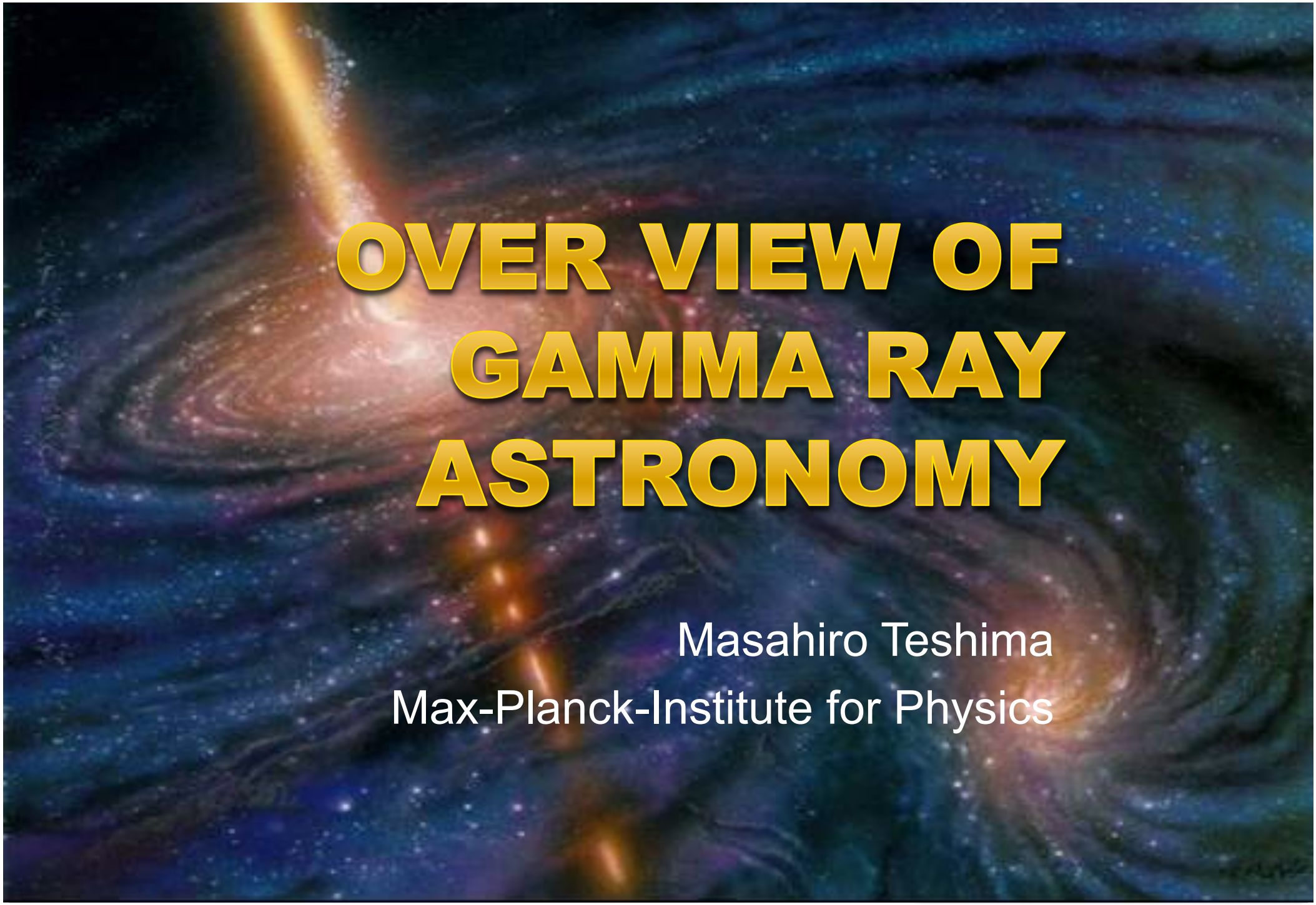


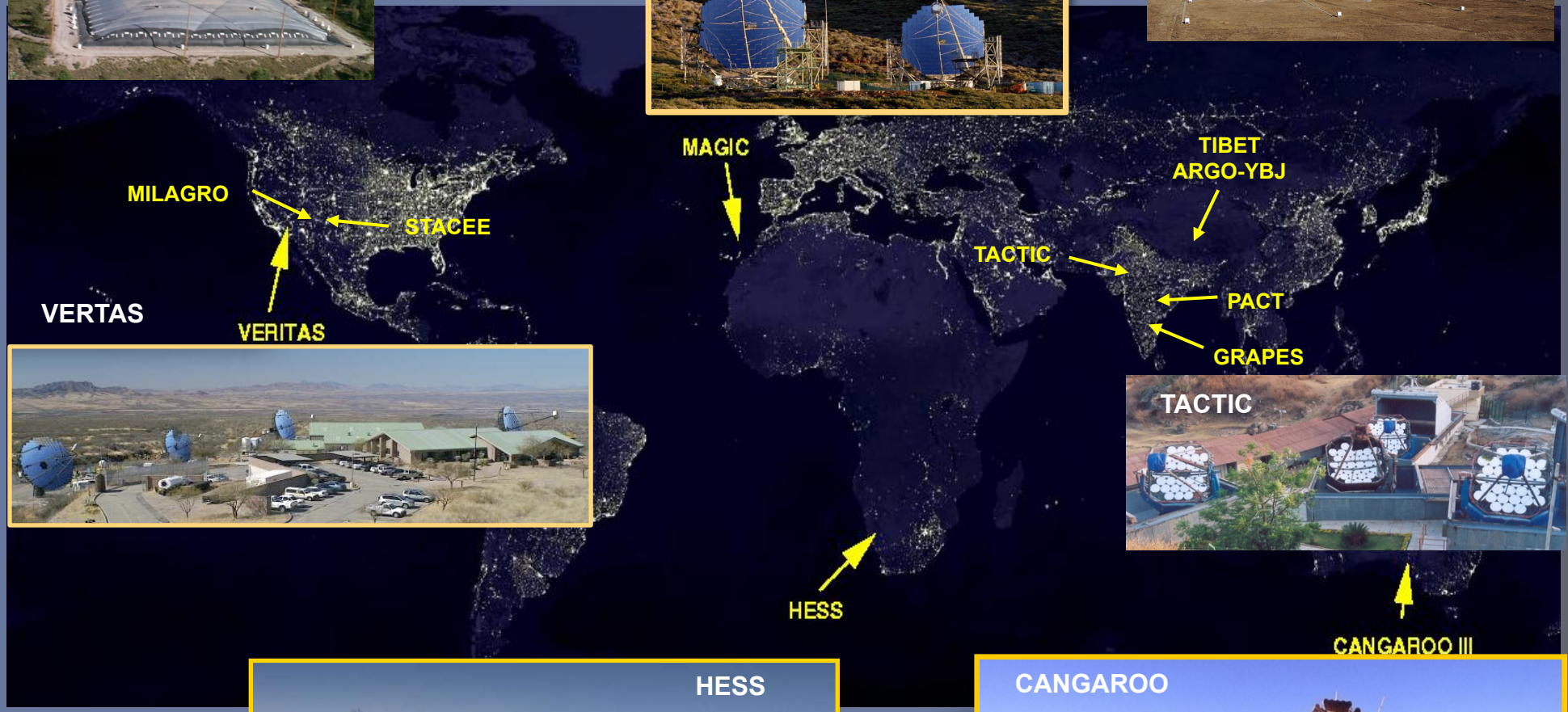
Masahiro Teshima
Max-Planck-Institute for Physics

