Gamma-ray Astronomy : HESS/CTA

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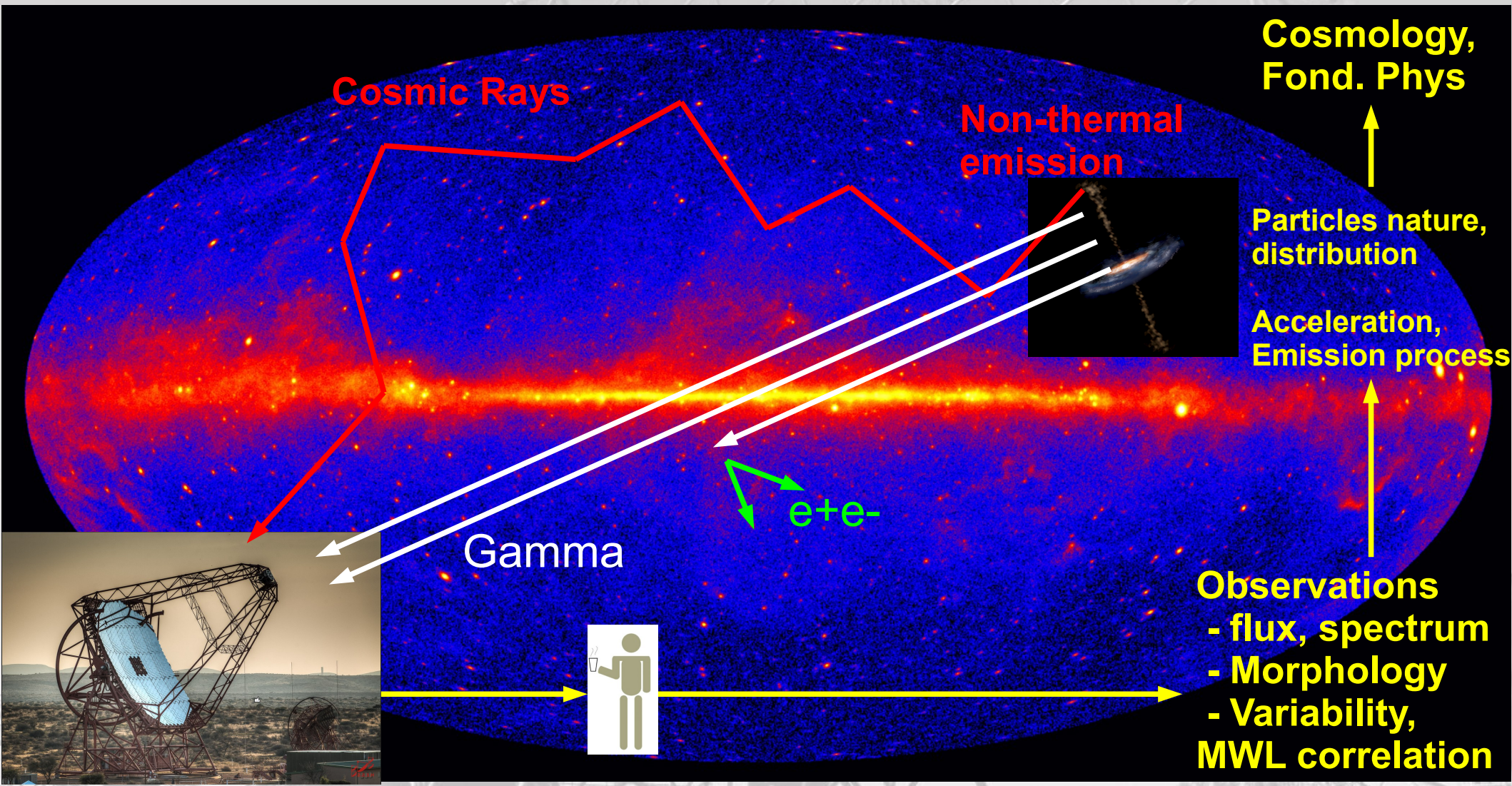
ENIGMASS :
General Meeting
8 November 2013

Laboratoire d'Annecy-le-Vieux
de Physique des Particules

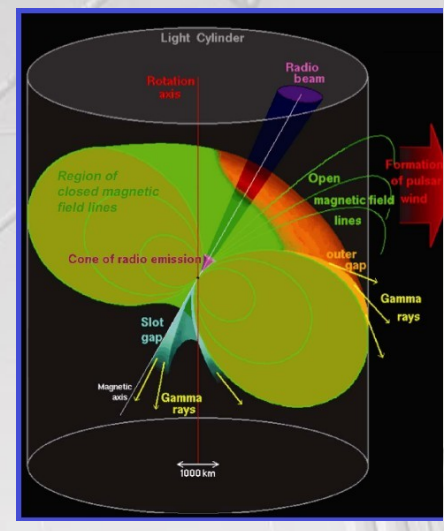
H.E.S.S.

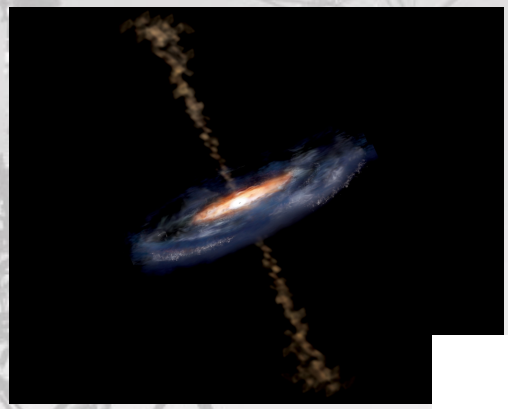
Gamma astronomy

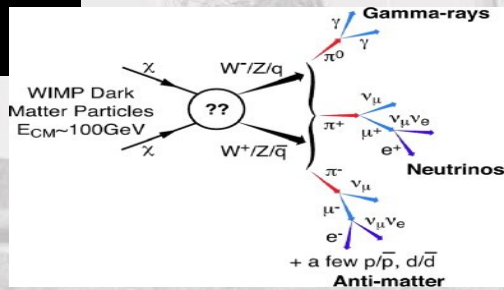


Gamma Astronomy in questions

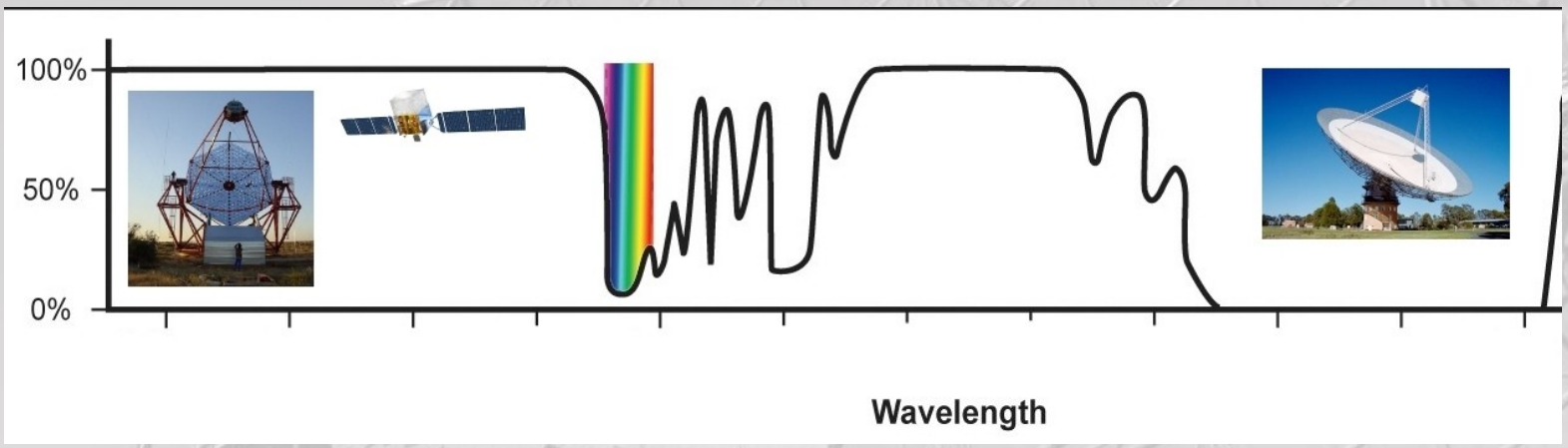
- Cosmic rays origins
- Objects nature, astrophysical sites
- Energy extraction process
  - Shocks (PWNe, SNR)
  - Gravitation/Accretion (AGN)
  - Dark Matter
- Laboratory for :
  - Cosmology
  - Fundamental physics



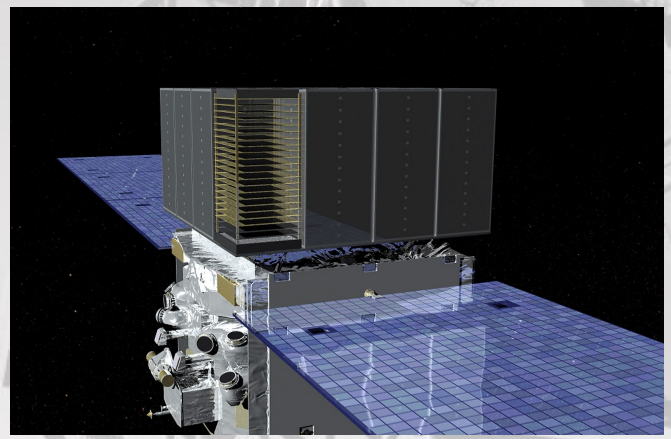




Instrumentation (I)



Fermi-LAT



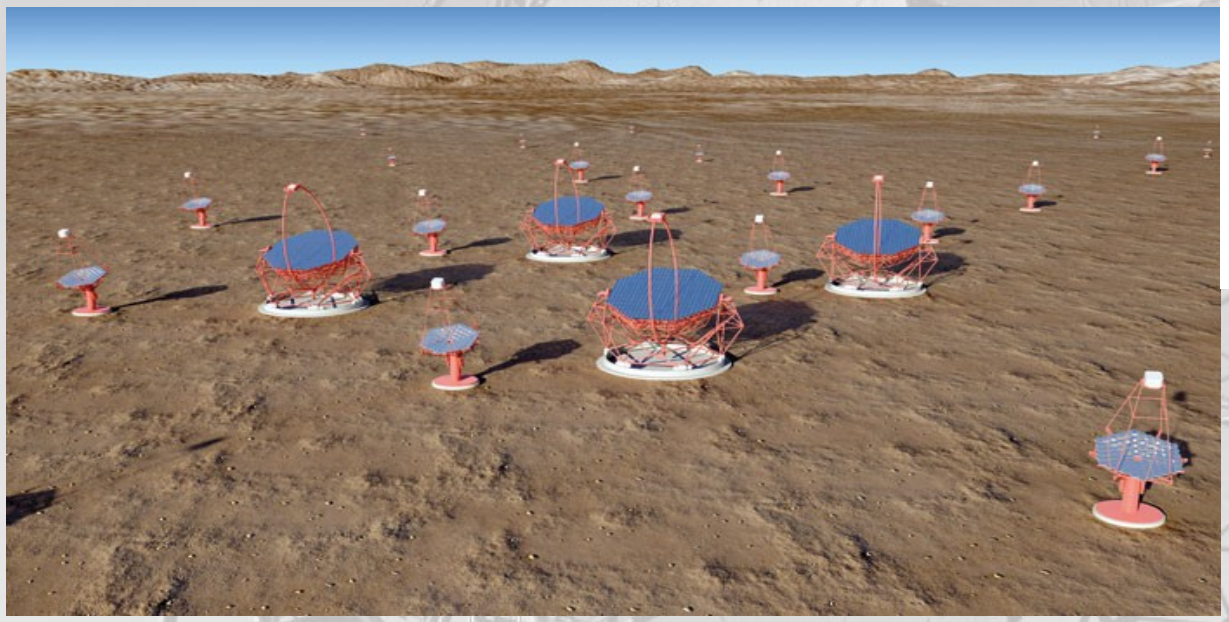
100 MeV - 300 GeV

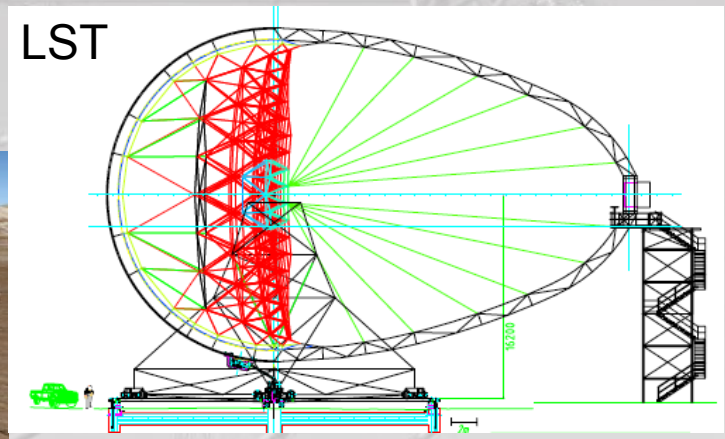
H.E.S.S.

