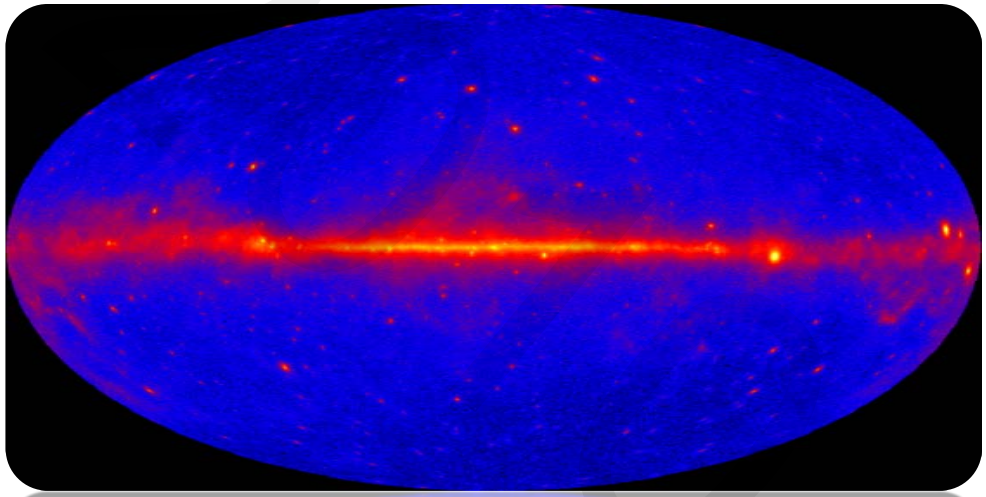
The gamma-ray blazar population and Cosmic Diffuse Backgrounds

Gino Tosti

On behalf of
M. Ajello for the LAT Collaboration



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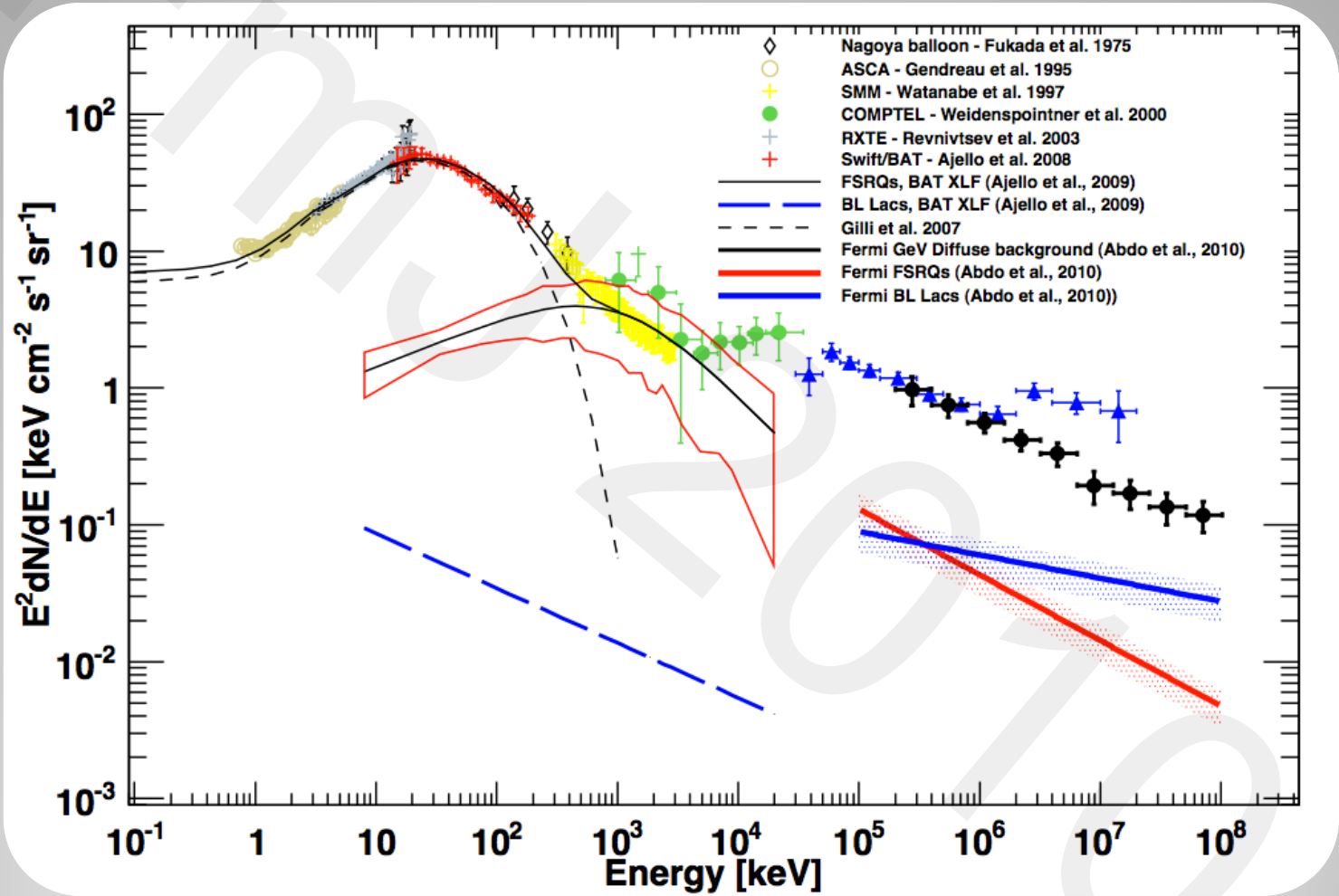
High-energy backgrounds



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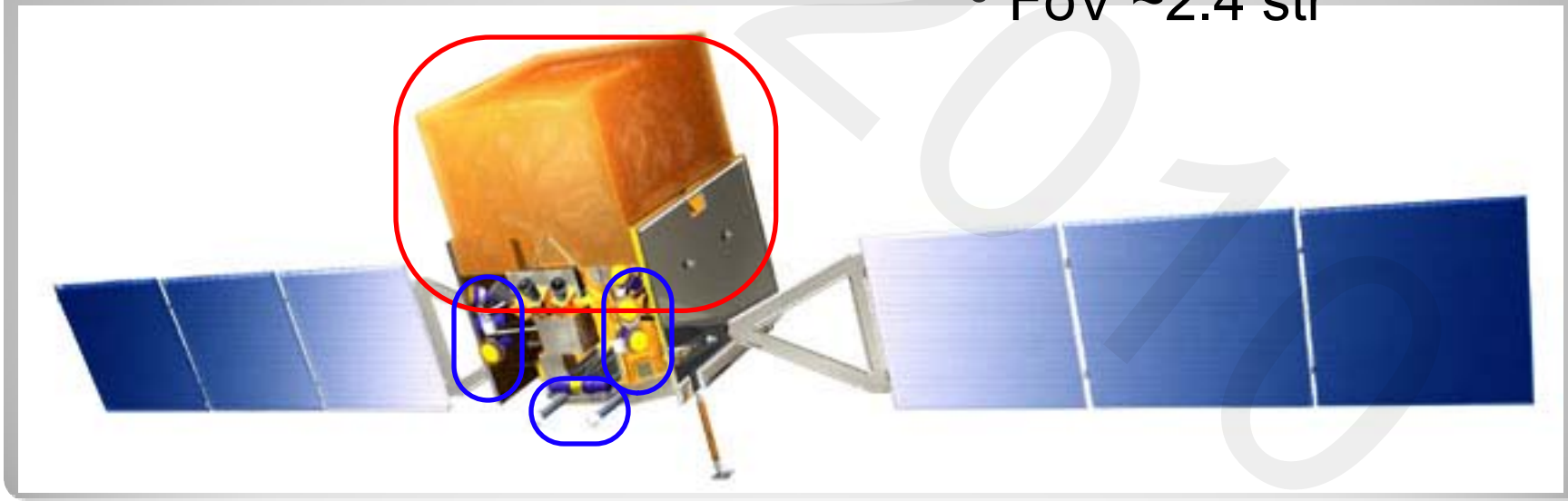
The Fermi observatory

- **Launch: June 11th, 2008**
- **Orbit: 565 km, 25.6° inclination**
- **Two instruments onboard:**

- Gamma-Ray Burst Monitor (GBM):
  - 8 keV -> 40 MeV

Large Area Telescope (LAT)
- 20 MeV -> 300 GeV
- FoV ~2.4 str



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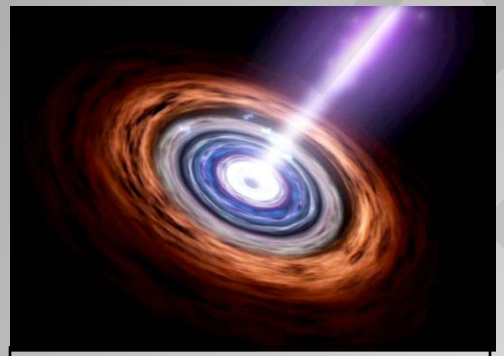
Why is this important ?

