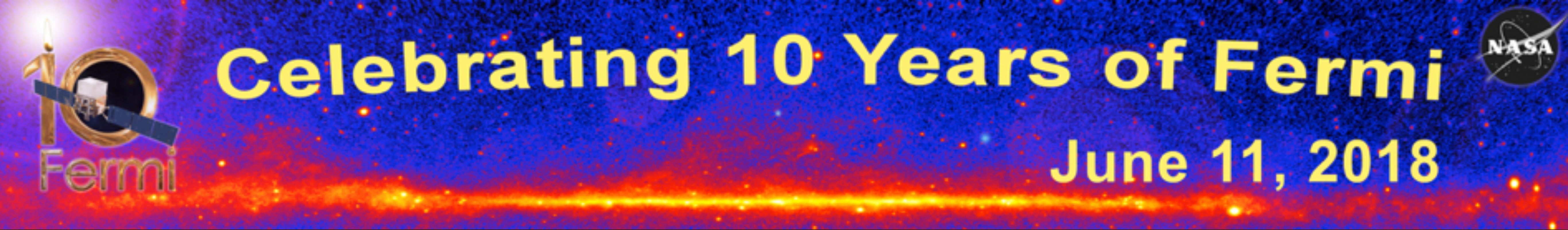


FERMI SATELLITE

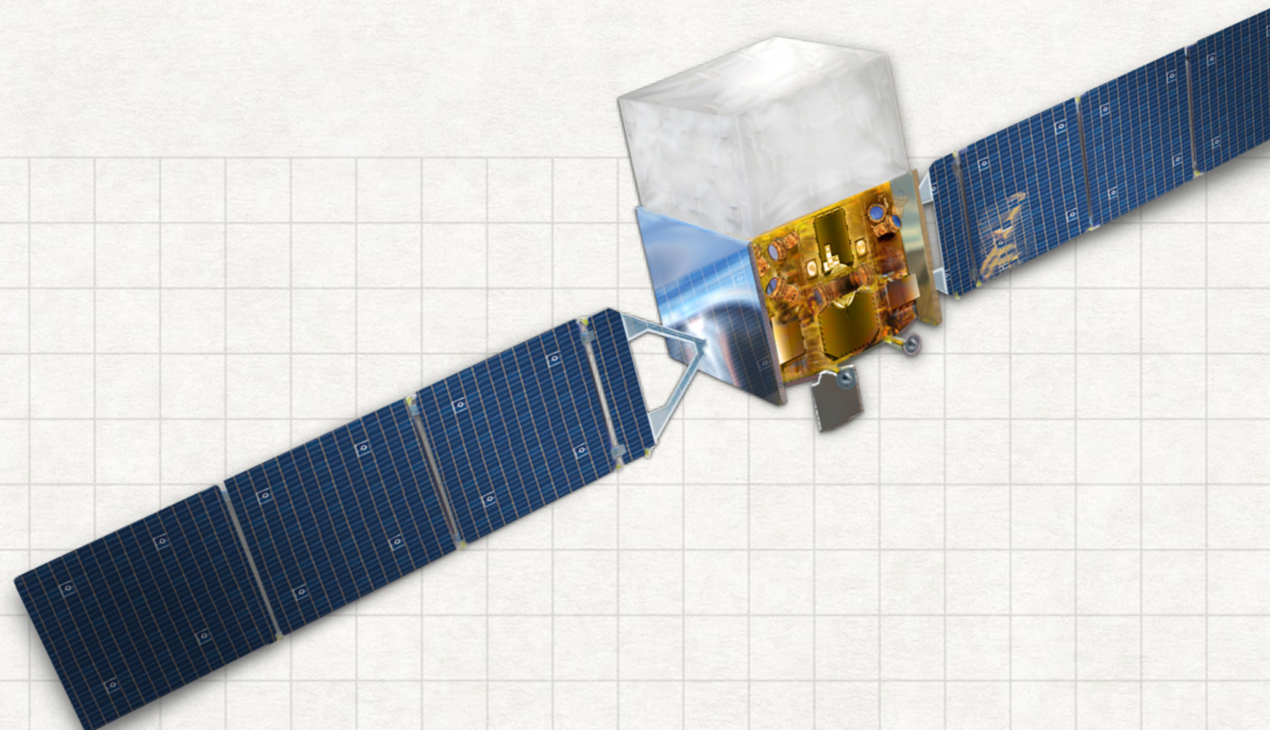
Gamma-ray Large Area Space Telescope

Kai Wang

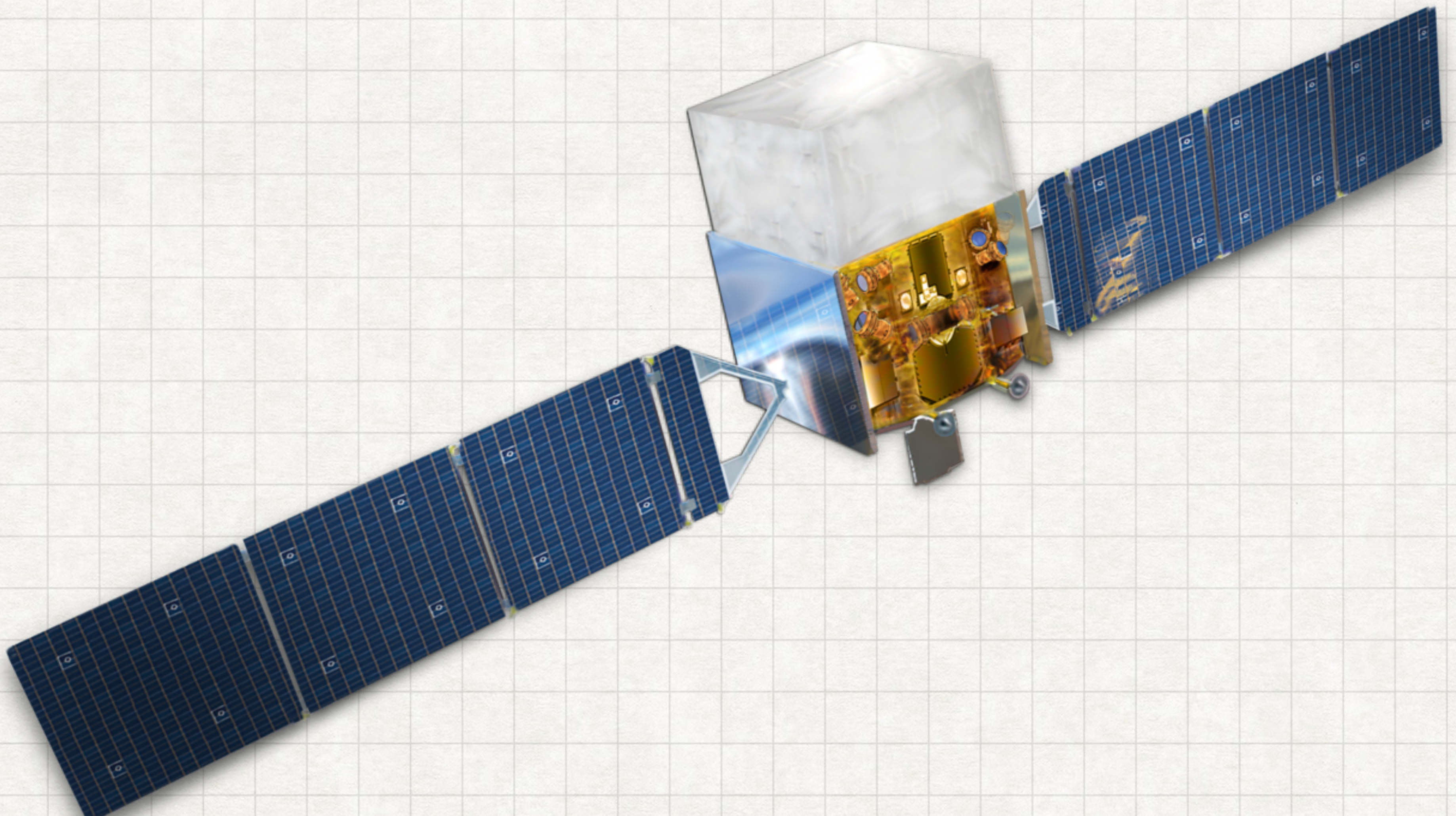
Advisor: Prof. Xuening Bai

CONTENT

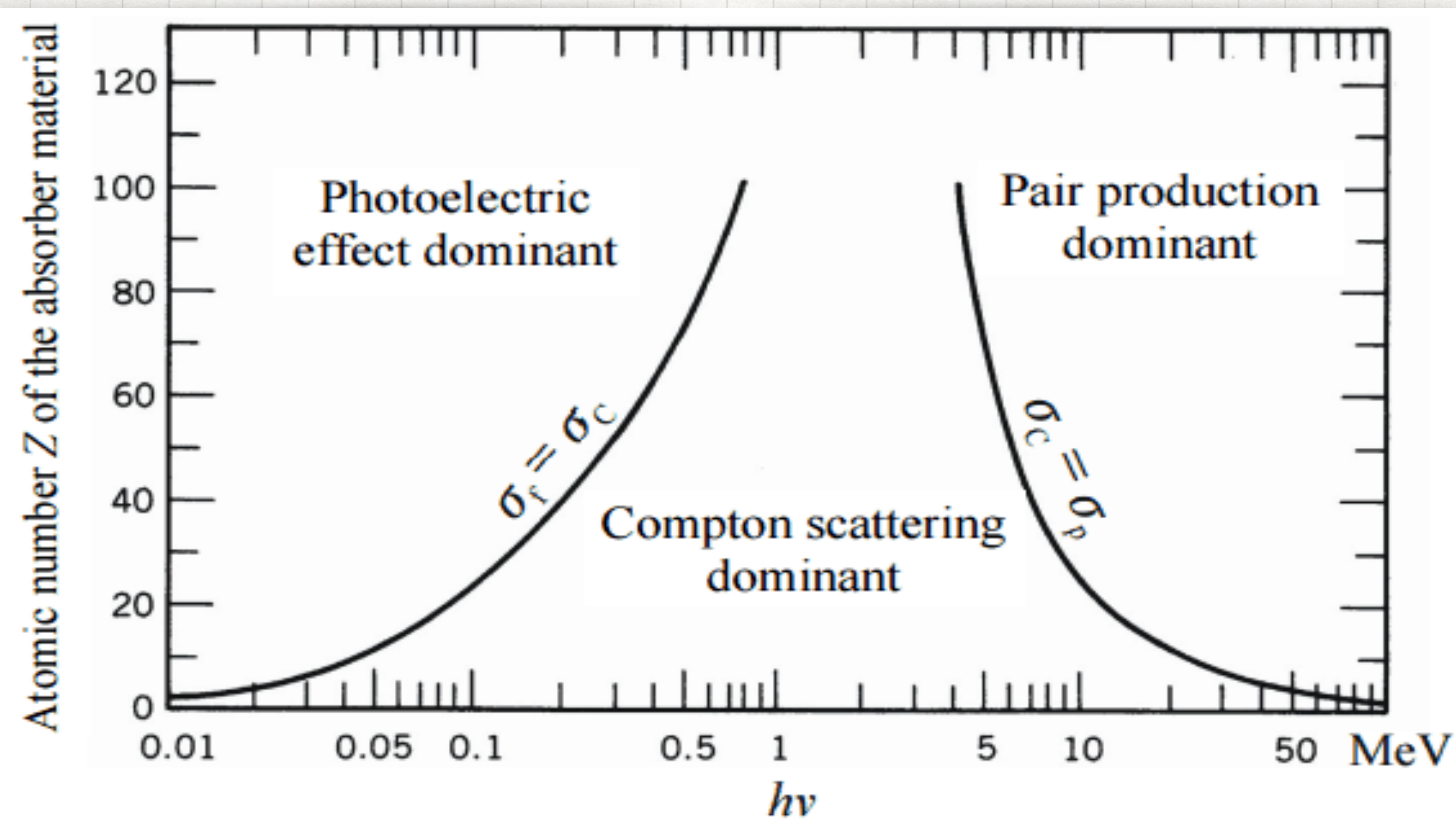
- Overview of the Fermi satellite
- Instrument(LAT)
- Discovery of Fermi Bubble
- Gamma-Ray AGN
- Summary



PART I. Instrument



Detection principle of high energy photon



Basic idea:

