The Highest Energy Gamma Sky

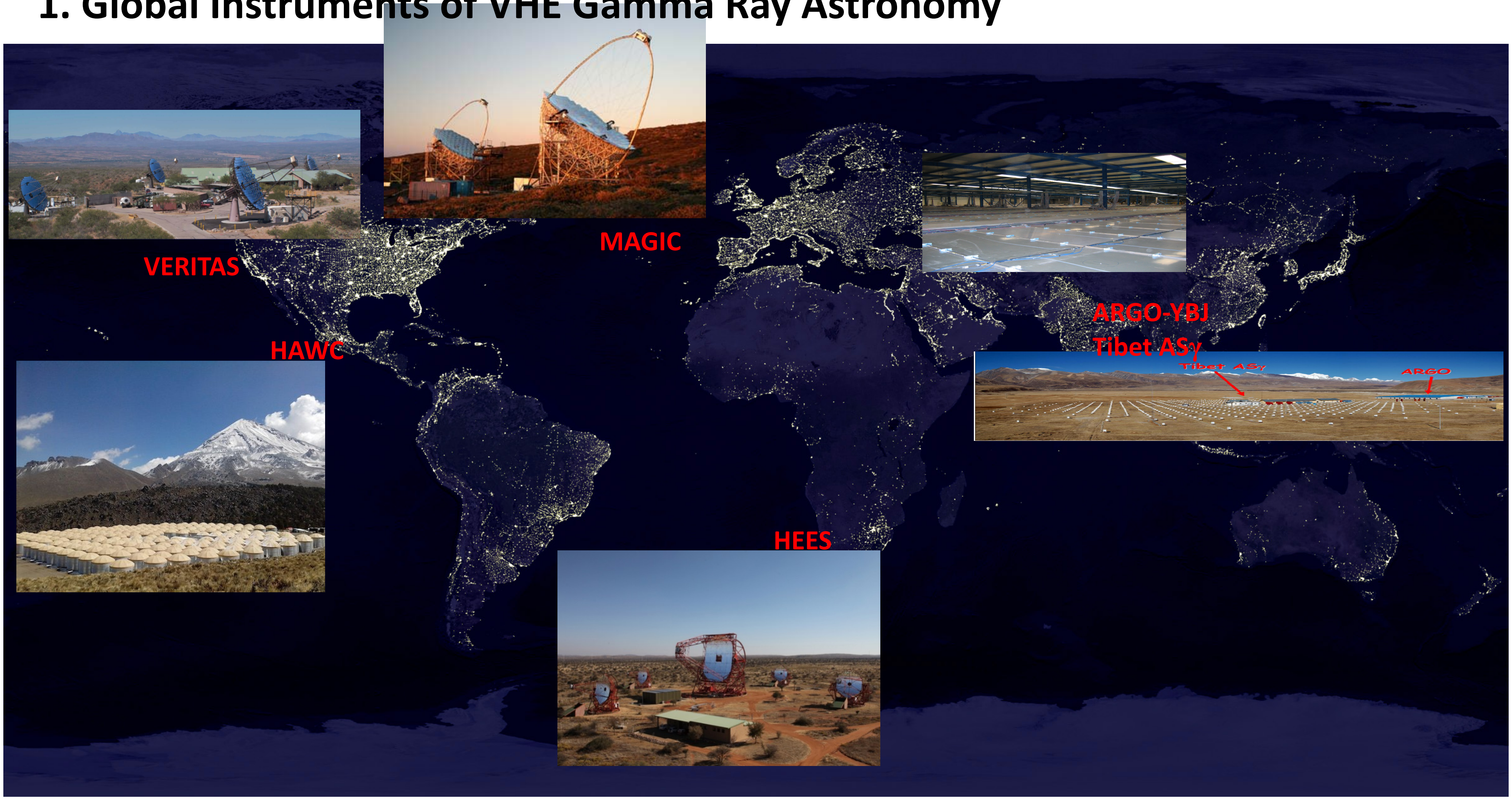
Zhen Cao

IHEP, China, Beijing

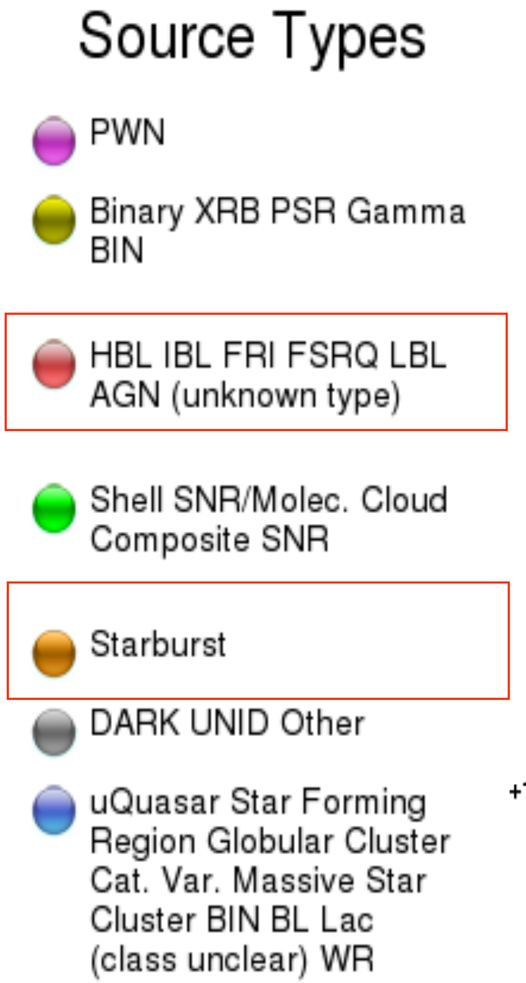
1st APPIC Meeting at APC, Paris, May, 2014

Contenet

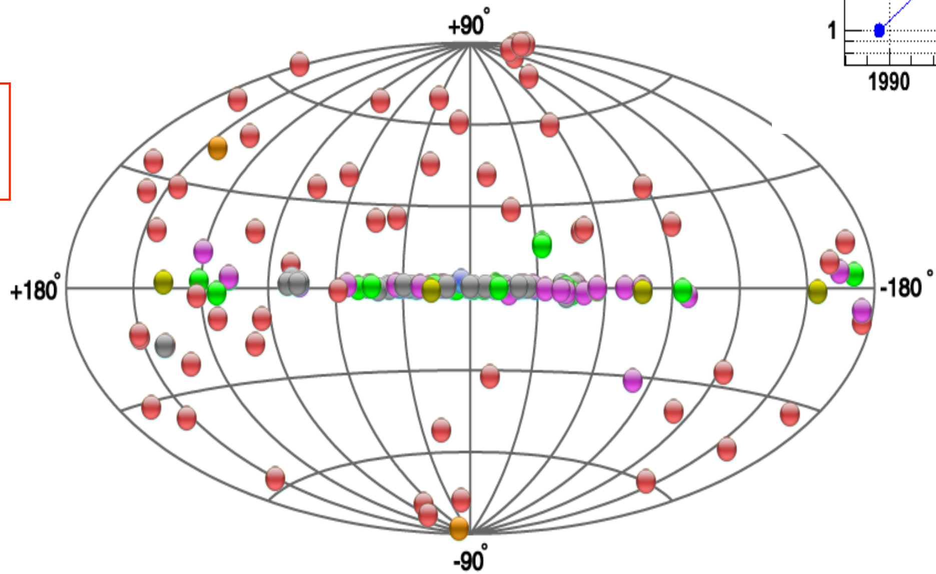
1. Global Instruments of VHE Gamma Ray Astronomy

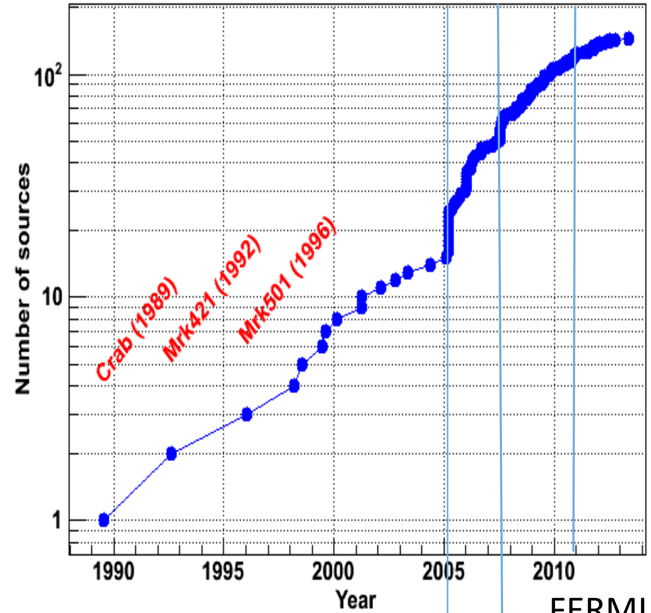


2. Map and number of the γ ray sources



147 sources





FERMI Catalog releasing

MAGIC Switch on

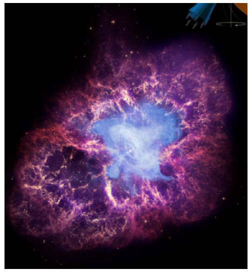
HESS Switch on

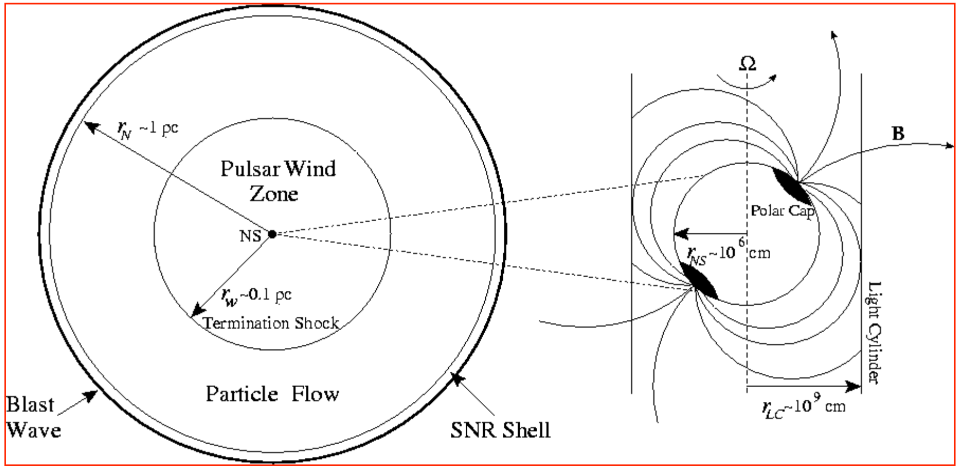
3. In Our Galaxy

- PWNs
- SNRs
- Binaries
- …

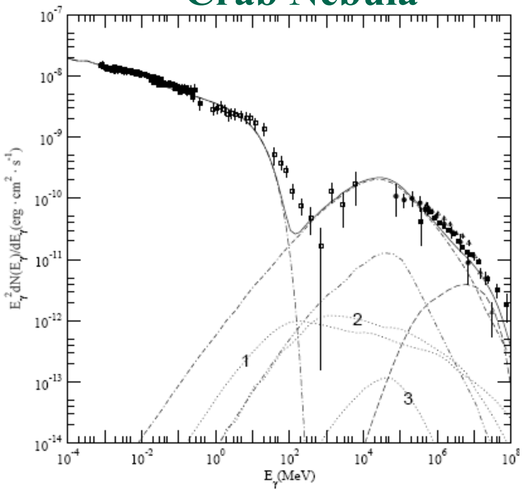
- Regions:
  - Cygnus region: Cocoon
  - G.C. and FERMI Bubble
  - Diffuse γ rays

