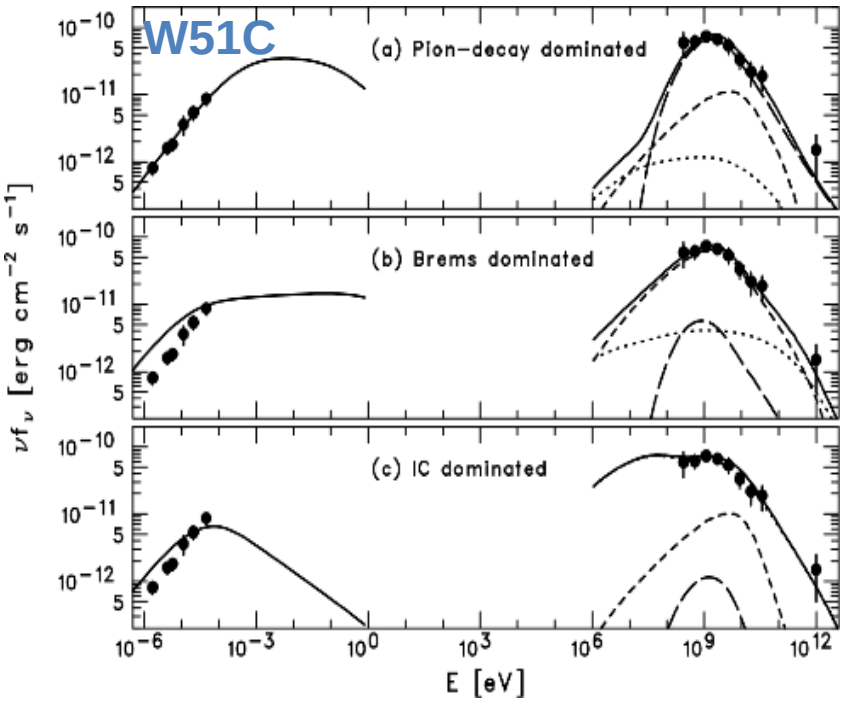



→Both gamma-rays and cosmic-rays can be used to study the Dark Matter and Cosmic evolution problems

# SuperNova Remnants

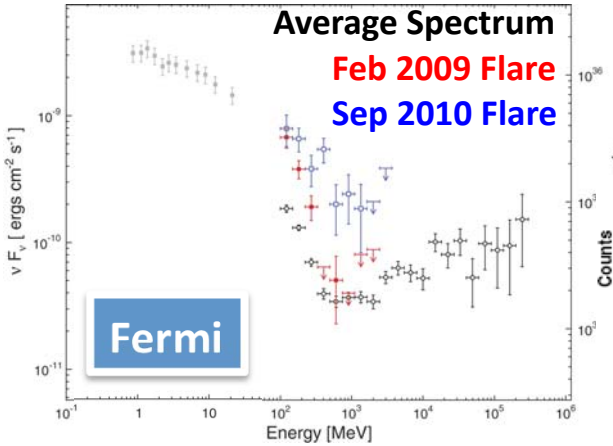


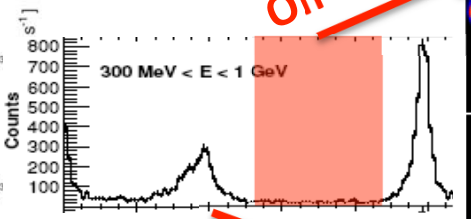

**SNRs**
→Some resolved
→Association between gamma rays and shock region
→Most associated with molecular clouds

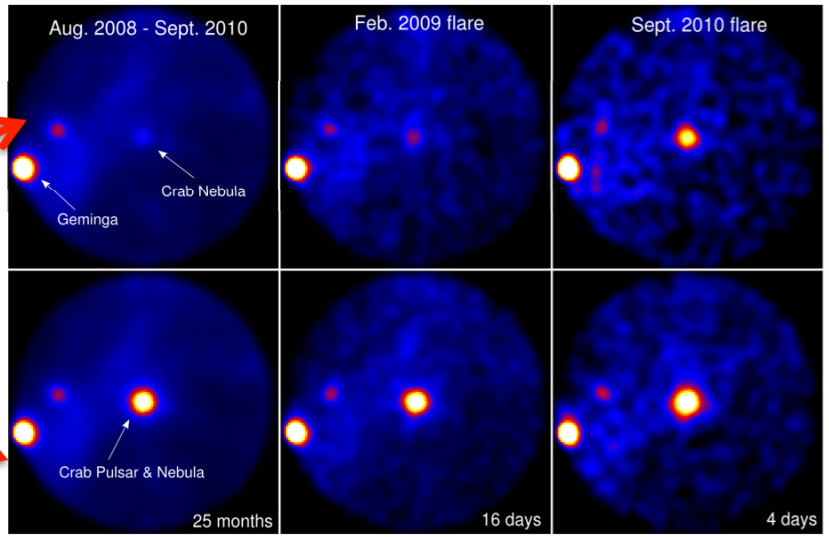


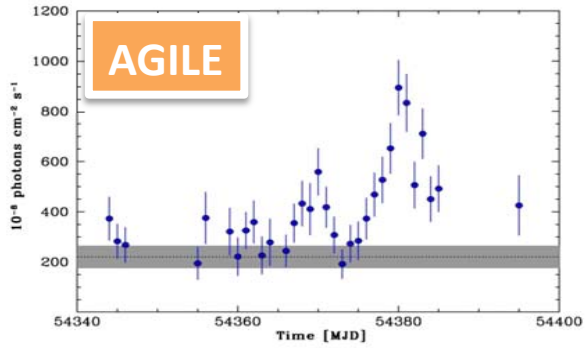

**Middle-aged SNRs (> $10^4$ years)**
→Show spectral break at few GeV
→Many favor hadronic scenario
→ $\pi^0$ from protons interacting with interstellar matter