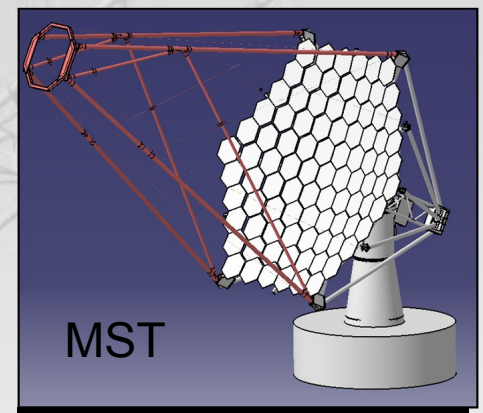
> 50 GeV

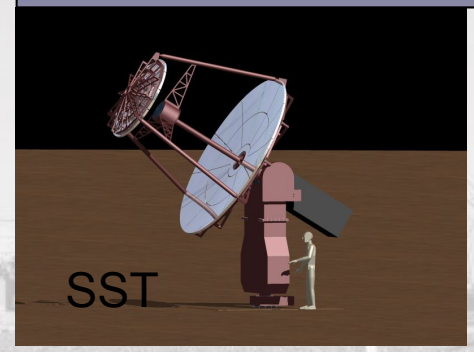
Instrumentation (II)

CTA : Cherenkov Telescope Array









- 3 telescope types: LST, MST, SST
- Consortium
  - 187 institutes from 28 countries

Outline

- AGN
  - Study the physical properties of the AGN
  - Future observations
- Use the AGN for other topics
  - Diffuse emission
  - Extragalactic background light
- Future projects

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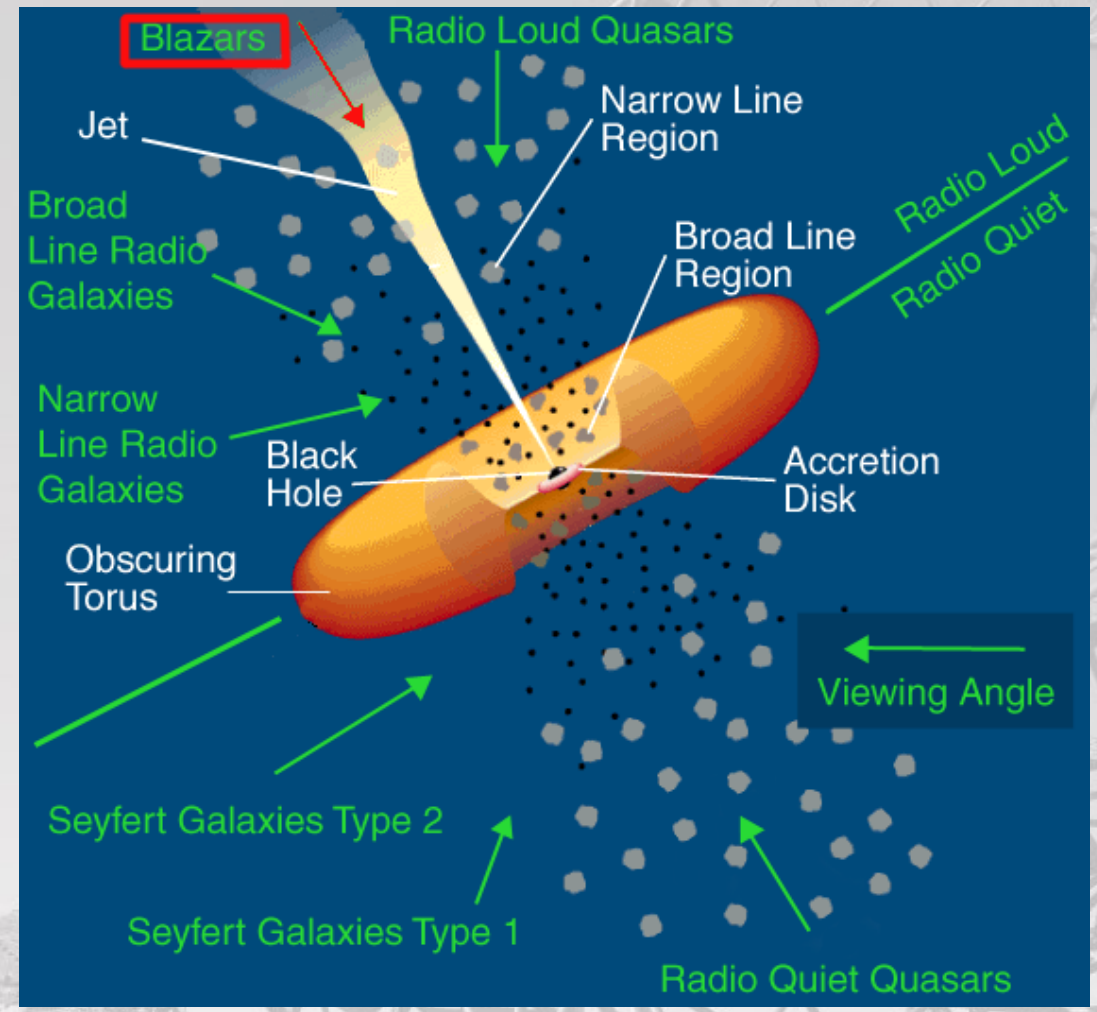
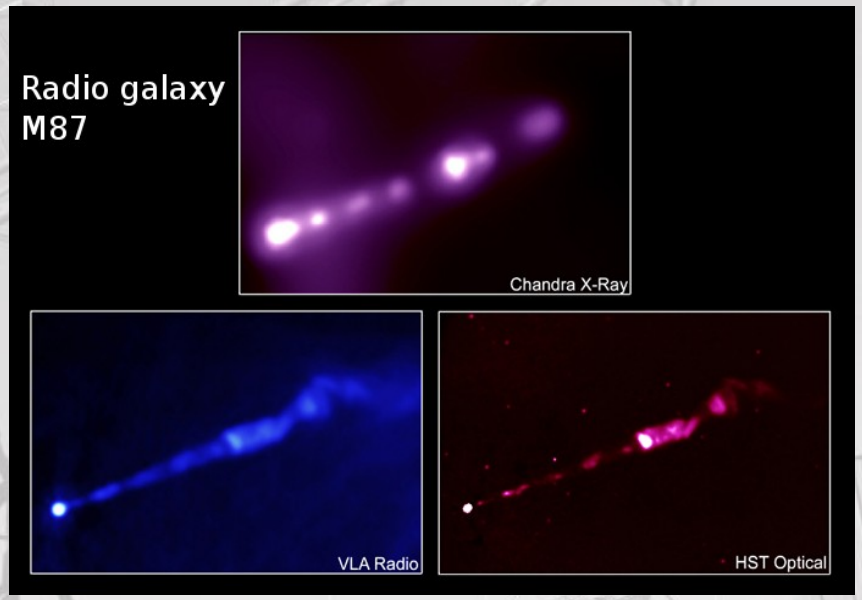
Active Galactic Nuclei