VHE Instruments

MILAGRO

MAGIC

TIBET



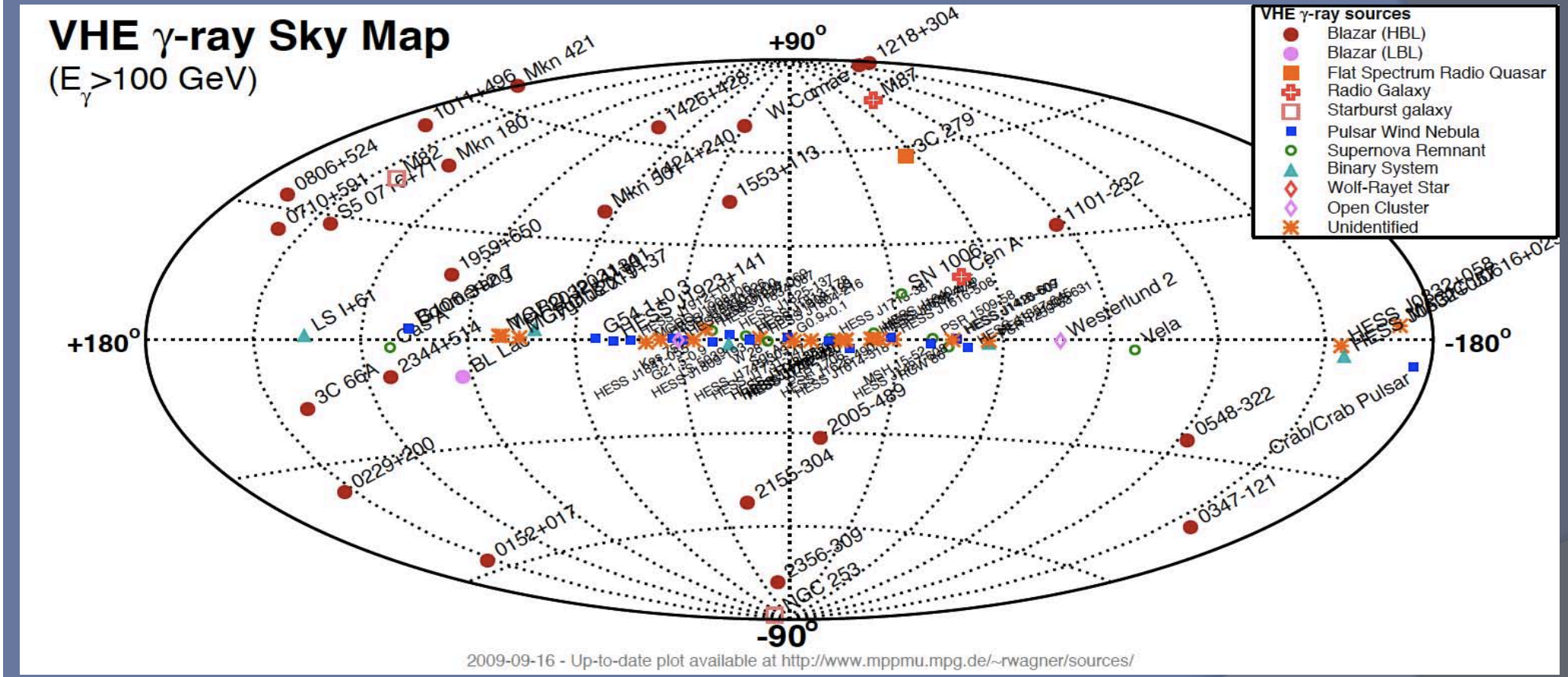
VERTAS

TACTIC

HESS

CANGAROO

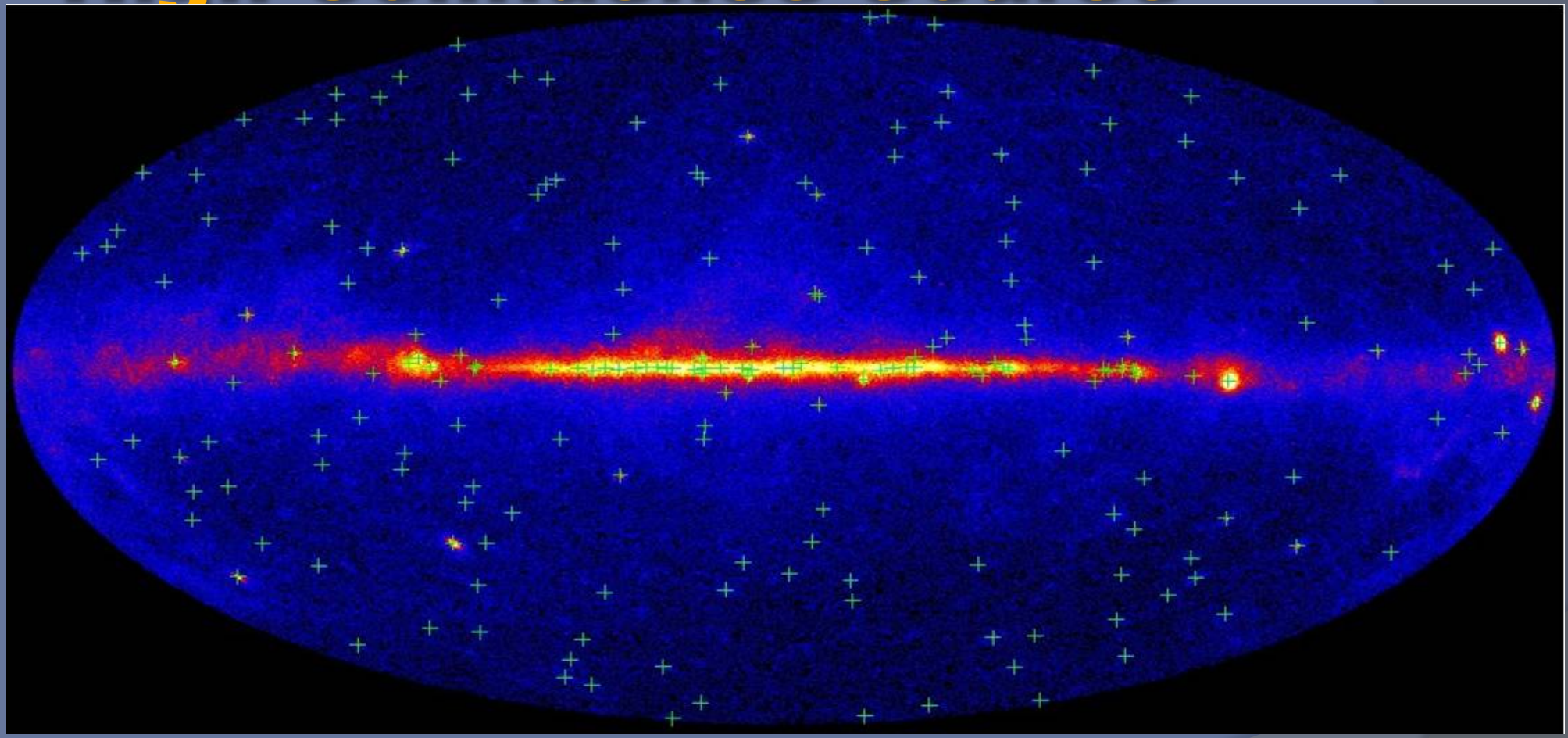
VHE Skymap



90 sources (30 Extragalactic + 60 Galactic)