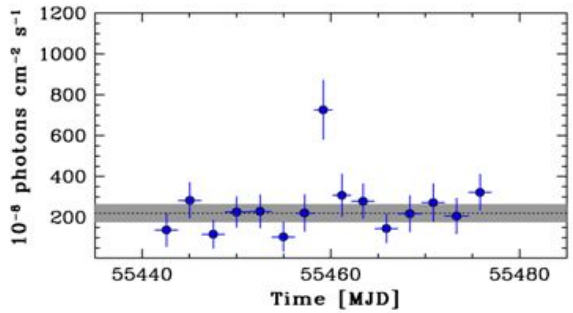
# Crab Nebula Flares




→AGILE first detection of a strong gamma-ray flare in Oct. 2007
→Several flares seen by AGILE and Fermi
→No variation in Infrared and X-ray
→ γ-ray with E>1 GeV interpreted as synchrotron from electrons with E ≥ 1 PeV
→ Highest Energy particles associated with a source
→Challenge for acceleration theory

# Other galactic transients

**Cygnus X-3**

→Microquasar

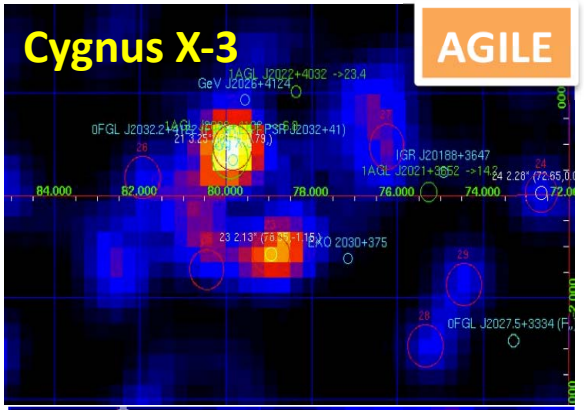
→First detection by AGILE: γ-ray flare usually before radio flare

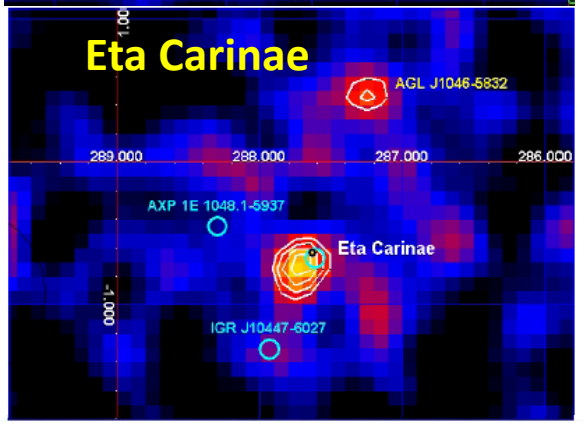
→Fermi measures 4.8 hours orbital modulation