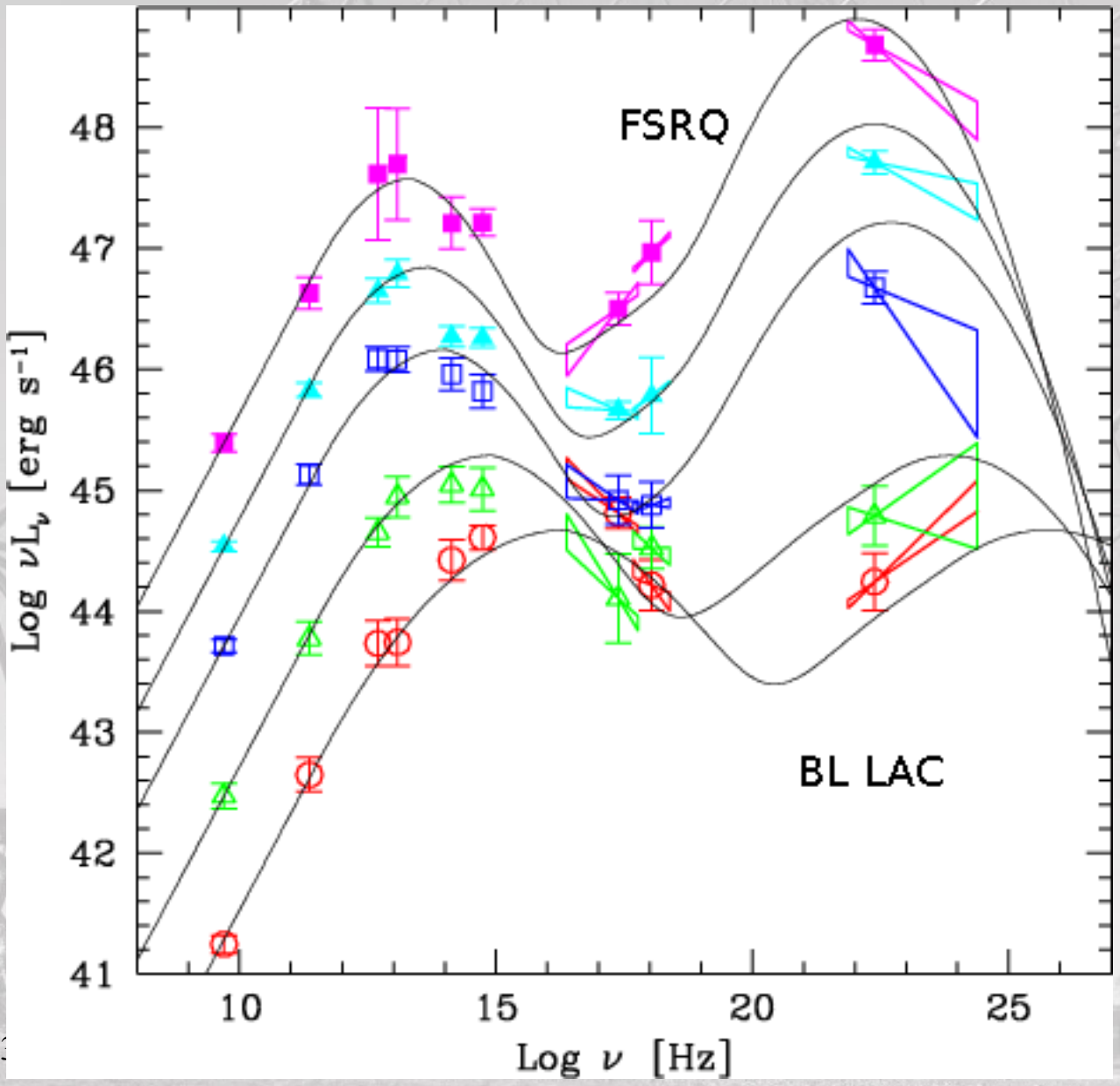


- SM Black Hole
- Torus
- clouds (BLR, NRL)
- Jet

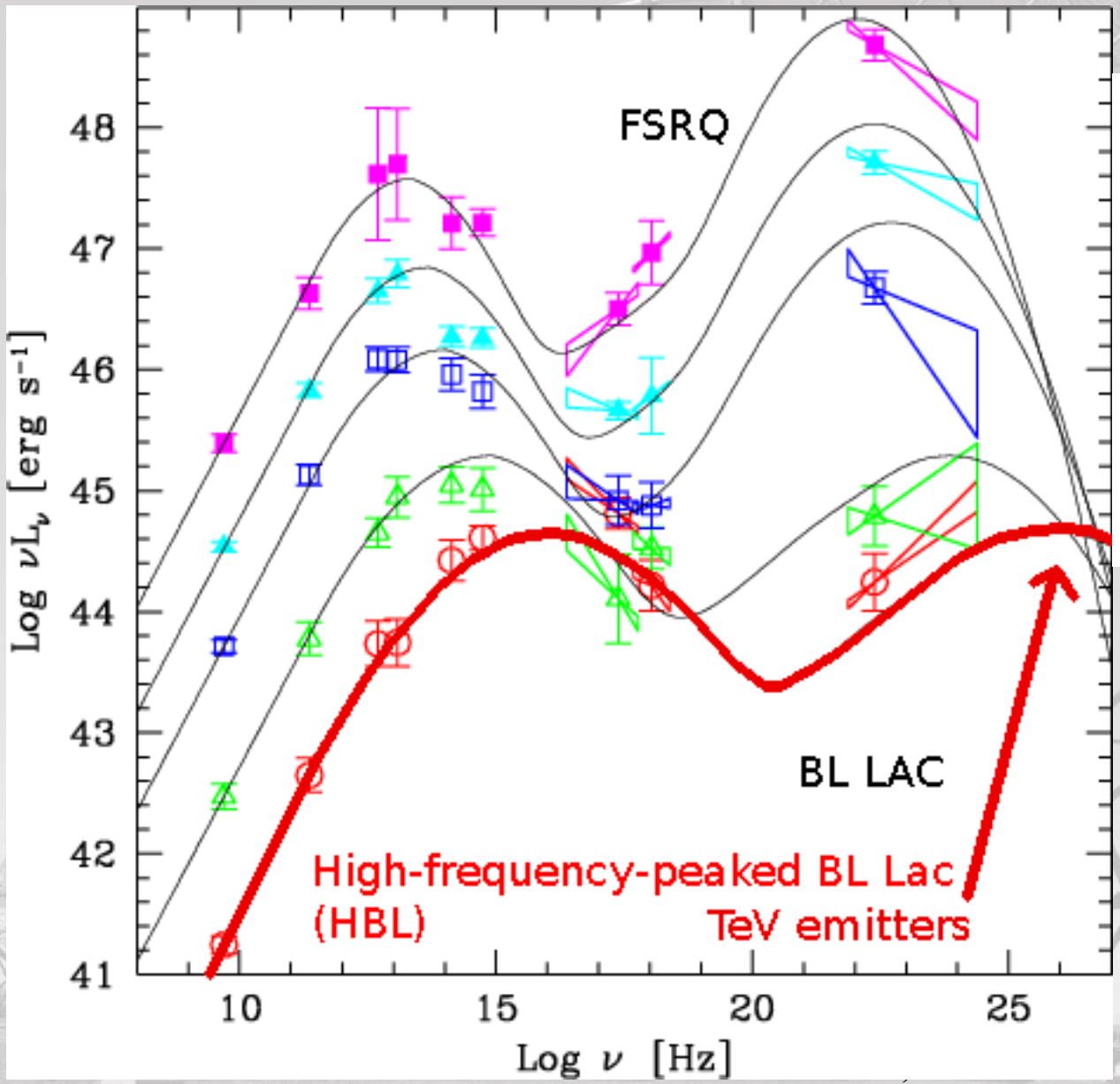


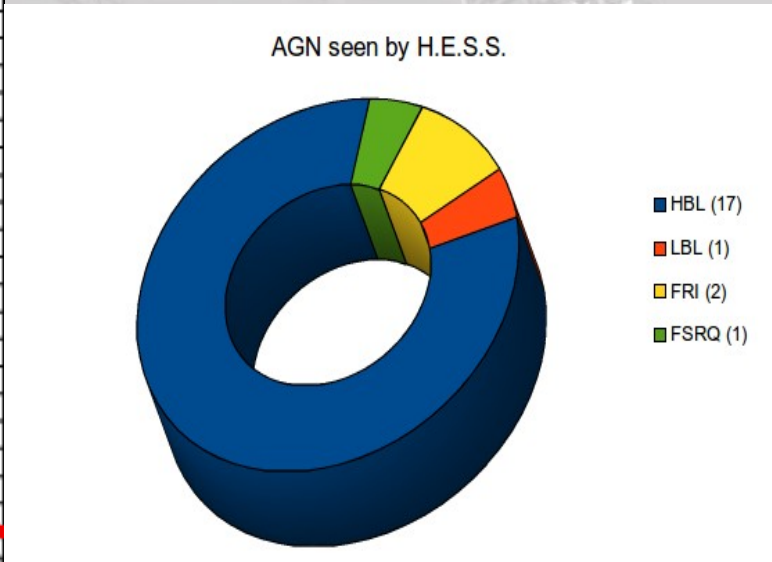
Candidate for UHECRs

Blazars sequence



Blazars sequence

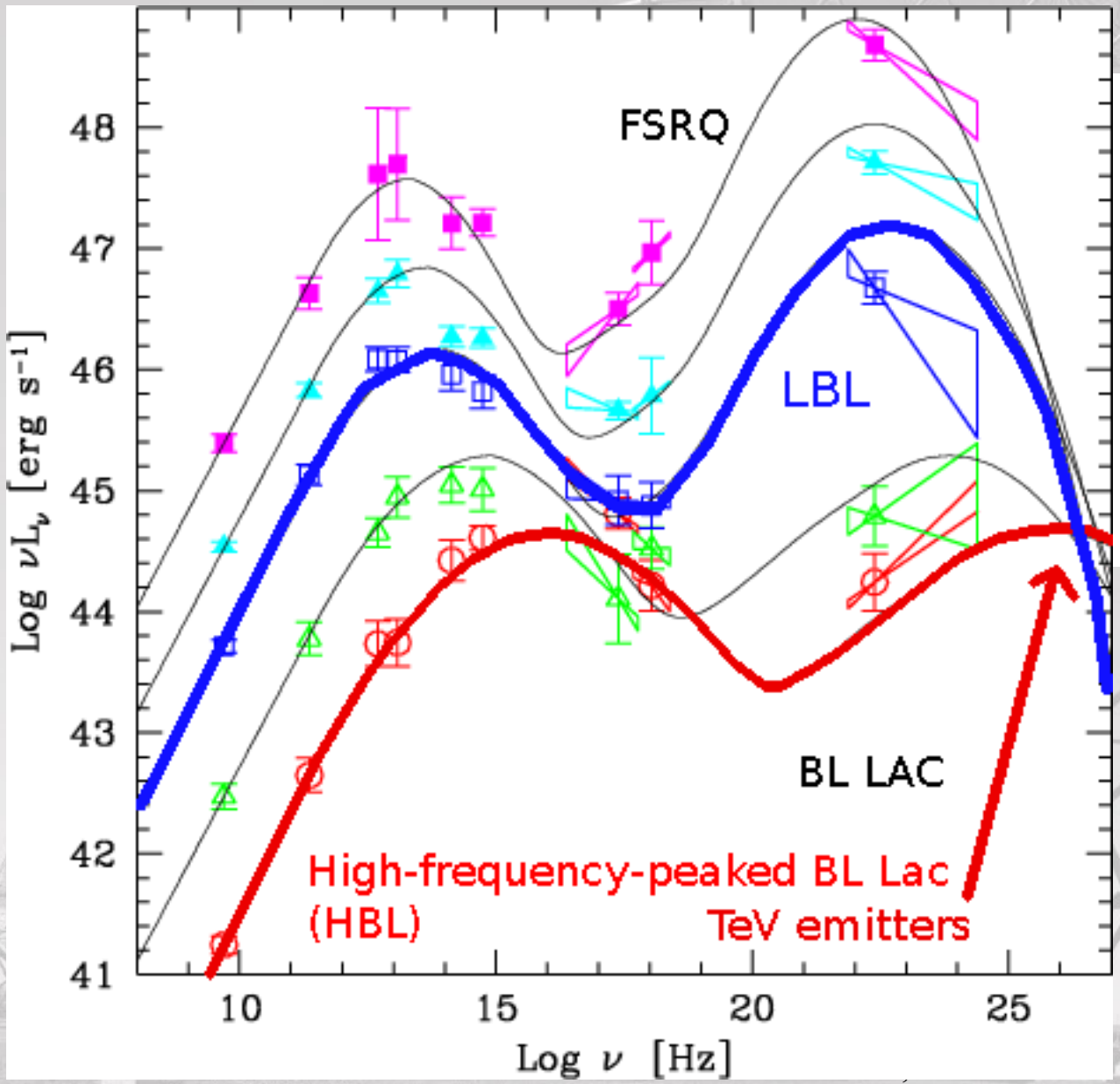


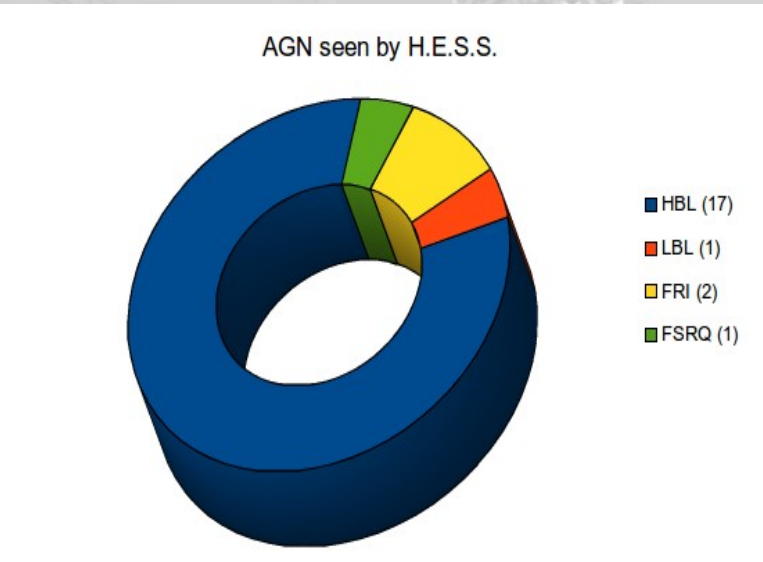


Observational bias

New types of sources
→ HESS II

Blazars sequence





Observational bias

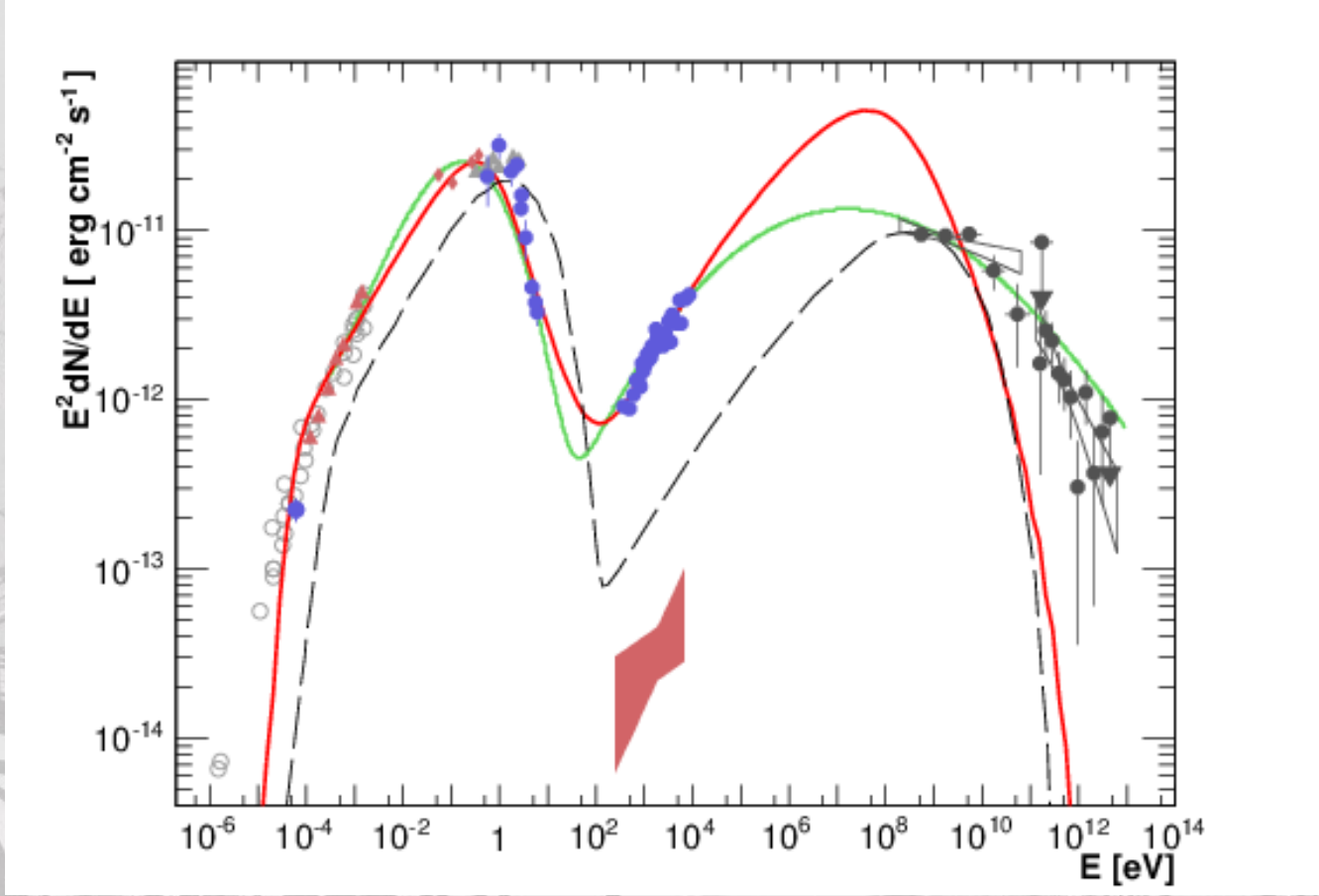
New types of sources
→ HESS II

AP Librae

- Classified as member of new BL Lac class in 1972. LBL class blazar