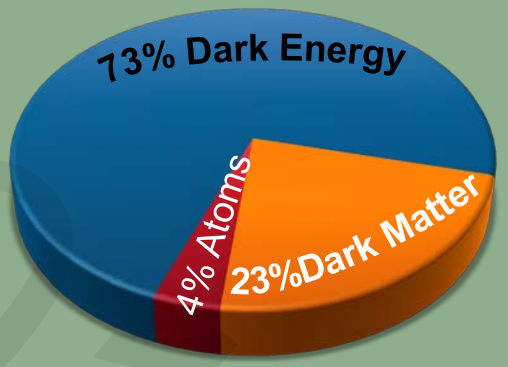
- **The Extragalactic Gamma-ray Background may encrypt the signature of the most powerful processes in astrophysics**



Blazars contribute 20-100% of the EGB (*Stecker&Salomon96, Mücke&Pohl00, Narumoto&Totani04,Dermer07 , Inoue&Totani09)*

Emission from star forming galaxies (*e.g. Pavlidou&Fields02)*

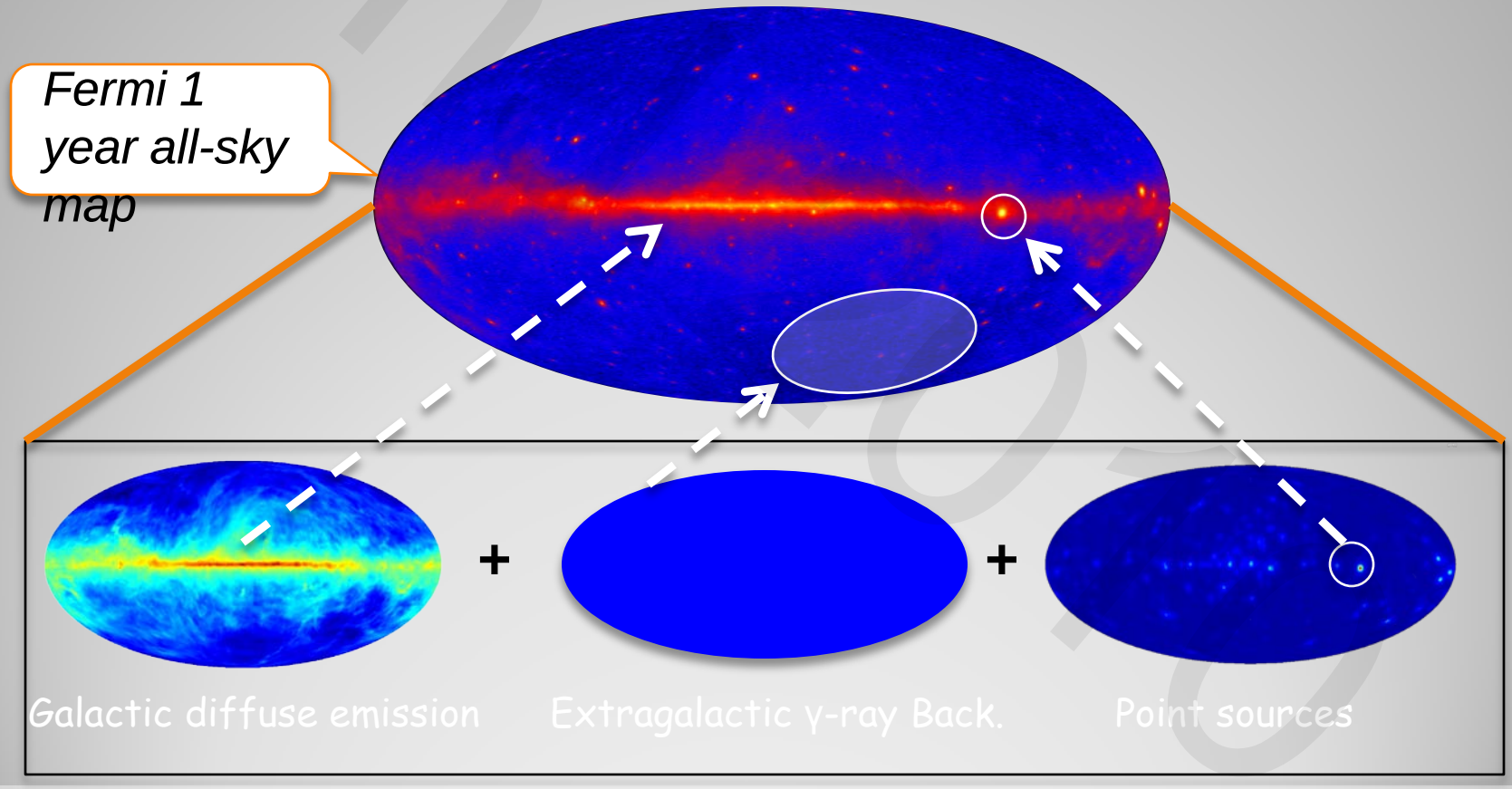
Emission from particle accelerated in Intergalactic shocks (*Loeb&Waxmann00)*



Emission due to the annihilation of Cosmological Dark Matter *(eg. Jungman+96)*

What is the Extragalactic Gamma-ray Background ?

- **The gamma-ray sky as observed by Fermi represents the sum of different components: one of them is the Extragalactic Gamma-ray Background**



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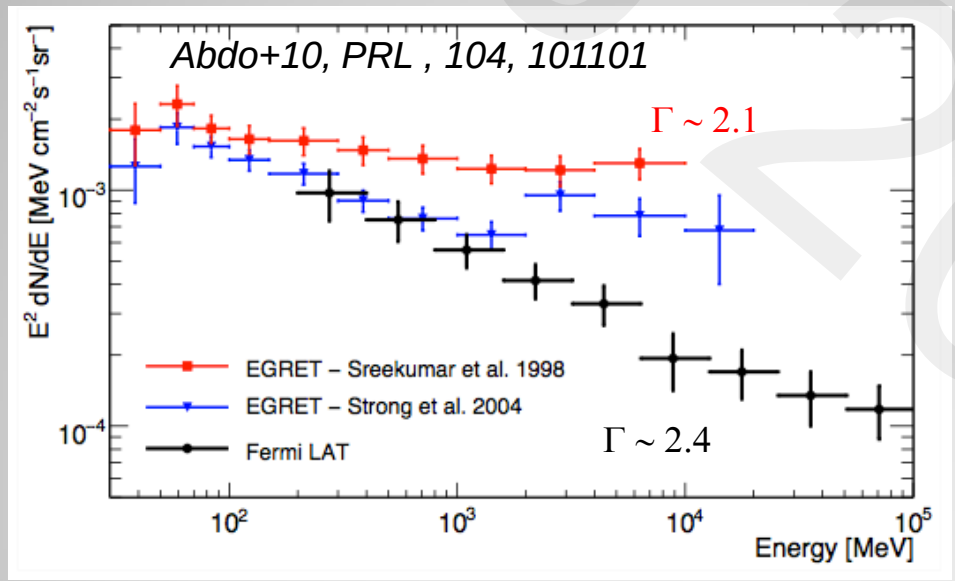
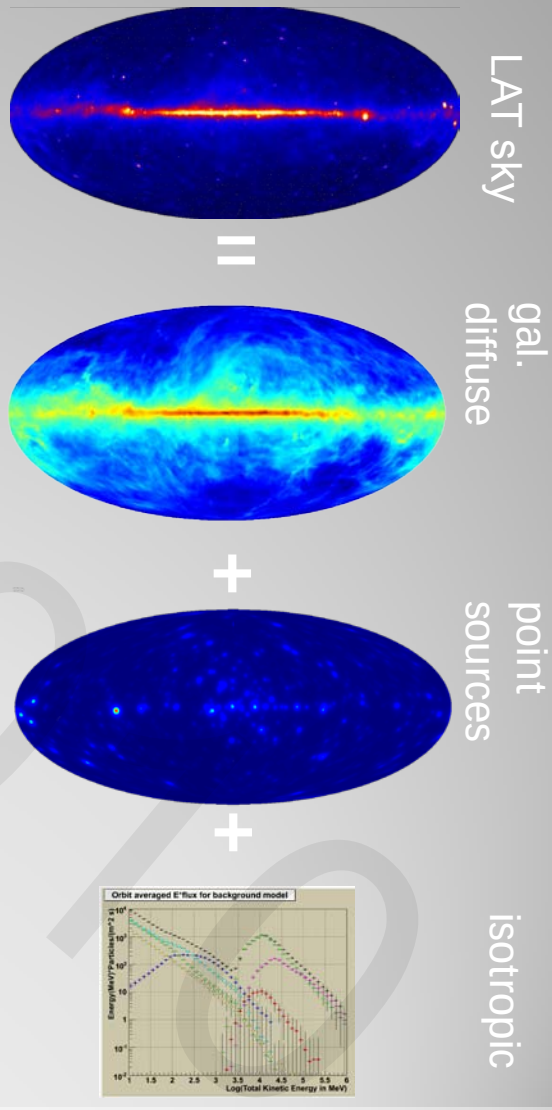
The new Fermi EGB