photon

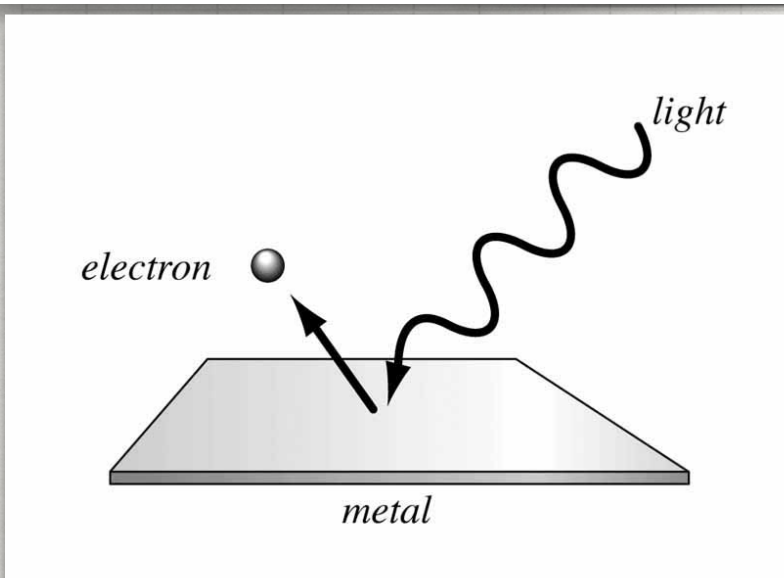
|

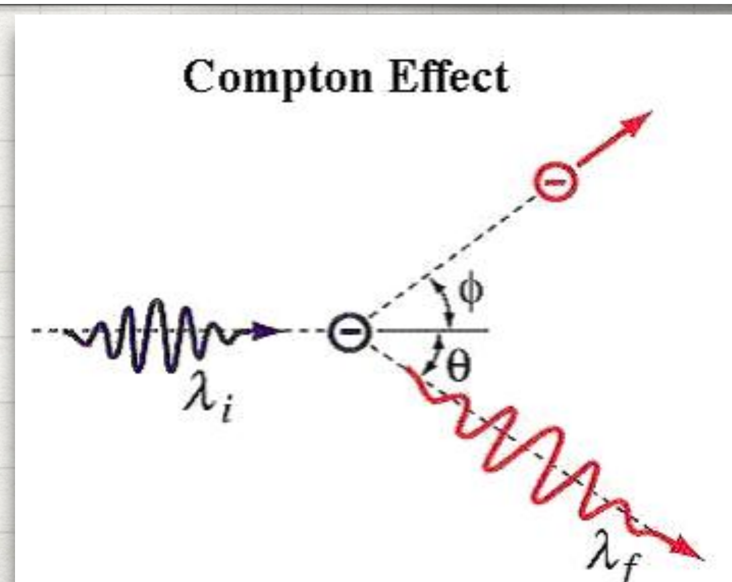
| energy

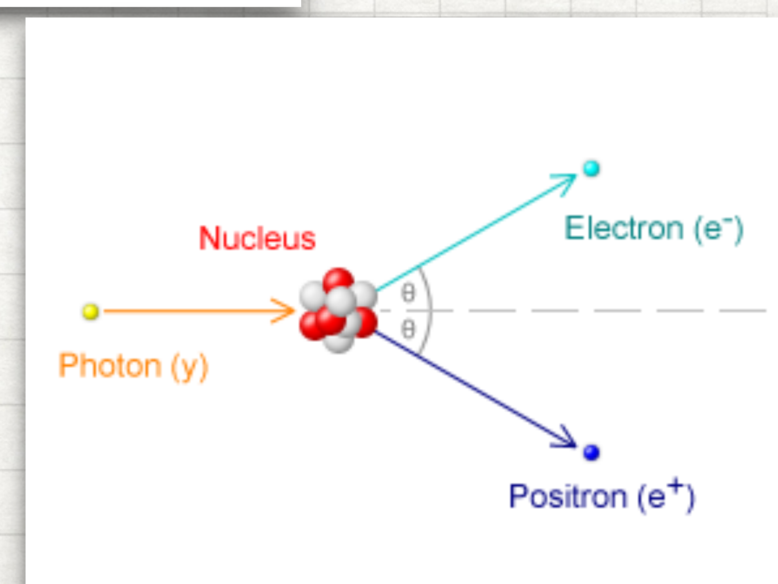
|

V

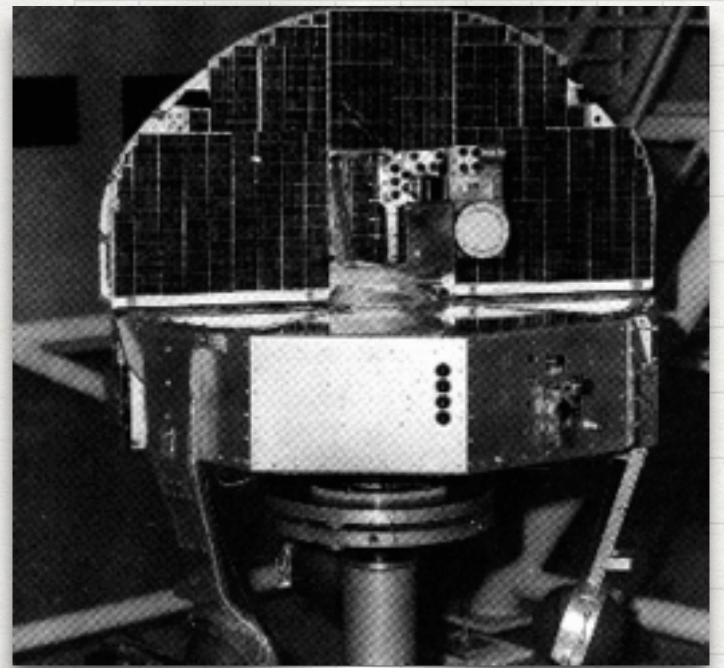
electron



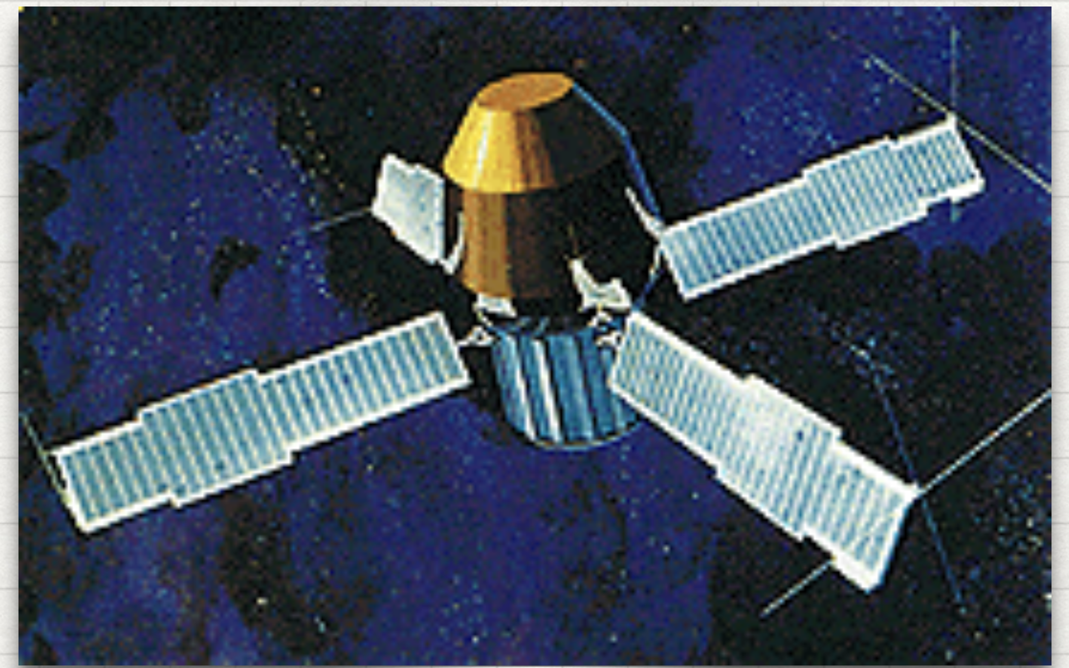




Historical overview of Gamma ray satellite

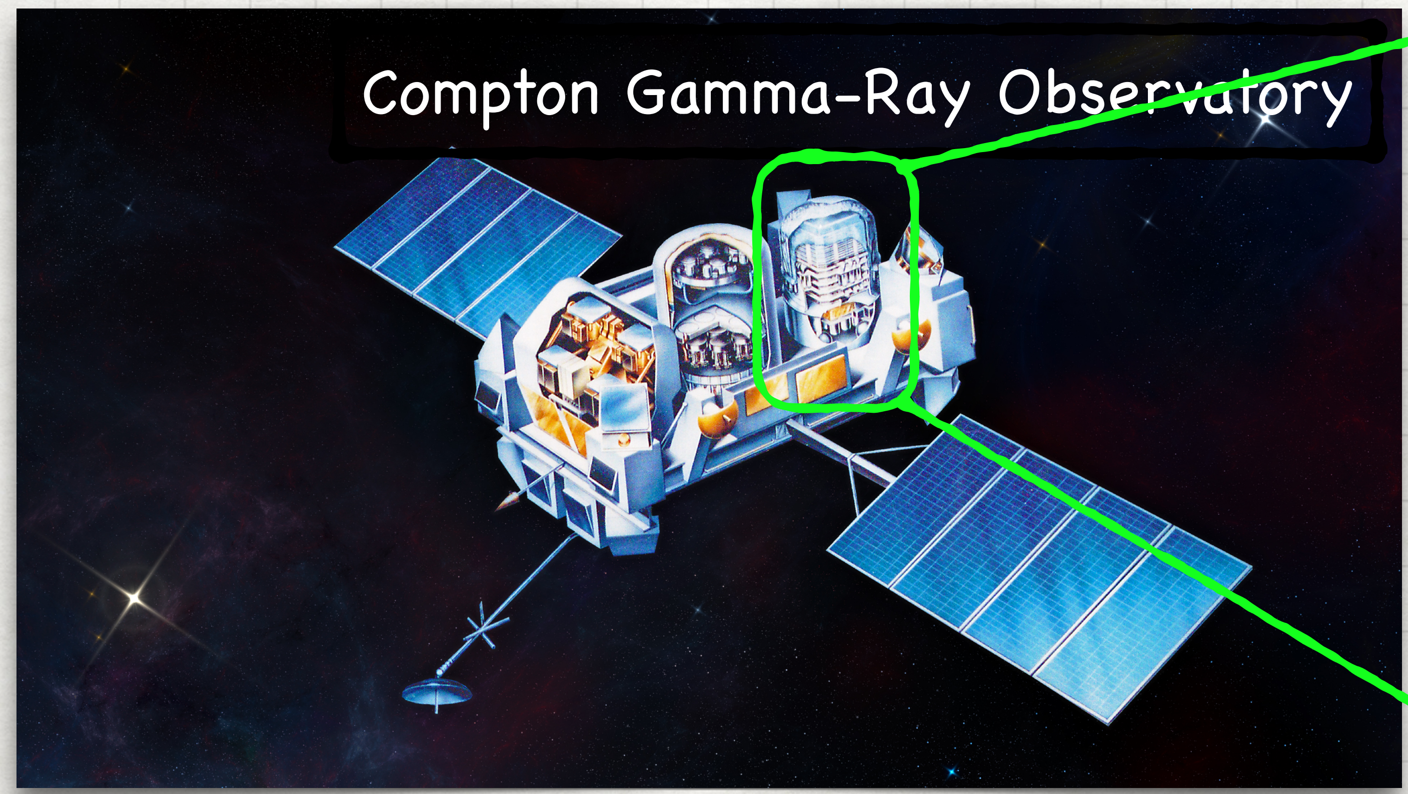


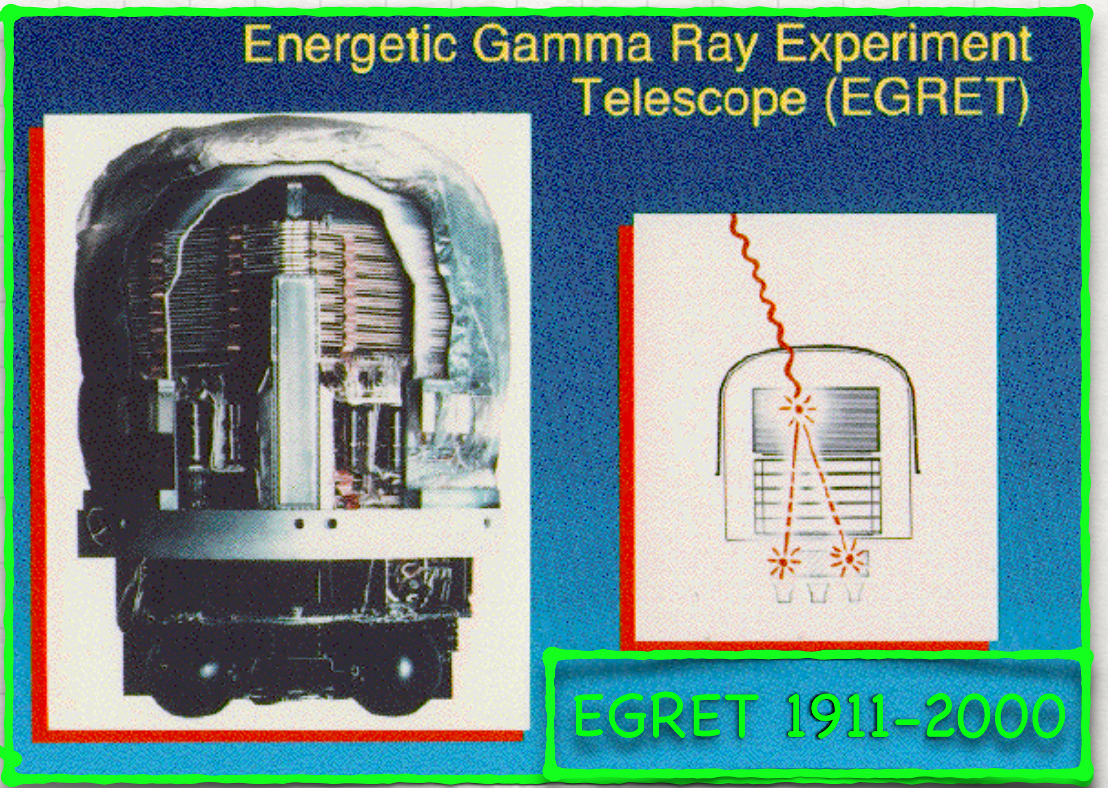
OSO III 1968-1969



SAS II 1972-1973

COS B 1975-1982



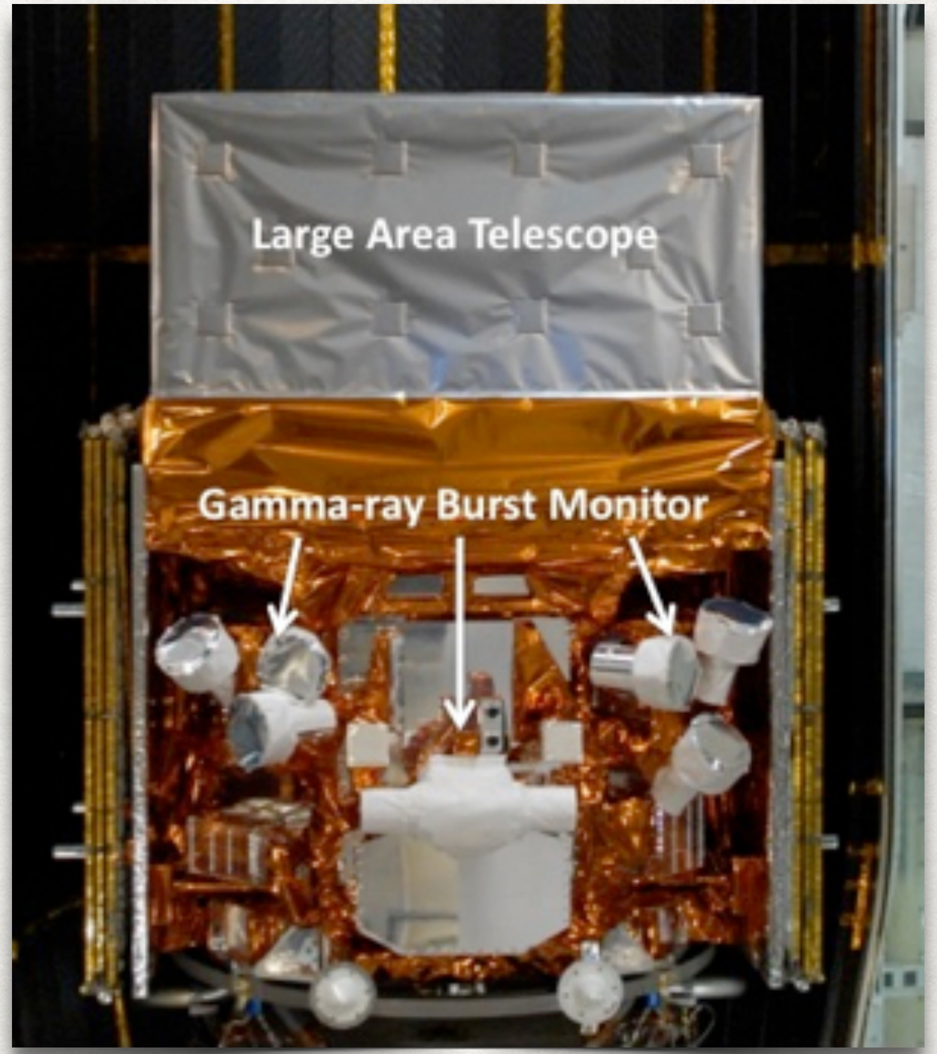


EGRET 1911-2000

I. Overview of the Fermi satellite

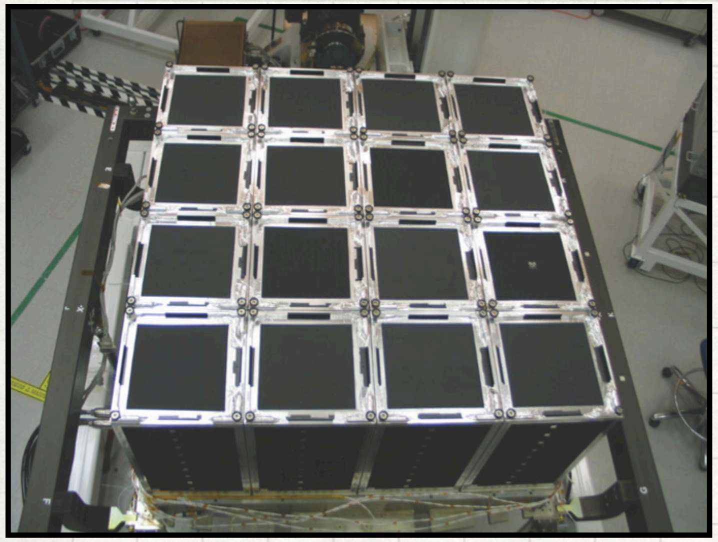
Launched on 11 June 2008
Cost: $690,000,000
publications: > 600