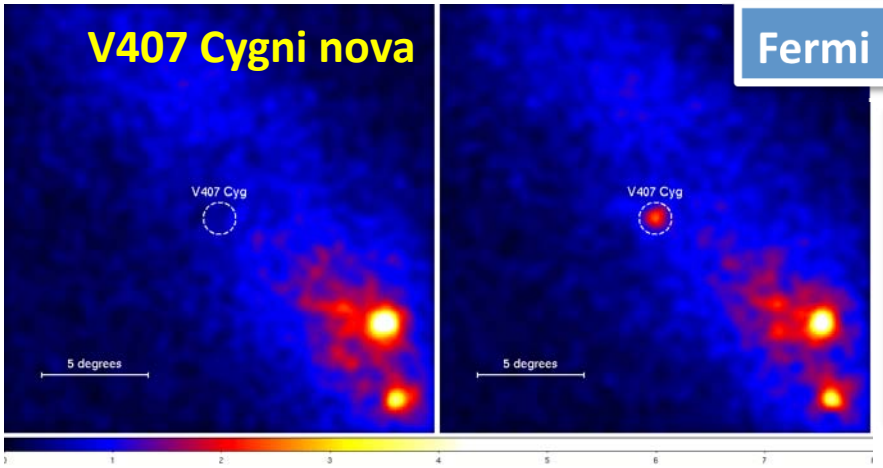
**Eta Carinae**

→First detection above 100 MeV of a colliding wind binary system

→Flaring episode Oct. 2008



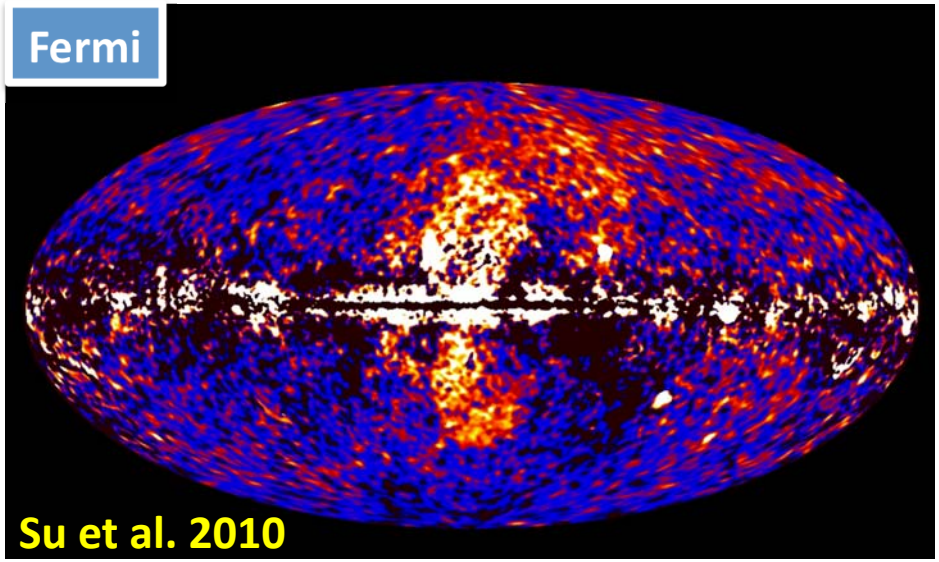

**V0407 Cygni nova**

→Red giant/white dwarf binary system

→Optical flare observed by amateur Japanese astronomers

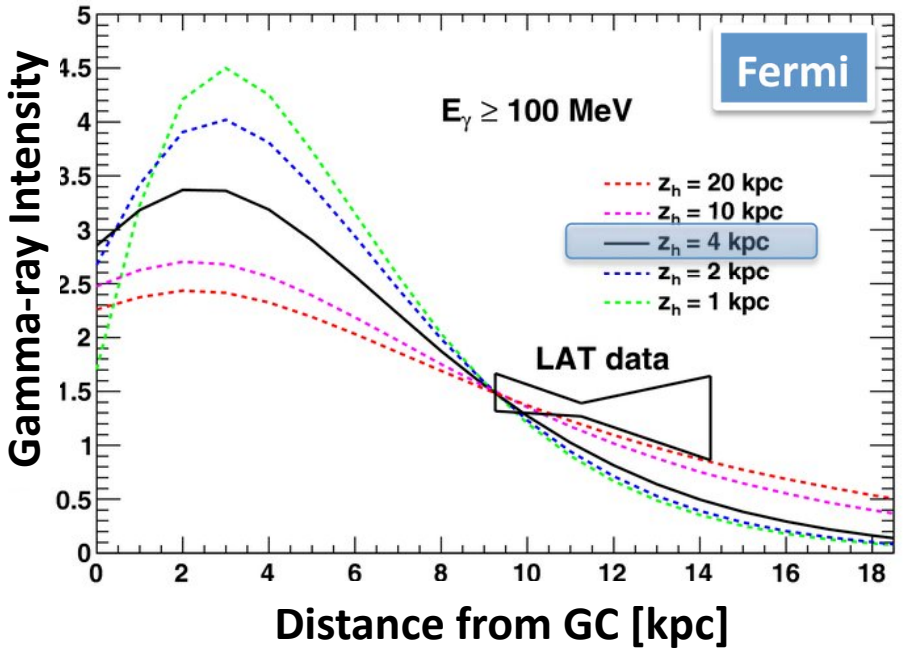
→Surprisingly detected by Fermi in γ-rays

# Milky Way

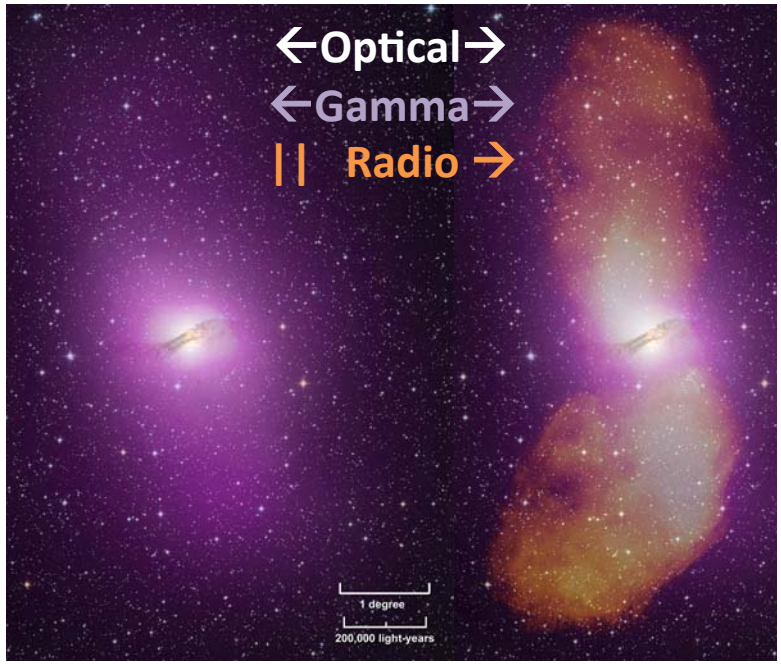



→Large γ-ray bubbles from Galactic Center
→Unexpected and not fully understood
→Possible origins:
- → remnant of particle jet from the supermassive black hole at the galactic center
- → result of gas outflows from a burst of star formation