- **Simultaneous Maximum Likelihood fit to all |b|>10° sky with:**
  - **Equal area pixels (0.8 deg^2)**
  - **Sky models compared to LAT data**
  - **All sources detected in 9months**
  - **9 energy bind, 200 MeV<E< 100 GeV**
  - **10 months of LAT data, 19 Ms exposure**



Fermi EGB ~ 40% lower than EGRET



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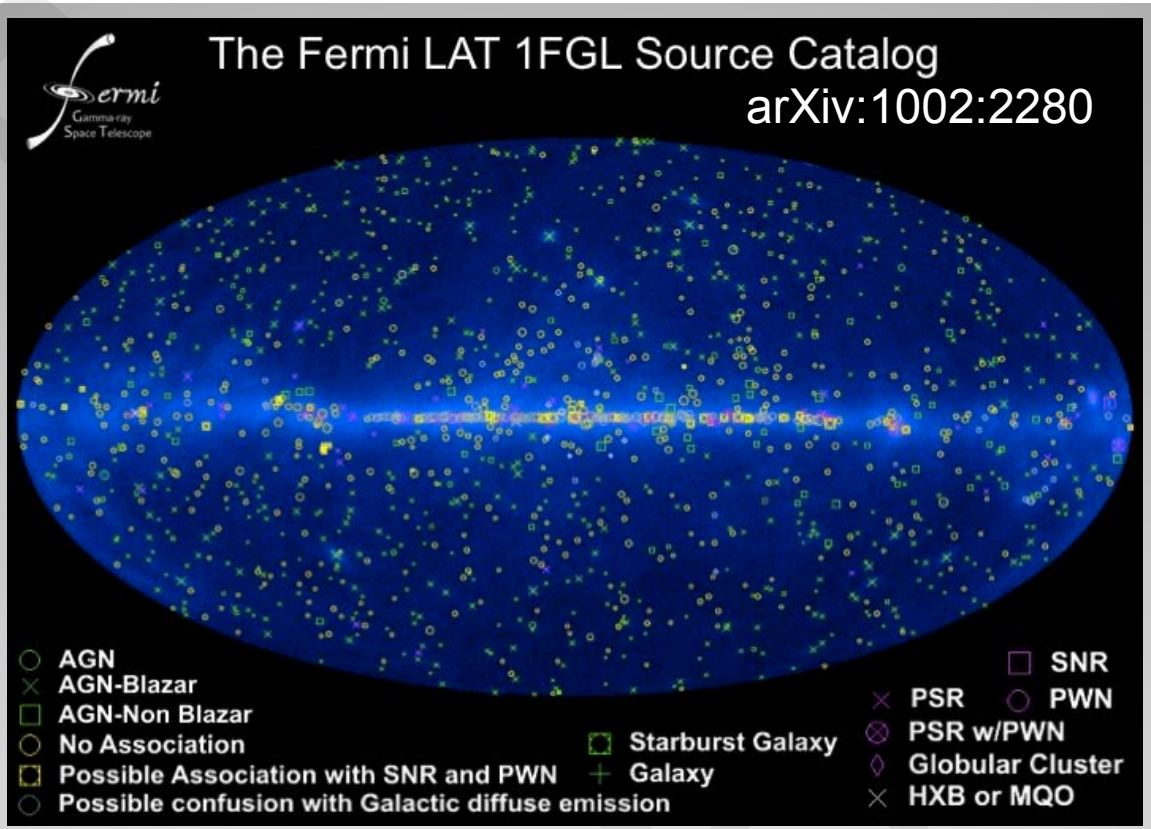


- **11 months of data 100 MeV to 100 GeV, 23.3 Ms live time**
- **10.6 M events over the whole sky (Pass 6 Diffuse class γ-rays)**
  - **Raw data are essentially pure cosmic rays (~2.5 kHz)**
  - **Diffuse-class γ-rays (>100 MeV) ~0.5 Hz**
- **Very uniform exposure (factor 1.25 between north and south)**

Source Classes

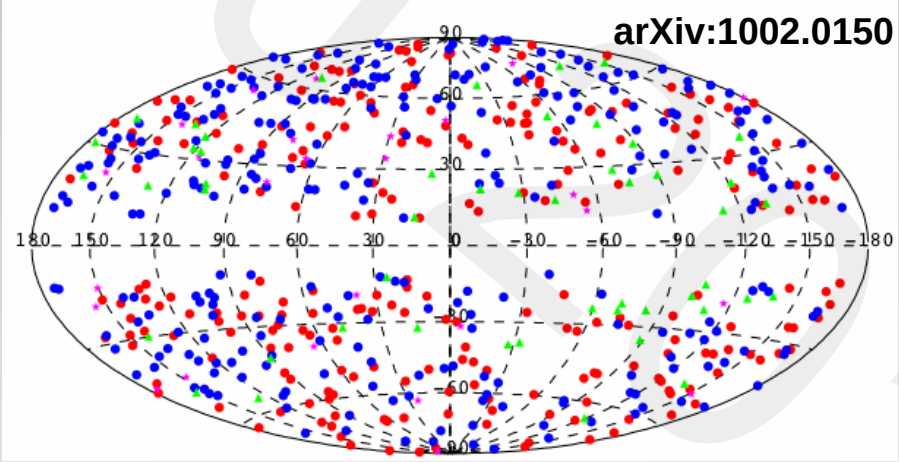
Table 6. LAT 1FGL Source Classes

Description	Designator	Number Assoc. (ID)
Pulsar, X-ray or radio, identified by pulsations	psr (PSR)	7 (56)
Pulsar, radio quiet (LAT PSR, *subset of above*)	PSR	24
Pulsar wind nebula	pwn (PWN)	2 (3)
Supernova remnant	† (SNR)	41 (3)
Globular Cluster	glc (GLC)	8 (0)
Micro-quasar object: X-ray binary (black hole or neutron star) with radio jet	mqo (MQO)	0 (1)
Other X-ray binary	hxb (HXB)	0 (2)
BL Lac type of blazar	bzb (BZB)	295 (0)
FSRQ type of blazar	bzq (BZQ)	274 (4)
Non-blazar active galaxy	agn (AGN)	28 (0)
Active galaxy of uncertain type	agu (AGU)	92 (0)
Normal galaxy	gal (GAL)	6 (0)
Starburst galaxy	sbg (SBG)	2 (0)
Unassociated		630

Note. — The designation '†' indicates potential association with SNR or PWN (see Table 7). Designations shown in capital letters are firm identifications; lower case letters indicate associations. In the case of AGN, many of the associations have high confidence (Abdo et al. 2010l). Among the pulsars, those with names beginning with LAT were discovered with the LAT. For the normal galaxy class, 5 of the associations are with the Large Magellanic Cloud. In the FITS version of the 1FGL catalog, the † designator is replaced with 'spp'; see Appendix D.