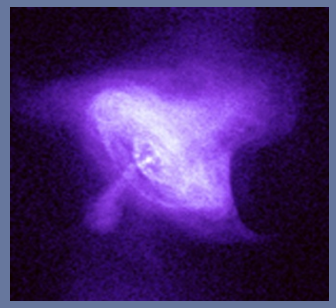
GeV instruments

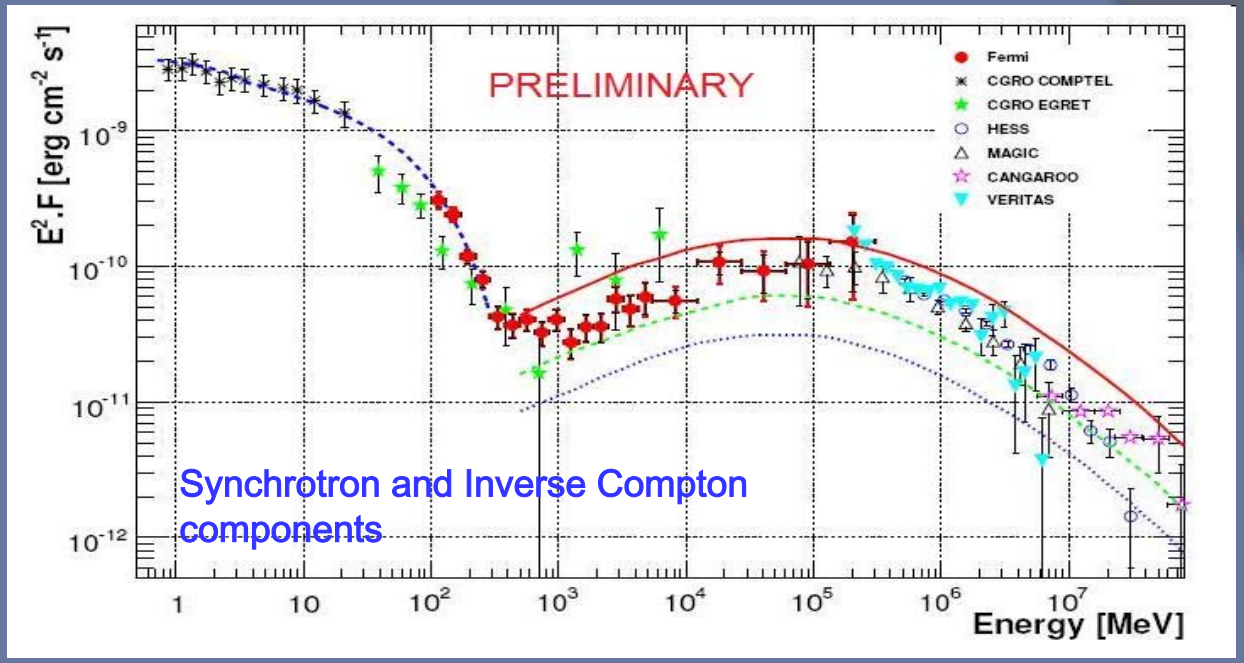
Fermi 3 Month High Confidence Source

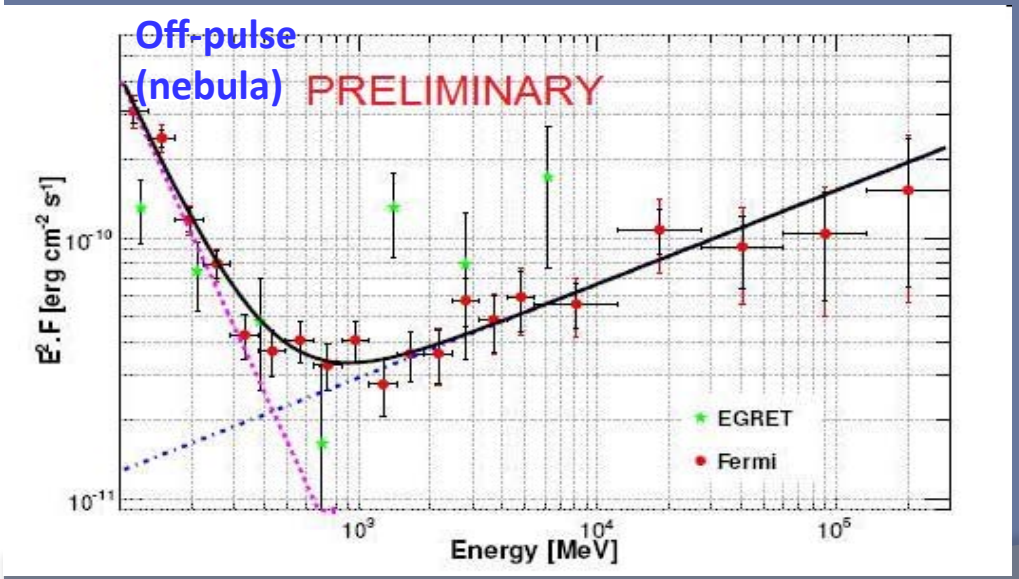


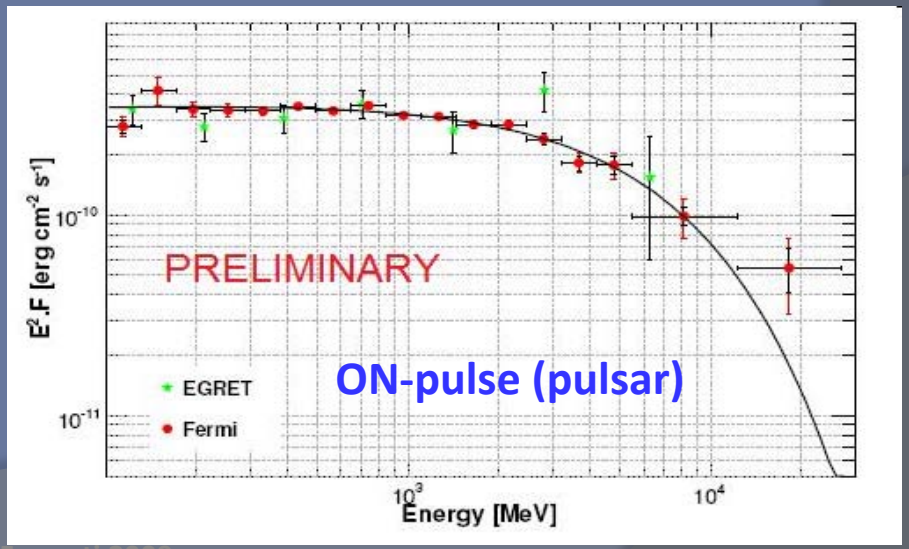
- 205 sources with significance > 10σ (EGRET found fewer than 30)
- Typical 95% CL error radius is <10 arcmin
  (Abdo et al. 2009 ApJS, 183, 46)