→Interstellar emission traces CRs throughout the Galaxy
→CR densities in outer Galaxy larger than expected
→Possible explanations:
- →CR sources other than SNRs
- →Propagation model issues
- →Missing gas



# External Galaxies




## Active Galactic Nuclei

Centaurus A

→Radio Lobes resolved in γ-ray

→Unexpected high luminosity for lobes in γ-rays (> Radio)

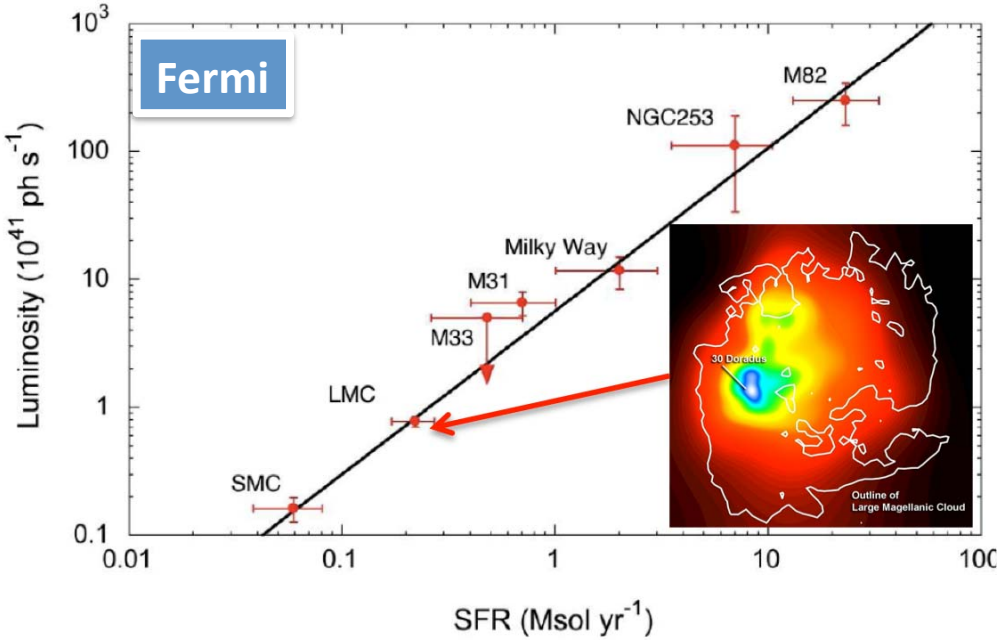
→γ-rays form Inverse Compton on CMB, EBL, star light

## Non AGN

→5 detected, 2 spatially resolved (SMC, LMC)