- Reliable redshift measurement in 1974 (z=0.049)

HE component over 10 decades

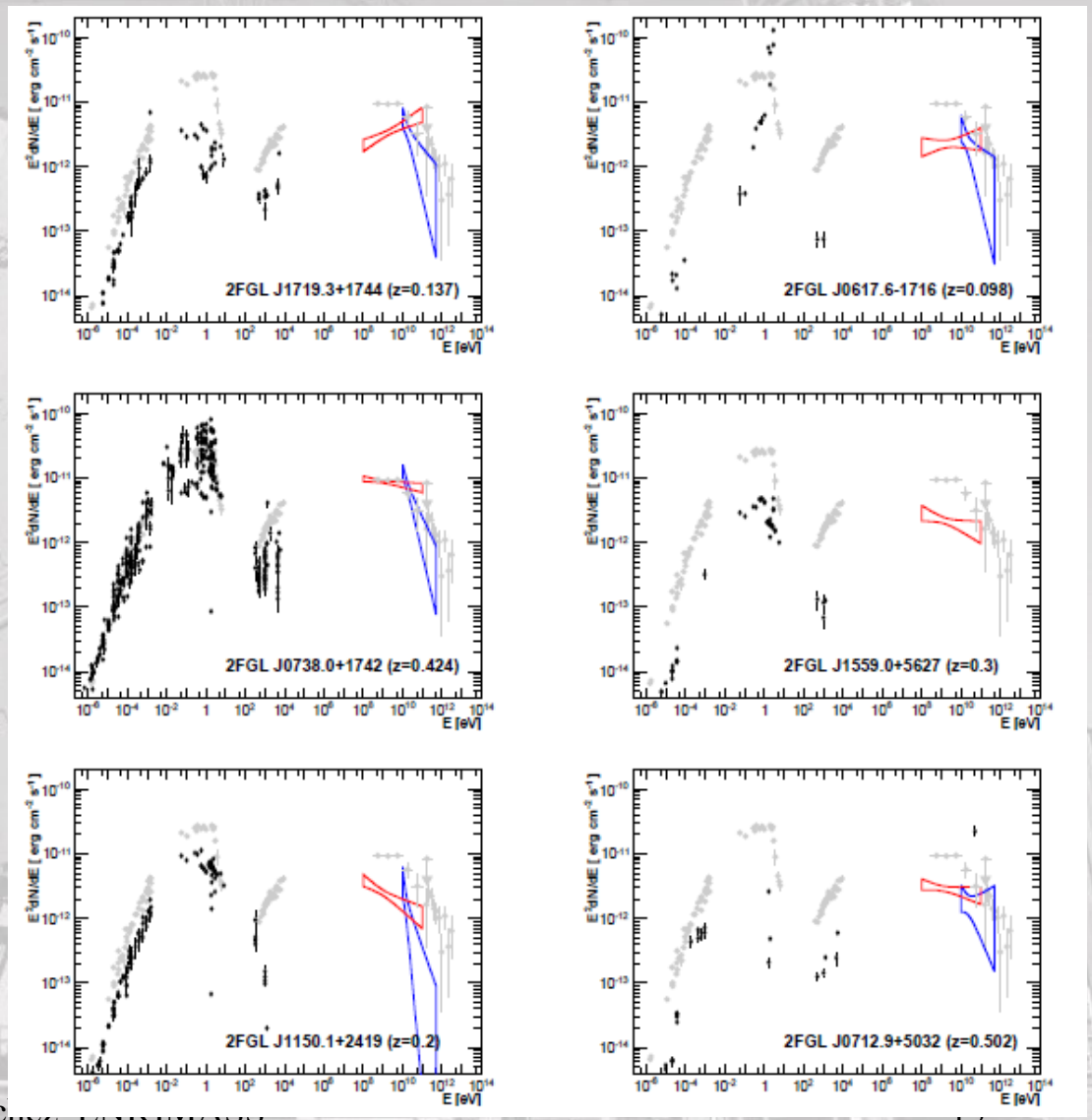
Questions on the Modelling



Ap Librae-like sources

- Observation proposals
  - 6 LBLs
  - Classified using HE flux

- Comparison with AP librae
- Blazars sequence
- Emission models



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  - Extragalactic background light
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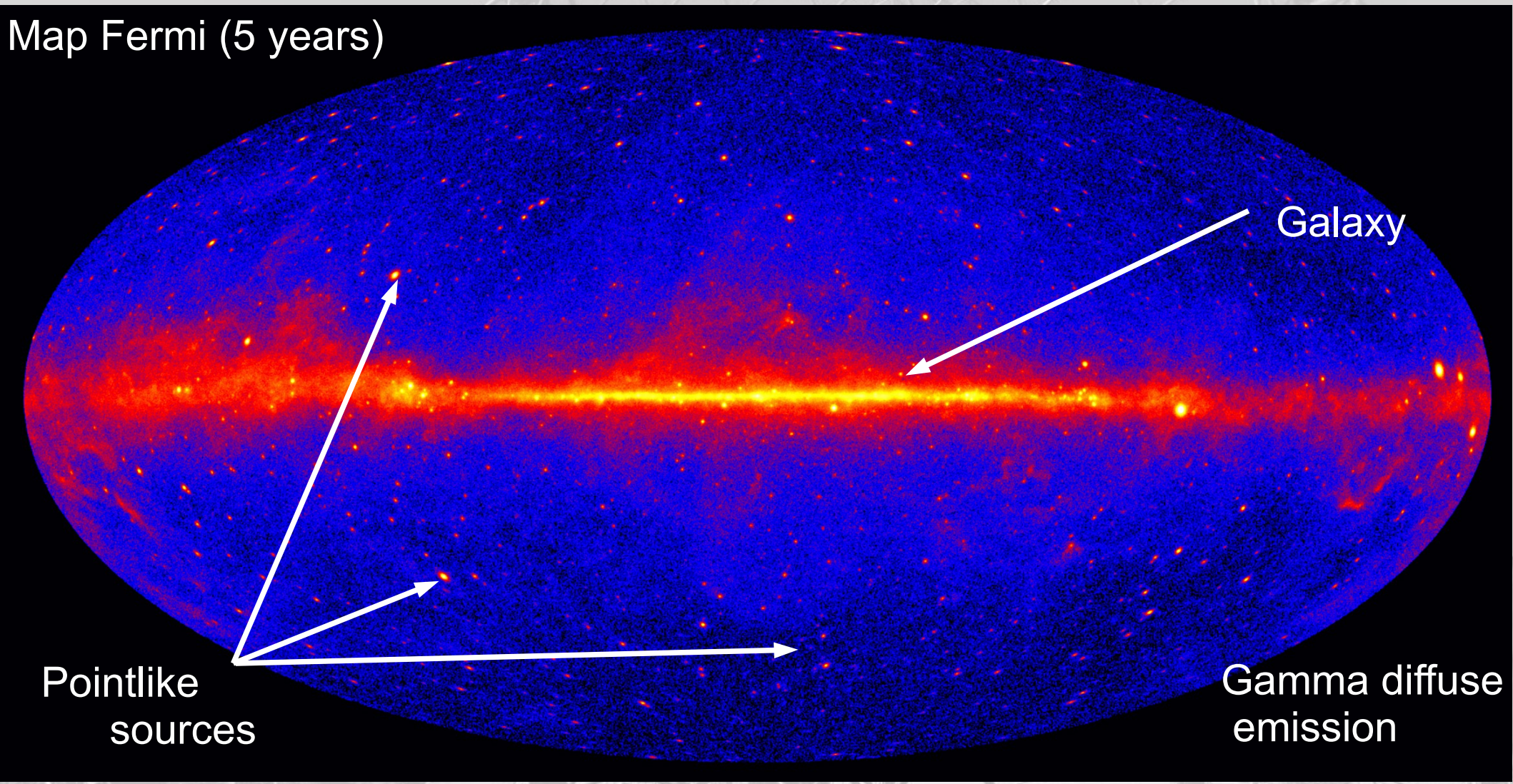
Measurement of the γ-rays diffuse emission