Large Area Telescope	Gamma-ray Burst Monitor
Pair-production instrument	NaI and BGO scintillators
20 MeV to 300 GeV	8 keV to 40 MeV
Field of view: 20% of the sky	Field of view: 9.5 steradians
angular resolution: <1° at 1 GeV	GRB localization: typical 3°
Timing accuracy: < 10 μs	Timing accuracy: 2 ms



(https://fermi.gsfc.nasa.gov/)

II. Instrument(Large Area Telescope)

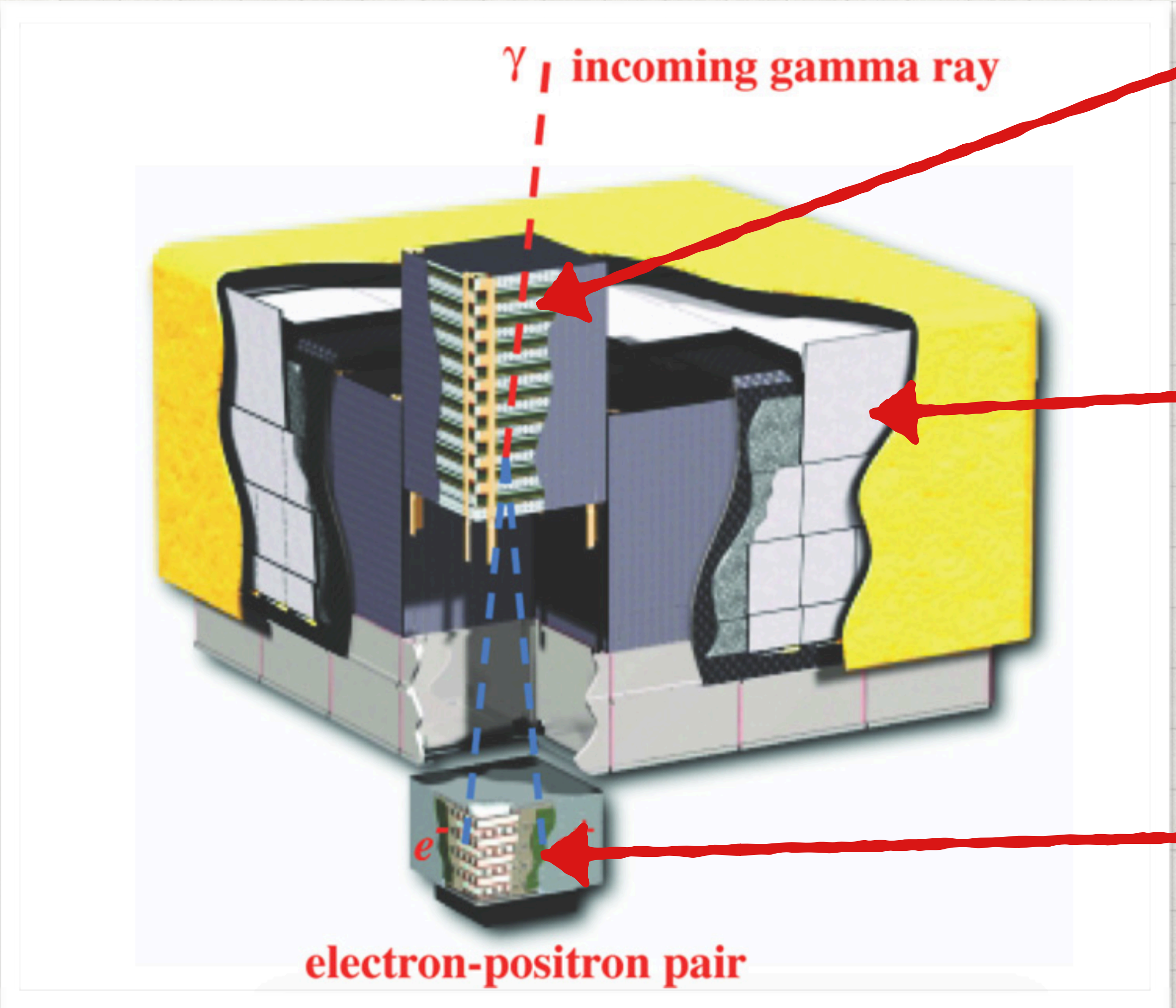


Top views:

A 4 × 4 array of 16 modules

Converter:
- For pair production

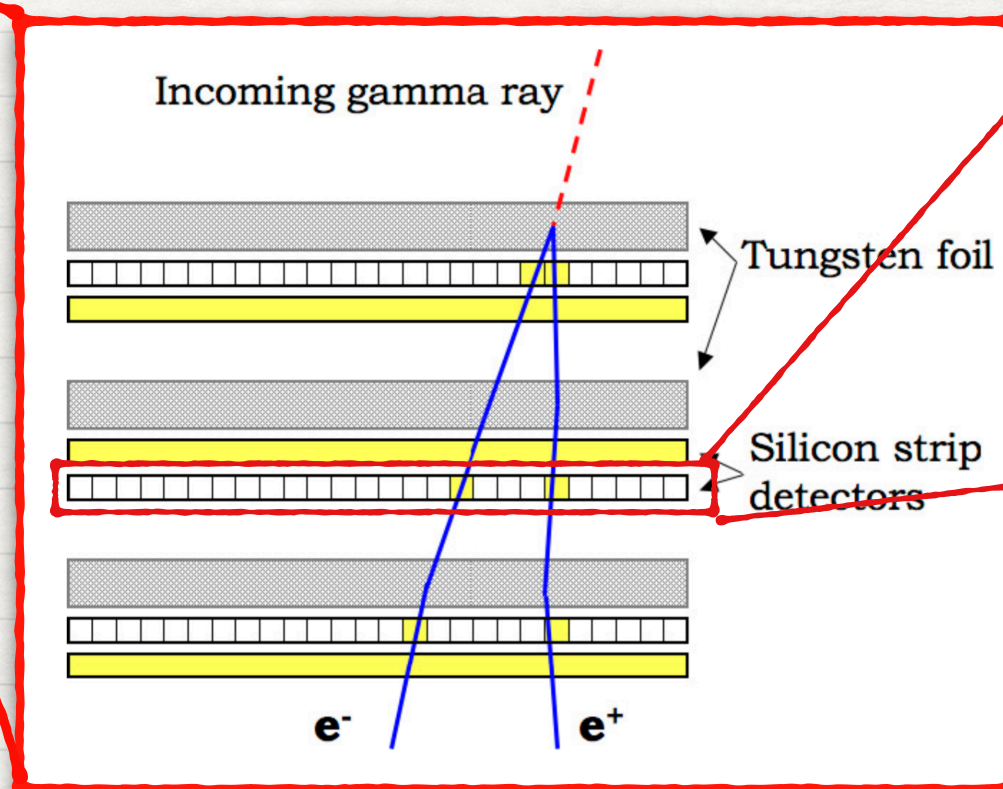
Tracker:
- Trace the electron/positron
- Determine the incoming direction of gamma-ray

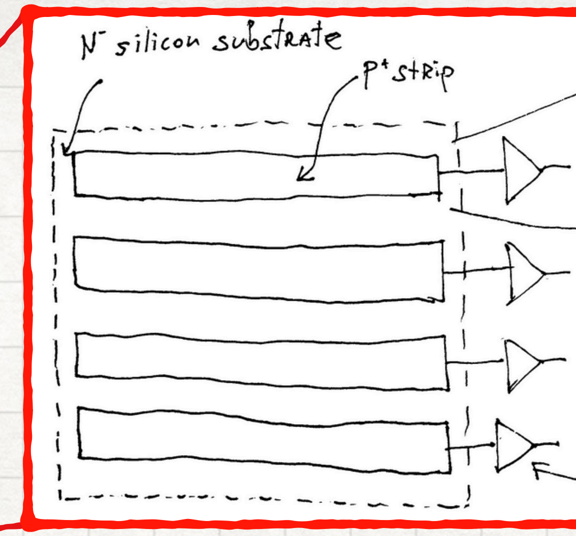


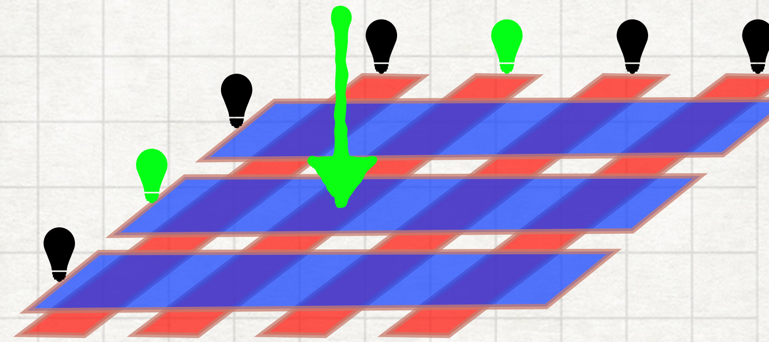
Anti-coincidence shield:
- Reject the charged-particle background

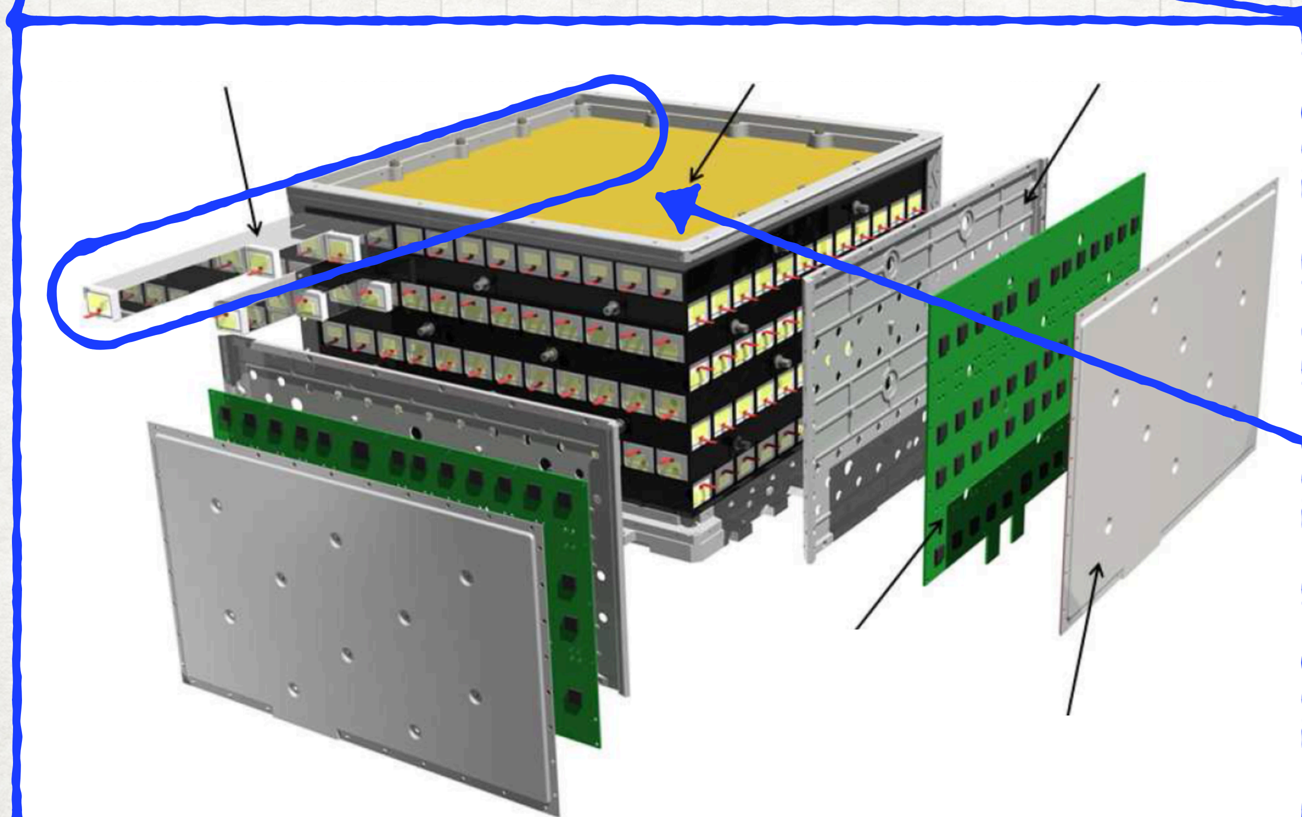
Calorimeter(热量计):
- To measure the energy deposition

(https://fermi.gsfc.nasa.gov/)