LAT AGN Catalog (1LAC)

- **Based on 1FGL sources associated with AGN**
- **1LAC sample is for $|b| > 10^\circ$ & includes lower-confidence associations (down to $P = 0.5$)**
  - **671 1FGL sources: 300 BL Lacs, 296 FSRQs, 41 AGNs of other types**

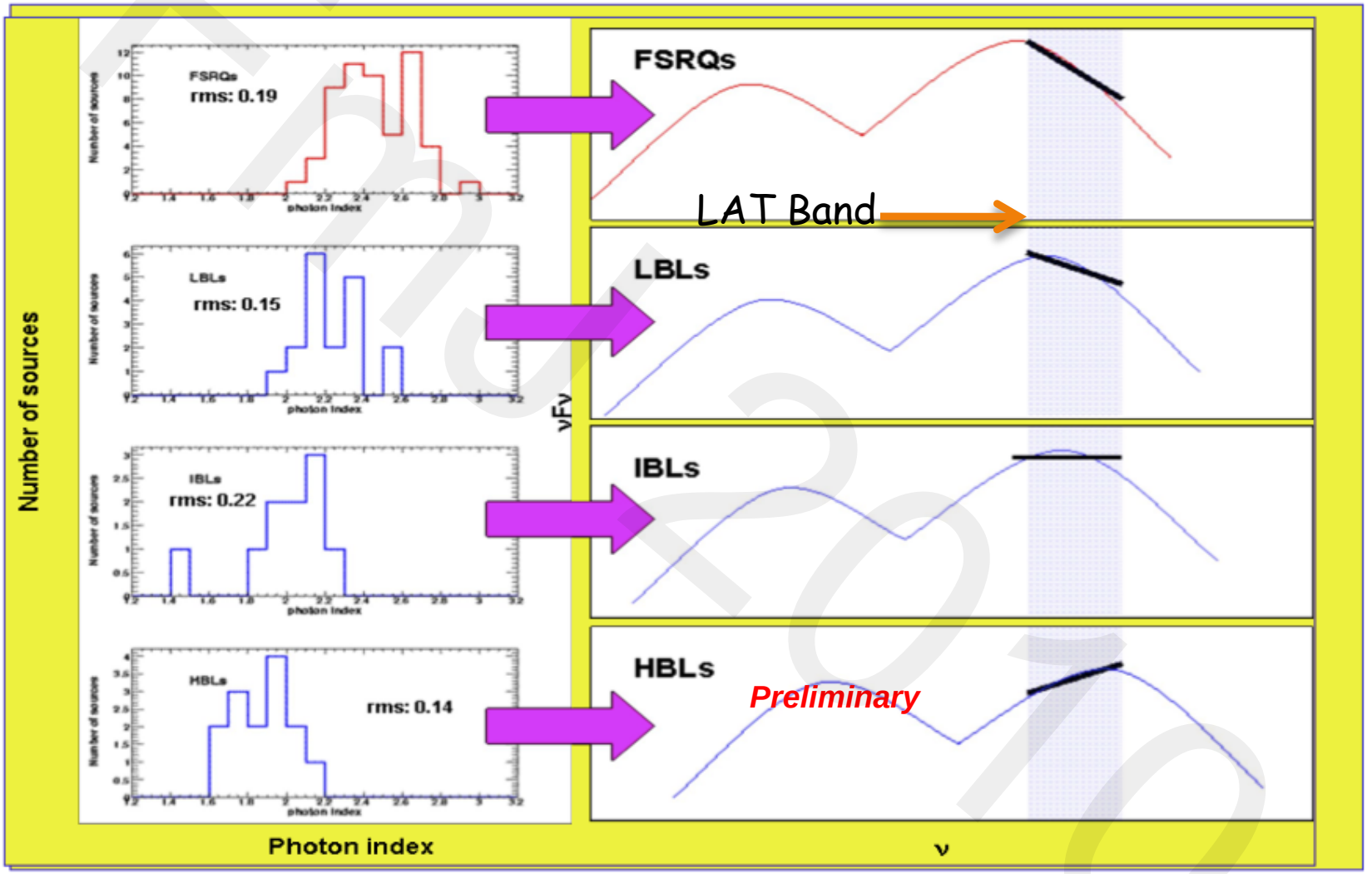


FSRQ
BL Lacs
Radio galaxies
AGNs unknown type

'Clean' subsample:
$P > 0.8$, singly assoc.

- **1LAC paper also lists 51 low-latitude associations and 104 high-latitude 'affiliations' (plausible associations)**

Blazars in LAT



Average $\Gamma \sim 2.2$ and dispersion ~ 0.3

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Addressing the Contribution from Blazars

- **Blazars potentially represent 85-95% of the high-b populations**
- **How to quantify their diffuse emission ?**
  - **Derive luminosity function and integrate**
  - **→ Derive logN-logS and integrate ←**
- **Select a 'clean' sample (TS>50, |b|>20°)**
- **To quantify selection effects 18 MC simulations were performed:**
  - **Receipt** (e,g. Hasinger+93, Cappelluti+07):
    - **Use up to date diffuse models and add a realistic source population**
  - **Detection:**
    - **Perform detection step as close as possible to real data** (Abdo+09, ApJS 183, 46)
    - **Use Maximum Likelihood to determine spectral parameters and significance**

arXiv:1003.0895

CLASS	# objects
Total	425
FSRQs	161
BL Lacs	163
Uncertain[a]	4
Blazar Candidates	24
Radio Galaxies	2
Pulsars	9
Others[b]	6
Unassociated sources	56

[a]Blazars with uncertain classification.

[b]It includes Starburst galaxies, Narrow line Seyfert 1 objects and Seyfert galaxy candidates.

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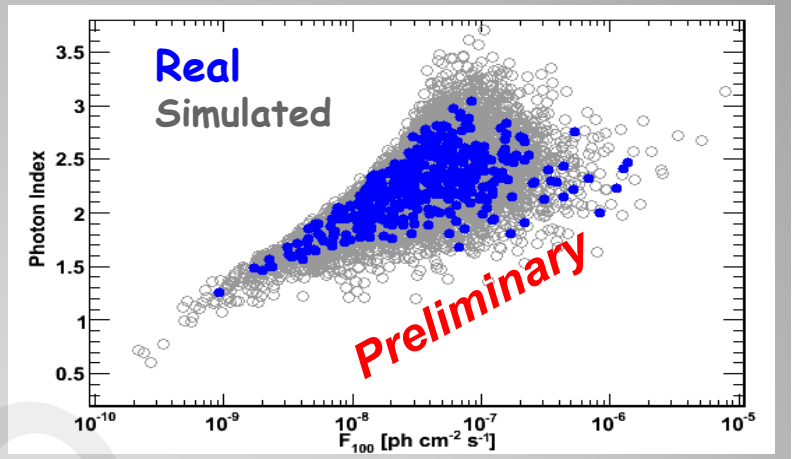
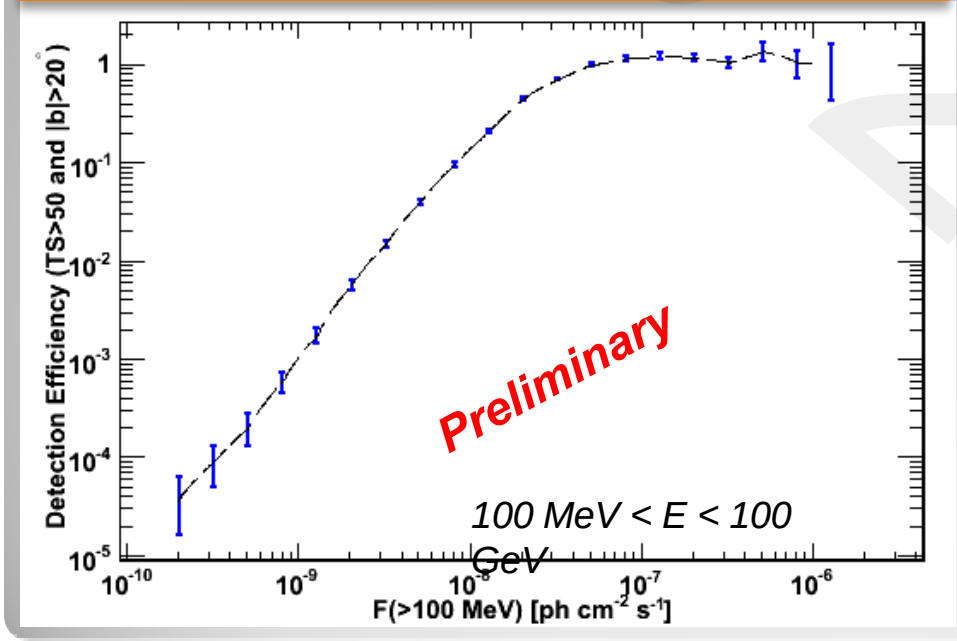
Detection Efficiency of LAT