Crab



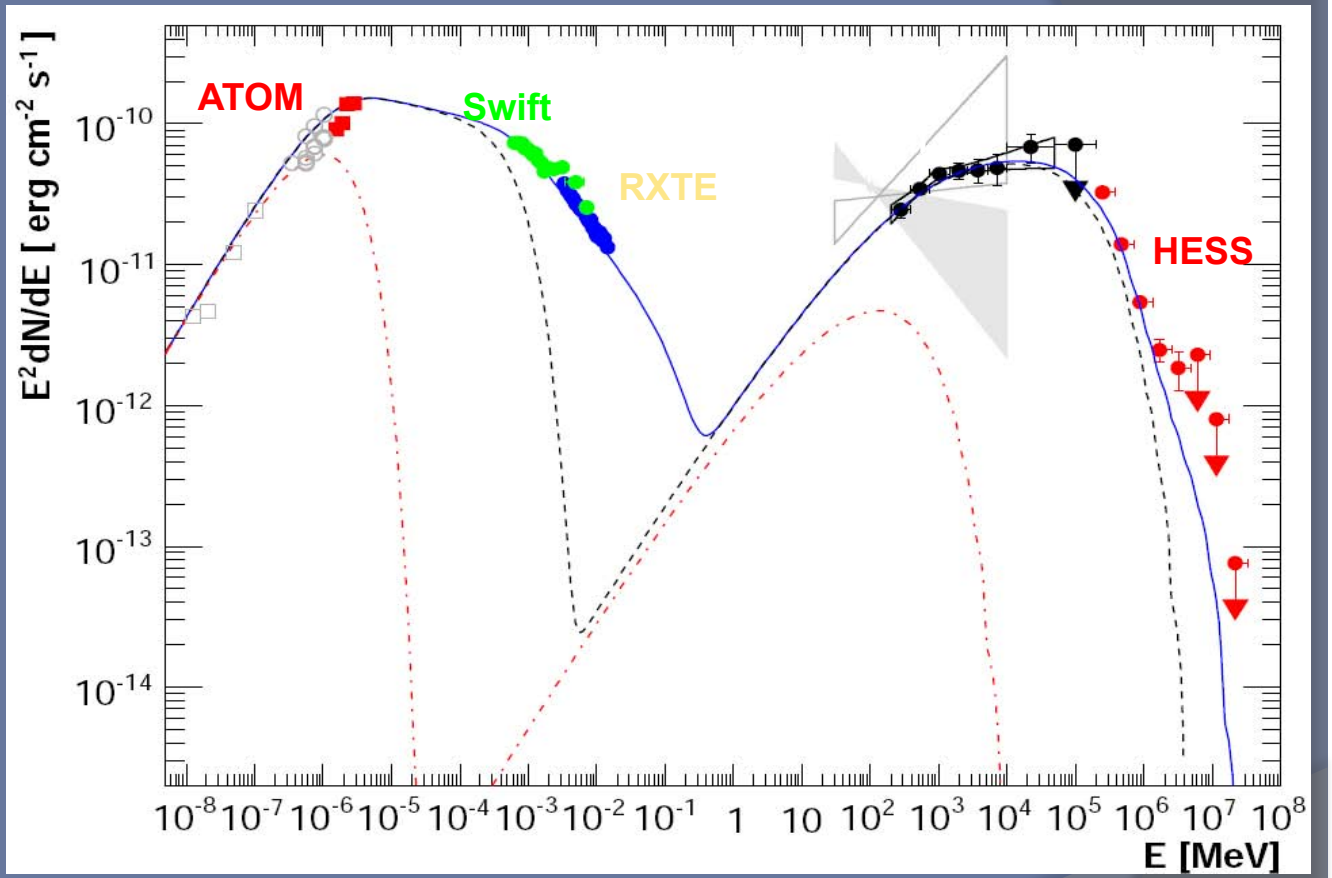

PRELIMINARY
Fermi
CGRO COMPTEL
CGRO EGRET
HESS
MAGIC
CANGAROO
VERITAS
Synchrotron and Inverse Compton components
E².F [erg cm⁻² s⁻¹]
Energy [MeV]


Off-pulse (nebula)
PRELIMINARY
EGRET
Fermi
E².F [erg cm⁻² s⁻¹]
Energy [MeV]


PRELIMINARY
EGRET
Fermi
ON-pulse (pulsar)
E².F [erg cm⁻² s⁻¹]
Energy [MeV]

PKS 2155-304: Spectral Energy Distribution

- Time-averaged SED is well described by a single zone SSC model:



Highest energy electrons (γ_e>2×10^5) produce the X-ray emission, but contribute relatively little above 0.2 TeV

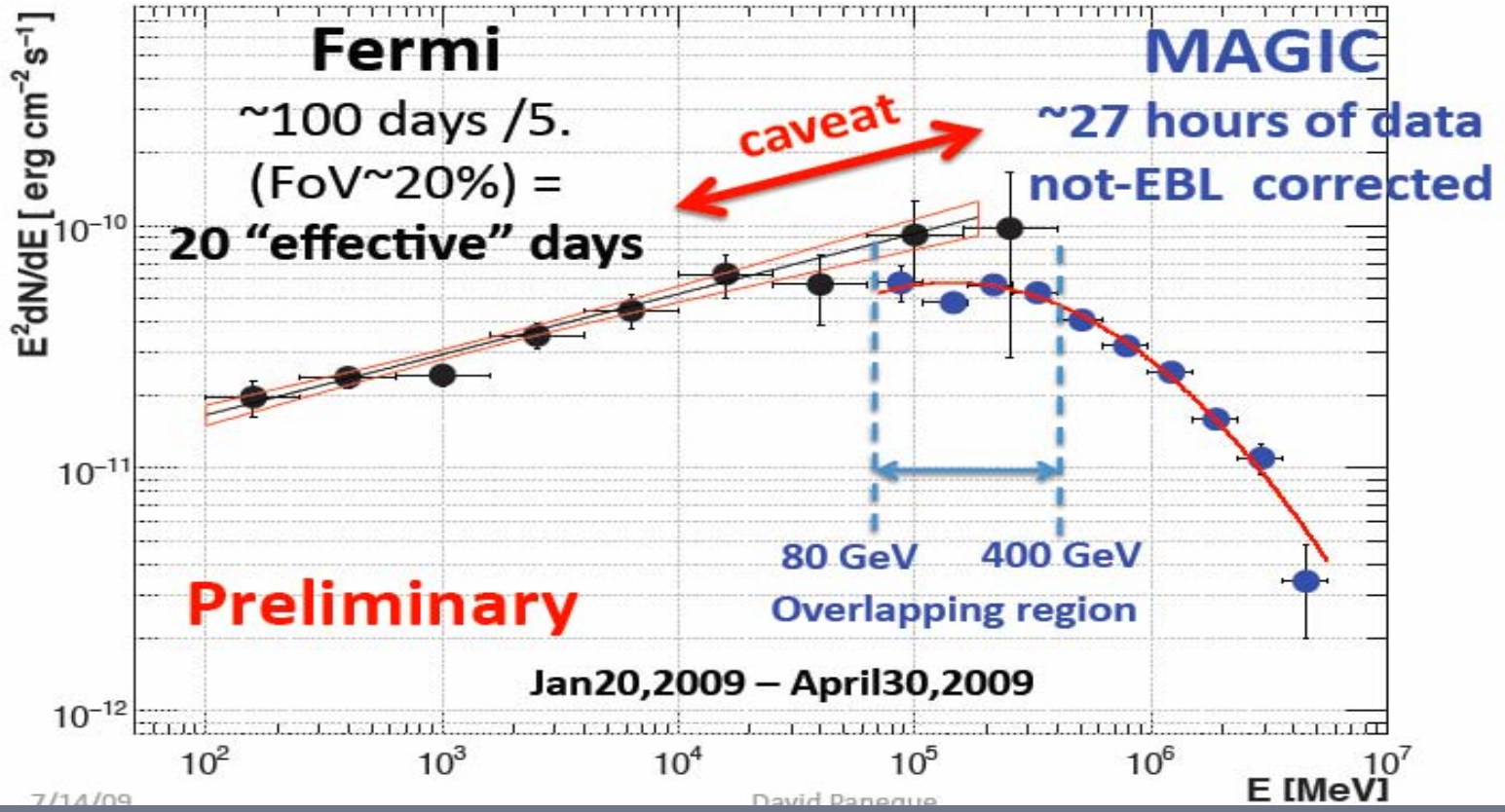
Mrk421 Simulataneous obs. FERMI + MAGIC

First "simultaneous" GeV-TeV spectrum of Mrk421

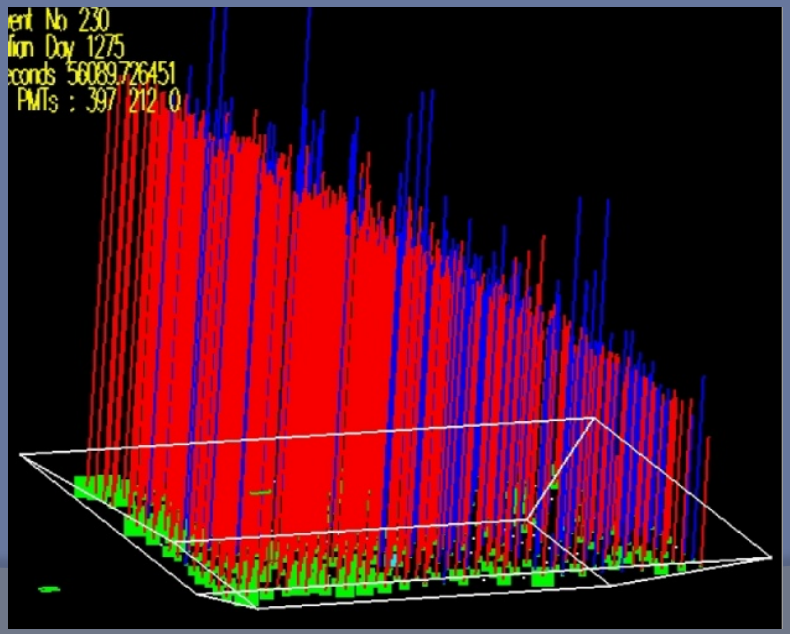
Good agreement between these 2 different instruments.