→ γ-ray from CR interactions with interstellar matter and photon field

→Star Formation Rate – γ Luminosity correlation



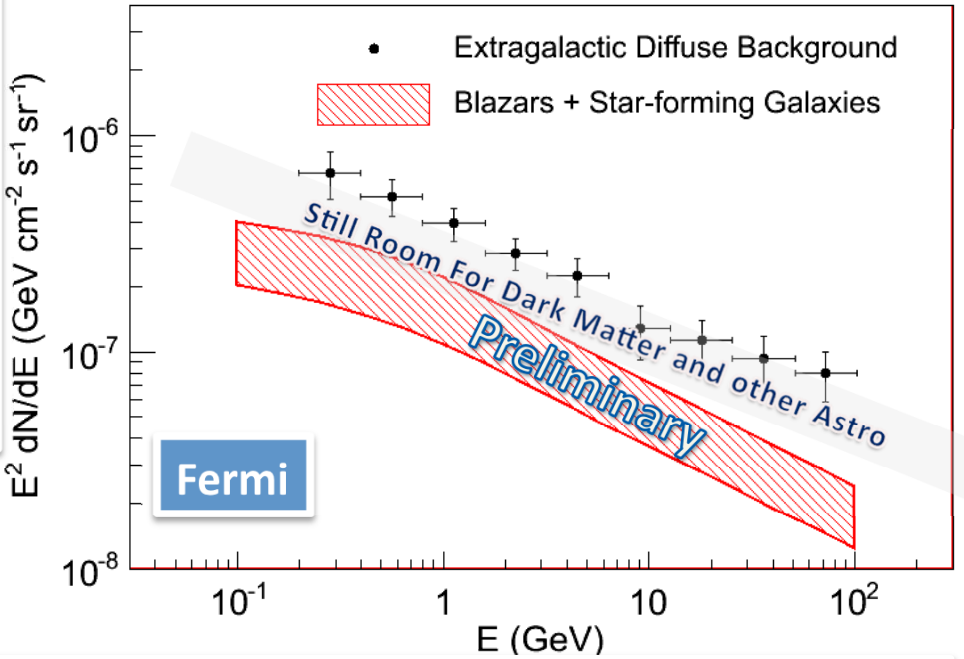
# Extragalactic Diffuse Emission

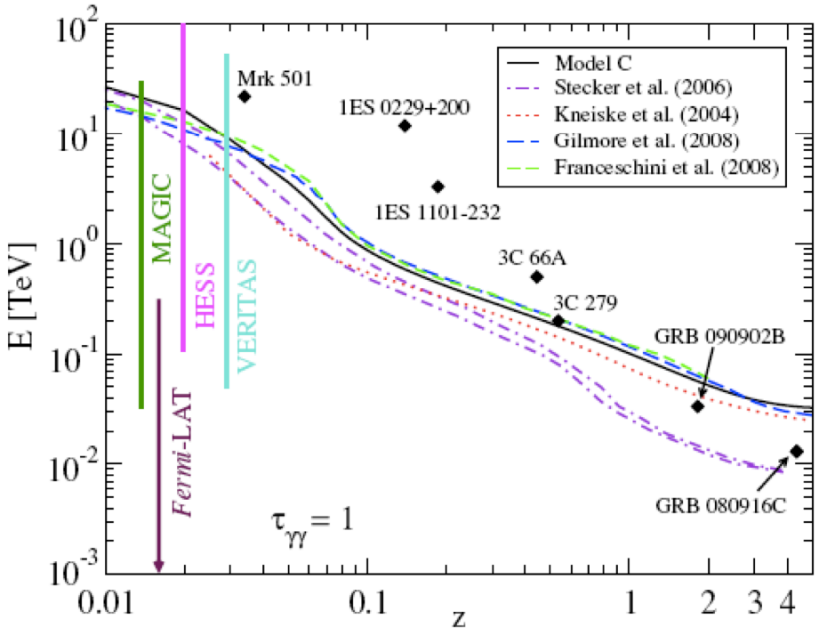
**γ-ray Extragalctic Diffuse**

→Fermi measured γ-ray extragalctic diffuse emission

→Estimation of unresolved sources contribution from population study

→Main considered source types (AGN, Star-forming Galaxies) contribute to only a fraction of the diffuse emission



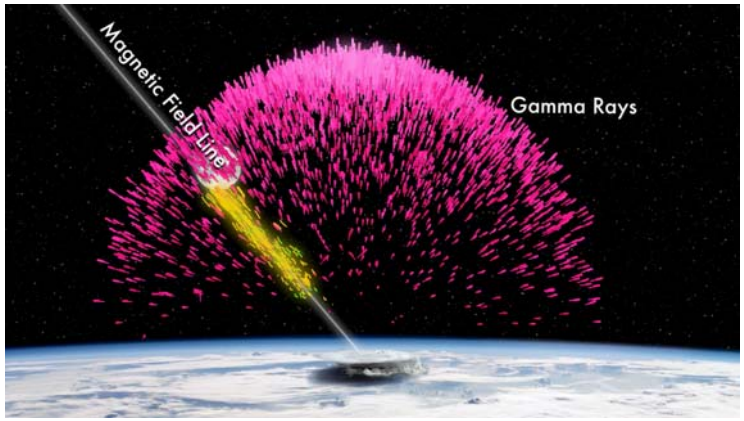

**Extragalactic Background Light (EBL)**

→Dominated by the background radiation from all the stars ever existed (IR,Opt.,UV)

→Contains information about the evolution of matter in the universe

→Direct measurment is very difficult con be inferred from γ absorption trough $\gamma_{ebl} + \gamma_{\gamma\text{-ray}} \rightarrow e^- + e^+$ vs distance