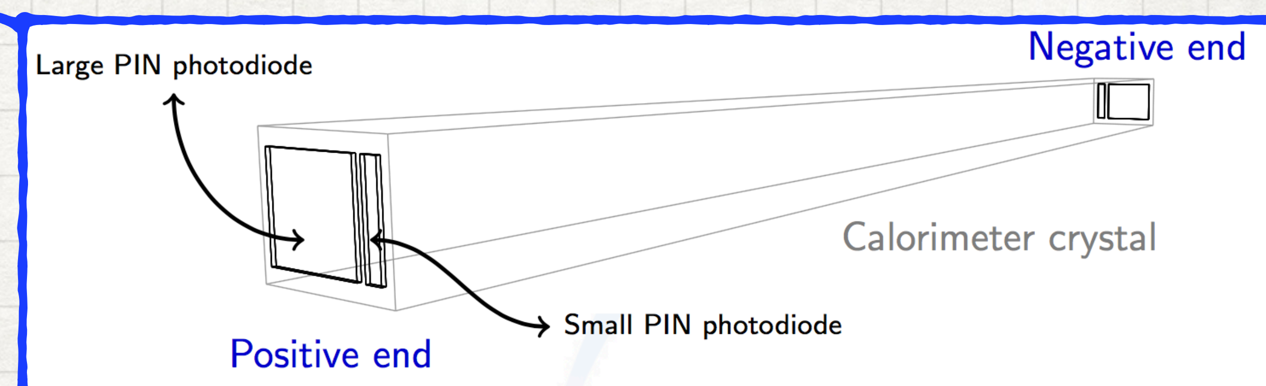


8 layers of 12 CsI(Tl) crystals per tower

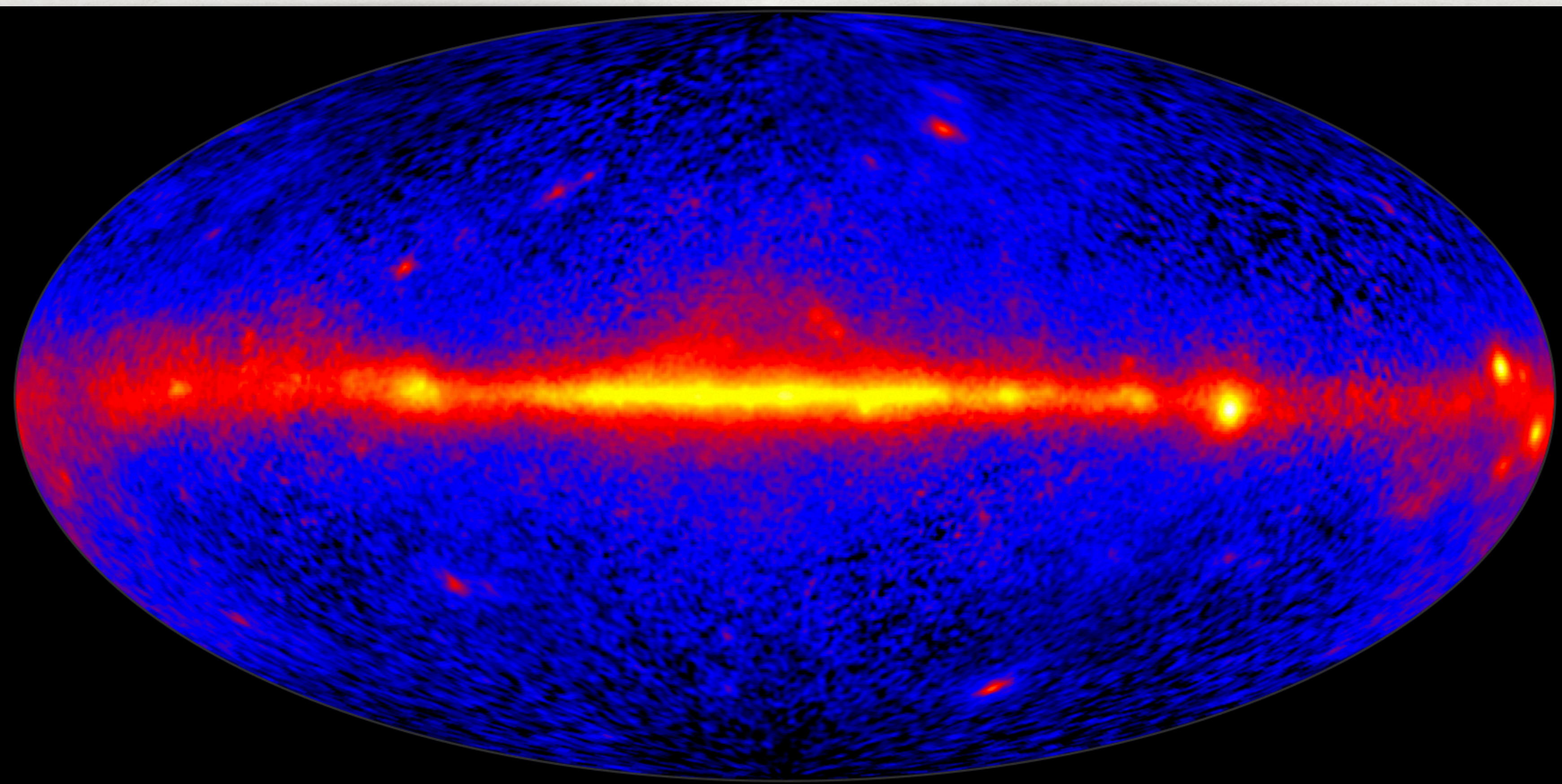
particle interact with scintillator(闪烁体)

=> produce photons

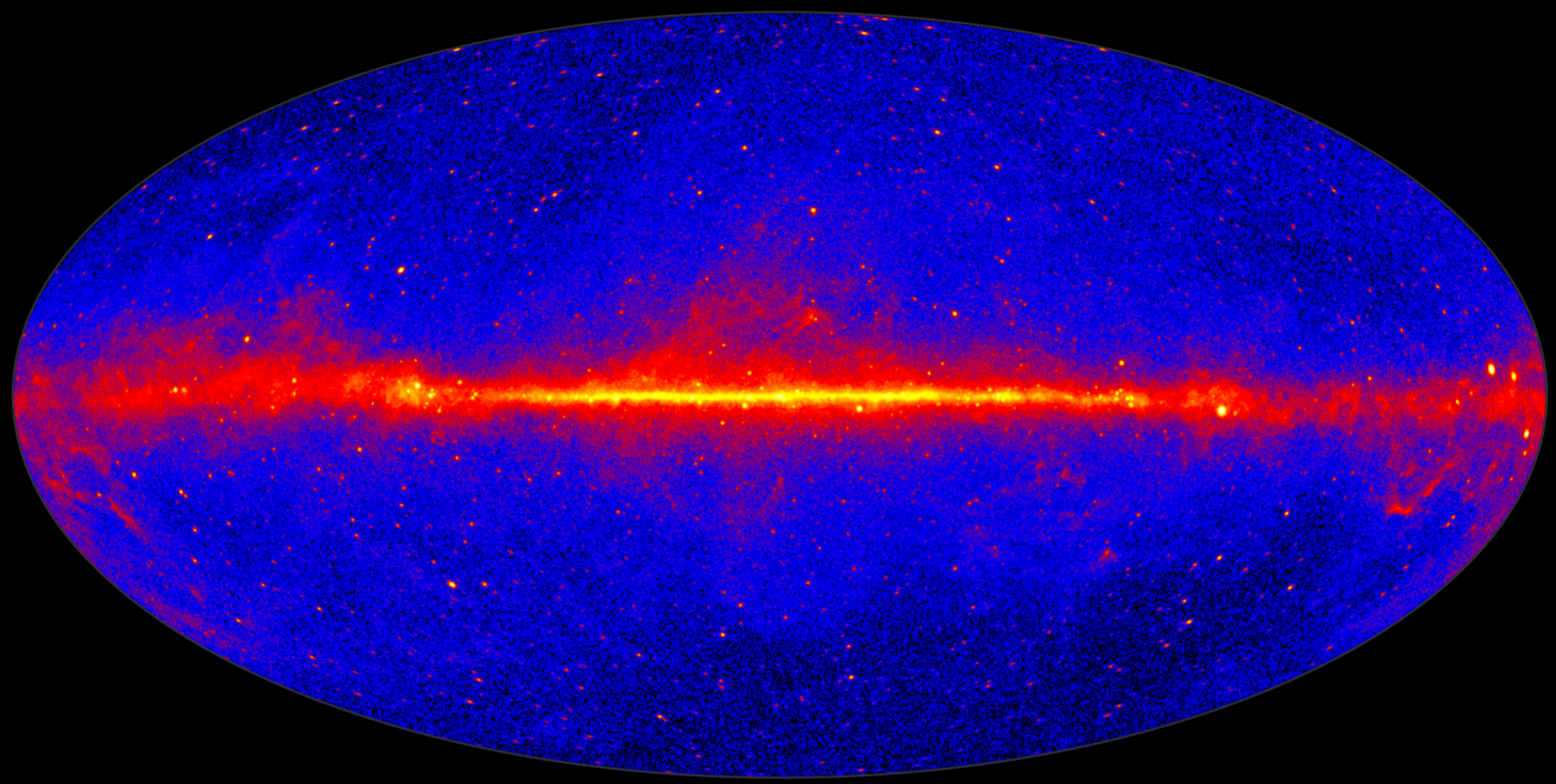
=> read out by PIN photodiodes (光电二极管)



Fermi Gamma-ray Space Telescope	VS	Egret GAMMA RAY OBSERVATORY
2008-2018		1991-2000
pair production	Detection principle	pair production
20MeV-300GeV	energy range	20MeV-30GeV
<10%	energy resolution	10%
< 3.5° (100 MeV) < 0.15° (>10 GeV)	angular resolution	5.8° (100 MeV)
2.4sr	Field of view	~0.5sr
<20μs	Time accuracy	50μs



EGRET all-sky map of gamma rays above 100 MeV

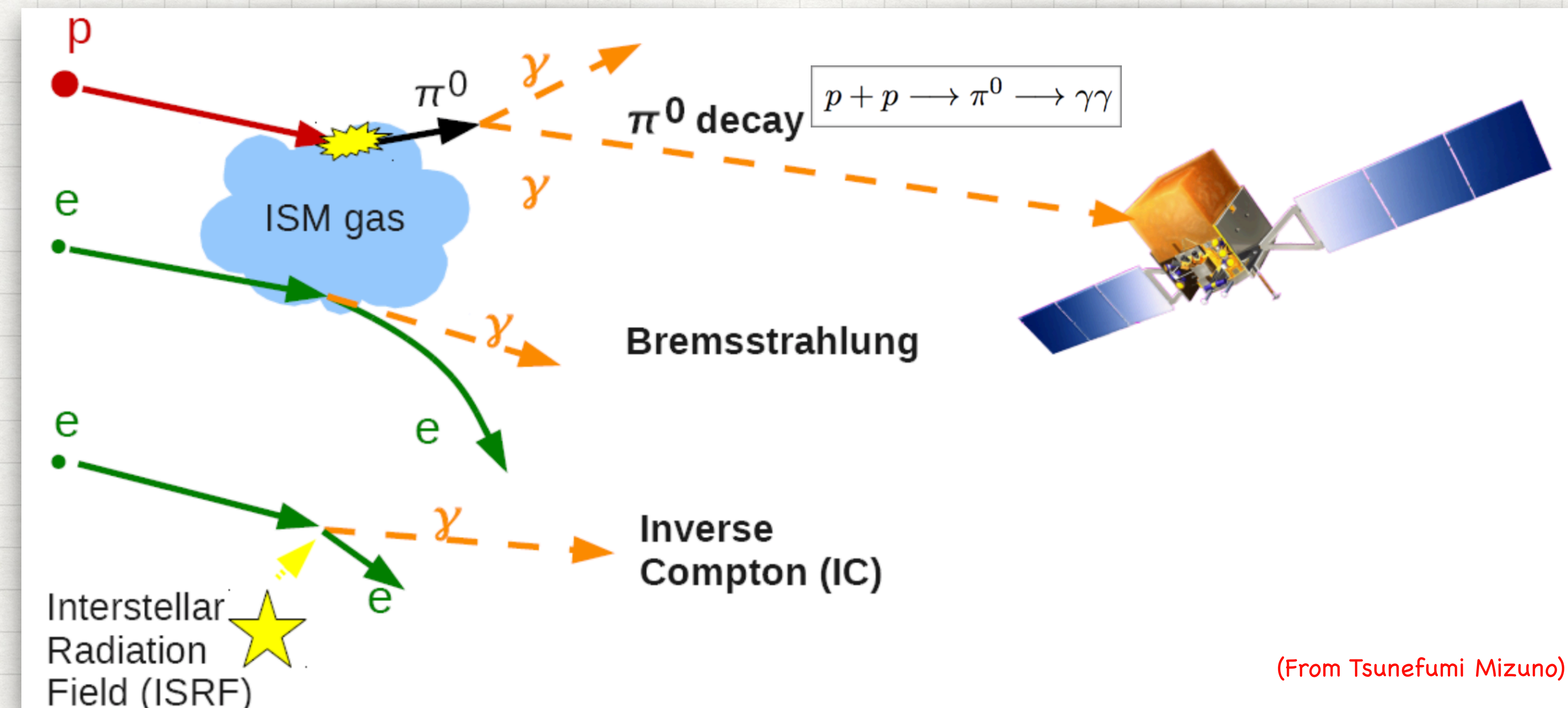


Fermi LAT 7-year all-sky map of gamma rays above 1 GeV

PART II. Science

III. Discovery of Fermi Bubble

Gamma ray with known source from the center of Milky Way:

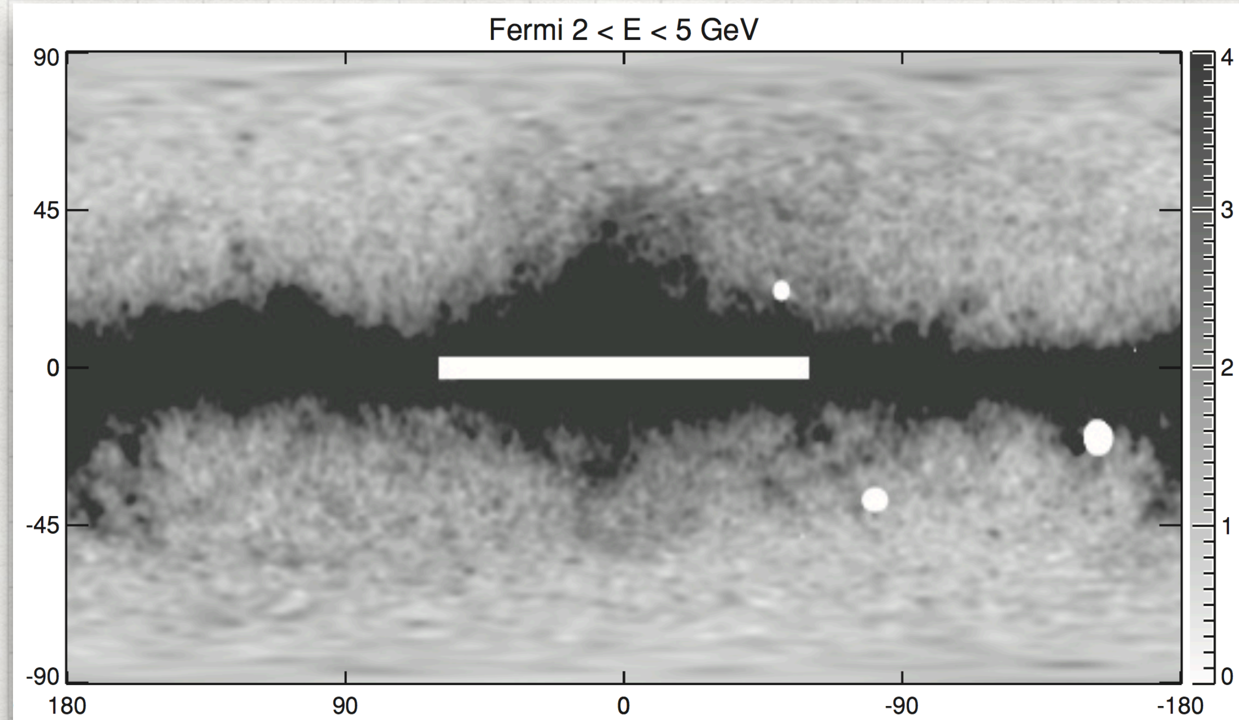


Subtract the radiation above, we will get the radiation we cannot explain

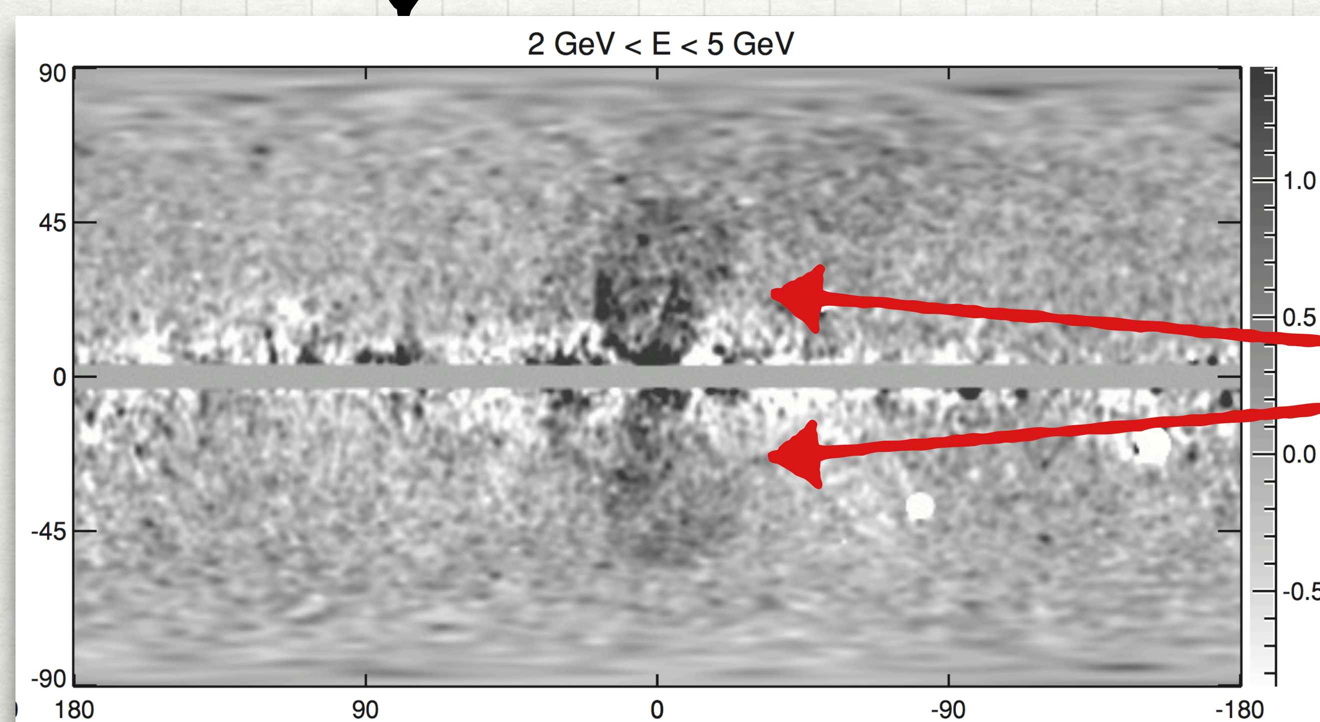
- Use the Fermi Diffuse Galactic Model provided by the Fermi team
- Employ a dust map to trace ISM related process, and a disk model to trace ISRF
- Use the lower energy band 0.5-1.0 GeV Fermi map as a template of a diffusion emission model

(Su et al. ApJ 724:1044-1082, 2010)

Method I. Fermi Diffuse Galactic Model



Subtract radiation from *Fermi* diffuse Galactic model



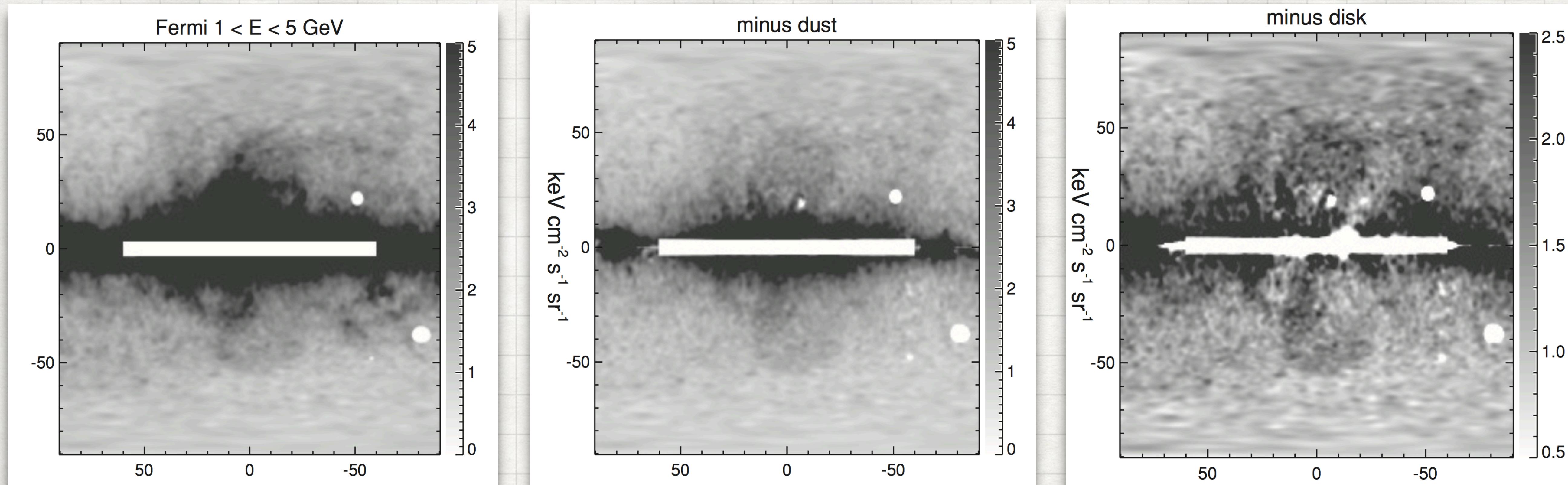
Fermi Bubbles!

Diffuse Galactic emission modeling

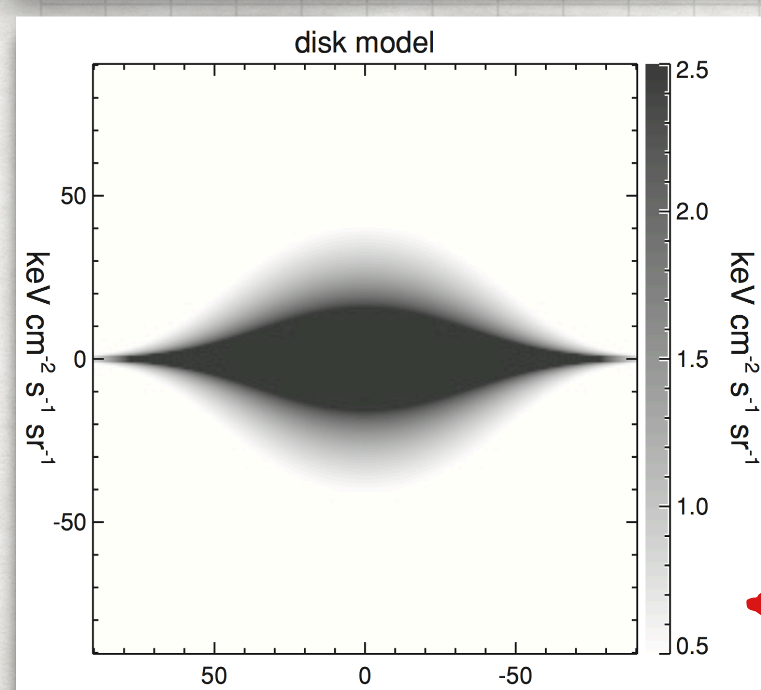
- Distribution of cosmic ray sources
  - Pulsars, SNRs, OB stars
    => from literature
- Propagation of cosmic ray
  - A bunch of equations
- Distribution of targets in the galaxy
  - Interstellar gas(HI, H_2, HII)
    => from observation
  - Interstellar dust
    => employ relation with gas
  - Interstellar radiation field(ISRF)
    => star light, CMB, IR from dust and star

(Su et al. ApJ 724:1044-1082, 2010)

Method II. Simple Template-based Diffuse Galactic Model



π^0 / bremsstrahlung gamma-ray intensity $\propto$ ISM density $\times$ the CR proton/electron



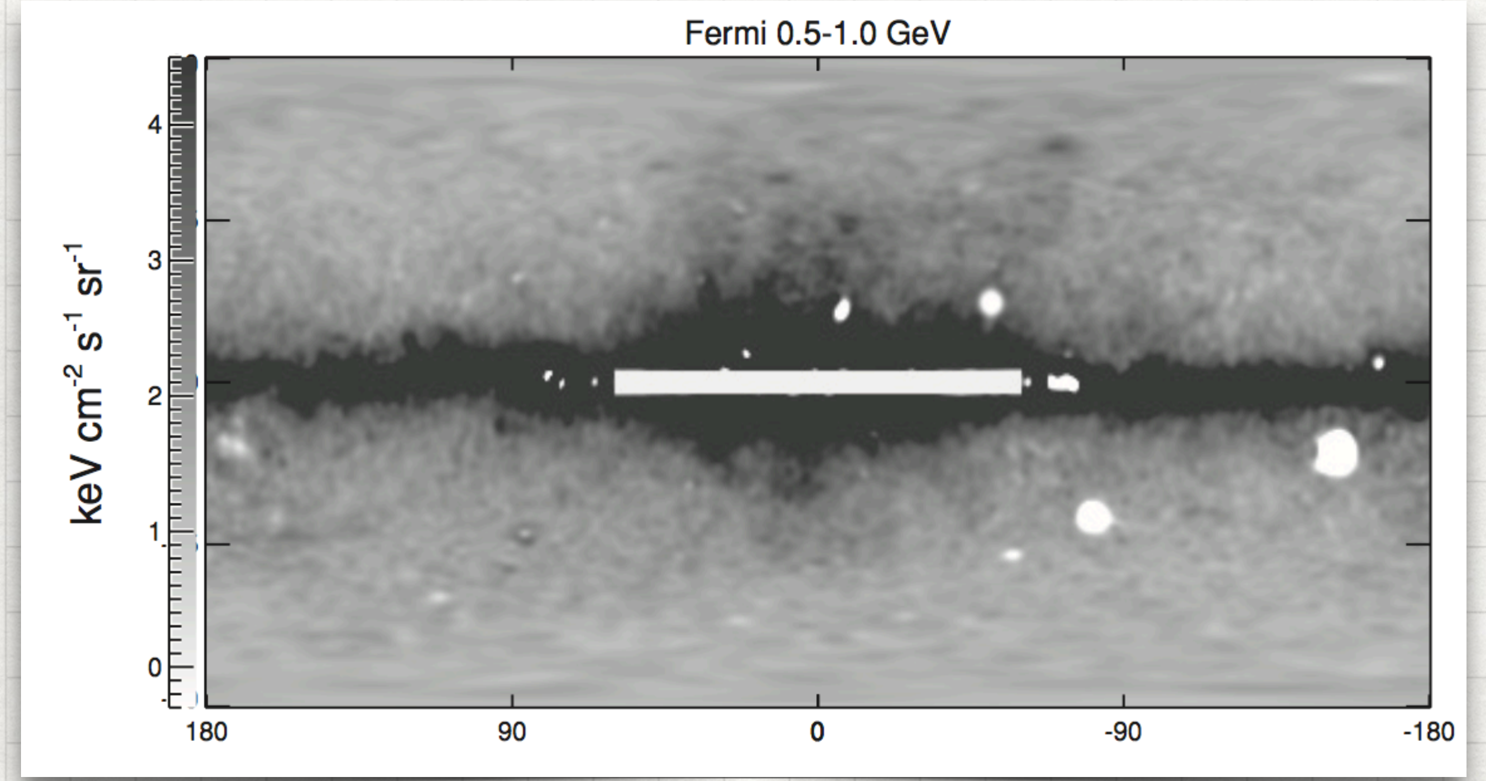
Schlegel, Finkbeiner, & Davis (SFD) dust map