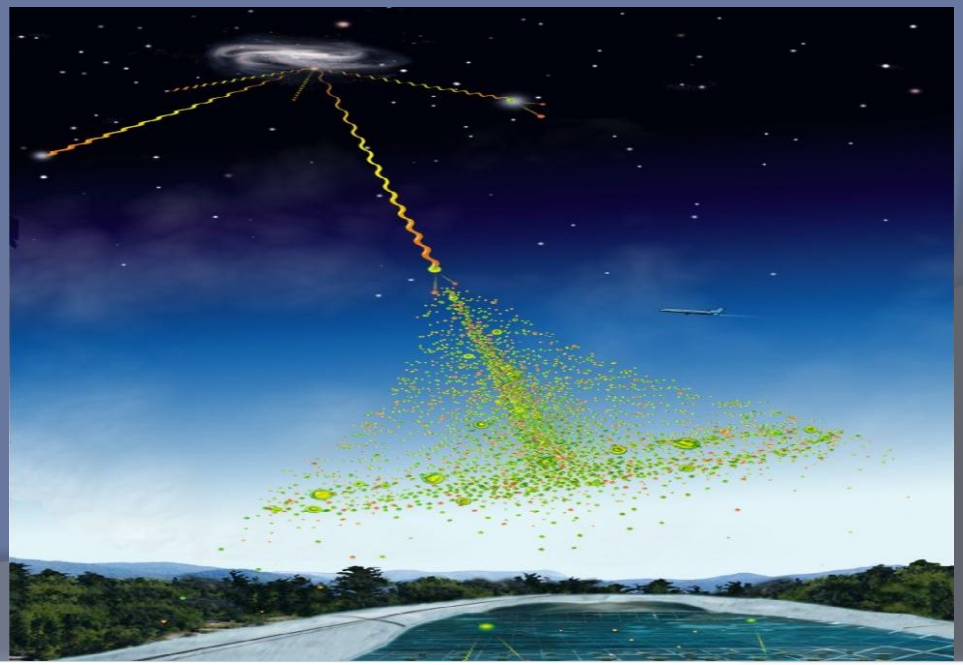
Energy coverage of 5 orders of magnitude without GAPS.