- Simulations reproduce well the photon-index dependent flux limit of LAT
- Confusion and Eddington bias affect <4% of the population



Detection Efficiency



- Det. Efficiency evaluated in bins of flux as N^{det}/N^{sim}
- It becomes 10^{-3} @ $F_{100}=10^{-9}$ ph cm^{-2} s^{-1}

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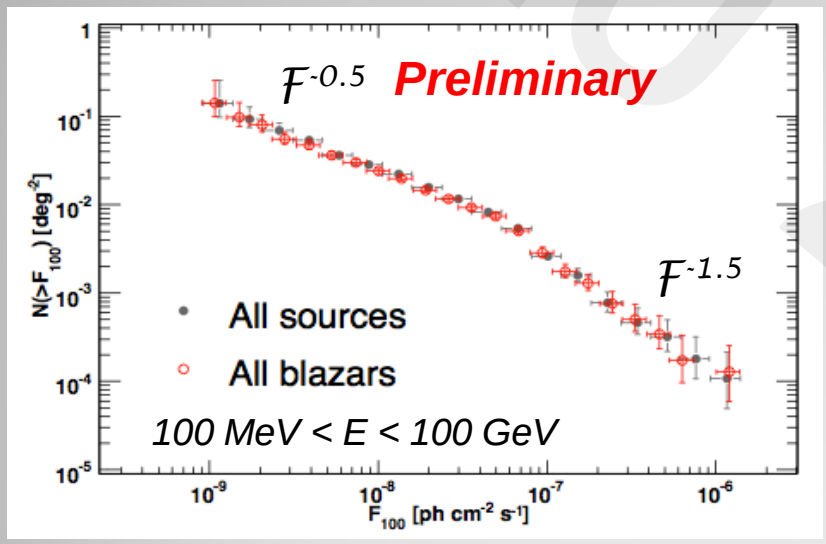
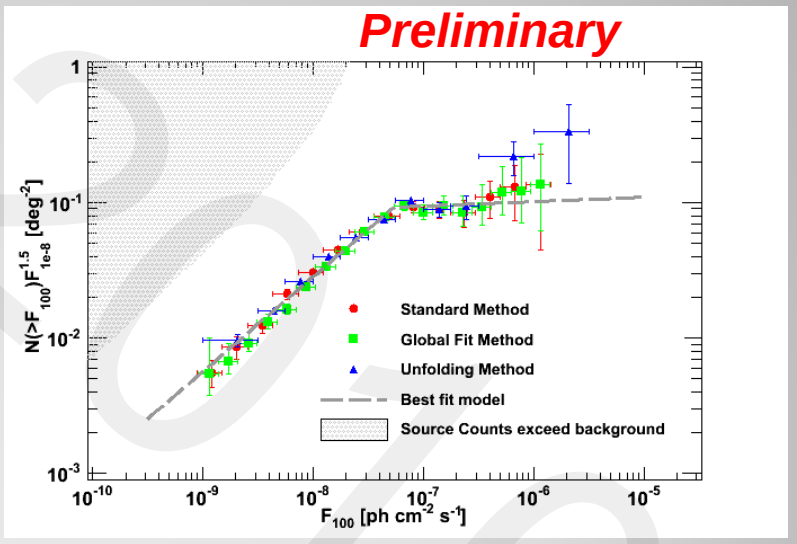
The logN-logS of point sources

- Used 3 methods to build source count distribution in the 0.1-100 GeV band
- Compatible with Euclidean at bright fluxes: $N(>F) \sim F^{-3/2}$
- It is flatter below $F_{100} \approx 5 \times 10^{-8}$ ph cm^{-2} s^{-1}

Most of the un-associated point sources are likely to be blazars





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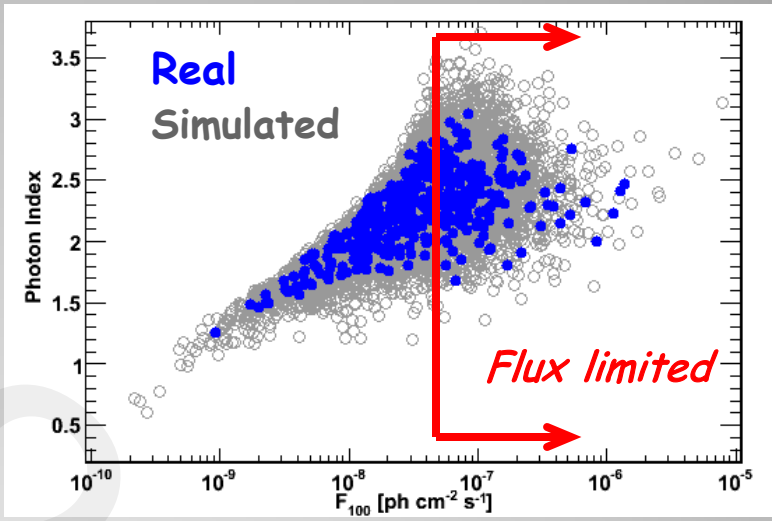
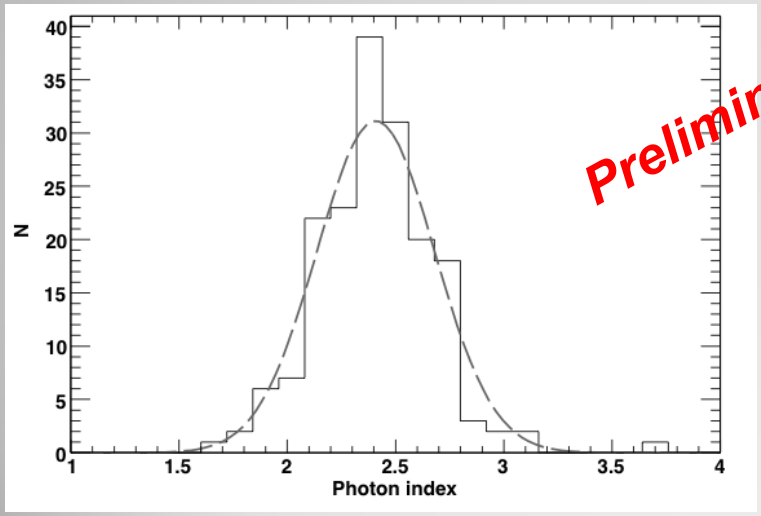
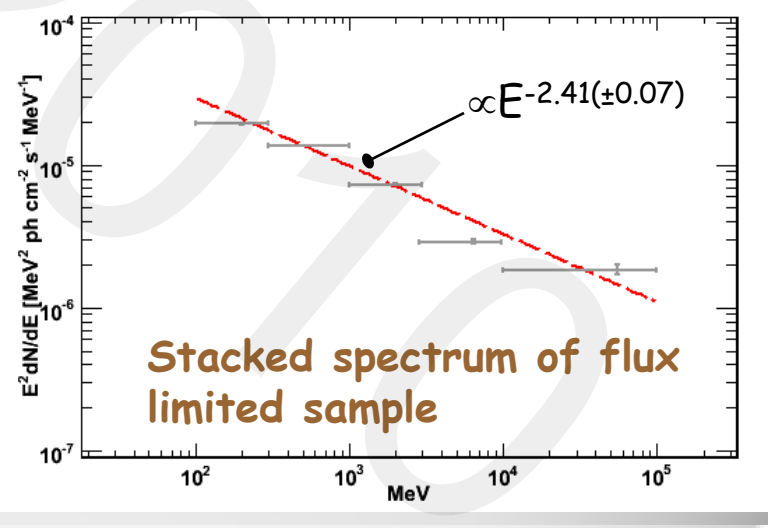
A look to the spectral properties

- **LAT detects preferentially hard faint sources**
  - Looking at the *flux-limited* sample: the average photon index is 2.40(±0.02) and not 2.24(±0.01)
  - Similar results from weighted average spectrum