34 Pulsar Wind Nebula

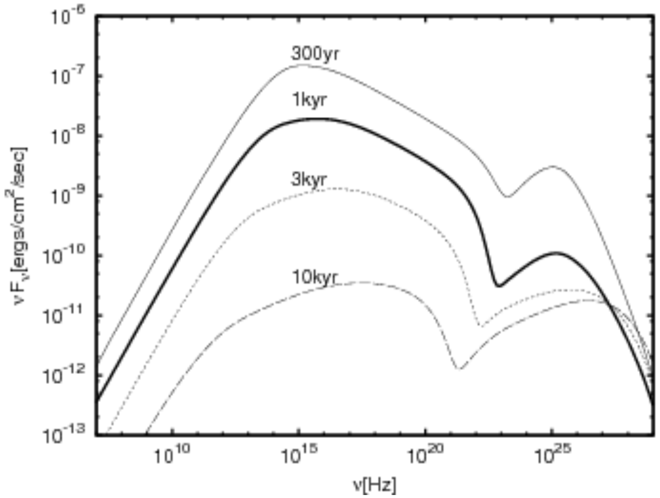




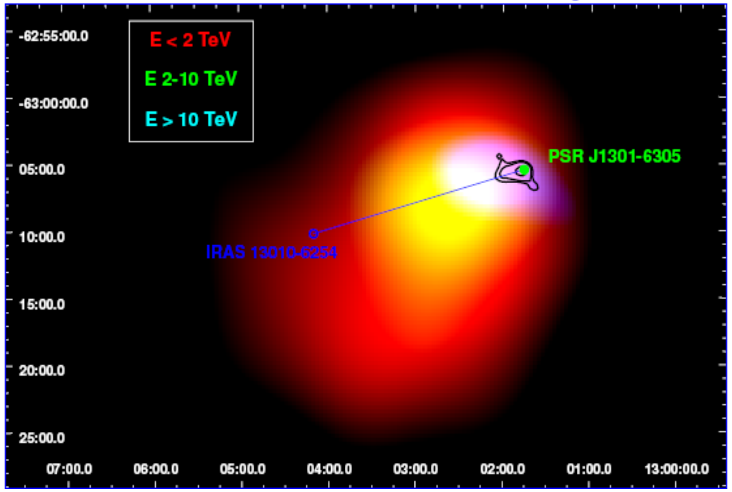
Standard Candle
Crab Nebula



Evolution



Spatial drifting



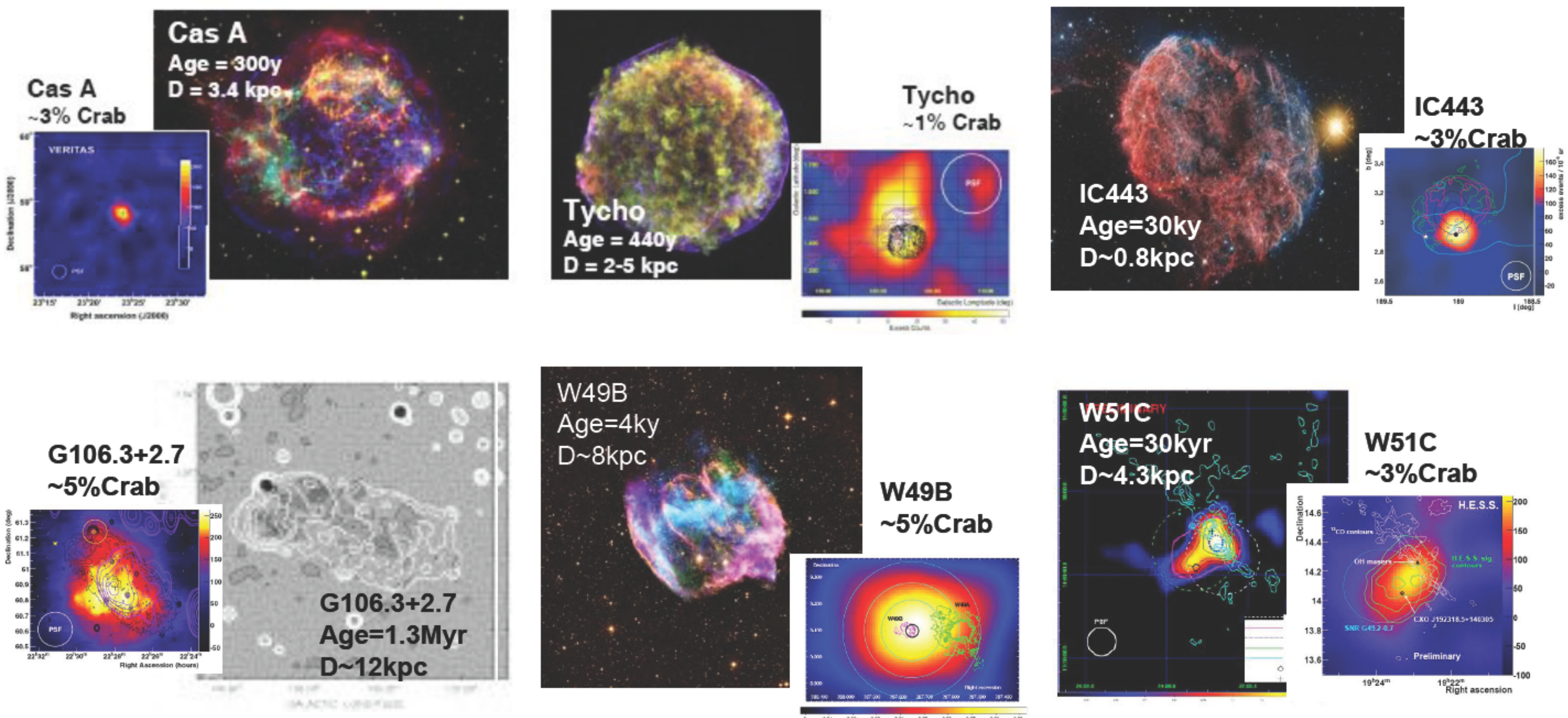
A&A 548, A46 (2012)

23 SNRs (Shell or Composite w/clouds)

6个SNR

壳型SNR：Tycho，CasA，G106.3+2.7，IC443

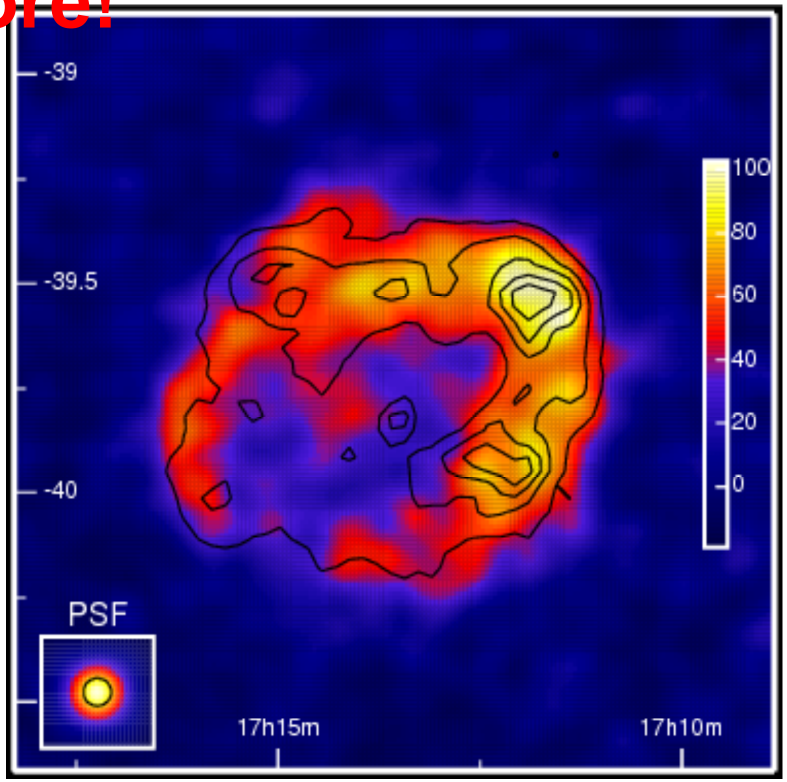
热混合型：W49B，W51C

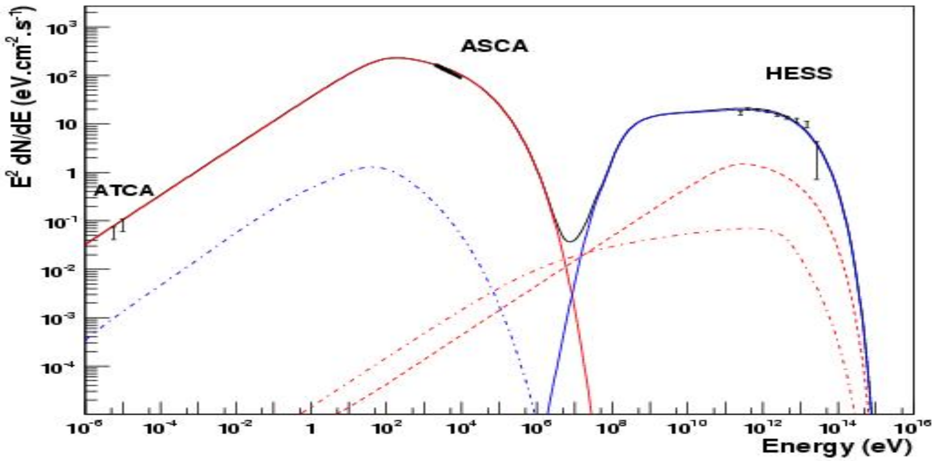


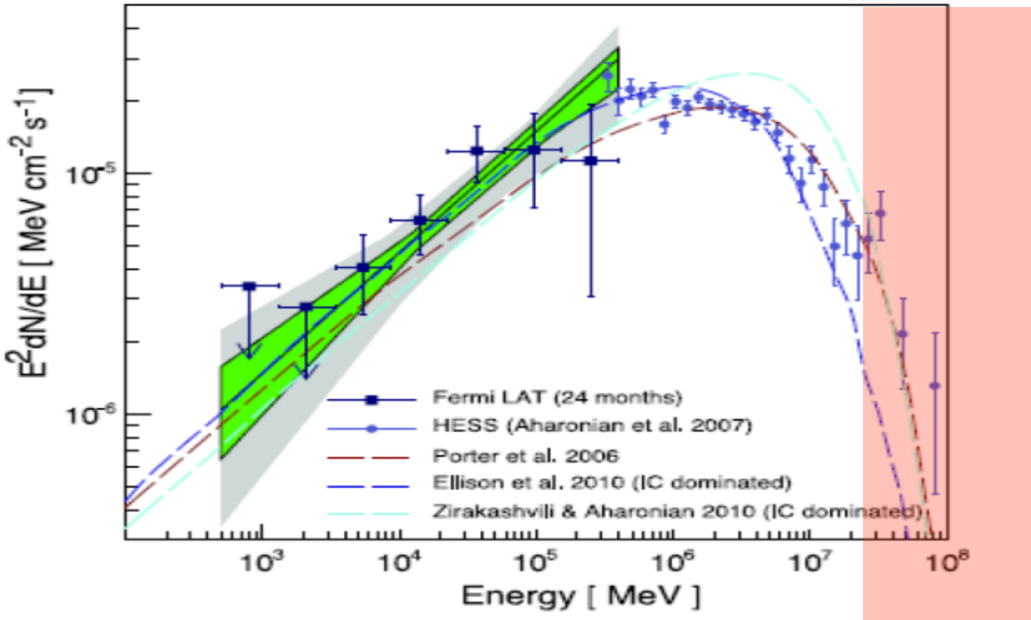
RXJ 1713.7-3946

Morphology is important,

Spectroscopy is even more!