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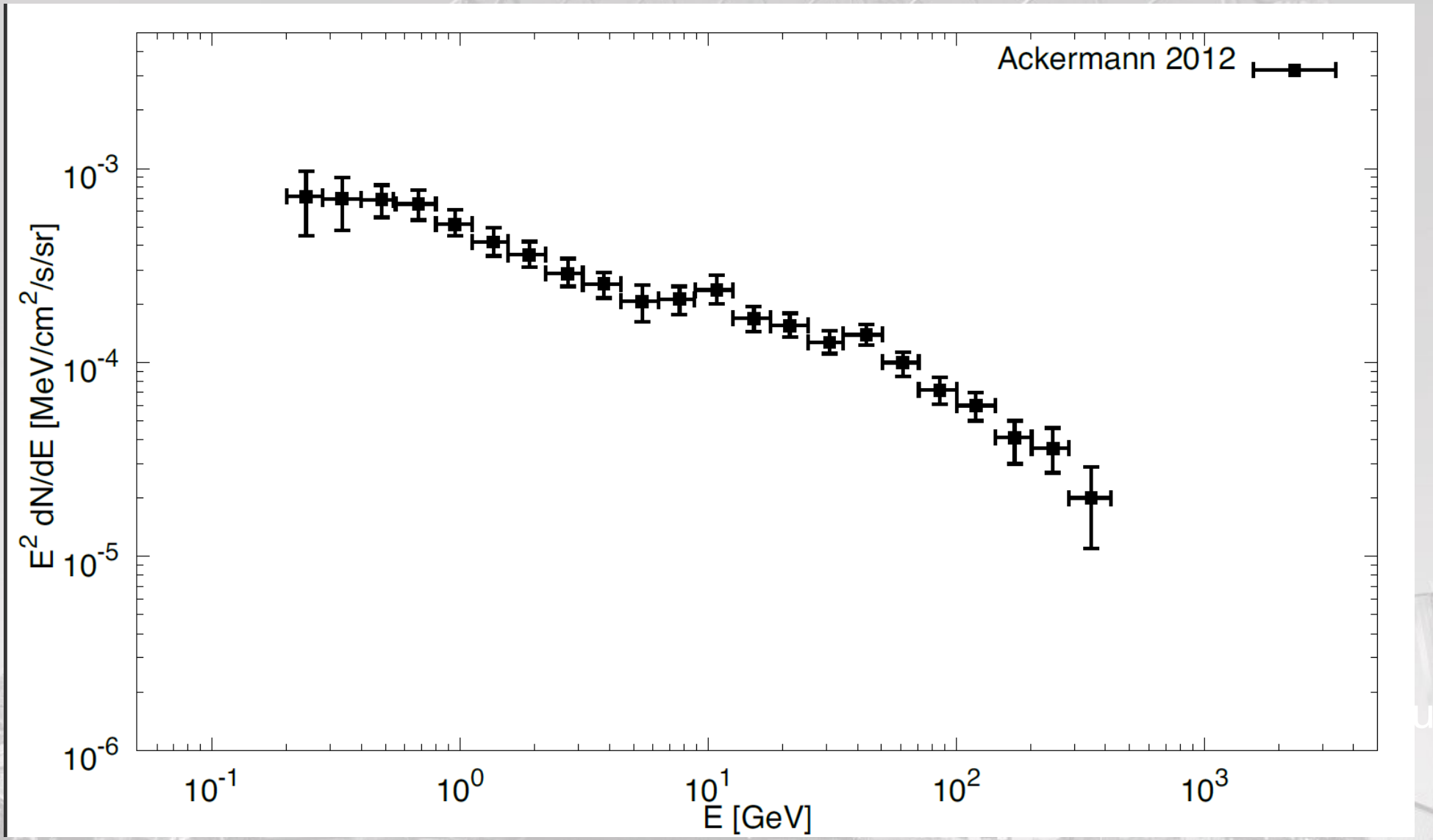
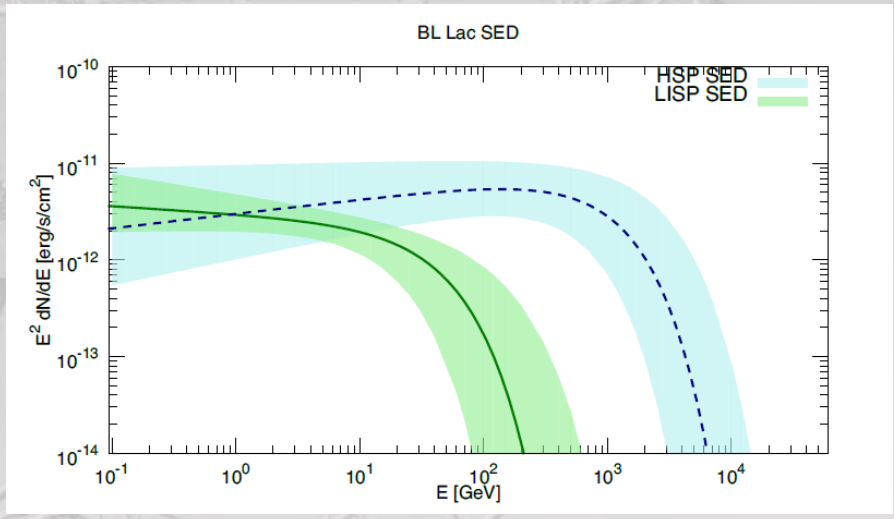
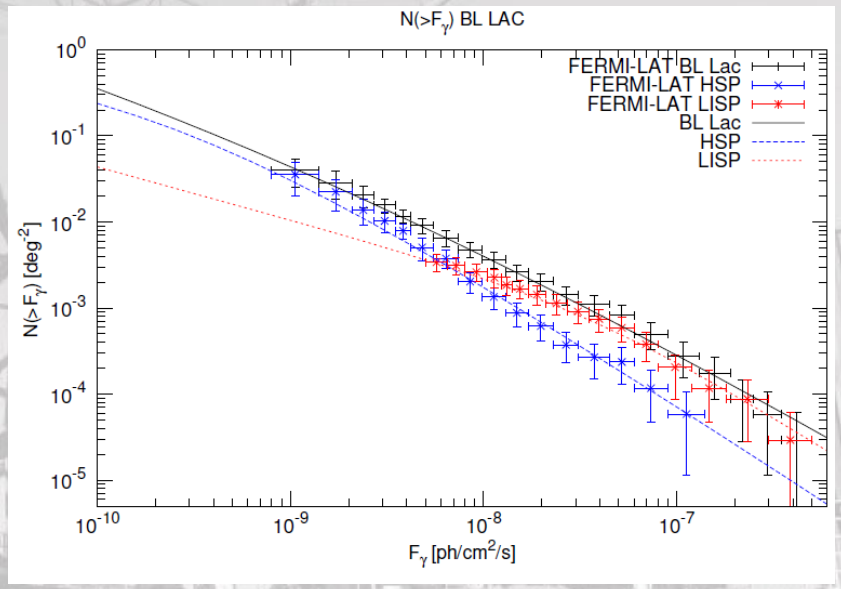


Measurement of the γ-rays diffuse emission

Does the BL LAC be Responsible for 'all' or 'a part' of the diffuse emission

- Ingredient
  - « Averaged » spectra
  - Luminosity function
    - Sources distribution
    - Redshift, numbers

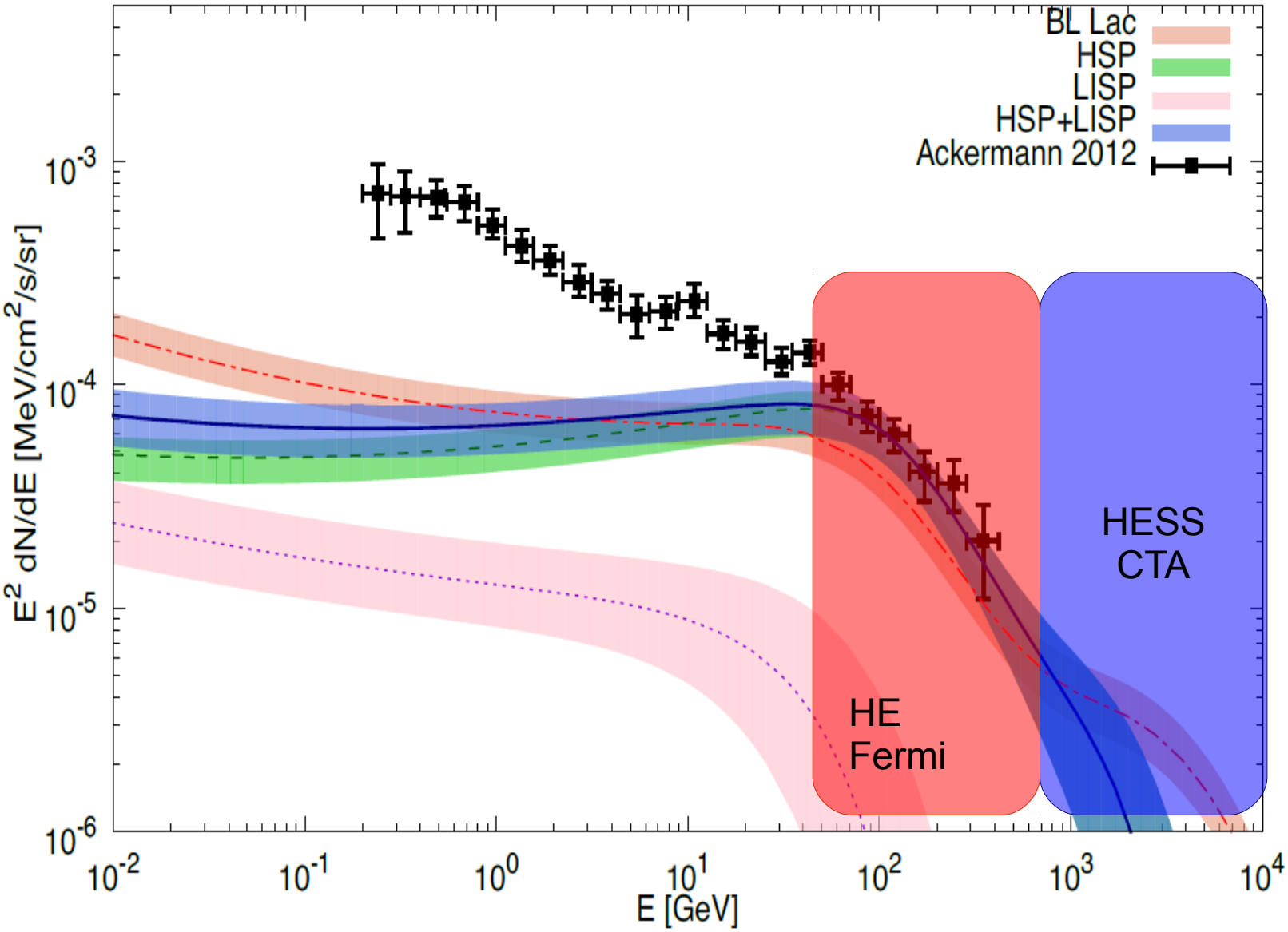




M. DI MAURO, F. DONATO, G. LAMANNA, D. A. SANCHEZ, P. D. SERPICO

LAPTH – LAPP collaboration

Results

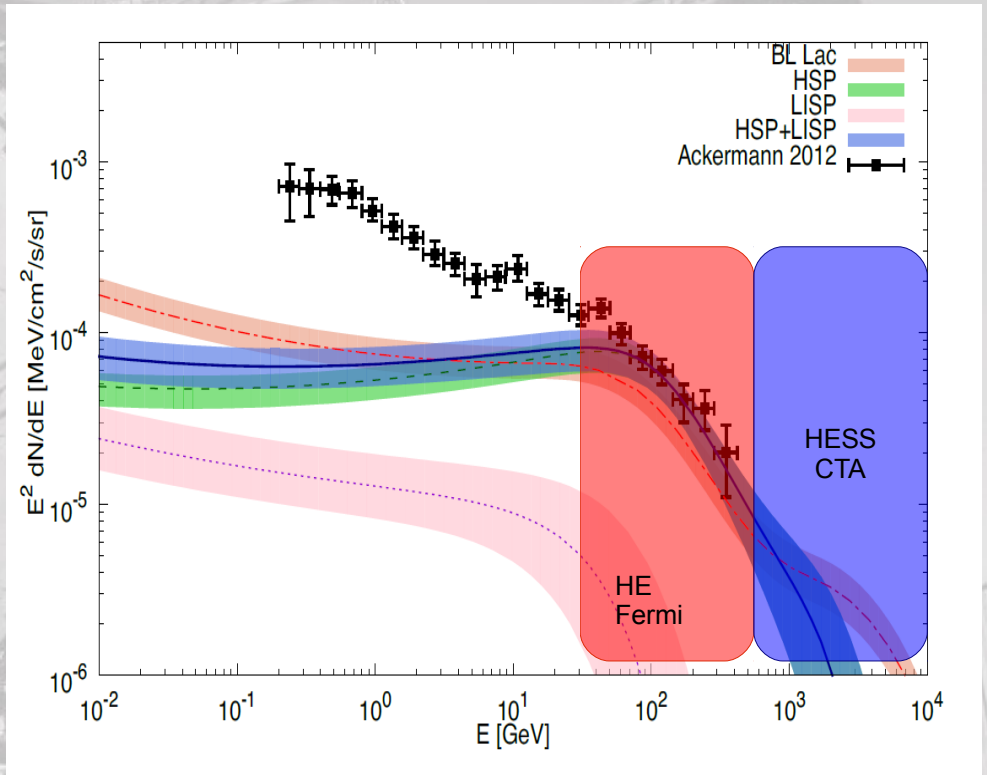

BL Lac
HSP
LISP
HSP+LISP
Ackermann 2012
HESS
CTA
HE
Fermi
E² dN/dE [MeV/cm²/s/sr]
E [GeV]
10⁻³
10⁻⁴
10⁻⁵
10⁻⁶
10⁻²
10⁻¹
10⁰
10¹
10²
10³
10⁴