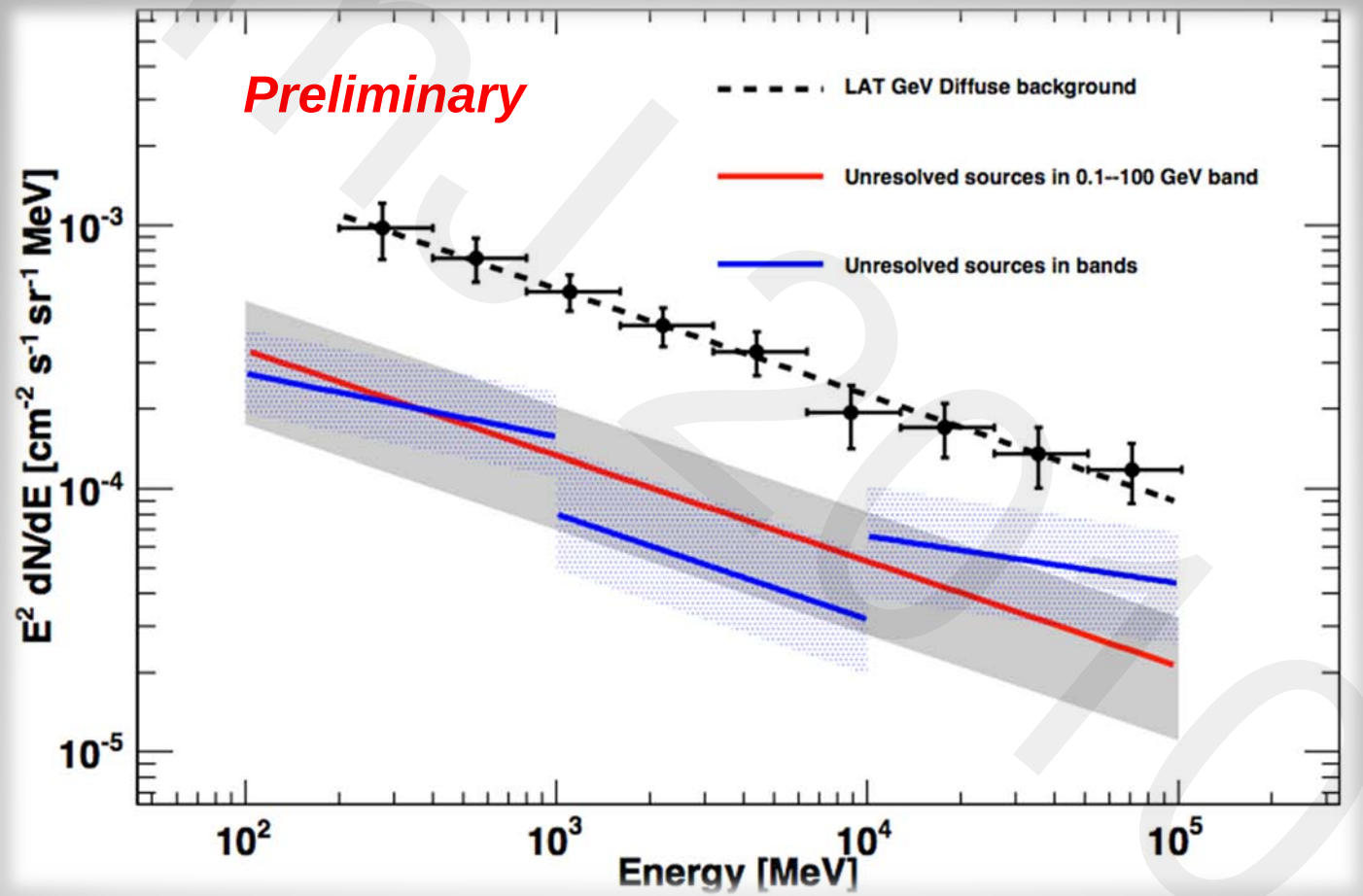


Diffuse emission from Blazars

To determine the diffuse flux from the blazar class one needs to integrate the logN-logS (e.g. dN/dS)

Contribution of blazars to the EGB

Blazars seem to account for <30% of the EGB for 0.1 GeV <E<100 GeV



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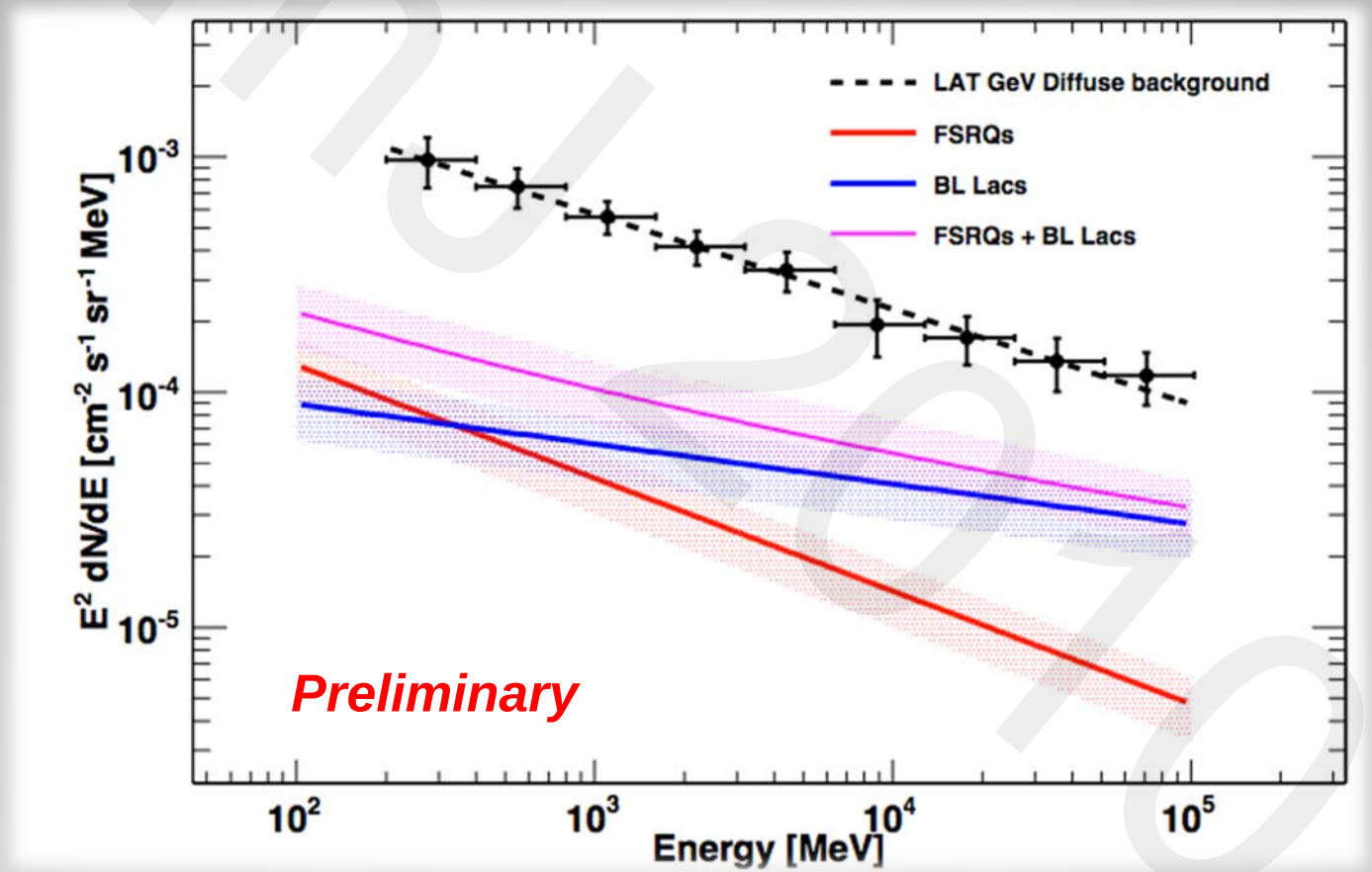
FSRQ and BL Lacs

BL Lacs dominate at high-E (caveat: broad band analysis)



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NASA's view of the thing...