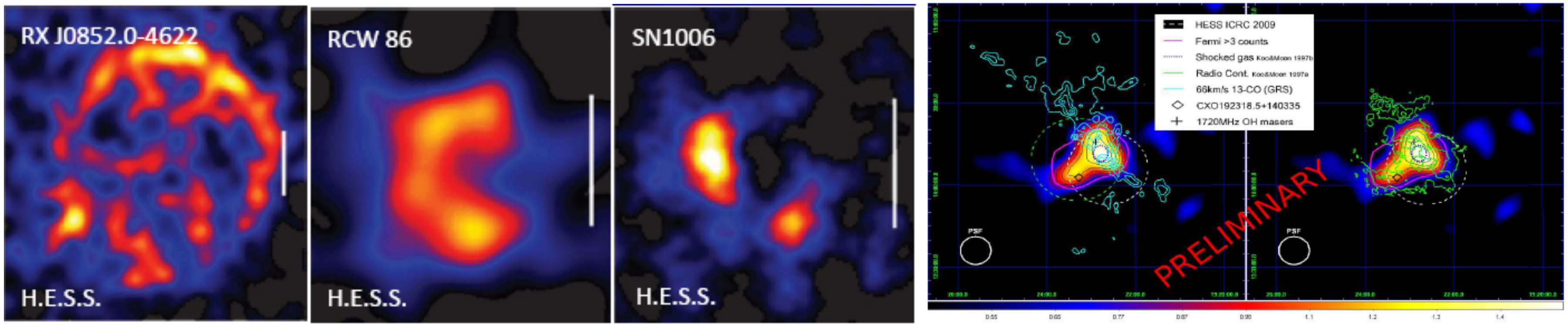




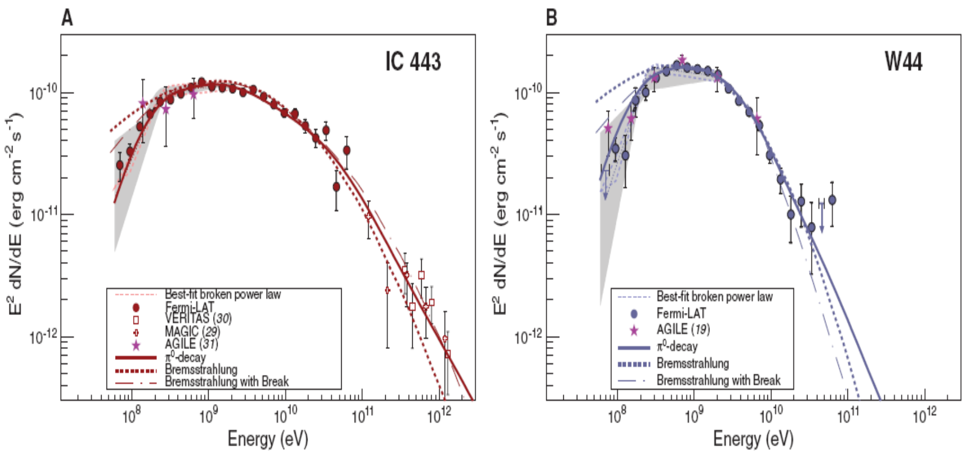


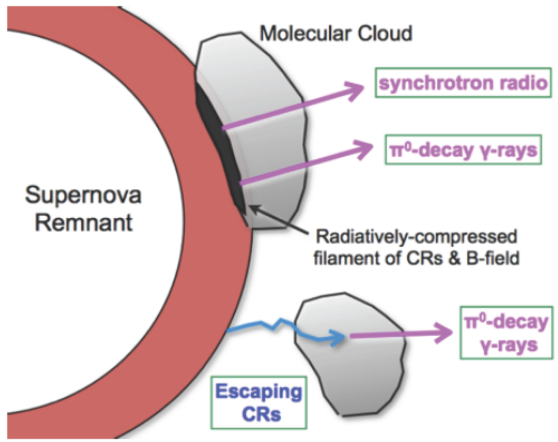
SNRs

Young SNRs



Old SNRs

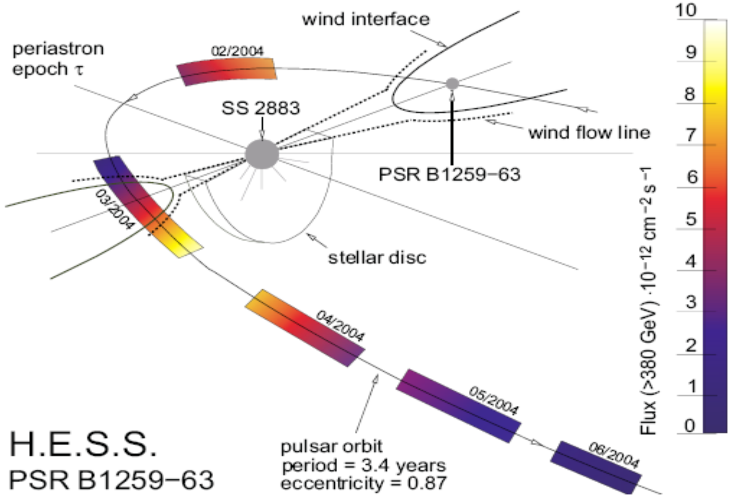


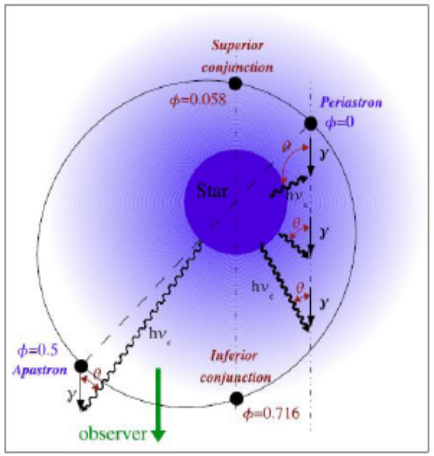


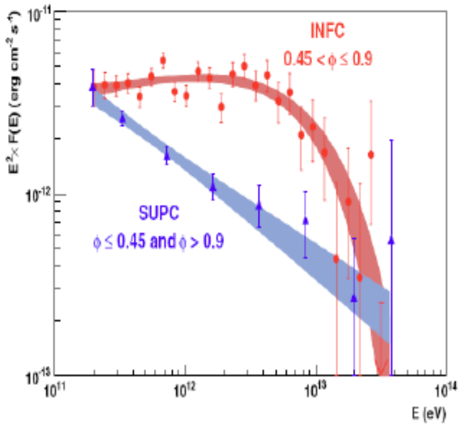
Science 339, 807 (2013)

CR sources?

5 Binaries







H. E. S. S. 在 LS 5039： Variation of γ flux in orbiting phase. Binaries have different behaviors, though.

(Aharonian et al. 2006b)。

Cygnus Region

Star Forming Regions

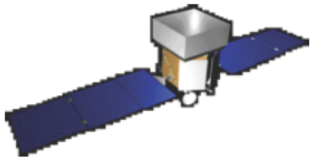
OB Assoc., WR stars
HII regions, molcular clouds

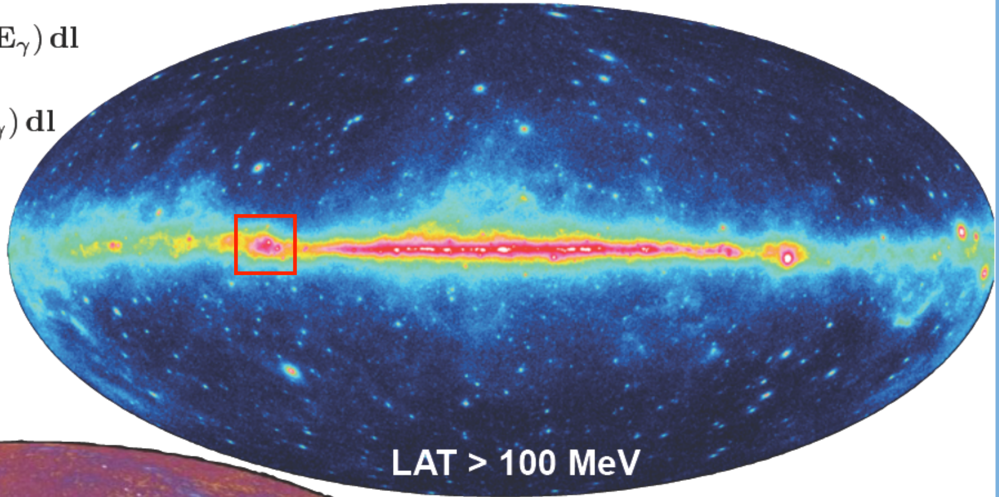
γ rays from the ISM

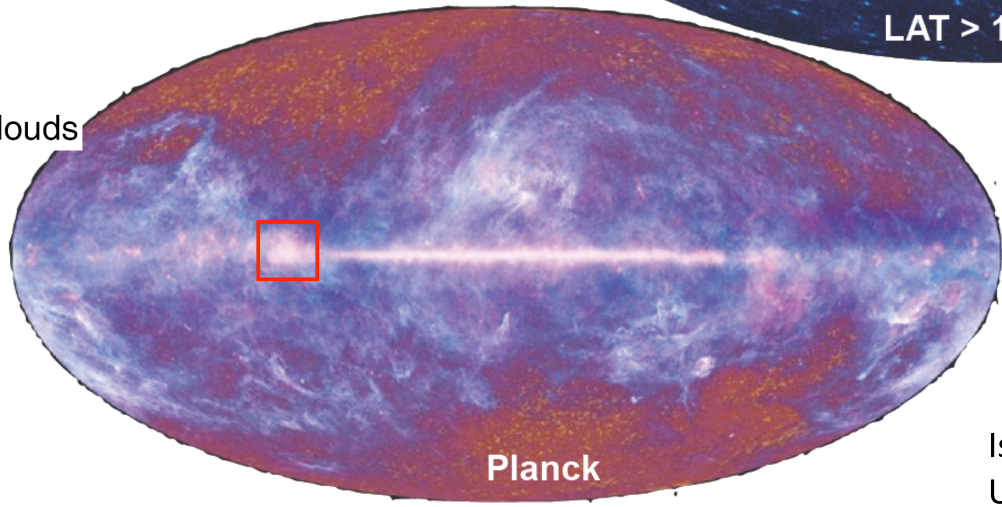
$$\mathbf{L}_\gamma(\mathbf{l},\mathbf{b},\mathbf{E}_\gamma) = \int_{\mathrm{l.o.s.}} \mathbf{n_e}(\mathbf{l},\mathbf{E_e})\,\mathbf{n_{ISRF}}(\mathbf{l},\nu)\,\sigma_{\mathbf{IC}}(\mathbf{E_e},\nu,\mathbf{E}_\gamma)\,\mathbf{dl}$$

$$+ \int_{\mathrm{l.o.s.}} \mathbf{n_e}(\mathbf{l},\mathbf{E_e})\,\mathbf{n_{gas}}(\mathbf{l})\,\sigma_{\mathbf{brem}}(\mathbf{E_e},\mathbf{E}_\gamma)\,\mathbf{dl}$$

$$+ \int_{\mathrm{l.o.s.}} \mathbf{n_A}(\mathbf{l},\mathbf{E_A})\,\mathbf{n_{gas}}(\mathbf{l})\,\sigma_\pi(\mathbf{E_A},\mathbf{E}_\gamma)\,\mathbf{dl}$$