Cosmological constraints

- Diffuse emission = Unresolved sources + DM

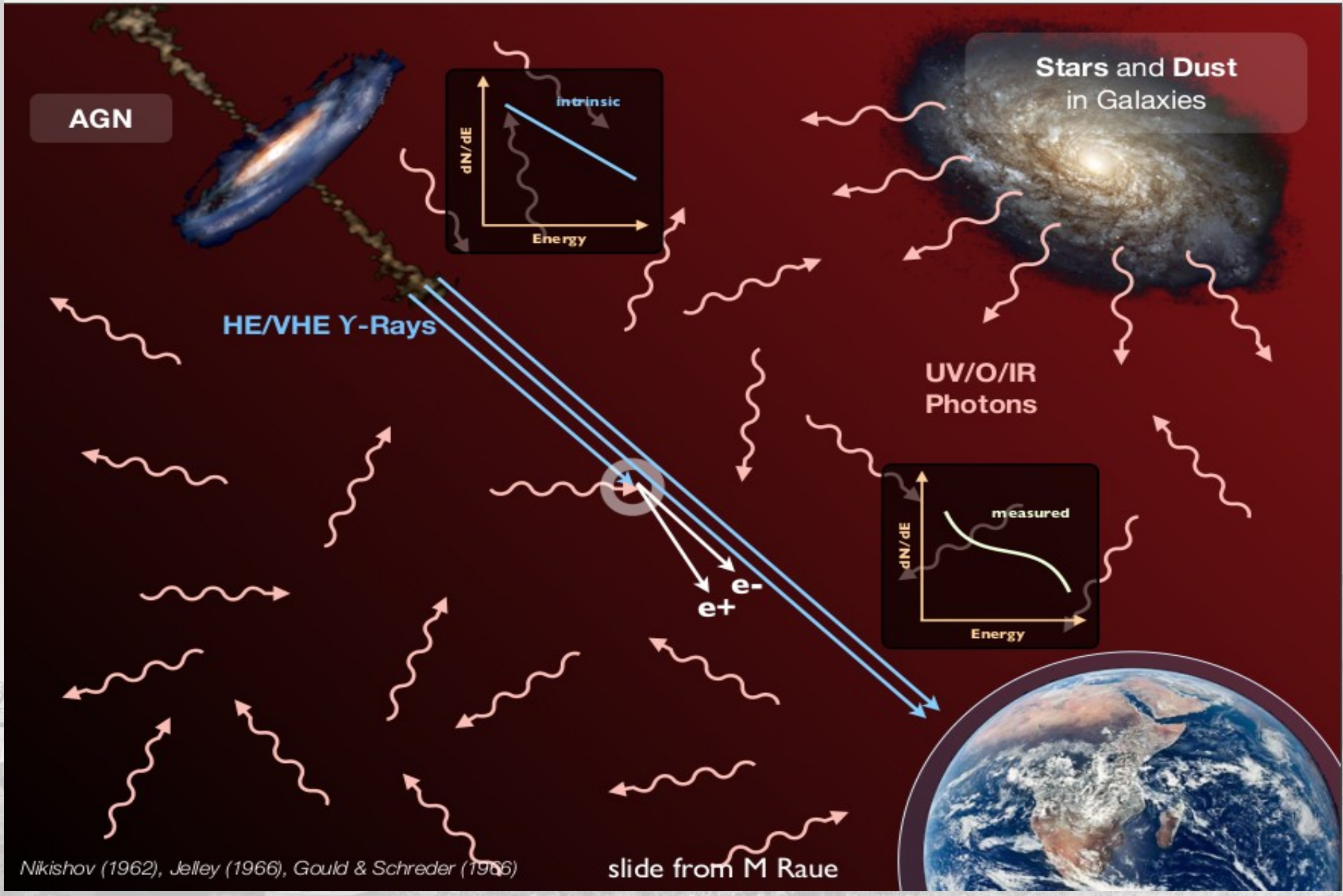
- Unresolved sources
  - Distribution of sources (z)
  - UHECR nature and origins

- DM
  - DM signal ?



Next: Population prediction for CTA scan

Extragalactic Background Light



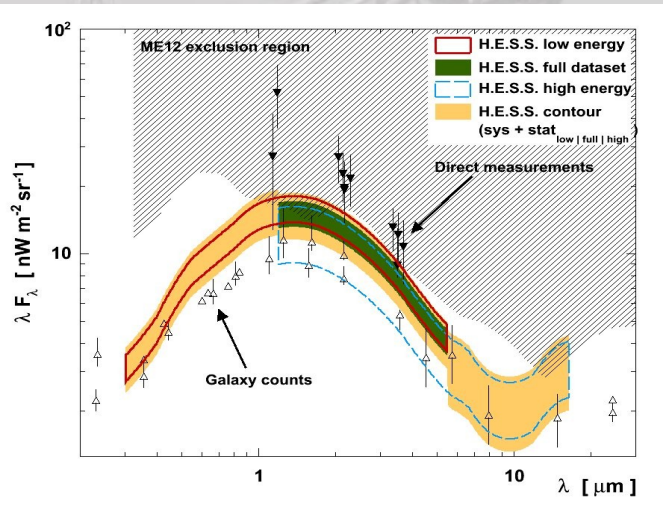
Extragalactic Background Light (II)

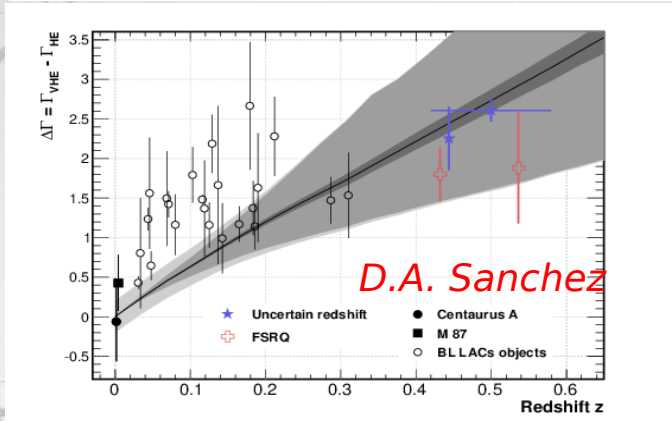
Flux_obs = $N_0\left(\frac{E}{E_0}\right)^{-\Gamma} \times exp(-\tau)$

Intrinsic spectrum

EBL unknown
z known

EBL determination





Constraints on cosmology

- SFR, first stars
- Galaxy formation

Can we use EBL?

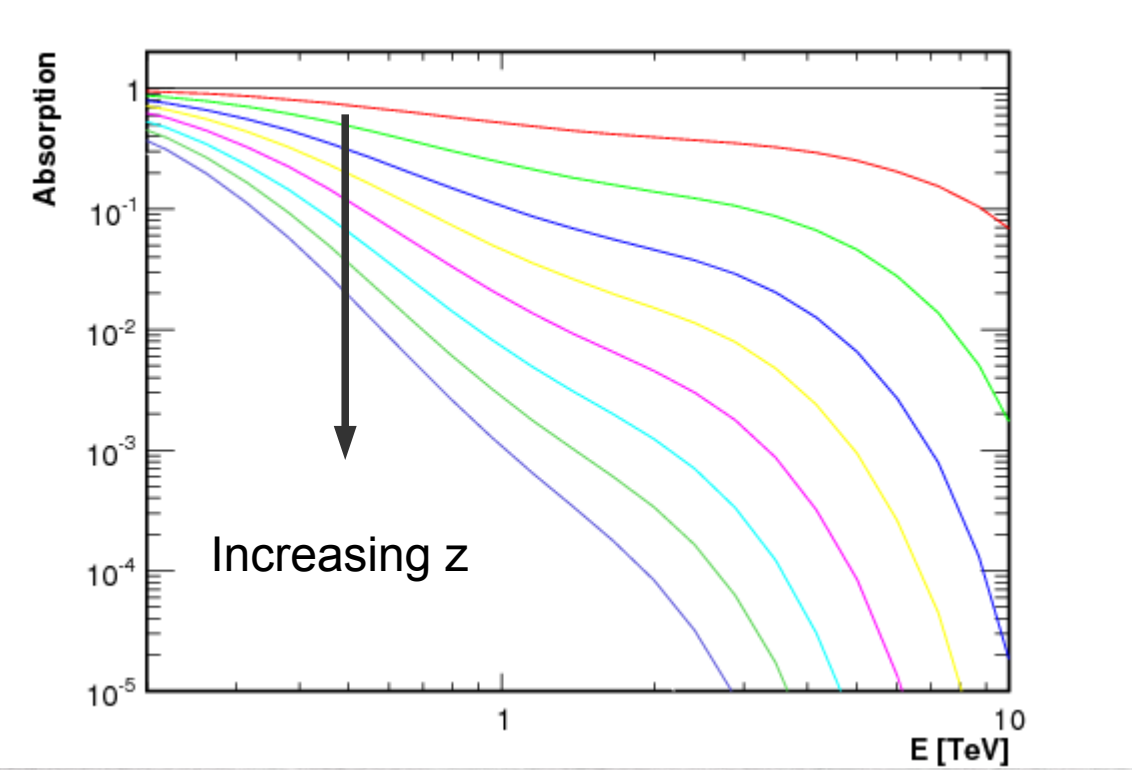
$$N_0\left(\frac{E}{E_0}\right)^{-\Gamma} \times exp(-\tau)$$

- Absorption $exp(-\tau)$ is redshift dependant

- Spectral features

  "wiggle"

Measure of z ?