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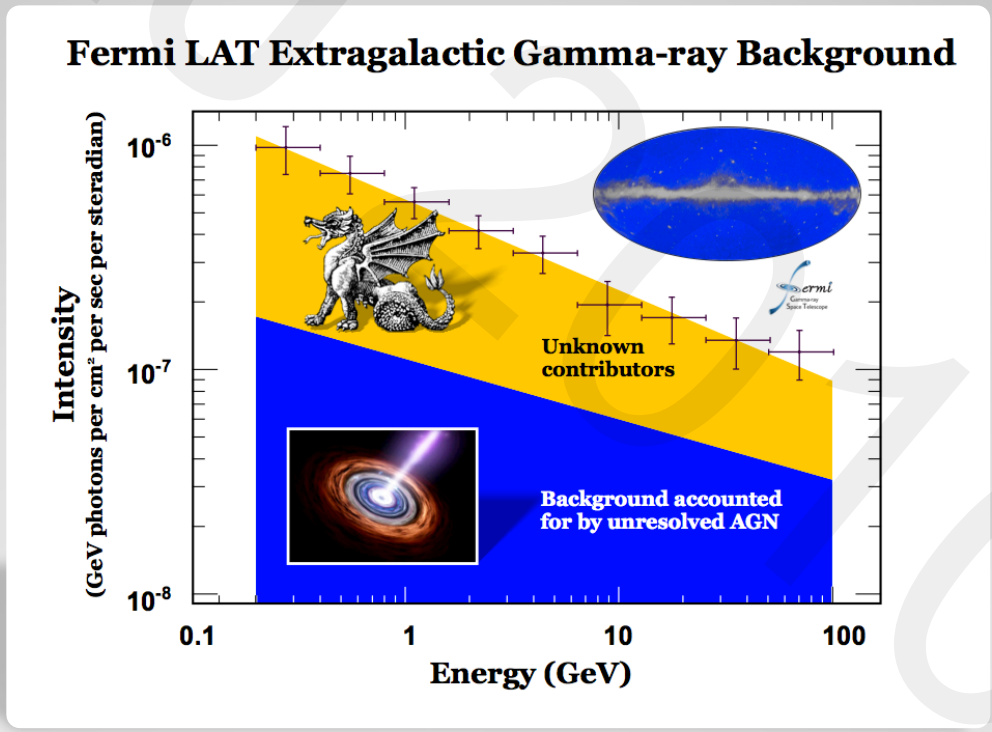
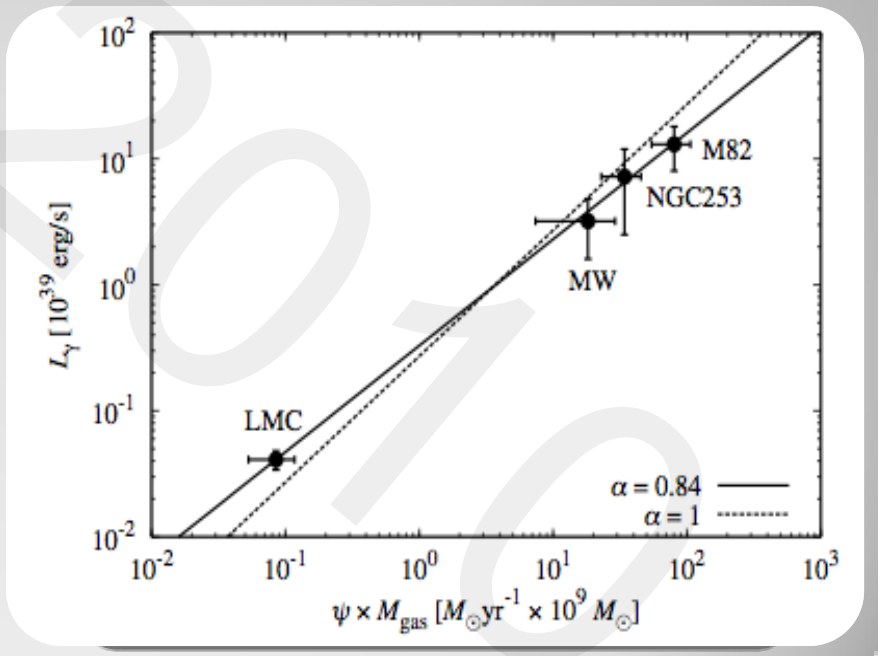
Mysterious "Dragons" Make Universe's Gamma Ray Fog

New Fermi space telescope results deepen cosmic mystery.



Other Populations ?

- Star forming galaxies emit γ-ray due to the interaction of CR and gas/radiation (e.g. like in our own Milky Way)
- *Fermi* detected already NGC 253, M82, LMC, SMC, NGC 1068 (?), NGC 4945 (?), etc.
- SF-galaxies can contribute up to 30% (e.g. Pavlidou&Fields02, Thompson+07, Lacki+10, Fields+10)



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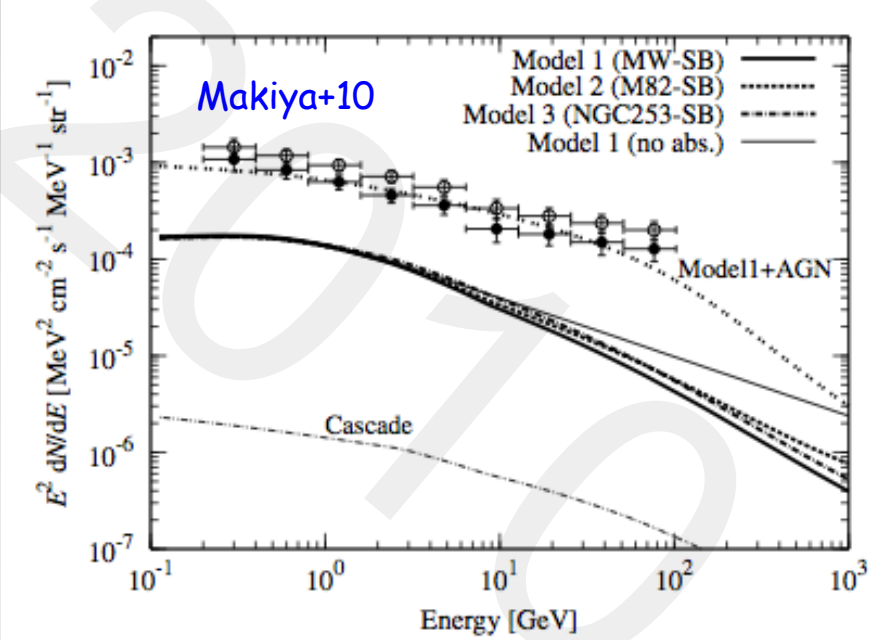
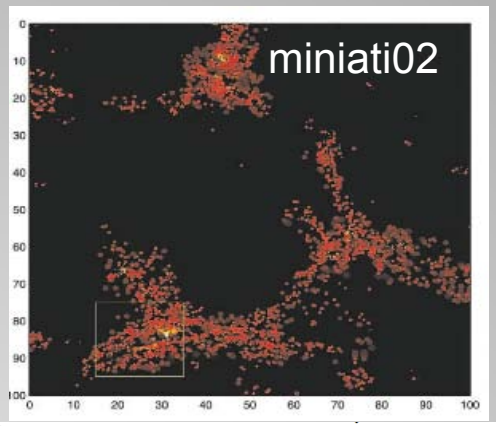
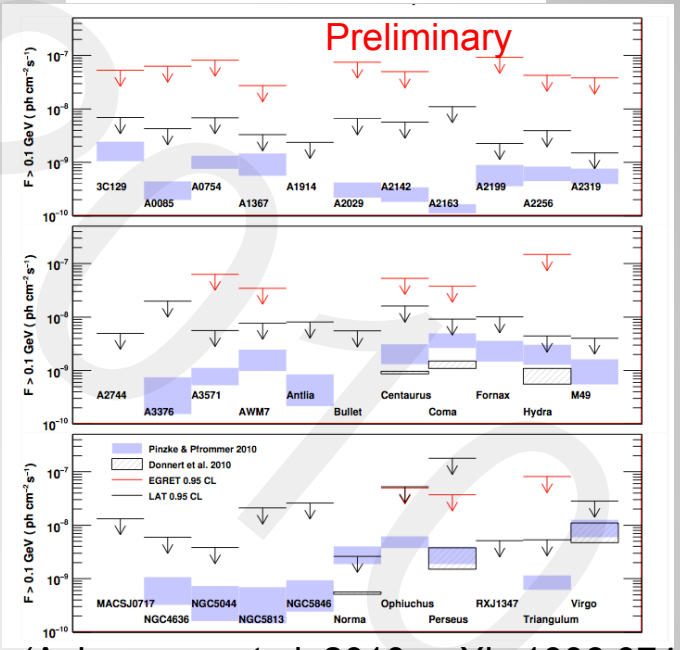


Cosmological Shocks ?