Important for modeling of the source

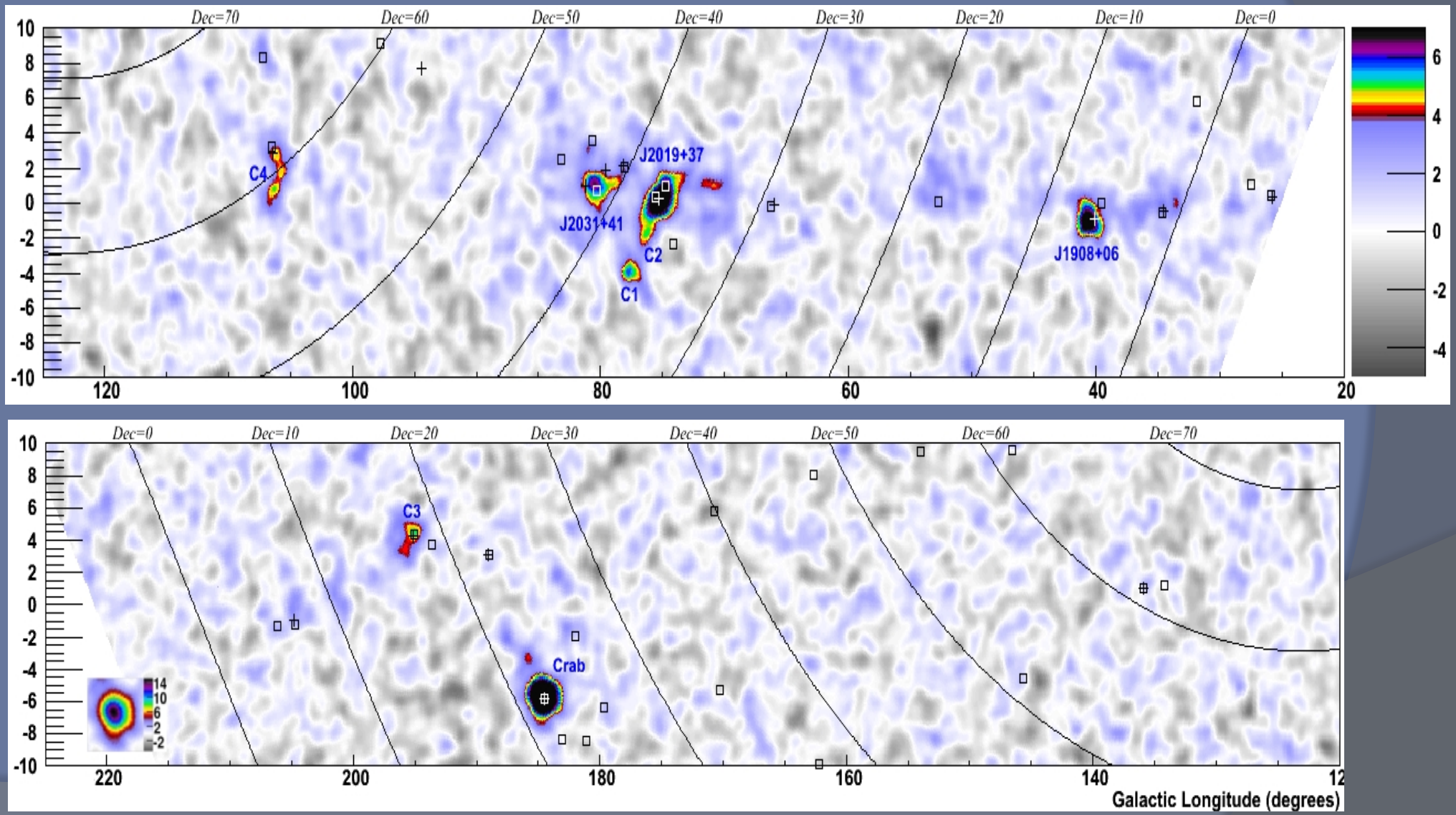


Water C-pool