Redshift measurement with H.E.S.S

Flux_obs = $N_0\left(\frac{E}{E_0}\right)^{-\Gamma} \times exp(-\tau)$

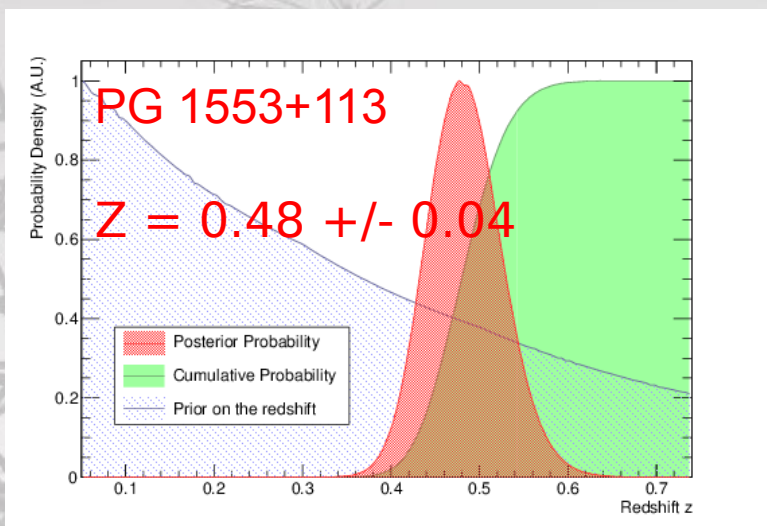
Intrinsic spectrum

Fermi (GeV)

EBL known, z unknown

Model from Franceschini et al

- Bayesian approach
  - Data HESS
  - Parameters N,Γ et z
- Allows systematics to be included



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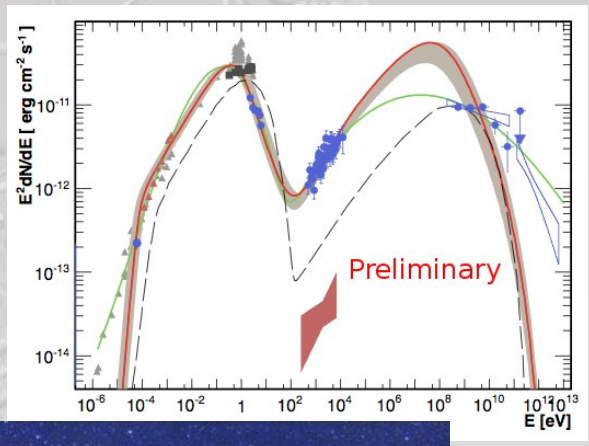
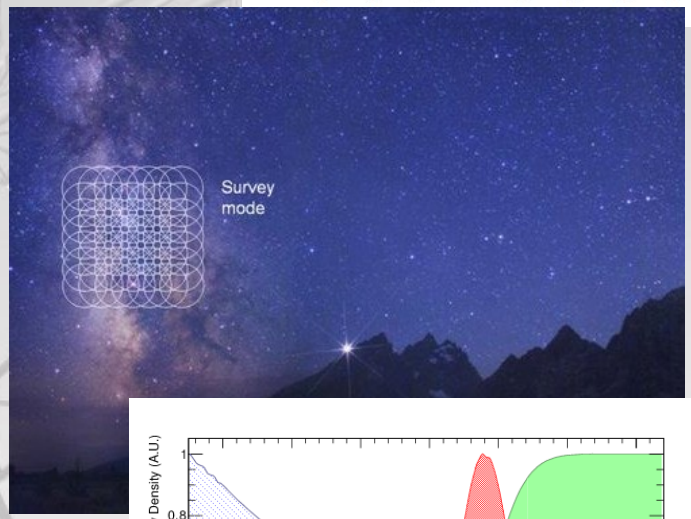
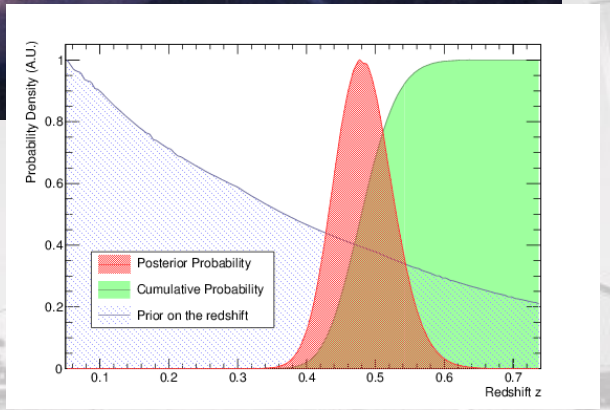
Projects with HESS II - CTA

- New types of sources (LLR, MPIK)
- MWL observations (Nustar, Fermi, etc)
- Extragalactic Survey (CTA)
  - Populations studies (LAPth, IPAG)
- Variability:
  - Indo-French project
  - Optical-Tev (MPIK)
- Redshift measurement
  - TeV data
  - MWL (LSST, X-shooter,...)







Projects linked with the LABEX

- Dark Matter indirect search
  - Collaboration LAPP-LAPTh
  - P. Serpico and A. Goudelis

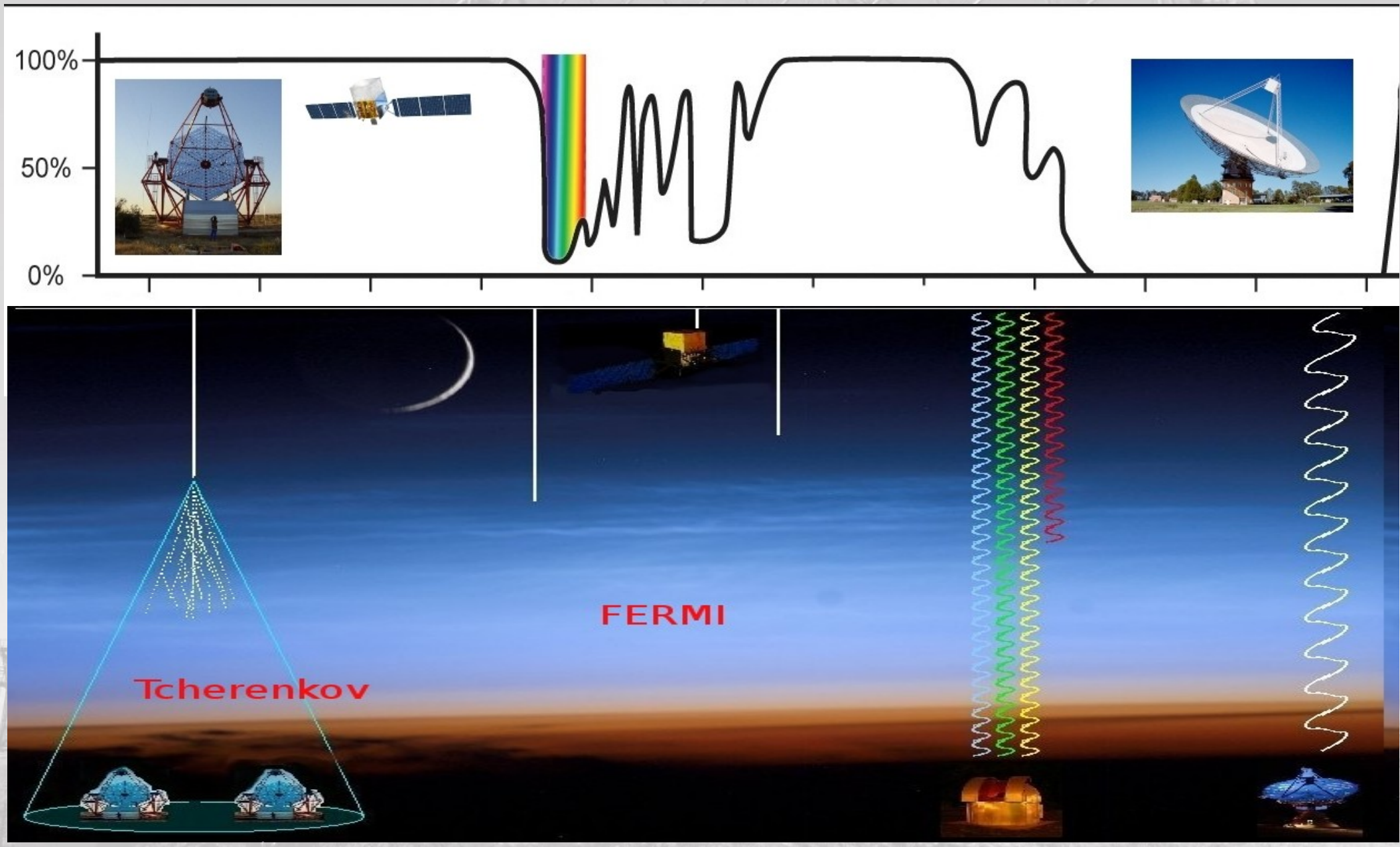
- Outside Gamma-ray Astronomy
  - LSST : stars and galaxies formation
  - Gravitational wave → CTA counterpart?

Aim :