# Terrestrial Gamma-ray Flashes

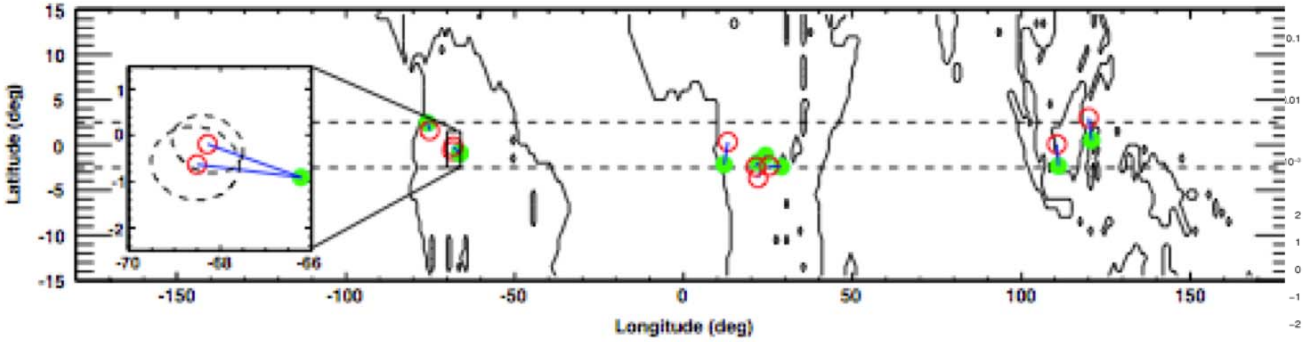


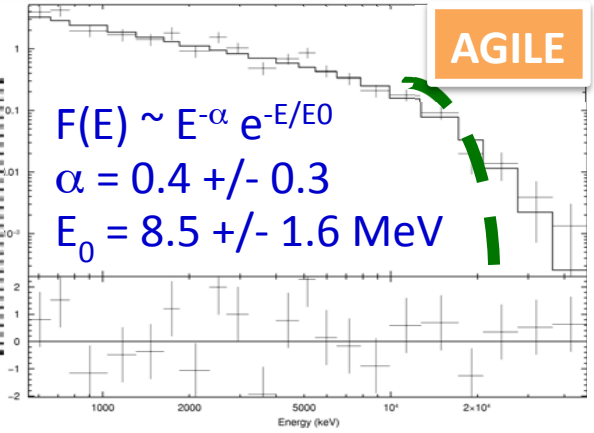

**Terrestrial Gamma-ray Flashes (TGF)**

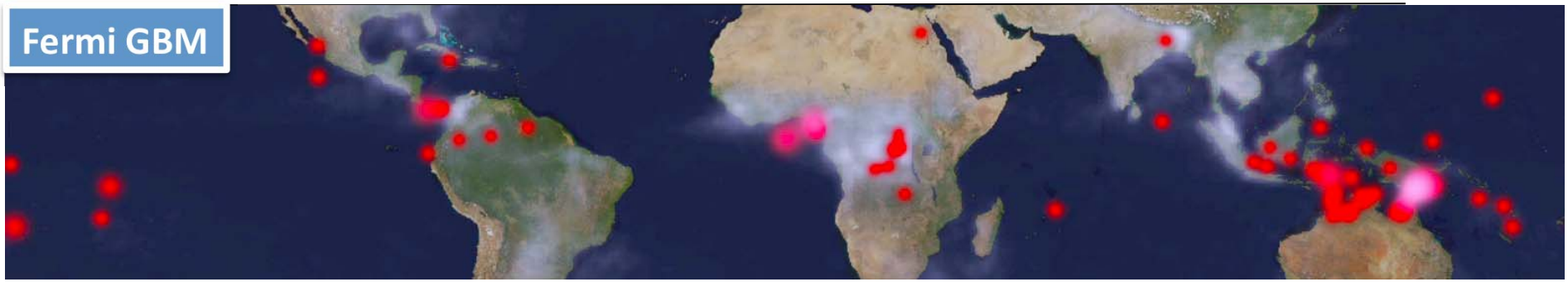
→Correlated with Equatorial or Tropical thunderstorms

→Usually contemporary to lightnings

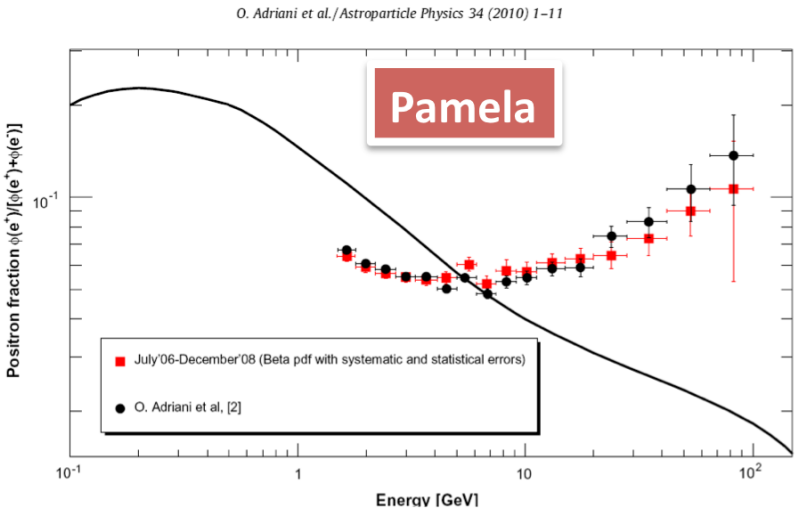
→Involve DV > 100 MVolts (normal lightning ~500 kV)