Assume uniform

To trace the ISRF for removing gamma ray produced by IC

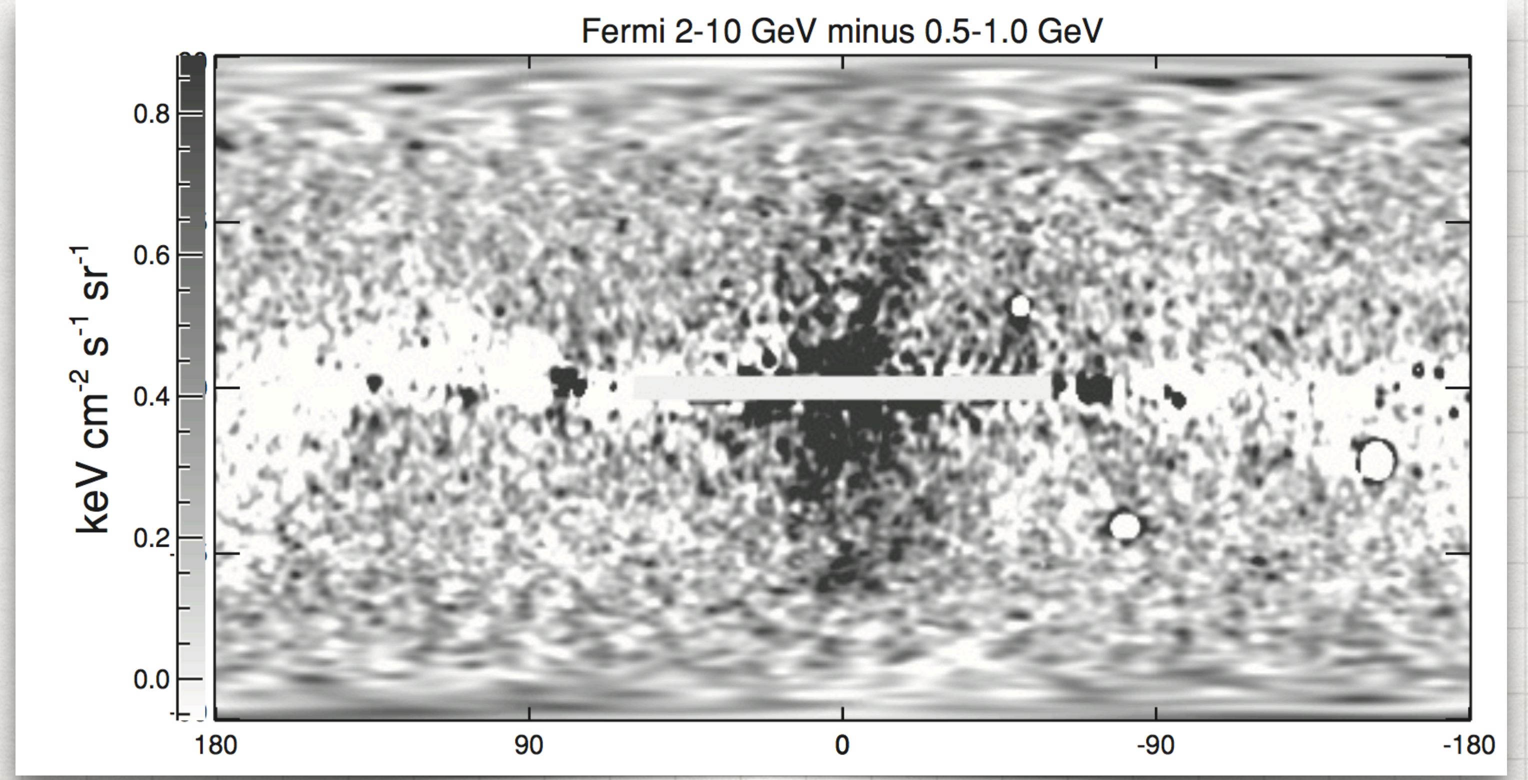
(Su et al. ApJ 724:1044–1082, 2010)

Method III. Low-energy Fermi Map as a Diffuse Galactic Model



Both already subtract the dust map

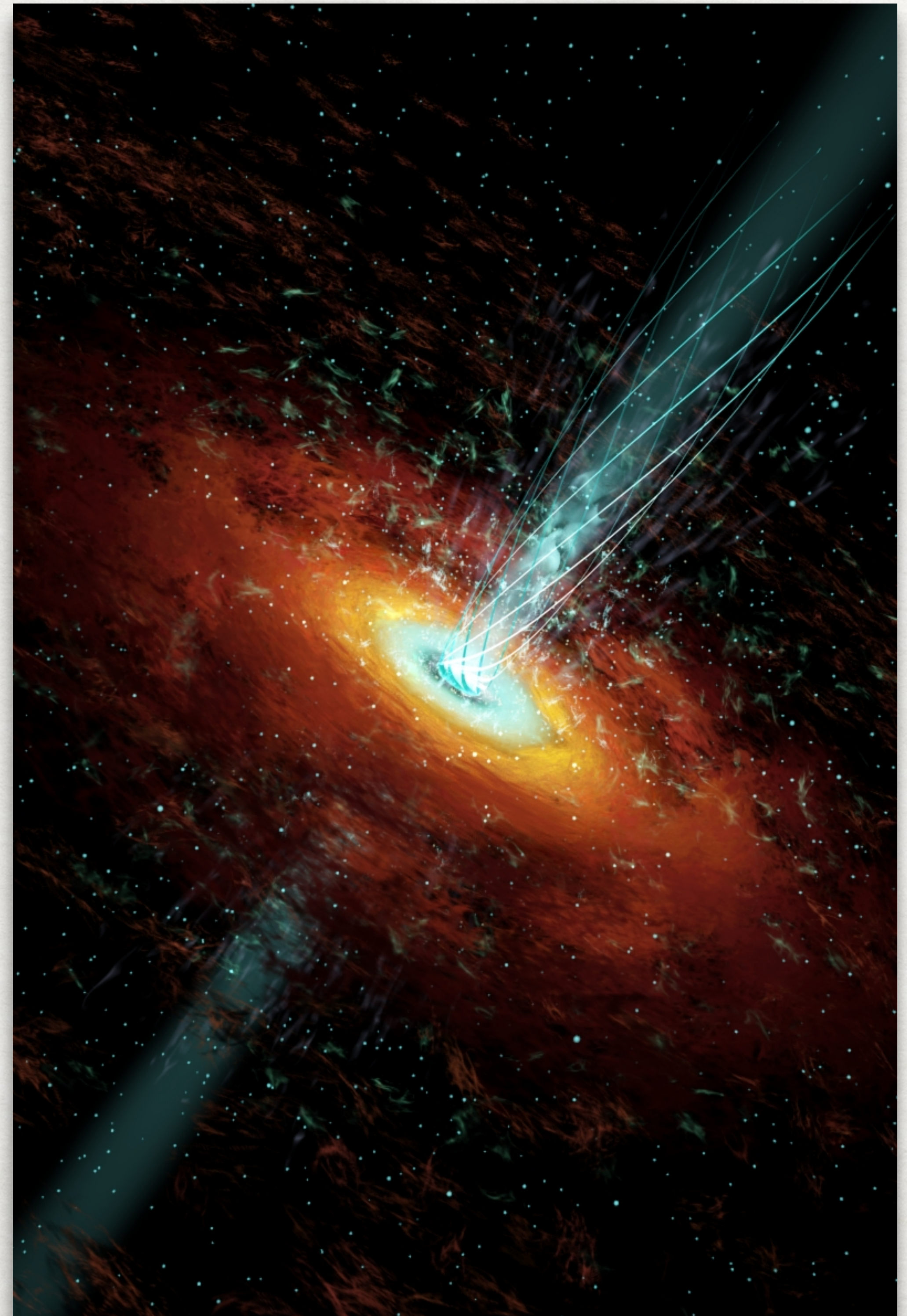
Use 0.5-1GeV map as a template of IC map



(Su et al. ApJ 724:1044-1082, 2010)

What is the origin of Fermi Bubble?

Past AGN jet?



Black halo burp?

Dark matter?

IV. Gamma ray observation of AGN

Gamma-ray AGN
Blazar

BL Lac
weak lines

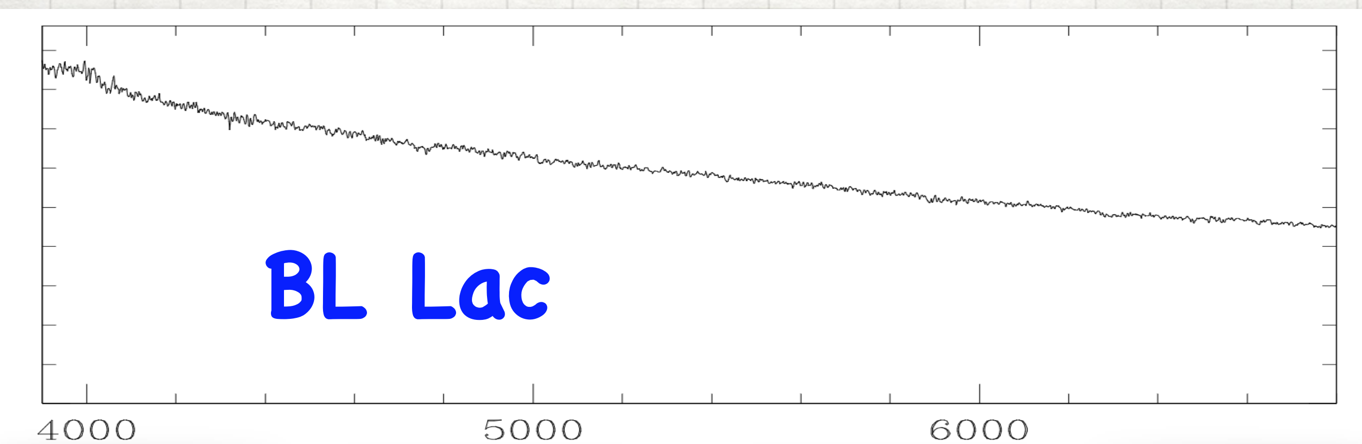
FSRQ(flat spectrum radio quasars)
strong lines

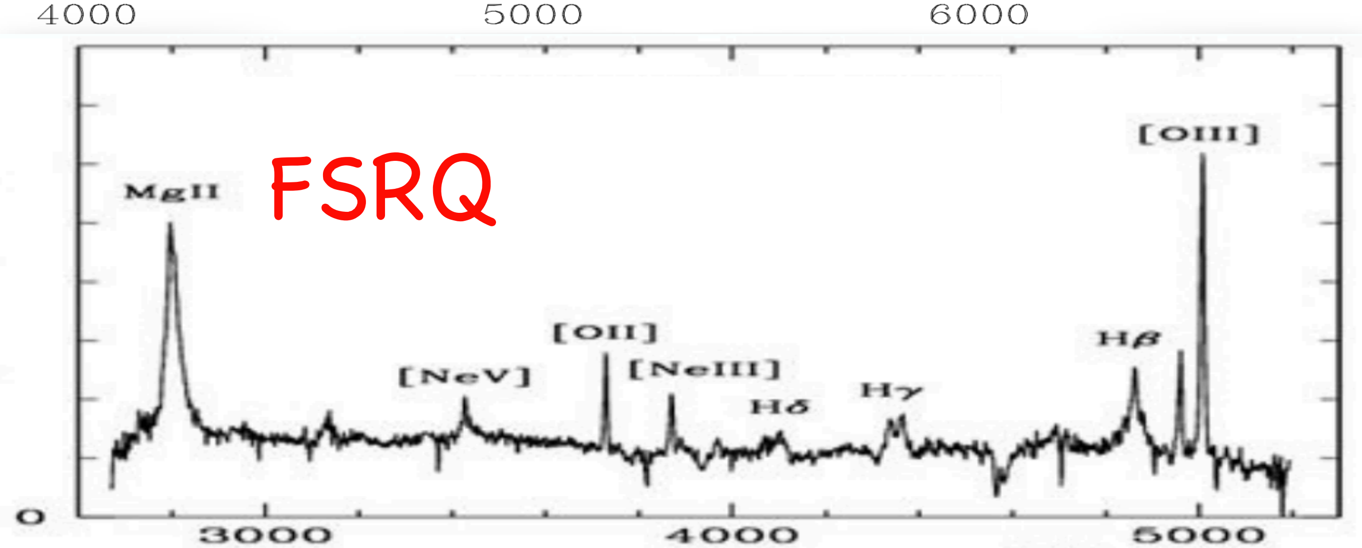
LSP
low Synchrotron Peaked
log(ν) < 14

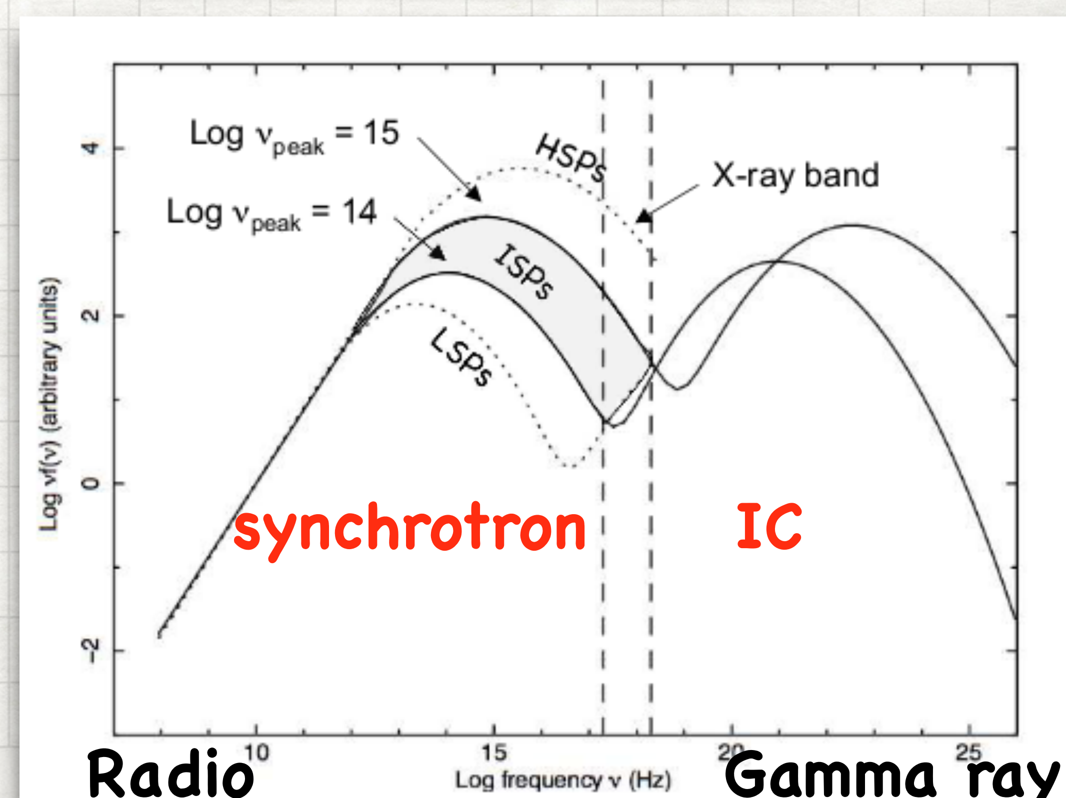
ISP
Intermediate Synchrotron peaked
14 < log(ν) < 15