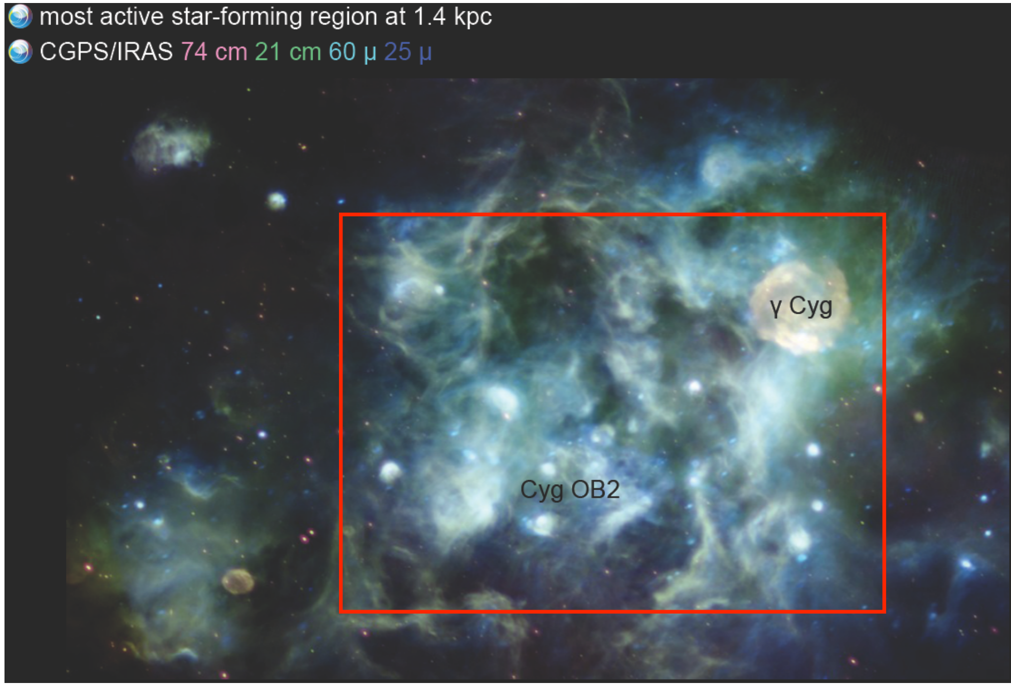


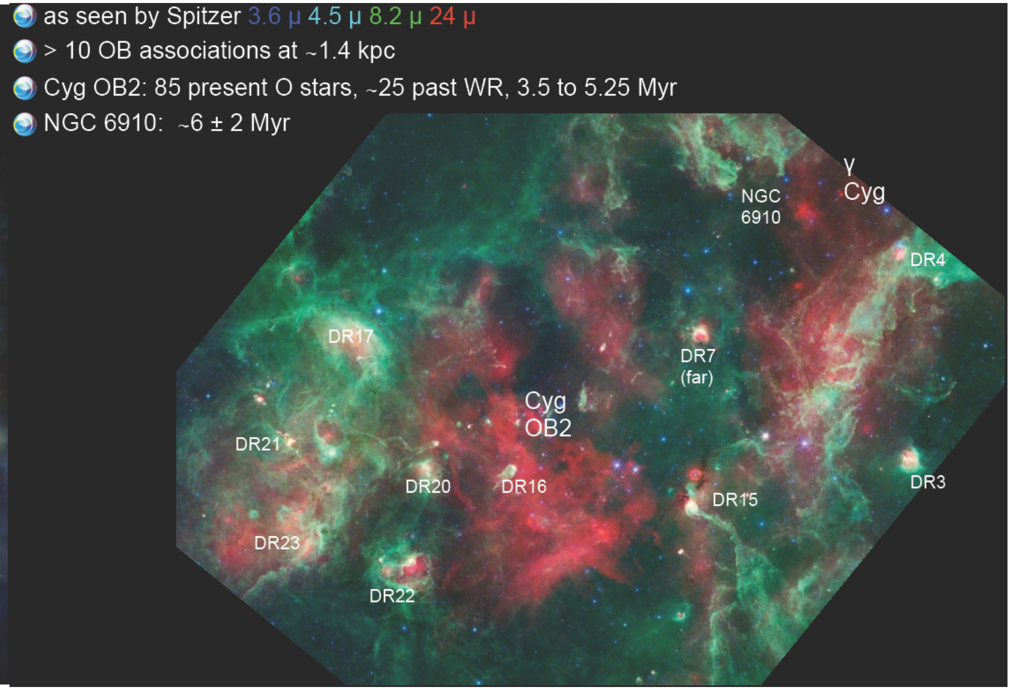


$$\mathbf{I}_\nu = \tau_\nu \mathbf{B}_\nu(\mathbf{T_{dust}})$$

Isabelle Grenier
Université Paris Diderot & CEA Saclay

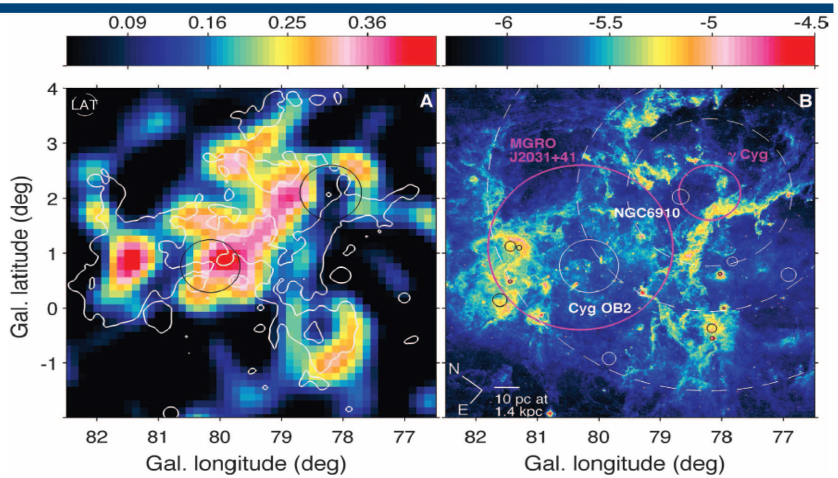
The most active region in the northern sky



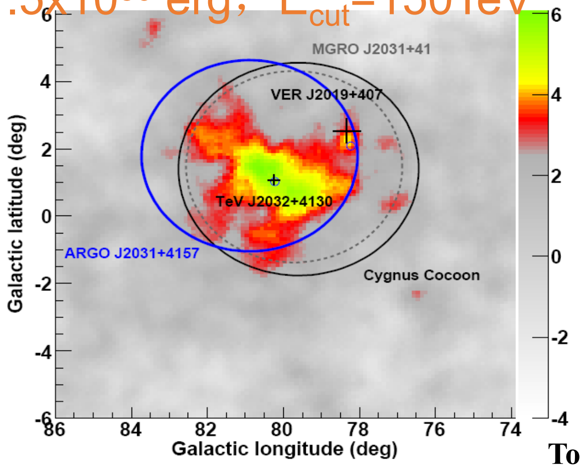


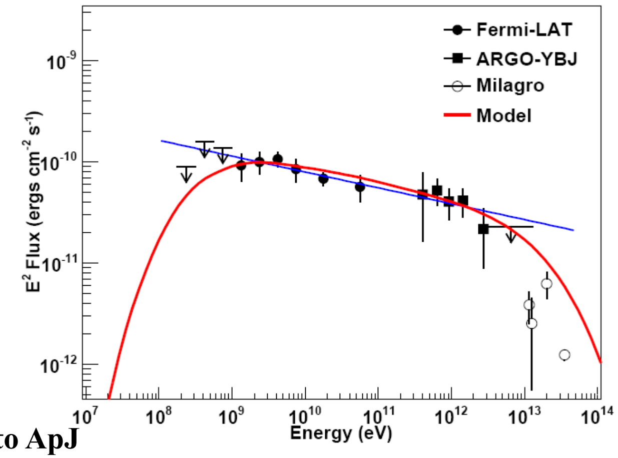
Cygnus Cocoon (FERMI Cocoon)

- FERMI Cocoon
- ARGO J3031+4157
- **The first γ ray Superbubble**
- **it is too big to IACT**
- Could be a possible hadronic source w/ total hadronic energy of 1.5×10^{50} erg， E_{cut}=150TeV



***Science* 334, 1103 (2011)**

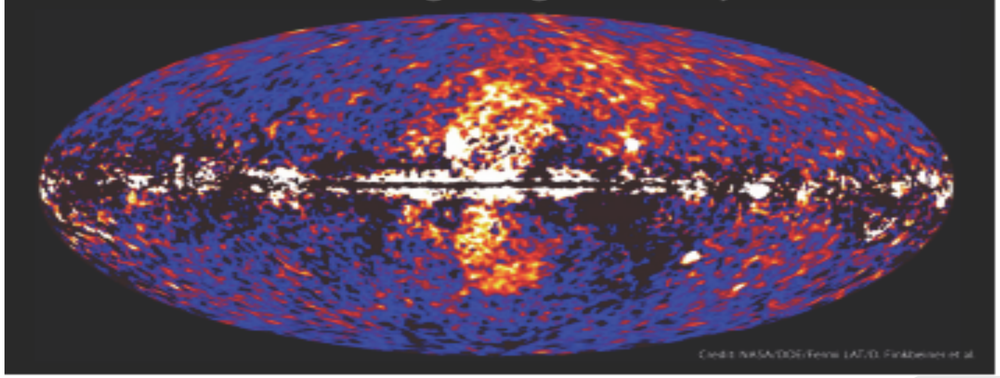




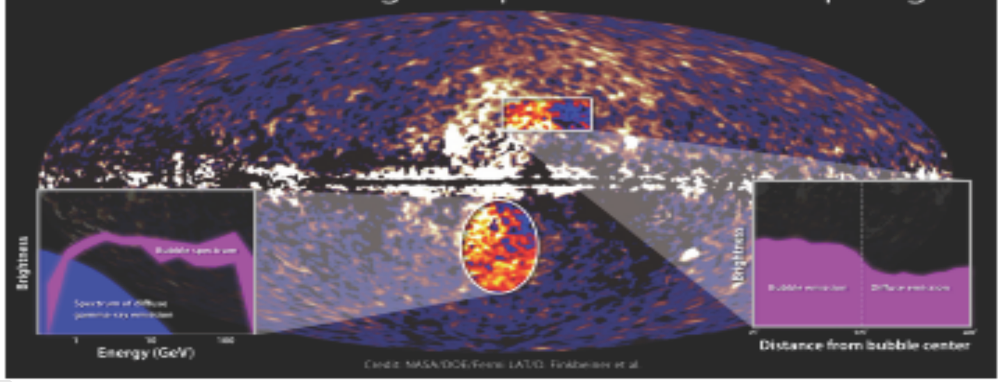
To be submitted to ApJ

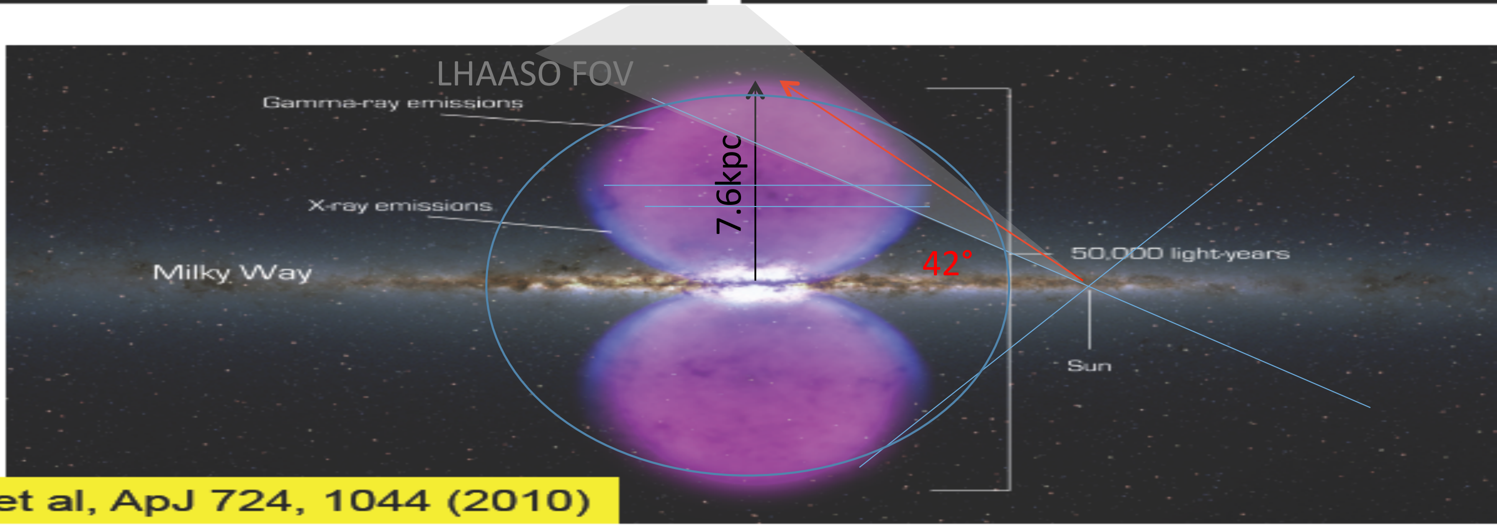
Energetic *bubbles* in our galaxy

Fermi data reveal giant gamma-ray bubbles



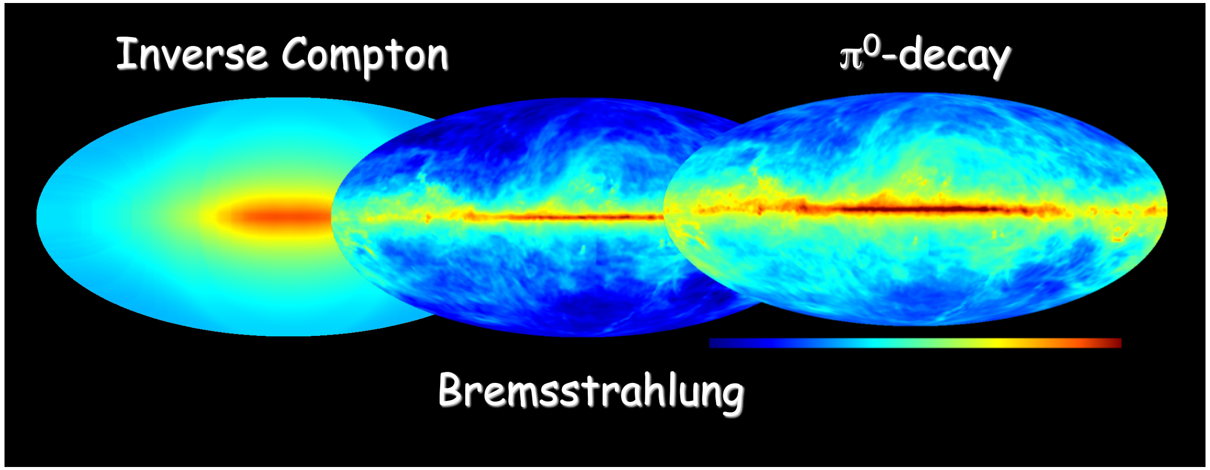
Bubbles show energetic spectrum and sharp edges





Meng Su et al, ApJ 724, 1044 (2010)

4. Galactic plane diffuse gamma-ray



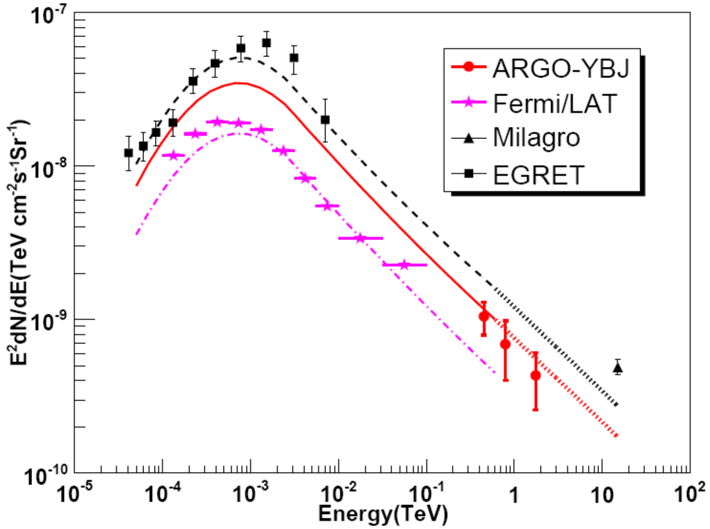
- **Diffuse gamma rays produced by interactions of cosmic rays with the interstellar medium and radiation fields. They can be used to probe the cosmic ray spectrum and density throughout the whole Galaxy.**