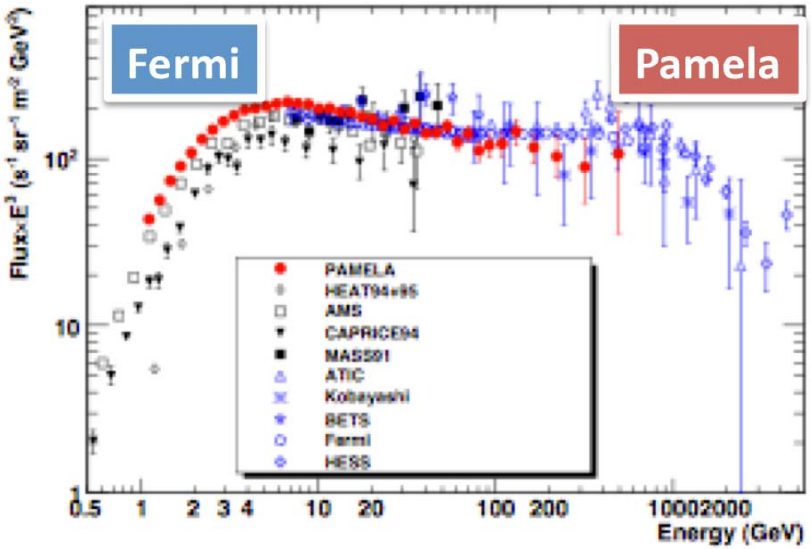


# Electrons and Positrons



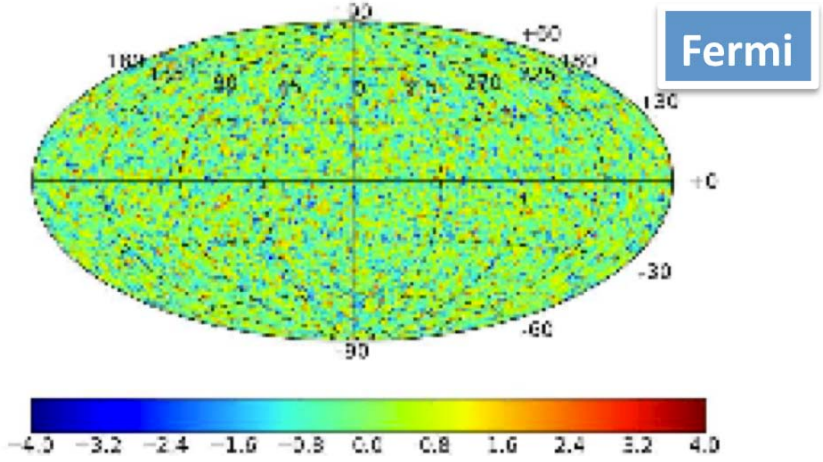




**Positrons/electrons ratio**
- →High energy rise of e+/e- ratio
- →Not foreseen by conventional models

**Electrons (+positrons) spectrum**
- →Harder than conventional models
- →Hints of non-power law spectrum

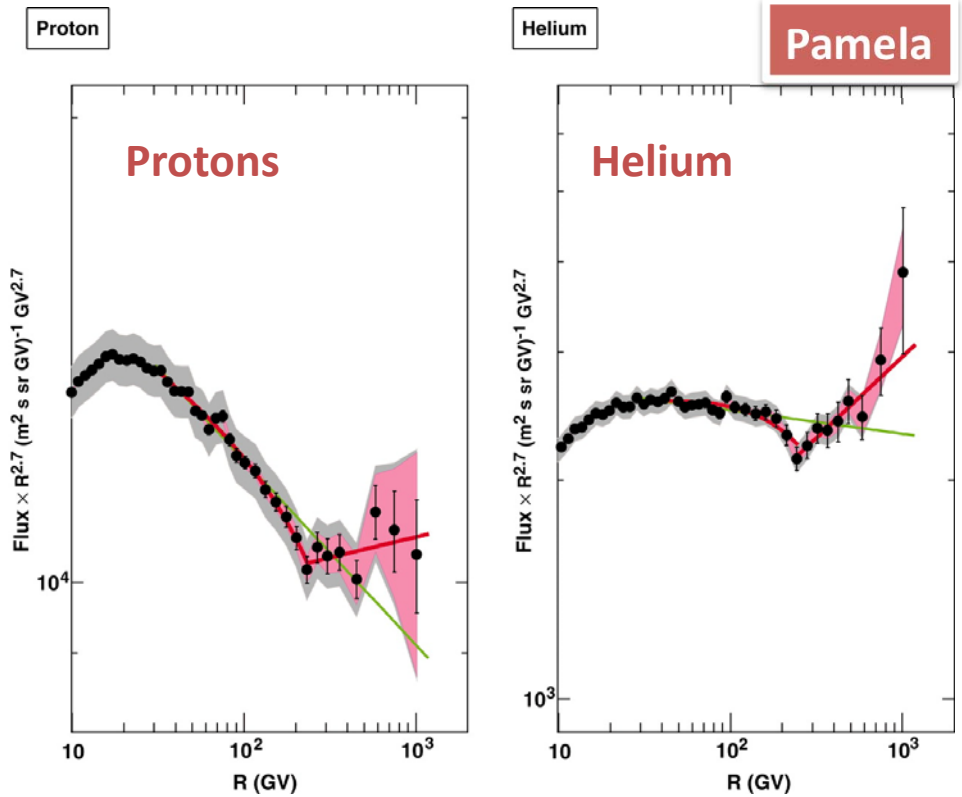
**Electrons+positrons anisotropy**
- →No significant anisotropy detected

**Possible intepretations for model discrepancies**
- →Nearby source (Pulsar)
- →Exotic (DM)




Electron unisotropy significance [σ]