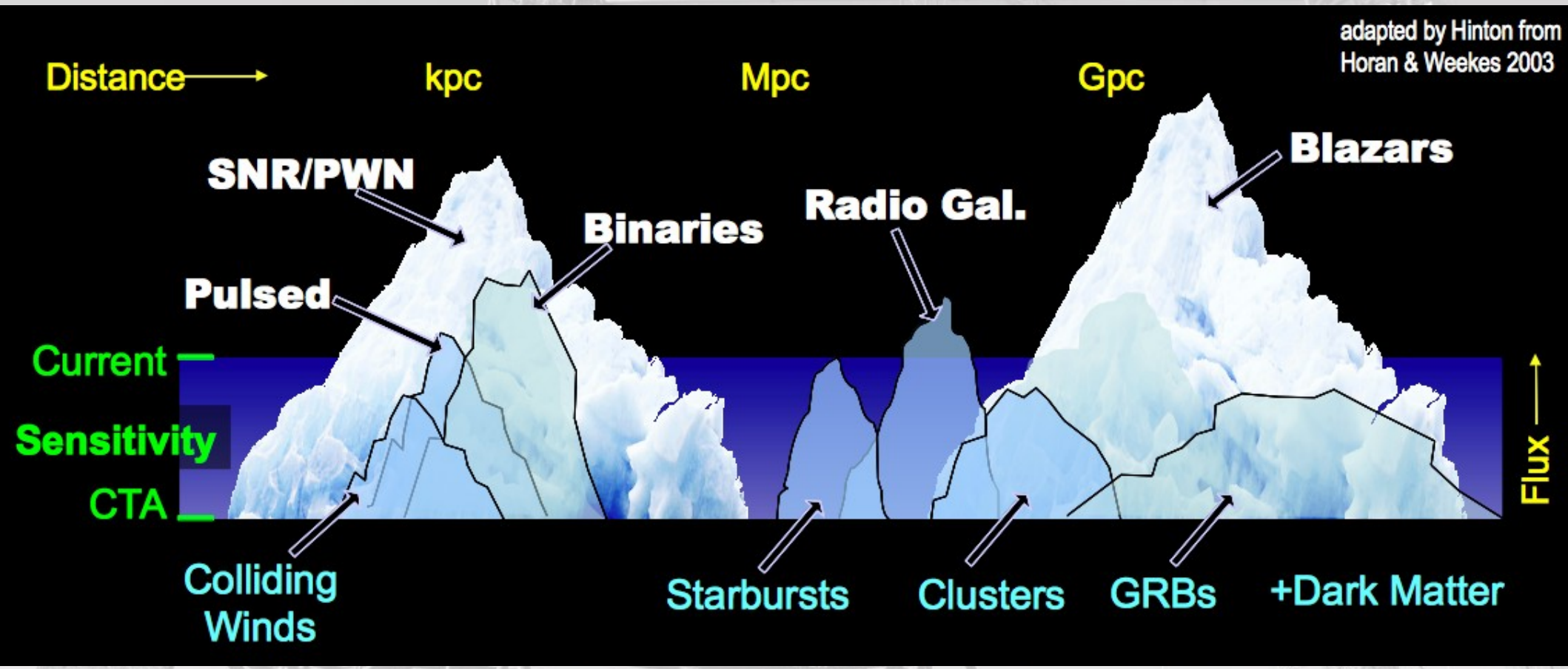
. Develop a lasting and solid activity

BACKUP

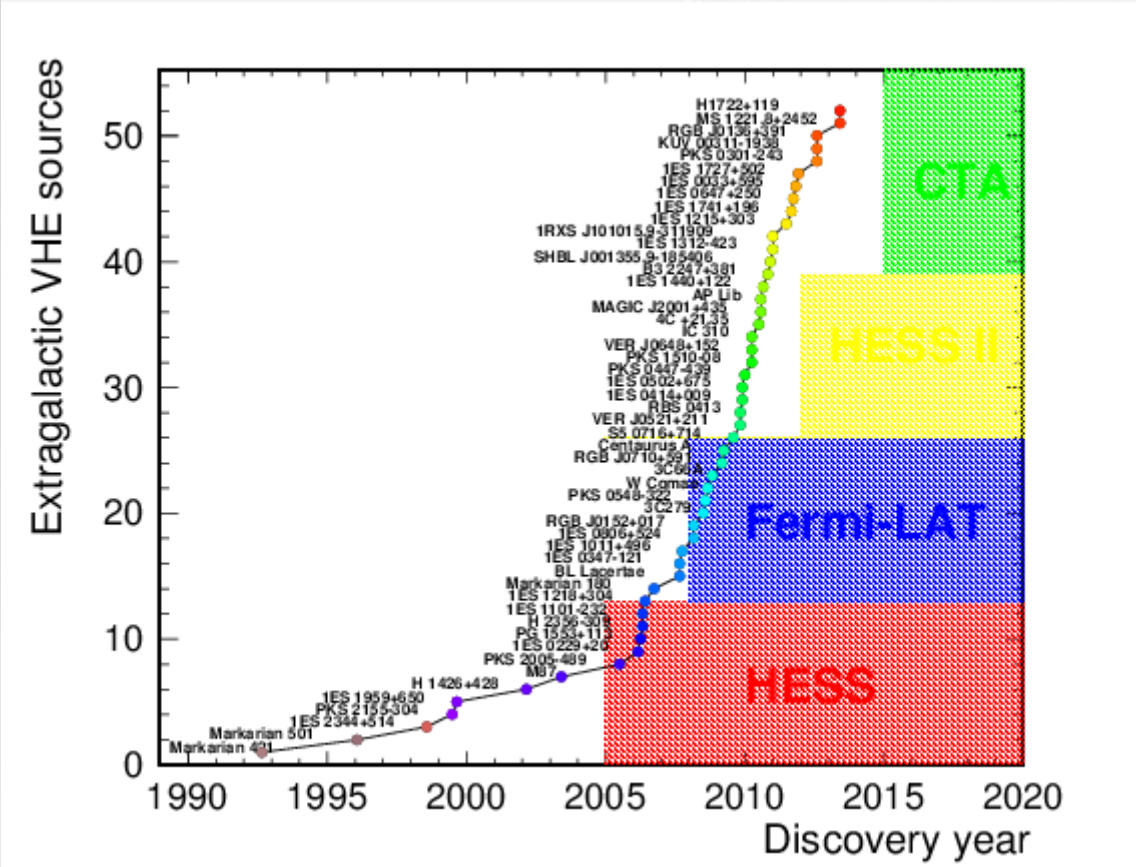
L'astronomie Gamma

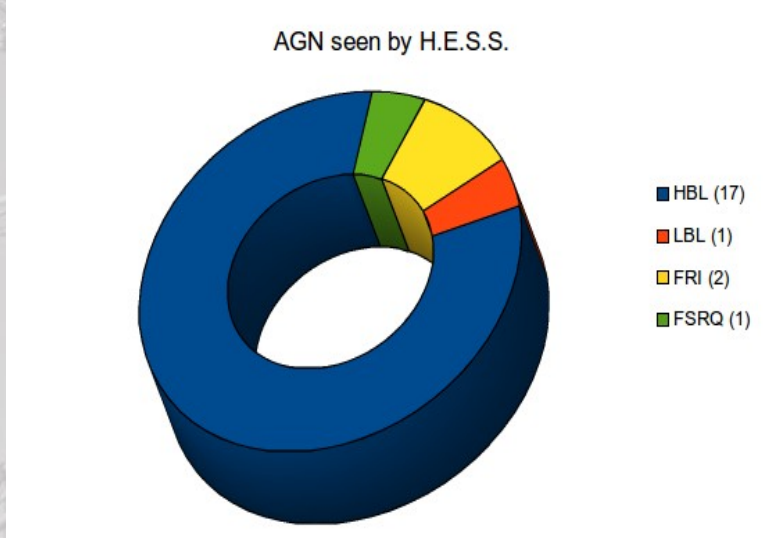


HESS I - II as Pathfinder

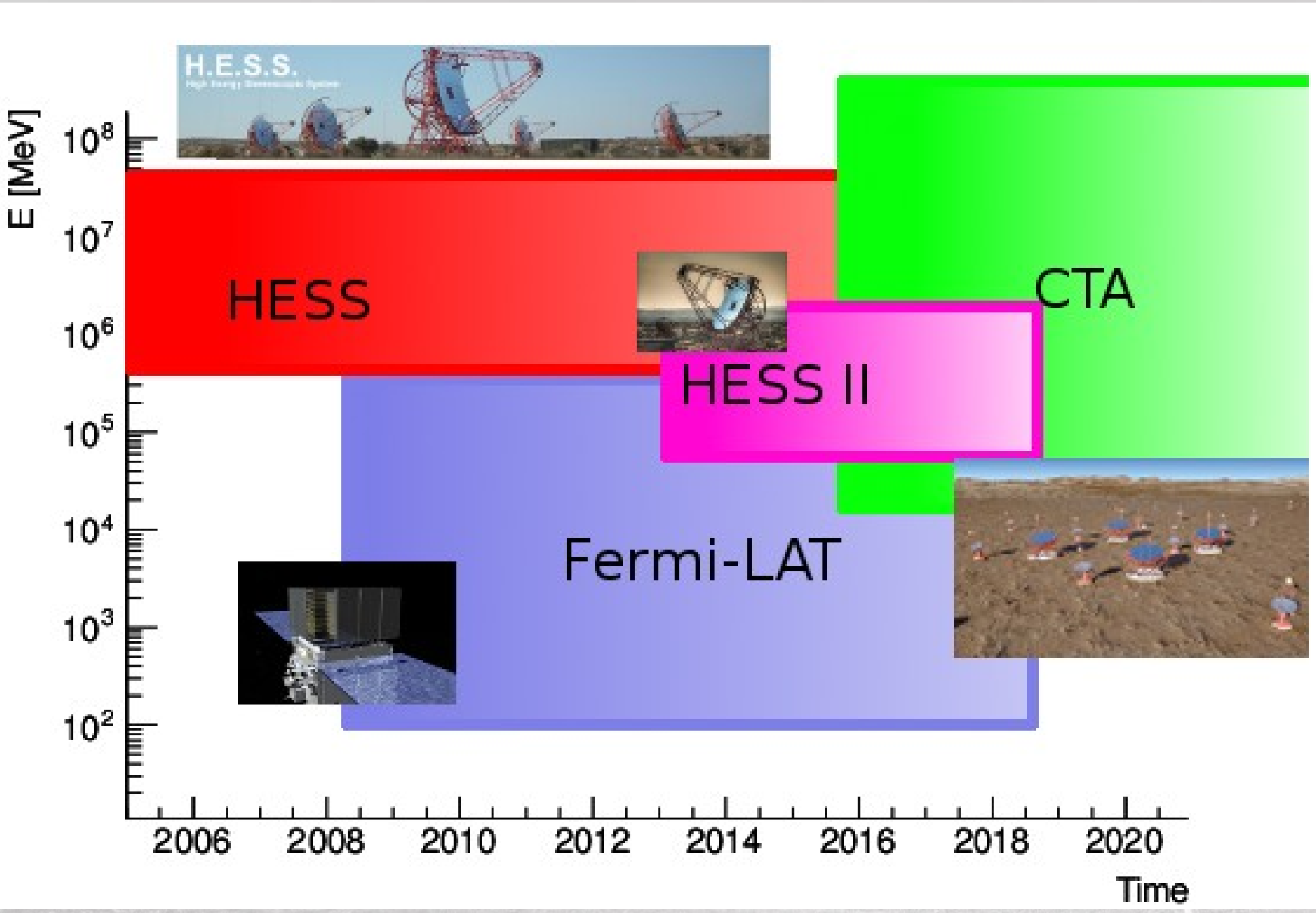


Objets Extragalactiques





- Evolution rapide
- Principalement 1 classe d'objet


H.E.S.S.
E [MeV]
10^8
10^7
10^6
10^5
10^4
10^3
10^2
HESS
HESS II
CTA
Fermi-LAT
2006
2008
2010
2012
2014
2016
2018
2020
Time

Bayesian approach: Introduction

Aim : derive an UL on z taken *Fermi* systematical and statistical uncertainties

Bayes Theorem: the posterior probability is

$$P(\theta|Y) \propto P(\theta)P(Y|\theta)$$

Bayesian approach $\Rightarrow$ need to specify:

- Data Y : **H.E.S.S. data**
- Model parameters $\theta = \{\mathbf{N}, \mathbf{\Gamma}, \mathbf{z}\}$

Assume a PL from 300 MeV to TeV energies absorbed by the EBL

$$\phi(\theta) = \phi(N, \Gamma, z) = N \times (E/E_0)^{-\Gamma} \times e^{-\tau(z)}$$

Likelihood and Prior

$P(Y|\theta)$ is the likelihood and is estimated **using the H.E.S.S. data.**

- Likelihood that the H.E.S.S. soft minimizes is mapped.
- Space parameters N,Γ, z

$P(\theta)$ is the prior.

We assume that **all the parameters are independents**.

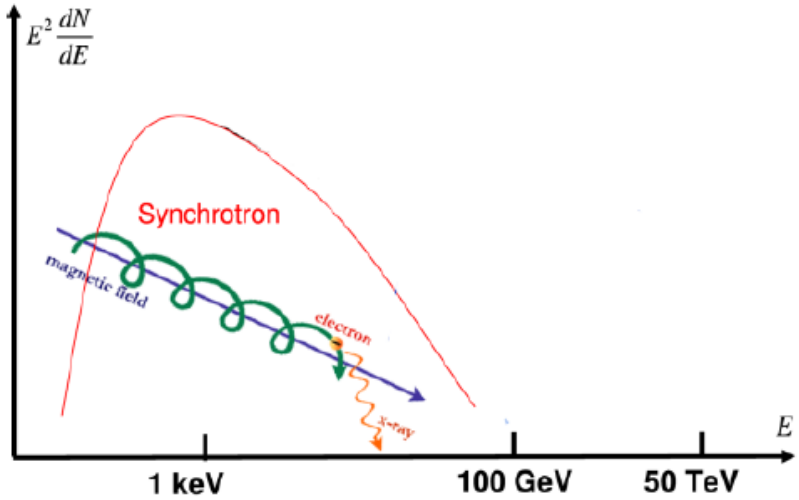
$$P(\theta) = P(z|N\Gamma)P(N)P(\Gamma)$$

- $P(N)$ =cst
- $P(\Gamma) \propto N(\Gamma, \Gamma_{\mathrm{Fermi}}, \sigma_\Gamma)$ if $\Gamma < \Gamma_{\mathrm{Fermi}}$ or $P(\Gamma)$ =cst
- $P(z) \propto exp(-\tau(z))$

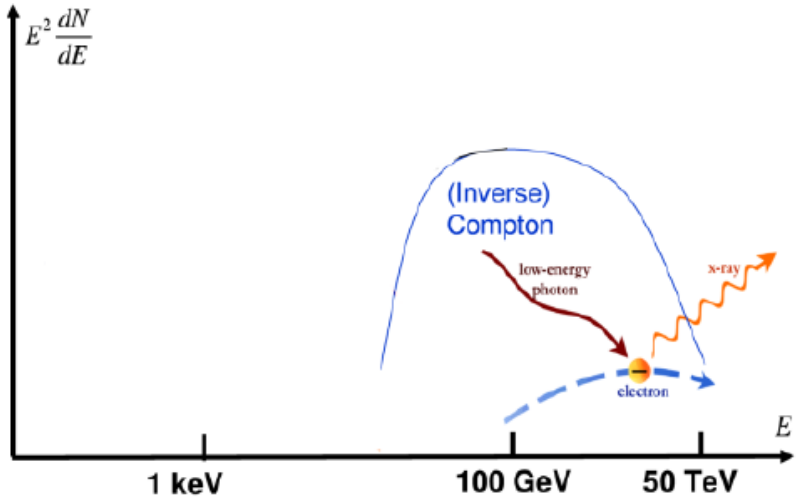
Fermi and H.E.S.S. systematic uncertainties included in σ_Γ

Emission Models

Synchrotron process:
Radio to X-ray emission



Inverse Compton process:
Soft gamma to TeV energies



Field of soft photons for IC scattering:

- External field: **External Compton (EC)**: FSRQ
- Synchrotron photons: **synchrotron self-Compton (SSC)**: HBL