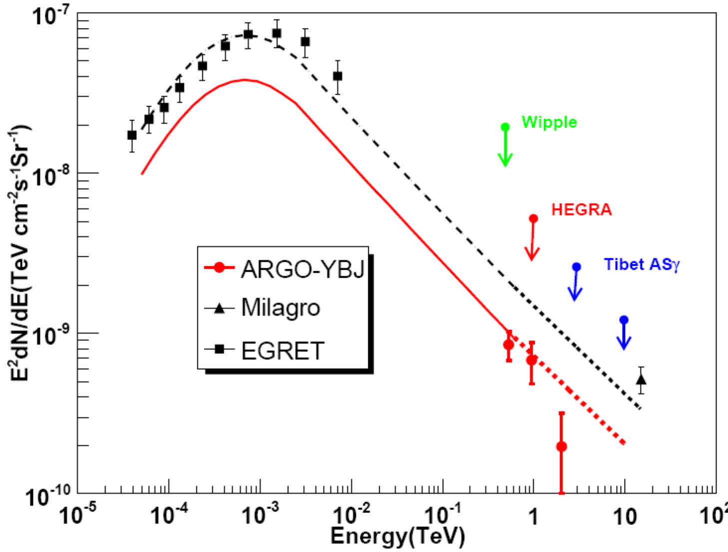
Diffuse γ rays: EGRET, FERMI, ARGO-YBJ and MILAGRO

$65° < l < 85°, |b| < 5°$

$25° < l < 65°$ and $85° < l < 100°, |b| < 5°$

Cygnus region

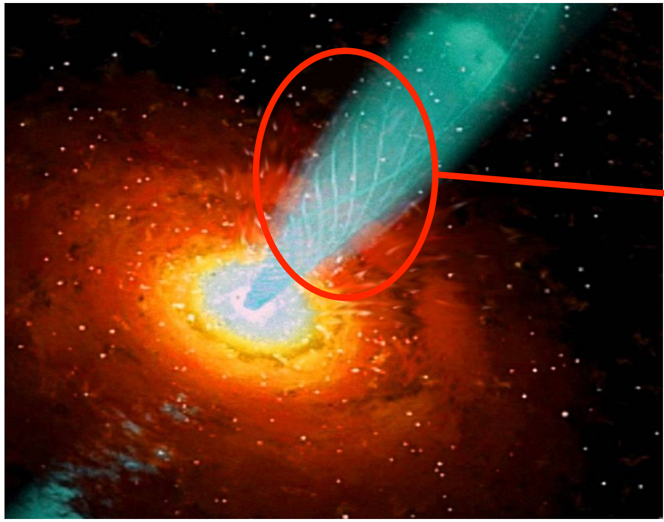


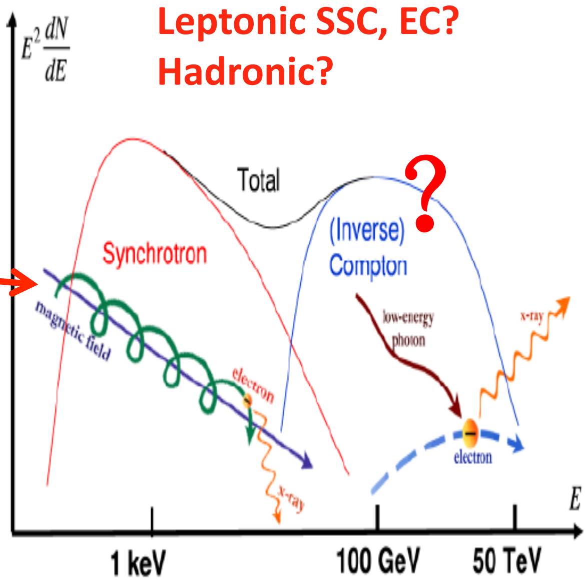


From 30MeV to 20TeV, traces CR propagation well.

To be submitted to ApJ

4. AGNs

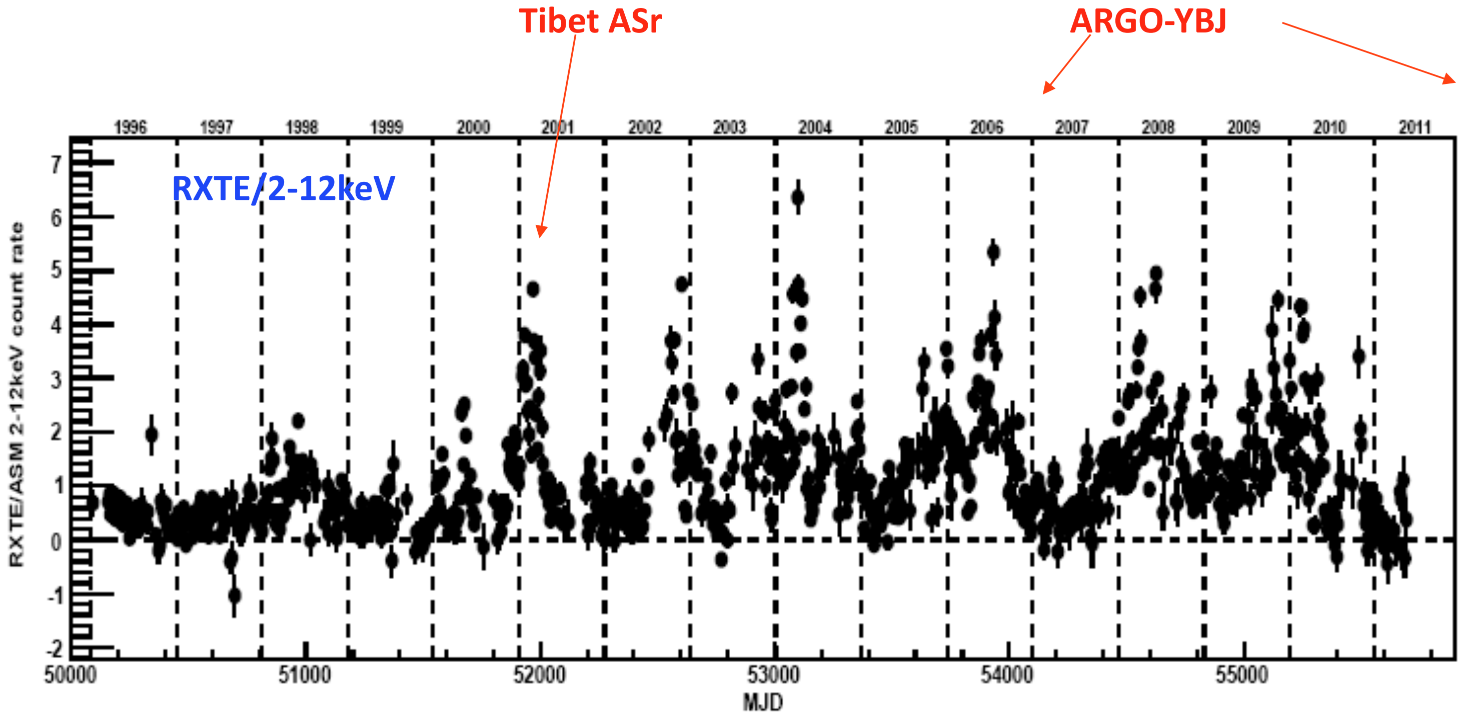




Different models will predict different correlations between low and high energy components. Thus, **long-term continuously multi-wavelength observations, especially at X-ray and TeV band,** are crucial to understand the emission mechanisms and underline processes of the outbursts.

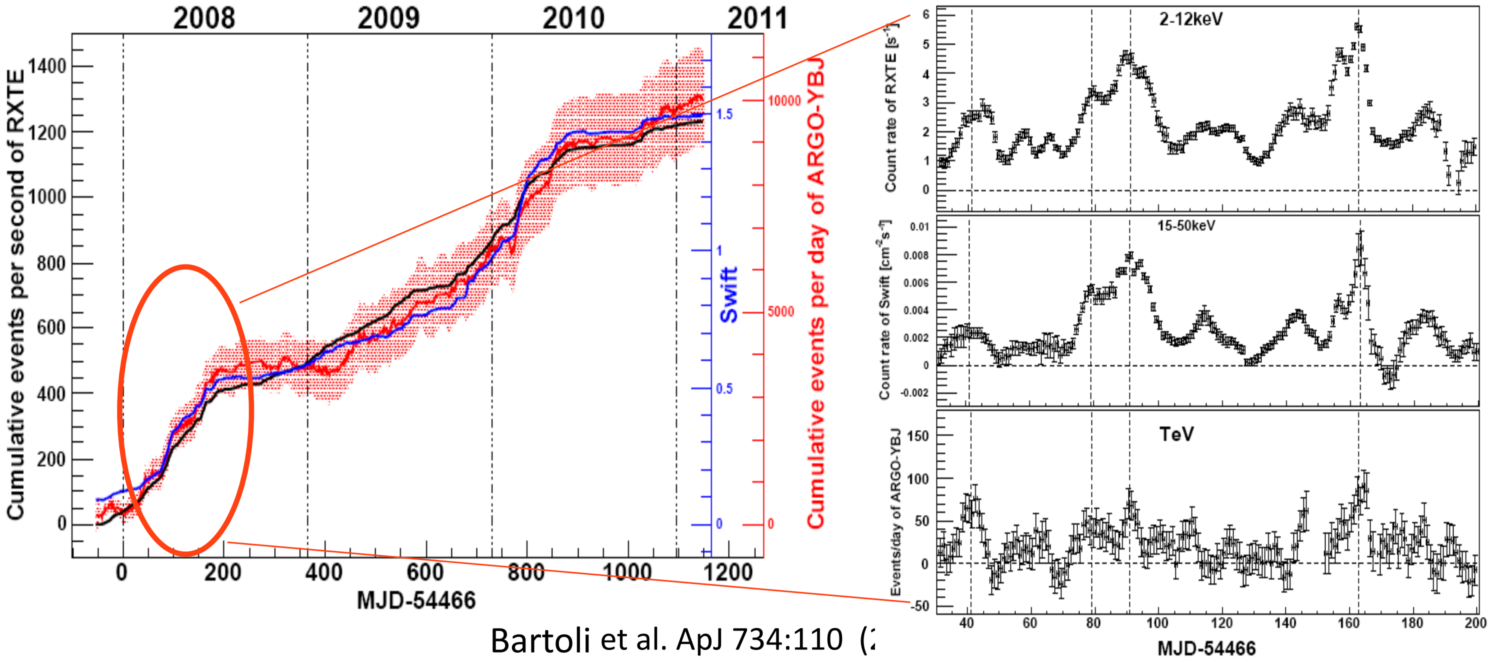
Mrk421

- An excellent candidate to study the jets of AGN. With frequent major outbursts about once every two years.



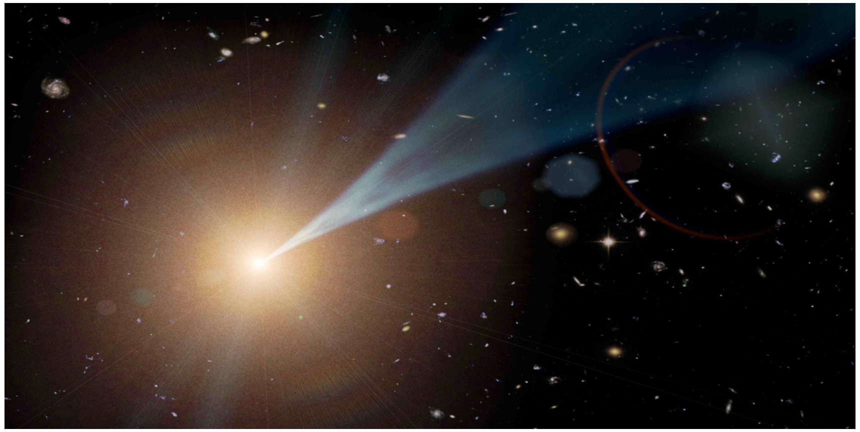
ARGO-YBJ observation

- A good several years long-term correlation between X-ray and TeV gamma-ray including both active and quiet phases.