# Nuclei

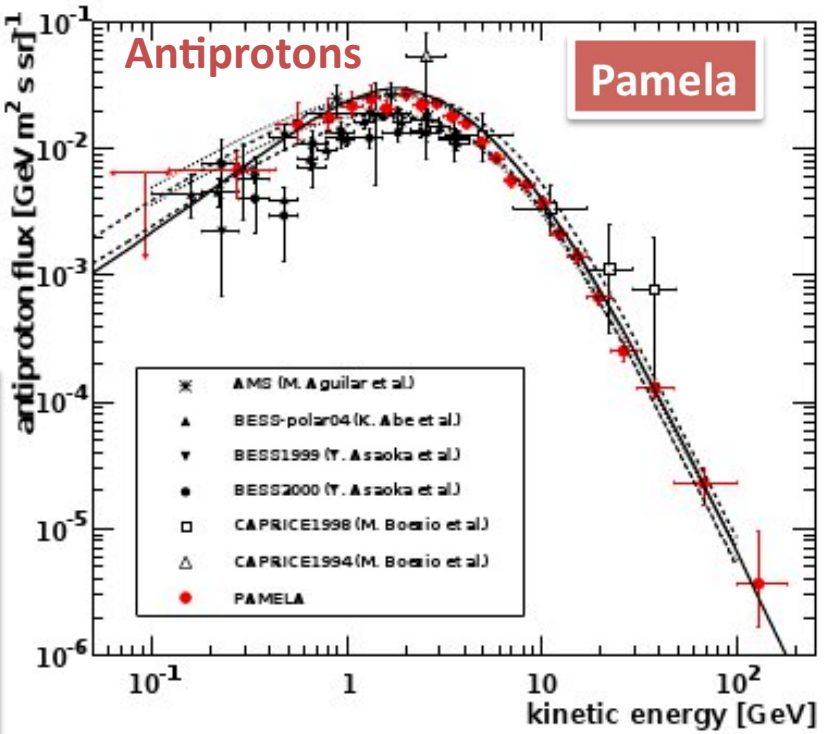



**H and He**

→H and He spectra are different

→Not described by single power law

→Spectral hardening not reproduced by conventional models



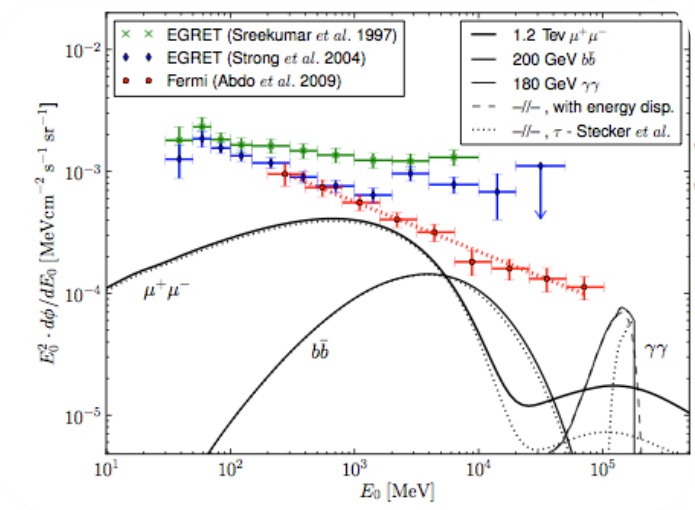

**Antiprotons**

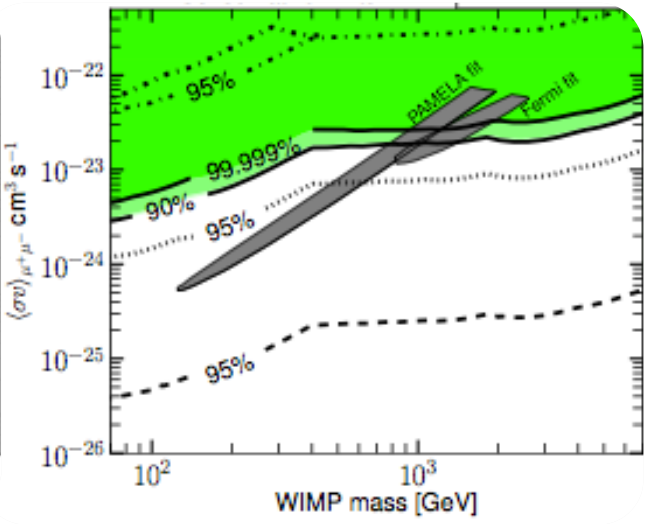
→Compatible with pure secondary production

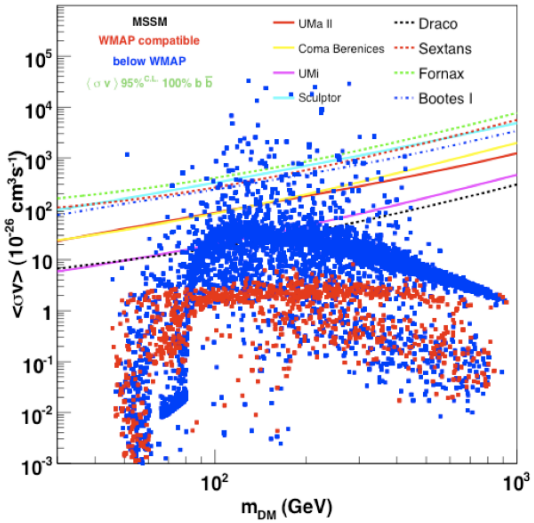
→Uncertainty smaller than spread within theoretical models

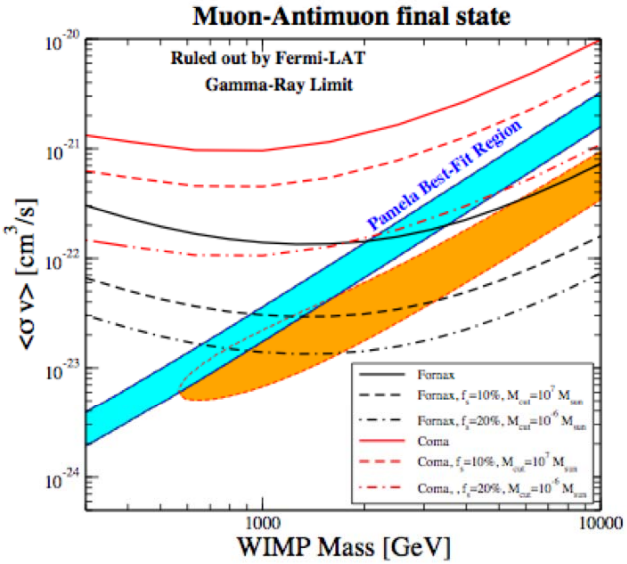
→ap/p ratio cannot rule out astrophysical or DM explanation for e+/e- rise at high energy

# DM




**Dark Matter signal searched for in several candidate γ-ray sources**

**Combining cosmic ray data and γ-ray limits on Dark Matter detection is constraining the theory Parameter space**

# Conclusions

- The outstanding results from space experiments in orbit are deeply improving our high energy astrophysics and astroparticle physics knowledge

- Many unexpected discoveries are unveiling new aspects of the Universe and opening interesting issues