- **Intergalactic shocks and Cluster shocks might provide a significant (~10%) contribution to the γ-ray background** (e.g.miniati02, keshet+02)
- **Intergalactic shocks emission dominated by Inverse Compton of e^- off CMB photons**
- **Cluster's emission dominated by hadronic interaction (p-p collisions), but *Fermi does not detect clusters* ….**

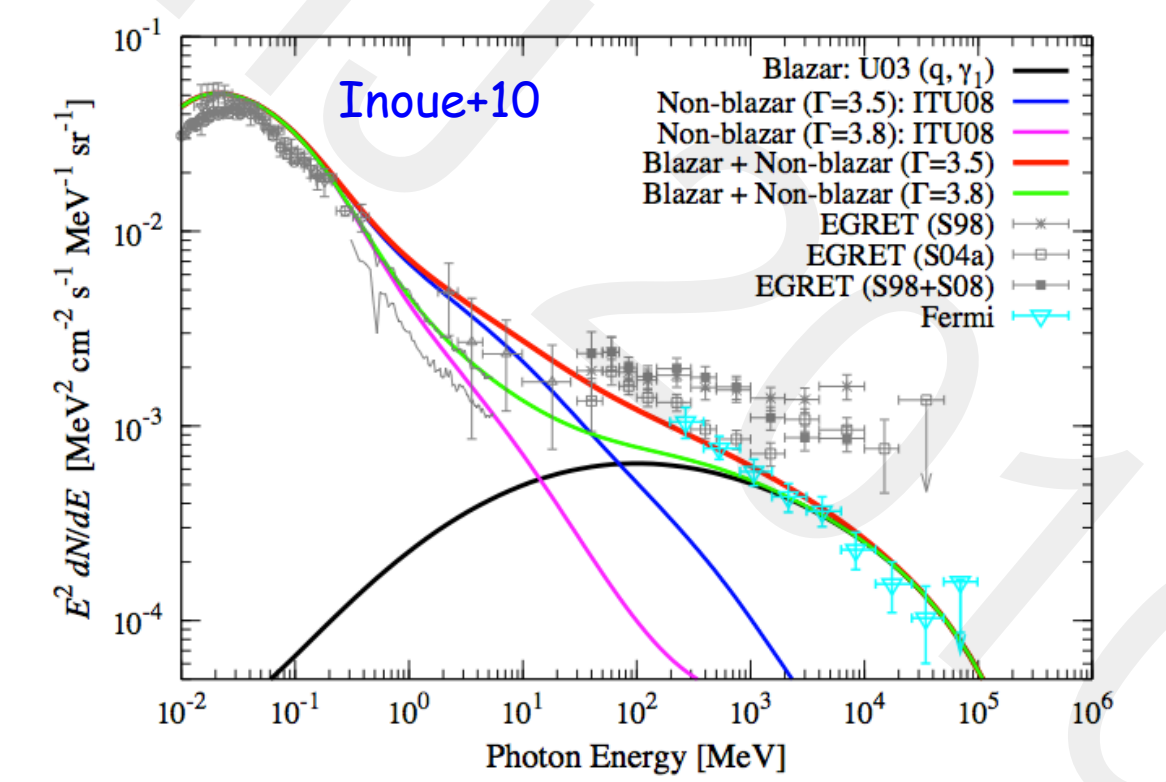




(Ackermann et al. 2010, arXiv:1006.0748)

Emission from radio-quiet AGN

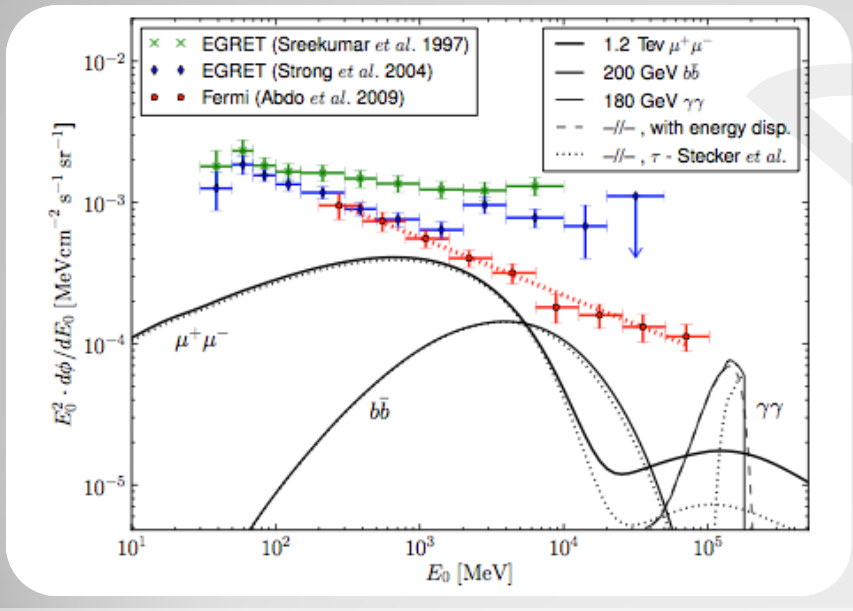
- **AGN hot coronae might host a population of non-thermal, relativisitic, e^- which comptonizing disk photons produce MeV-GeV background** (e.g. Inoue+09, Inoue+10)

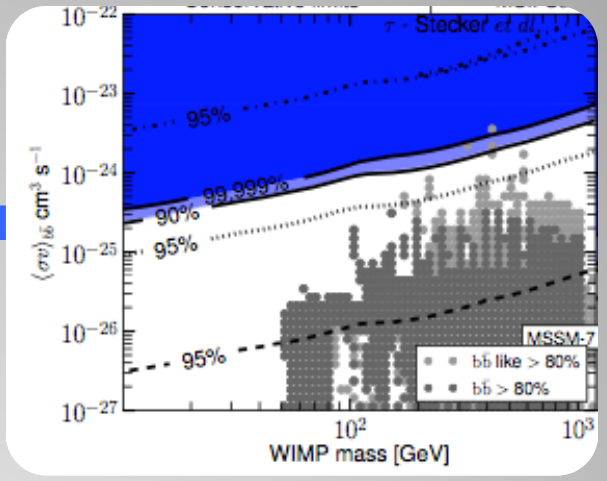


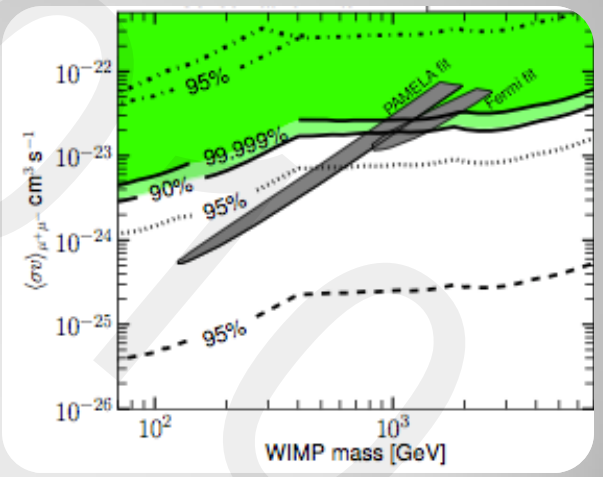
Limits on DM annihilation

Abdo, JCAP 2010, 014

- **DM annihilation limits can be obtained imposing that the EGB spectrum is not violated**
  - **Degeneracy between the cross-section and the clustering scenario**
  - **Limits close to those expected for a thermal relic neutralino**







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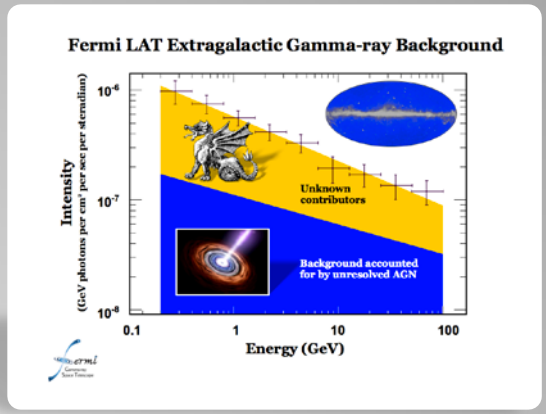
Gamma-ray Background Recap

- ***Fermi*** **measured the new spectrum of the Extragalactic Gamma-ray Background after careful modeling of all other components**
  - **→ It has lower intensity than the one measured by EGRET and it is featureless (it has no bumps)**



- ***Fermi*** **allowed us to quantify with unprecedented accuracy the diffuse emission arising from Active Galactic Nuclei and this accounts for <30% of the Extragalactic Gamma-ray Background**

- **70% of the EGB is produced by unknown source classes or can be truly diffuse (e.g. Intergalactic shocks, Dark Matter, etc.)**

- ***Fermi will allow us to investigate this in great detail***

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