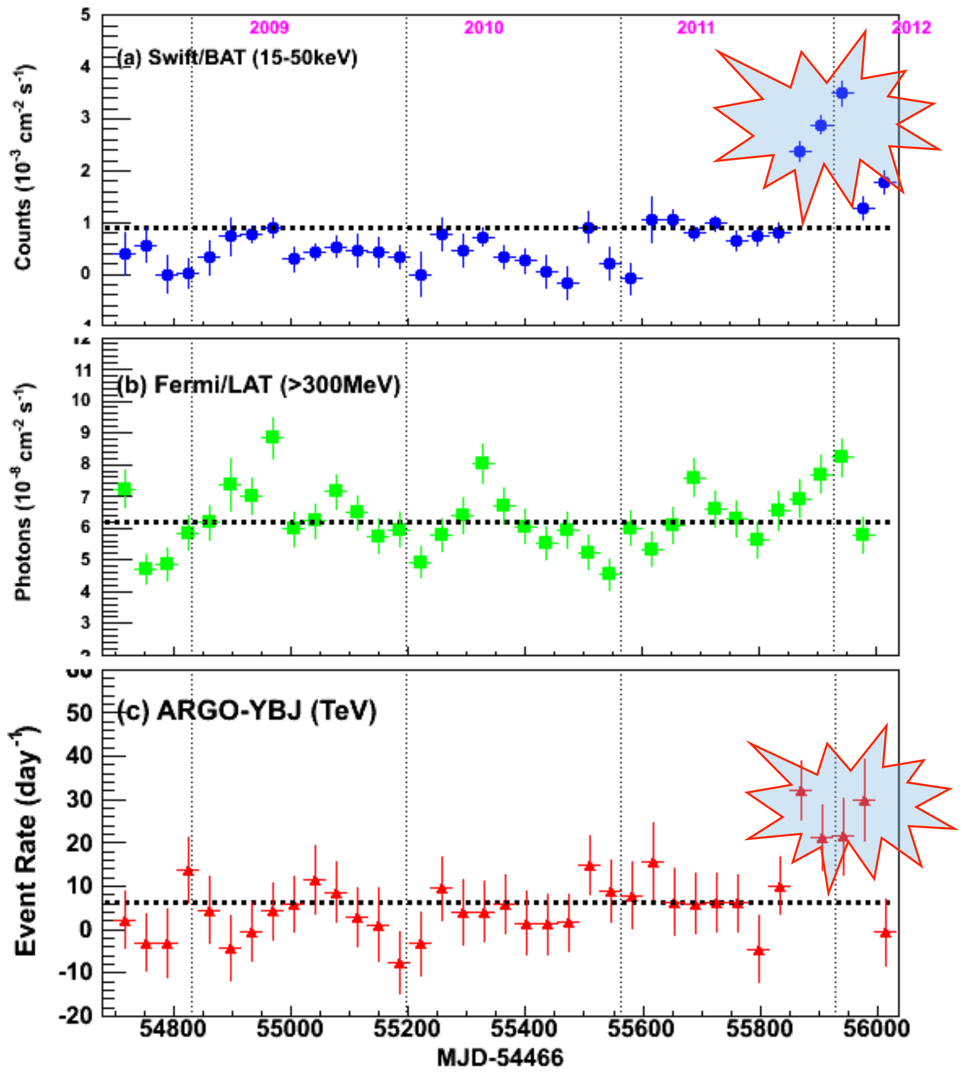


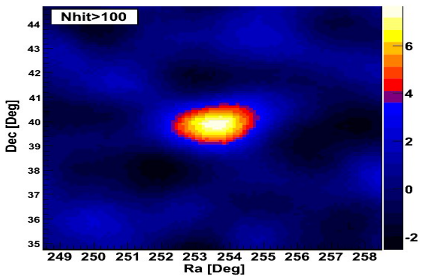
Bartoli et al. ApJ 734:110 (2

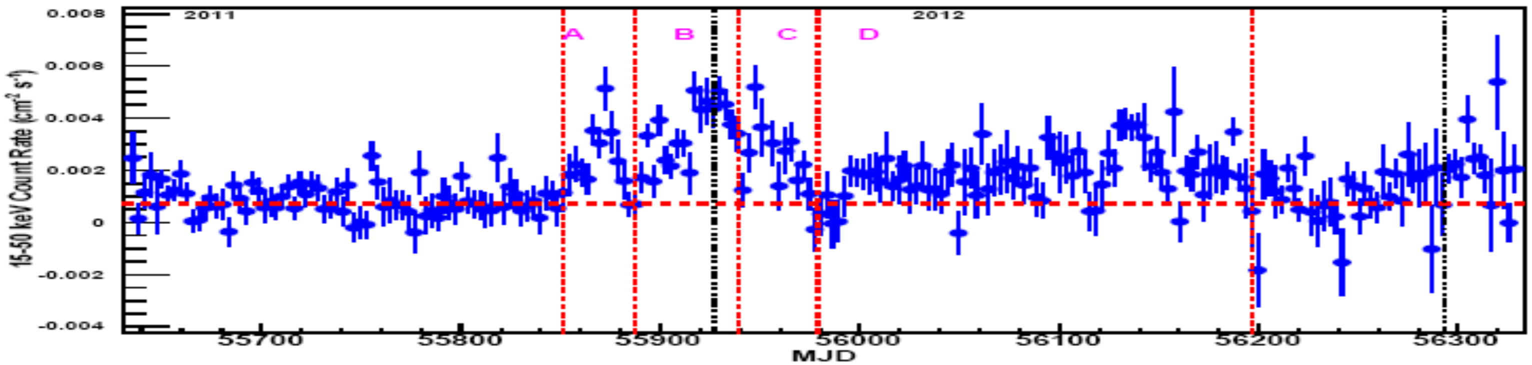
Survey of transient AGNs



Transient AGNs：Mrk501

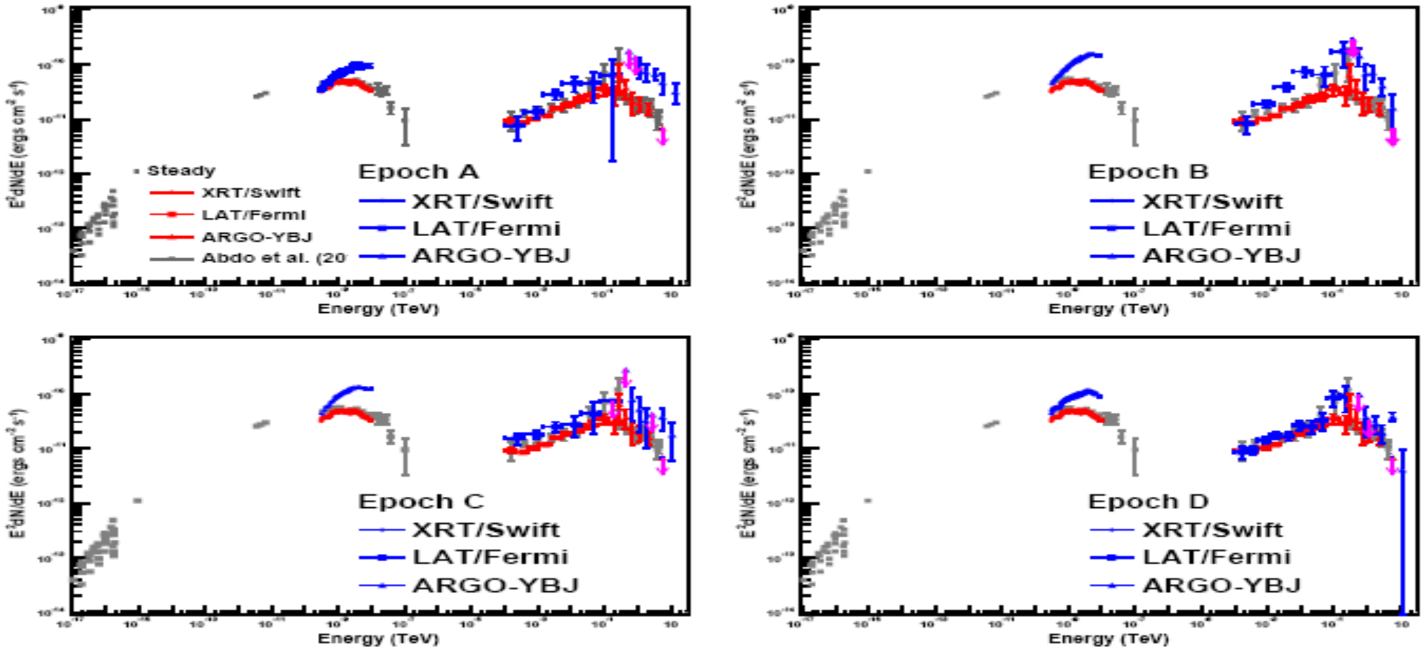






2011flare
S=7.7σ

ʼig. 3: Three day-averaged light curve of Mrk 501 at 15−50 keV measured by BAT/*Swift*. The vertical dashed lines ndicate the four epochs analyzed in this paper. All the errors are statistical at 1 σ.



The evolution

of the Spectrum

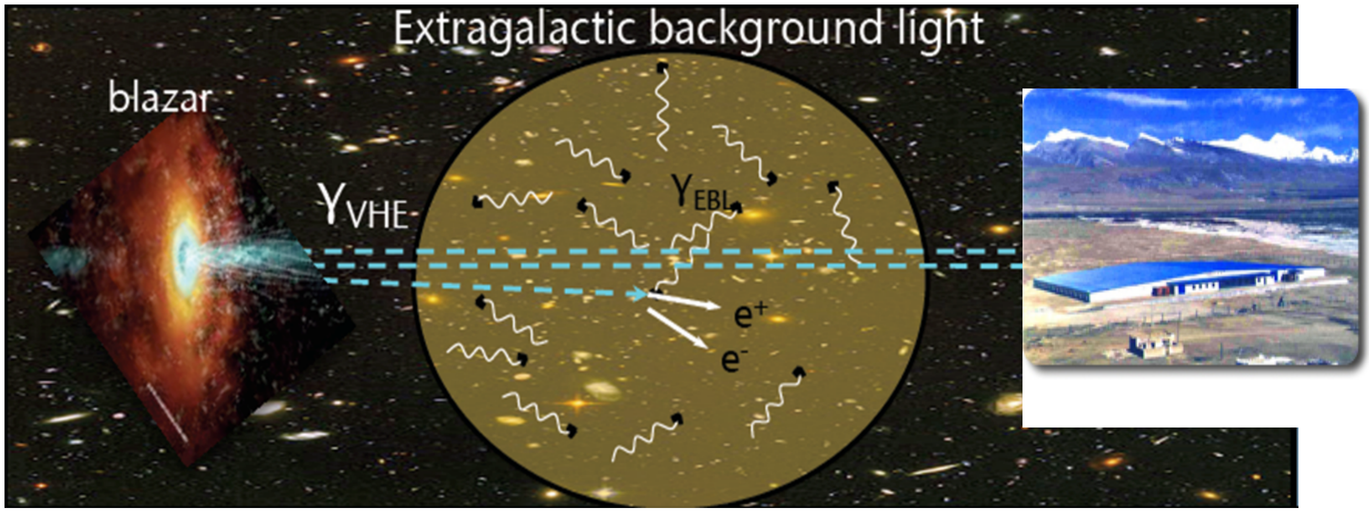
during flares

IGMF measurement

Emitting Mechanism

Probing the EBL with VHE gamma-rays

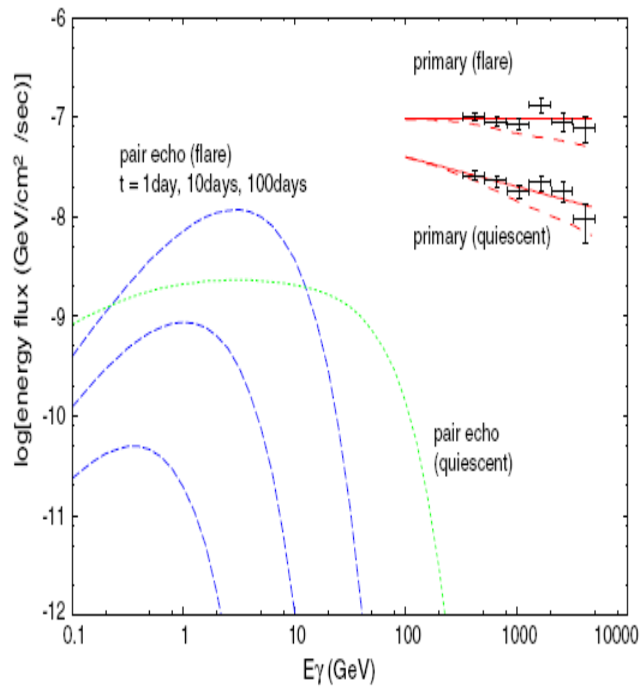
- **On their way from the AGNs to us, a fraction of the VHE gamma-rays are absorbed by the extragalactic background light (EBL), due to electron-positron pair production.**
- **The imprint on VHE spectra can thus be used to probe the EBL density.**
- ARGO-YBJ observation on Mrk 501 2011-2012 flare favor least absorption EBL models.