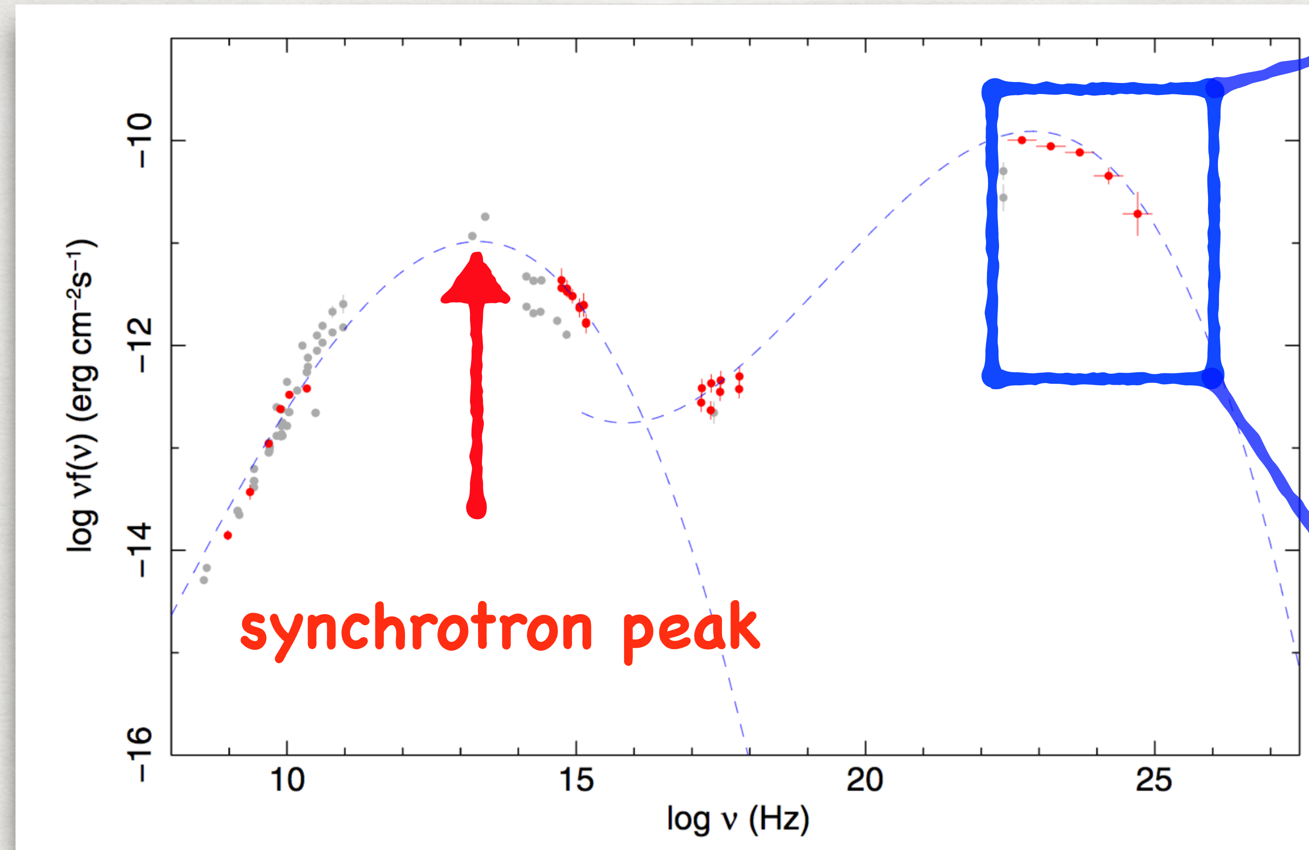
HSP
High Synchrotron Peaked
15 < log(ν)

- dramatic variability
- strong radio emission
- high flux in X-ray band



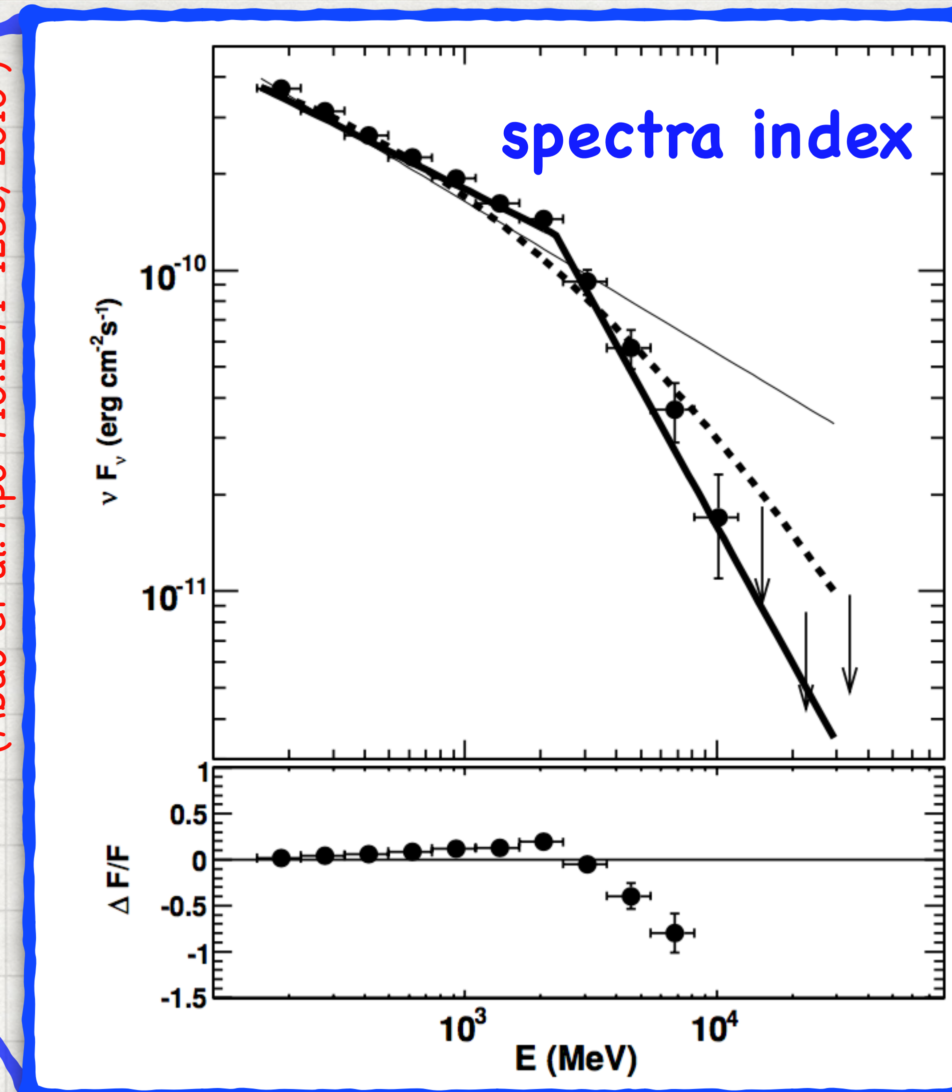


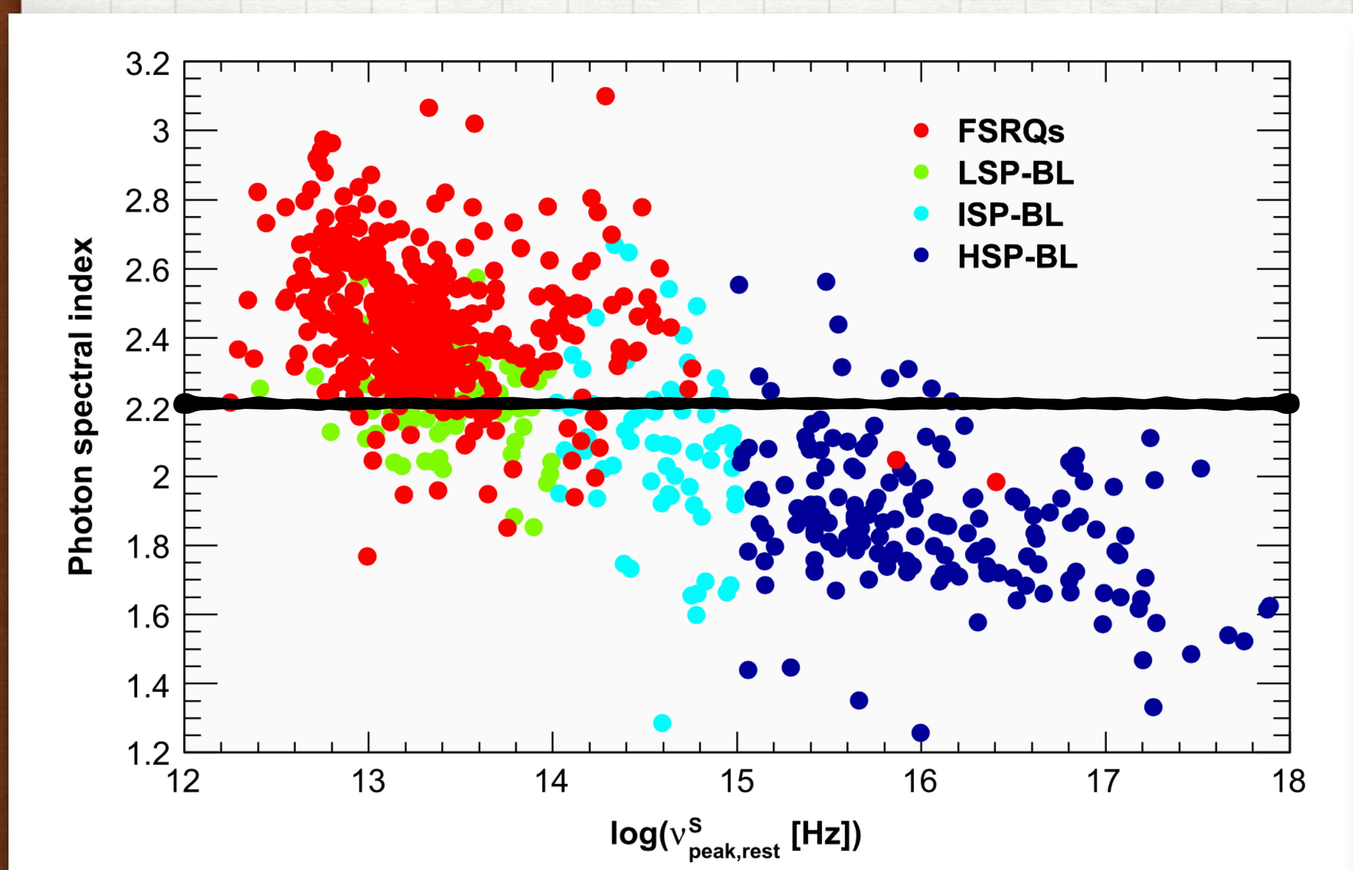


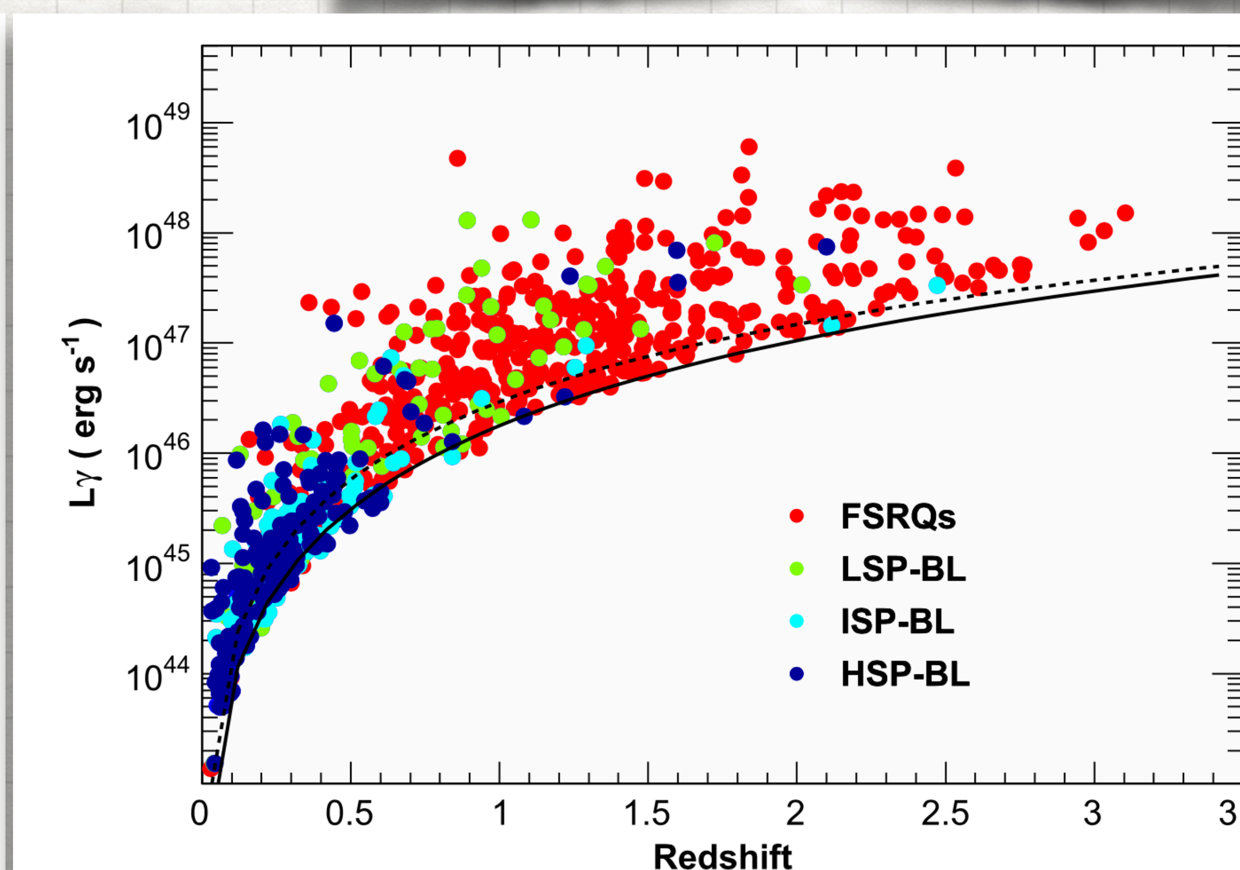


(Abdo et al. ApJ 716:30–70, 2010)

(Abdo et al. ApJ 710:1271–1285, 2010·)