Probing the intergalactic magnetic fields (IGMFs) with VHE gamma-rays

- IF IGMF is weak, TeV flare could lead to delay GeV flare. The GeV-TeV observation could be used to constrain IGMF.

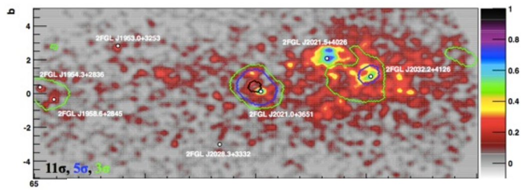
- According to Takahashi et al. (arXiv:1303.3069), IGMF B < $10^{-20.5}$ G can be excluded at ~ 4σ level using long-term, simultaneous Fermi-LAT and ARGO-YBJ observation on Mrk 421.



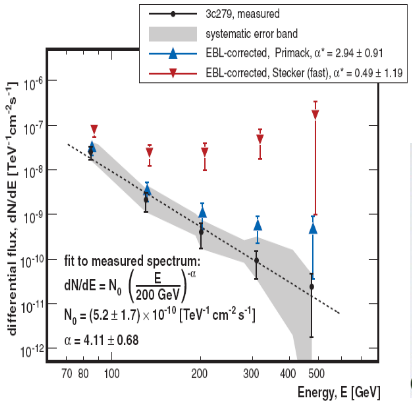
Takahashi et al. ApJL 744:L7 (2012)

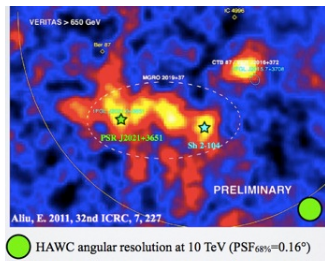
5. Summary of the status

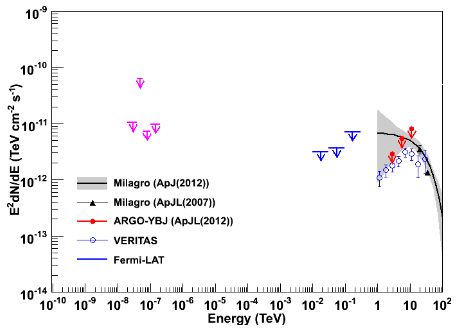
- The most fascinating discoveries in TeV gamma ray astronomy
  - RXJ 1713: a possible hadronic source
  - Fast transient AGNs: PKS 2155-304,Mrk501,…
  - Very remote Quasar: 3C279 (z=0.5362)
  - Very hard spectrum of very extended source in Cygnus region
  - Cygnus Cocoon
  - ………



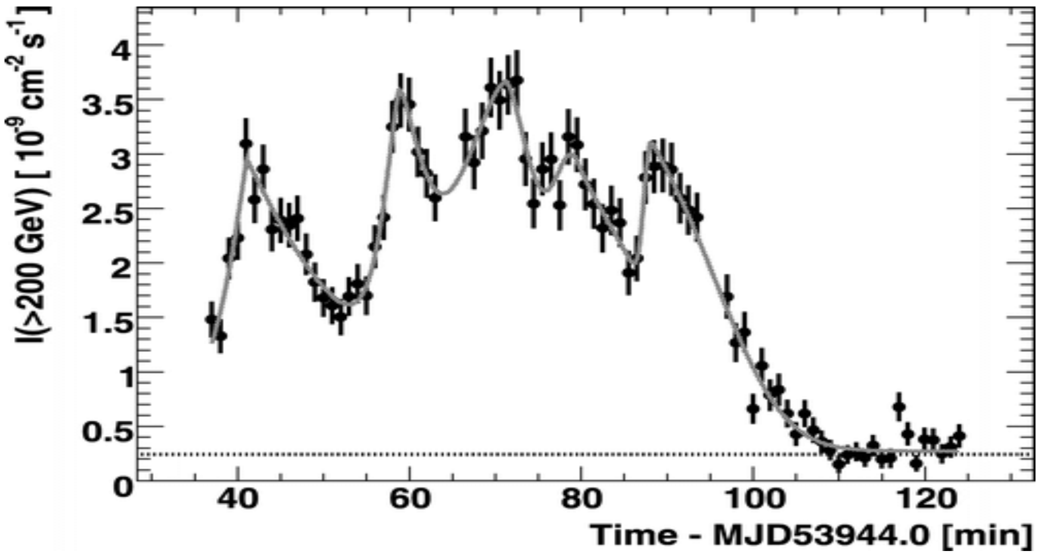
3C279
Science **320, 1752 (2008); MAGIC**





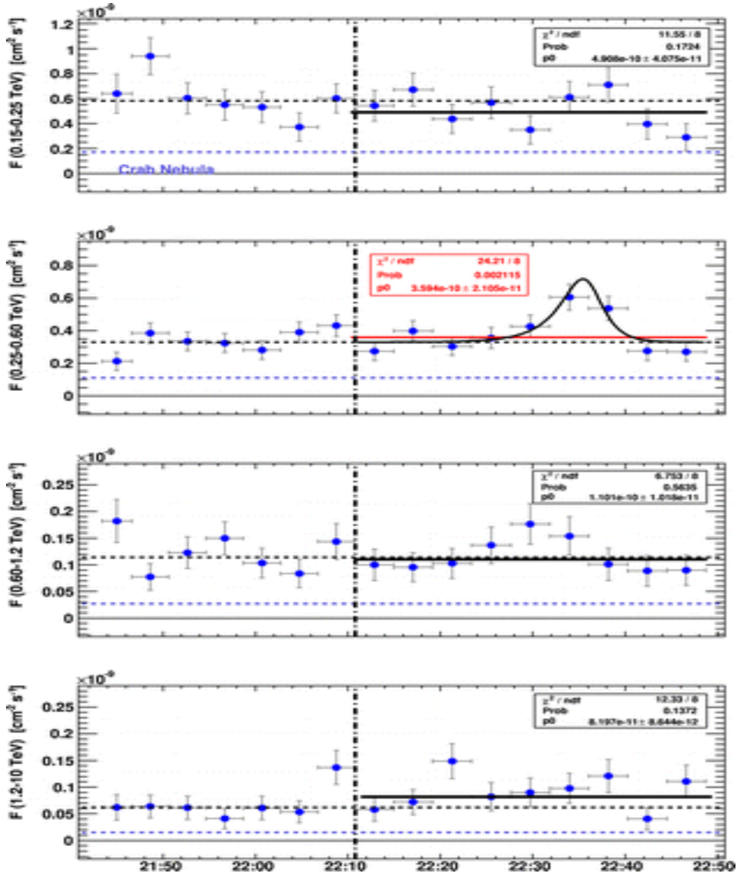


PKS 2155-304



Aharonian et al. 2007 - H.E.S.S.

Mrk 501



Albert et al. 2007 - MAGIC

6. lookout

1 yr for Ω ~ 2 sr

- Past EAS arrays (before 2014)

  Tibet ASr: 1990-2008

  Milagro: 1999-2008

  ARGO-YBJ: 2006-2013

  50~200% Icrab

- Currrent EAS arrays (~2014)

  Tibet ASr+MD,

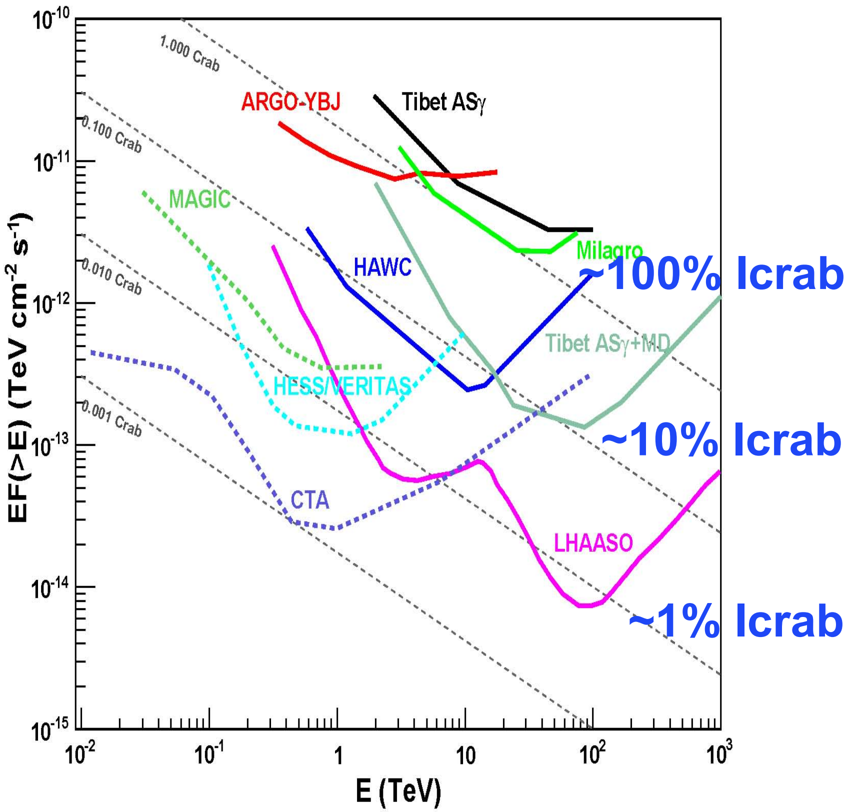
  HAWC

  ~10% Icrab

- Future EAS arrays (~2018?)

  LHAASO

  ~1% Icrab, 0.3~1000 TeV



50 hrs for single source

- Past IACT arrays (before 2014)

  few percent of Icrab

- Current IACT arrays (~2014)

  HEES (I + II)

  MAGIC (I + II)

  VERITAS (upgraded)

  ~1% Icrab

- Future IACT arrays (~2018?)

  CTA

  ~0.1% Icrab, 10GeV~10 TeV

HAWC
High Altitude Water Cherenkov
Gamma-Ray Observatory

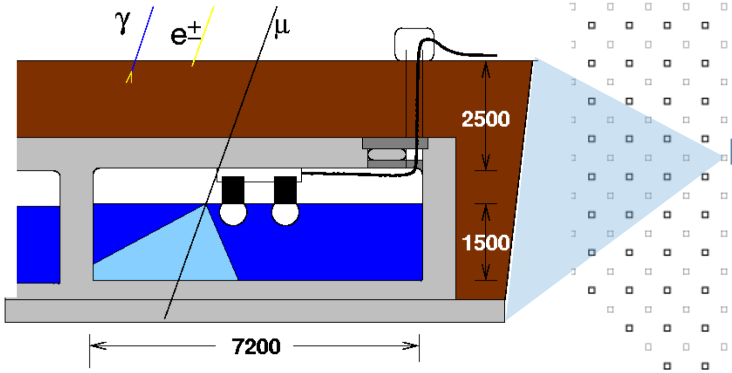
Some Numbers:
- Location: 19° north, 97° west (Sierra Negra, Pico de Orizaba, Mexico)
- 4100 meters a.s.l.
- 300 detector stations ("tanks", 7.3m x 4.5m)
- Area: ~22,000 m^2.
- Water volume: ~200,000 l /tank
- **3rd of the array online (data)**
- **Array complete: 2014**
- 15 x more sensitive than Milagro

petra@mtu.edu

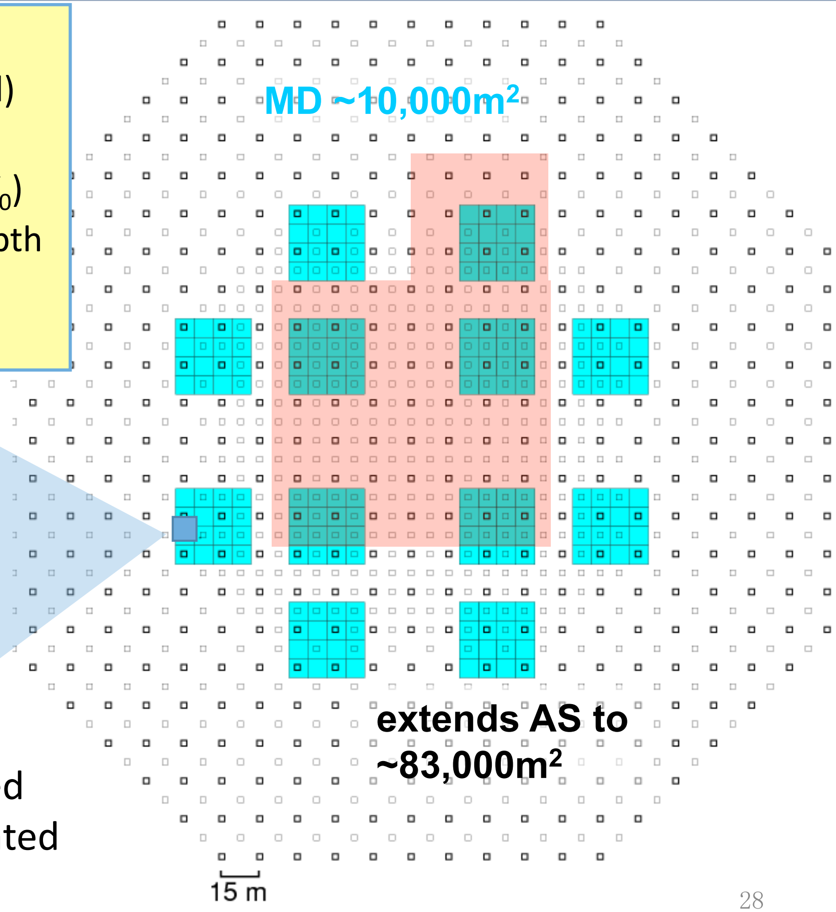
Michigan Tech

Major Upgrading of Tibet Array: MD (1/4 century after the array built)