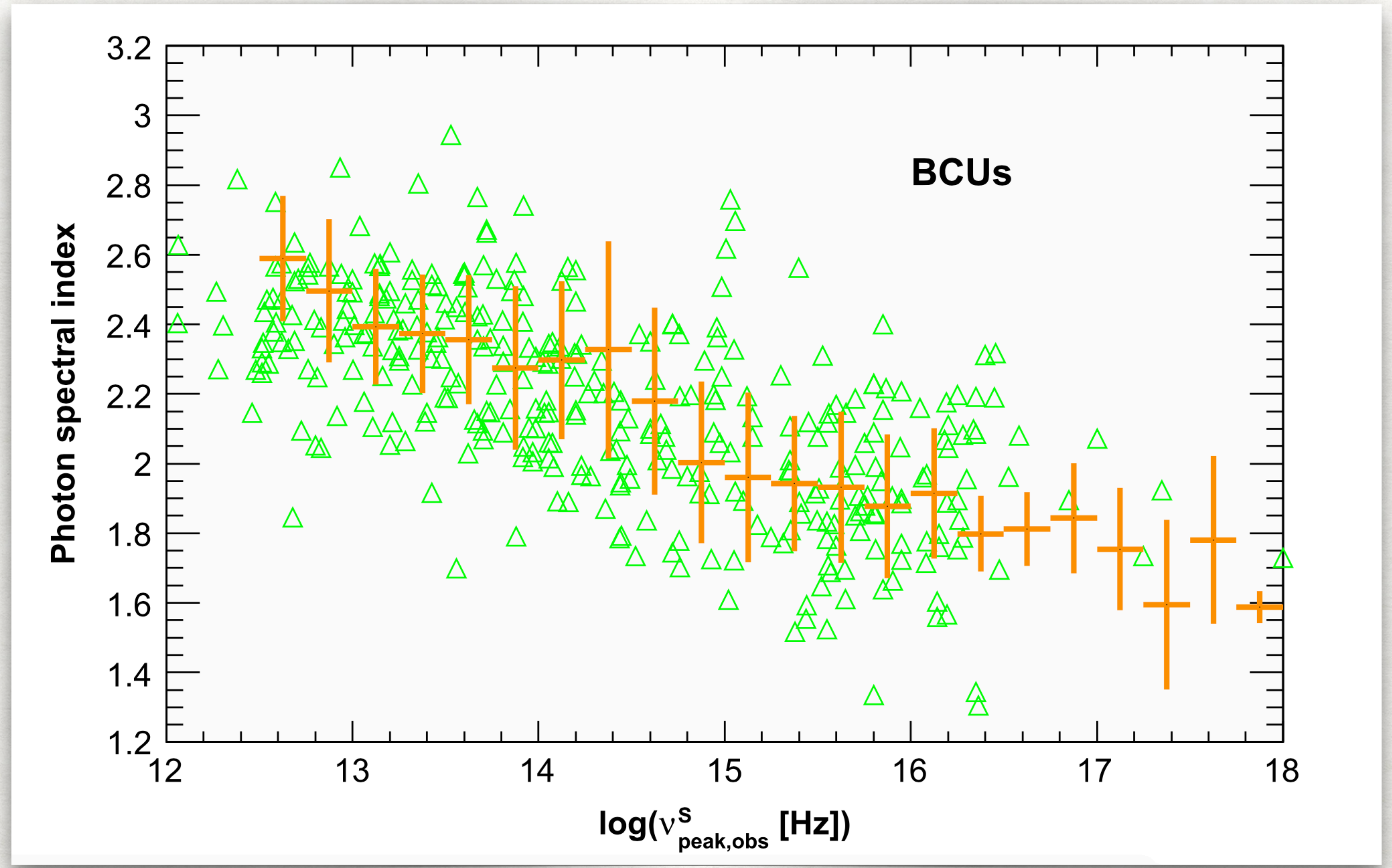




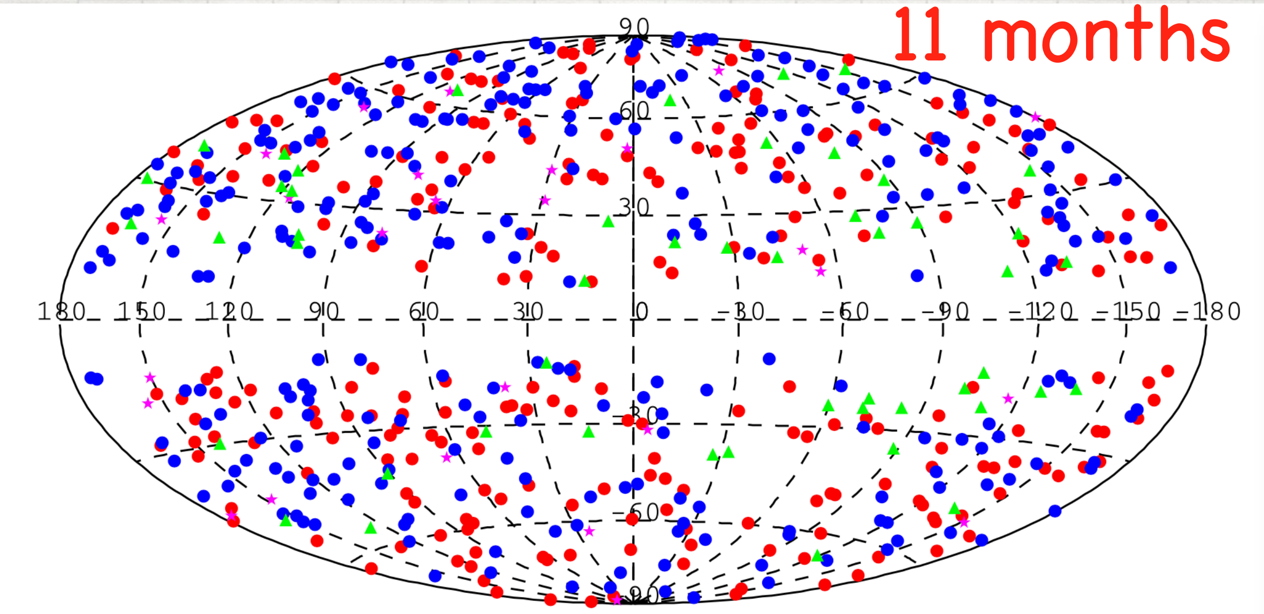


(Ackermann et al. ApJ 810:14 (34pp), 2015)

BCU: Blazar Candidates of Uncertain type
They are blazars according to observation in other bands, but we are not which which kind of blazar it is.

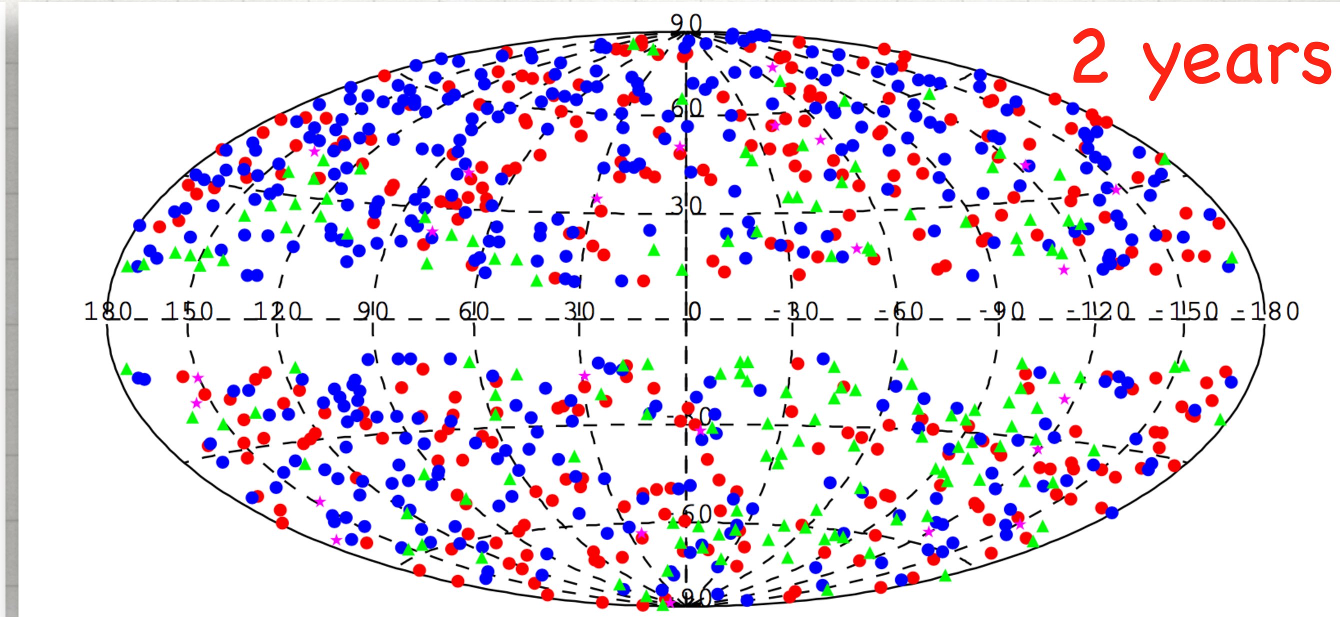


First LAT AGN catalog(1LAC)



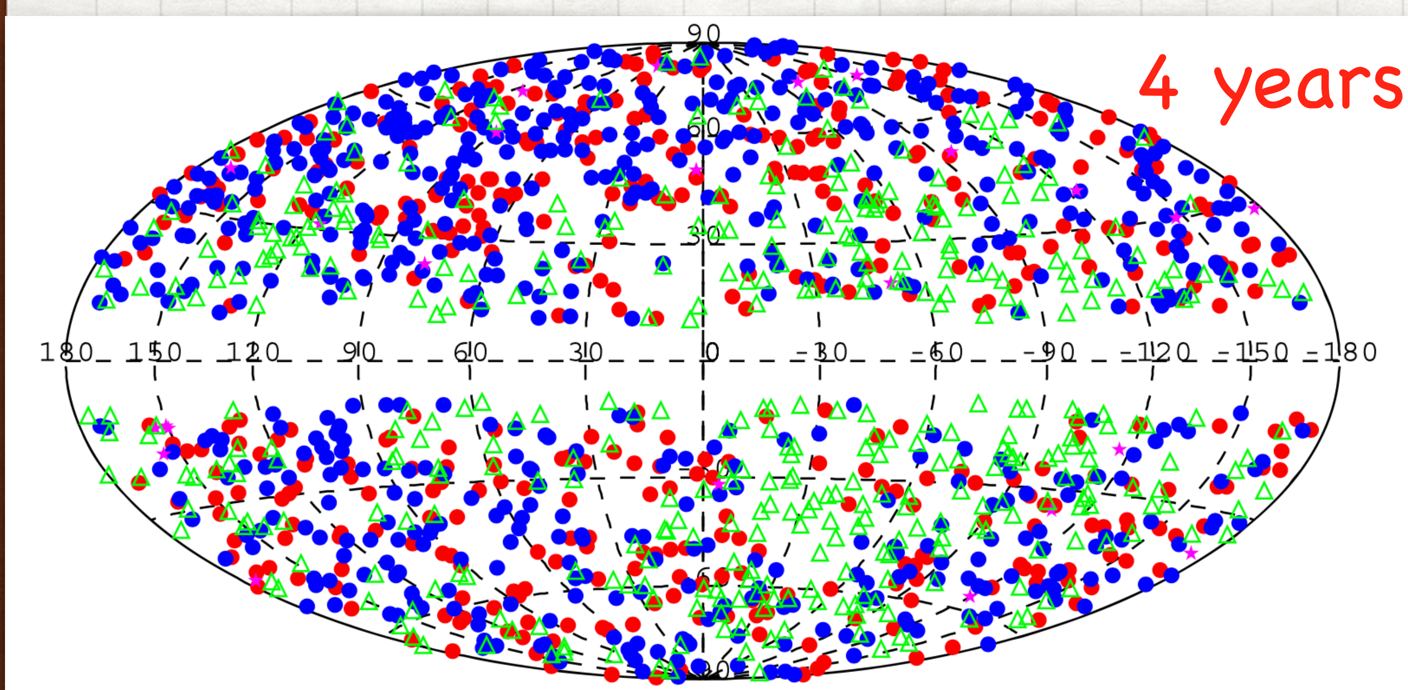
(Adbo et al. ApJ 715:429-457, 2010)

Second LAT AGN catalog(2LAC)

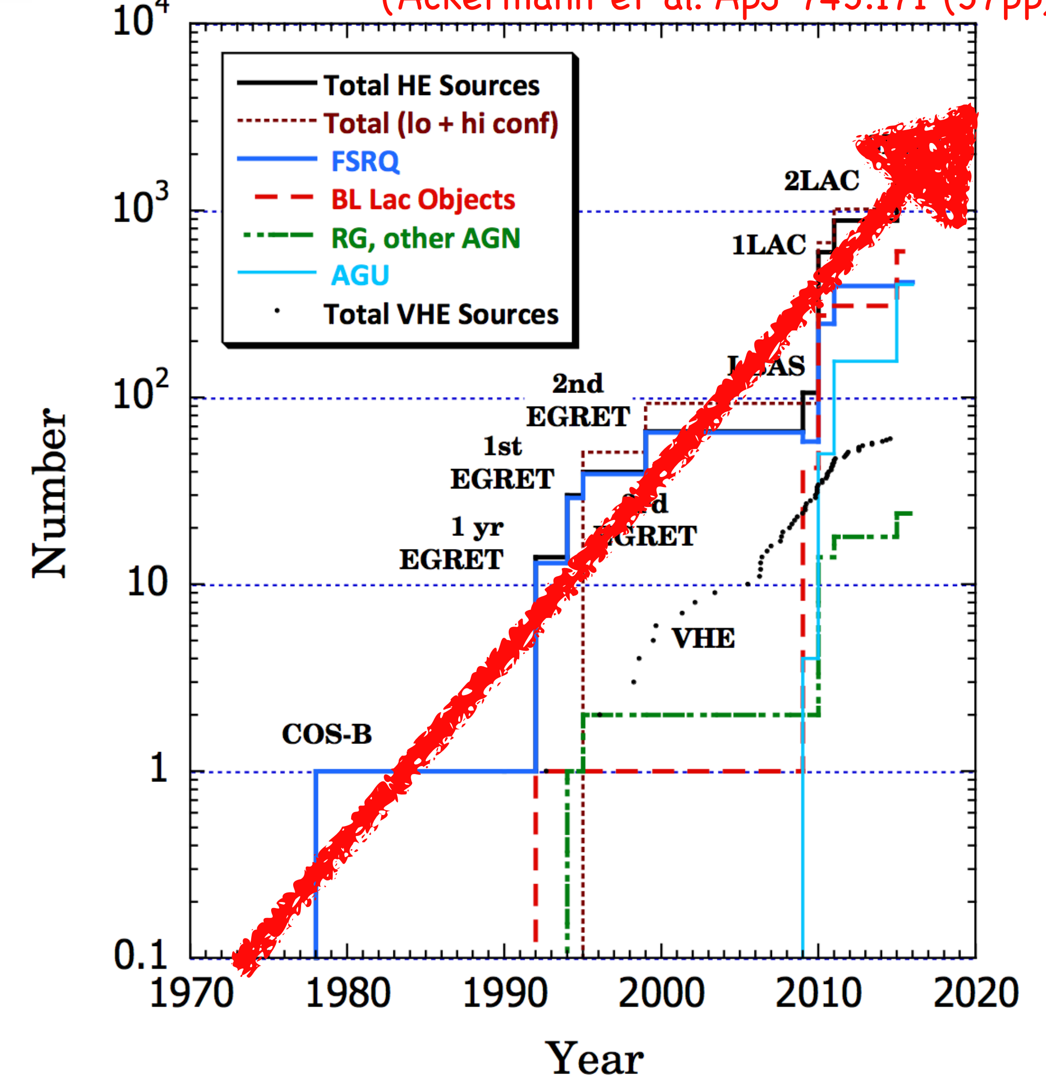


(Ackermann et al. ApJ 743:171 (37pp), 2011)

Third LAT AGN catalog(3LAC)



(Ackermann et al. ApJ 810:14 (34pp), 2015)



(Dermer & Giebels arXiv:1602.06592v1)

IV. Summary

1. Fermi satellite has two instruments: LAT and GBM
2. Fermi LAT uses pair production to detect gamma ray with $20\text{MeV} < E < 300\ \text{GeV}$
3. Fermi LAT has a much better performance than its progenitor — EGRET
4. Fermi bubble can be discovered after careful subtraction of radiation from known sources
5. Fermi LAT provide a huge dataset for the study of AGN in gamma ray band

Thank You!