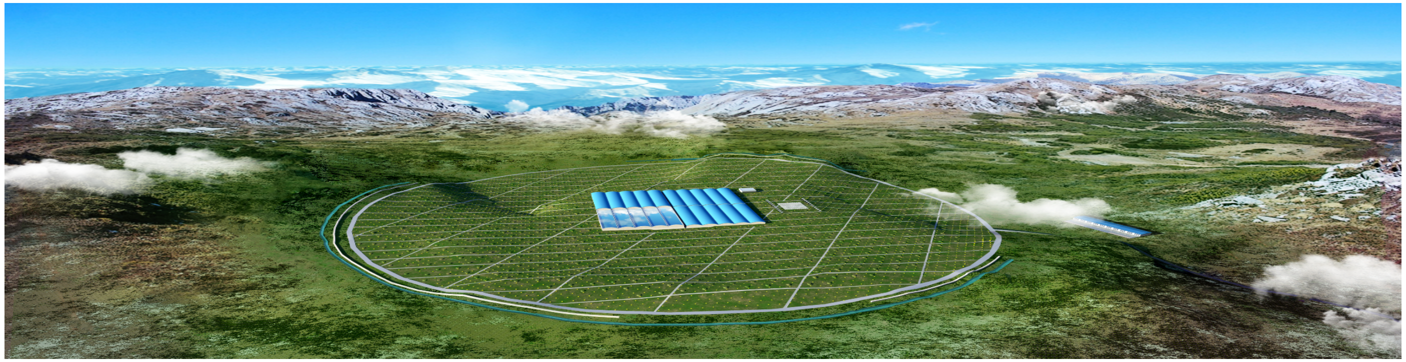
- Water Cherenkov type detector
- 12 concrete pools (10,000 m^2 in Total)
- A concrete pool = 16 water cells
- Underground 2.5m (515 g/cm^2 = 19X_0)
- A water cell = 7.2m x 7.2m x 1.5m depth
- With two 20"ϕ PMTs (HAMAMATSU R3600)

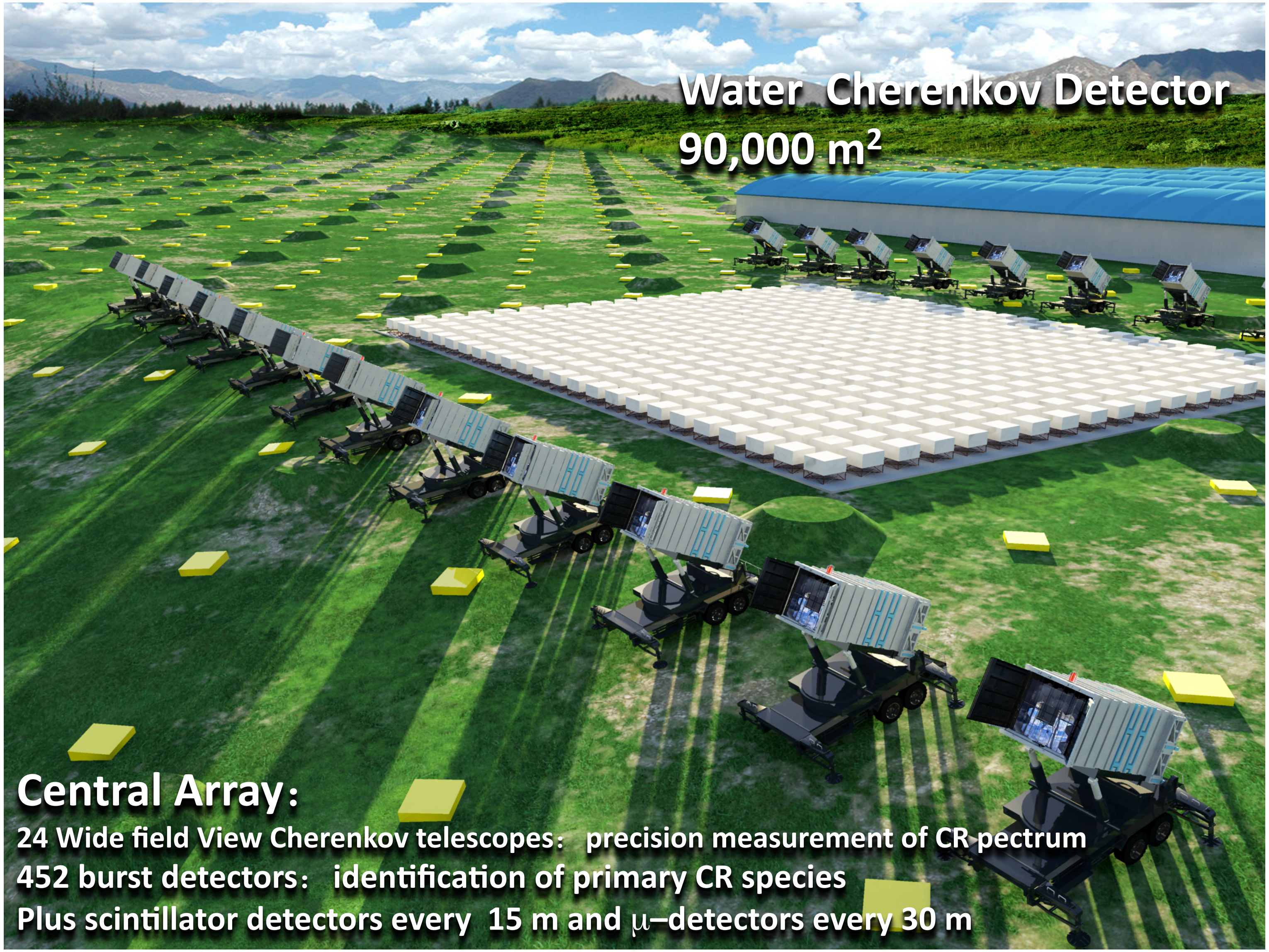


Muon data is passively recorded as an air shower trigger generated



Future: LHAASO Project

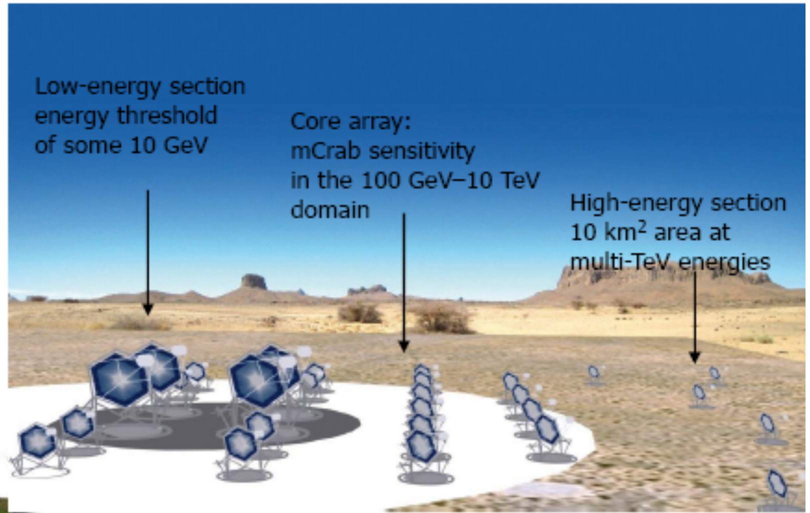


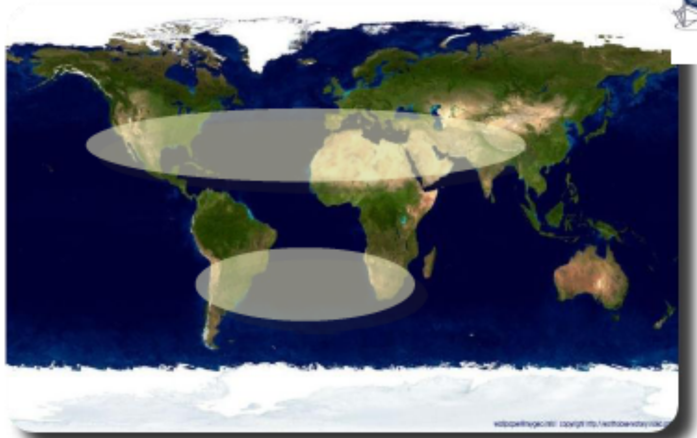

Water Cherenkov Detector
90,000 m²
Central Array：
24 Wide field View Cherenkov telescopes： precision measurement of CR pectrum
452 burst detectors： identification of primary CR species
Plus scintillator detectors every 15 m and μ–detectors every 30 m

CTA- Cherenkov Telescope Array

❖ Cherenkov Telescope Array

- Aim: 10x sensitivity and precision of current instruments
- 2 sites: south and north
- Operate as an observatory



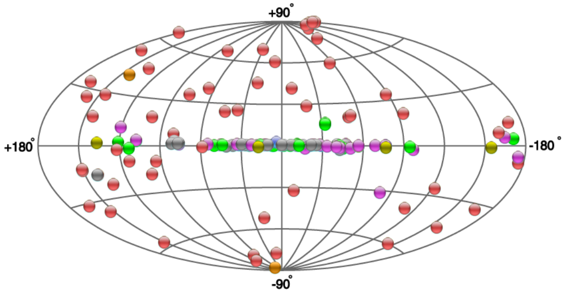


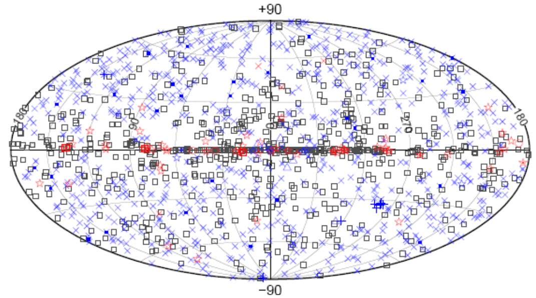
An array of > 60 telescopes of 3 classes for a wide energy range of sensitivity

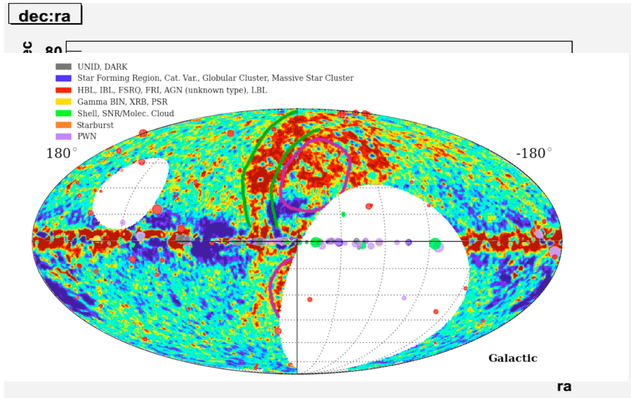
(~ 20 GeV – hundreds of TeVs)

CTA in FP7- Preparatory Phase (2010-2013)

Flavor of future (Conclusion)

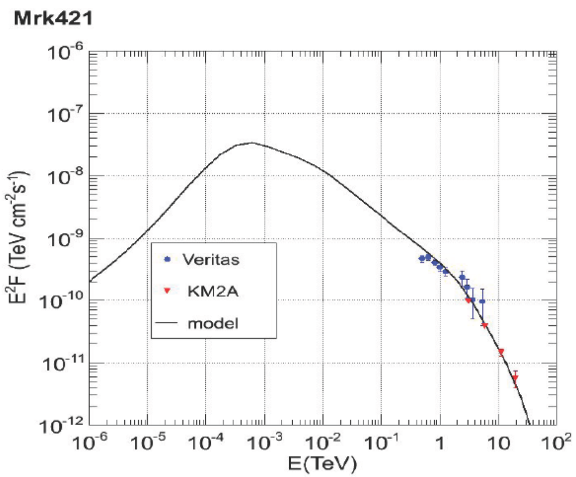






Mrkn421（高态）：

observation time~ 2 day



Mrkn501 （高态）：

observation time~ 35 day