and AS array at high altitude Non-biased Sky Survey

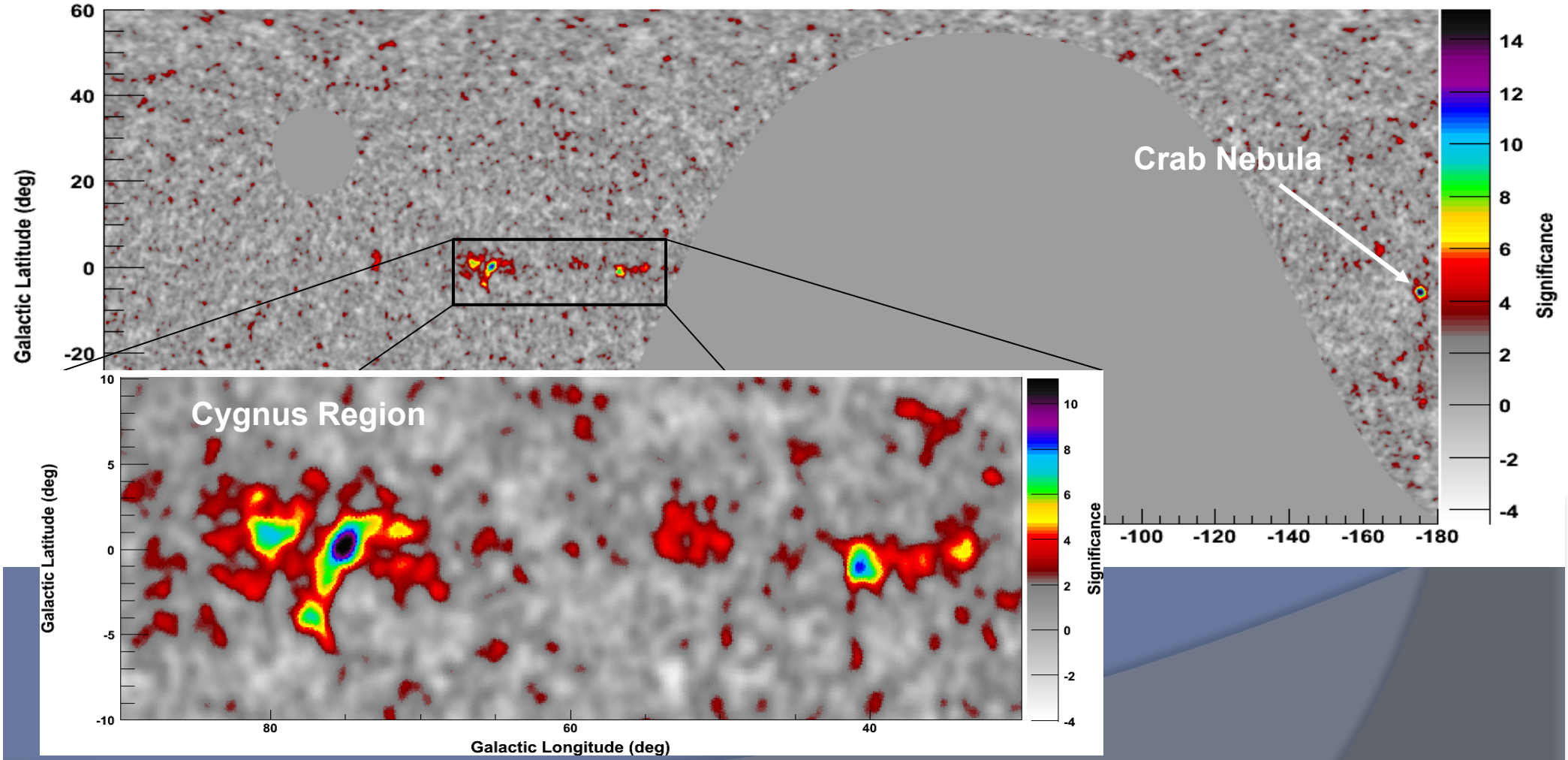




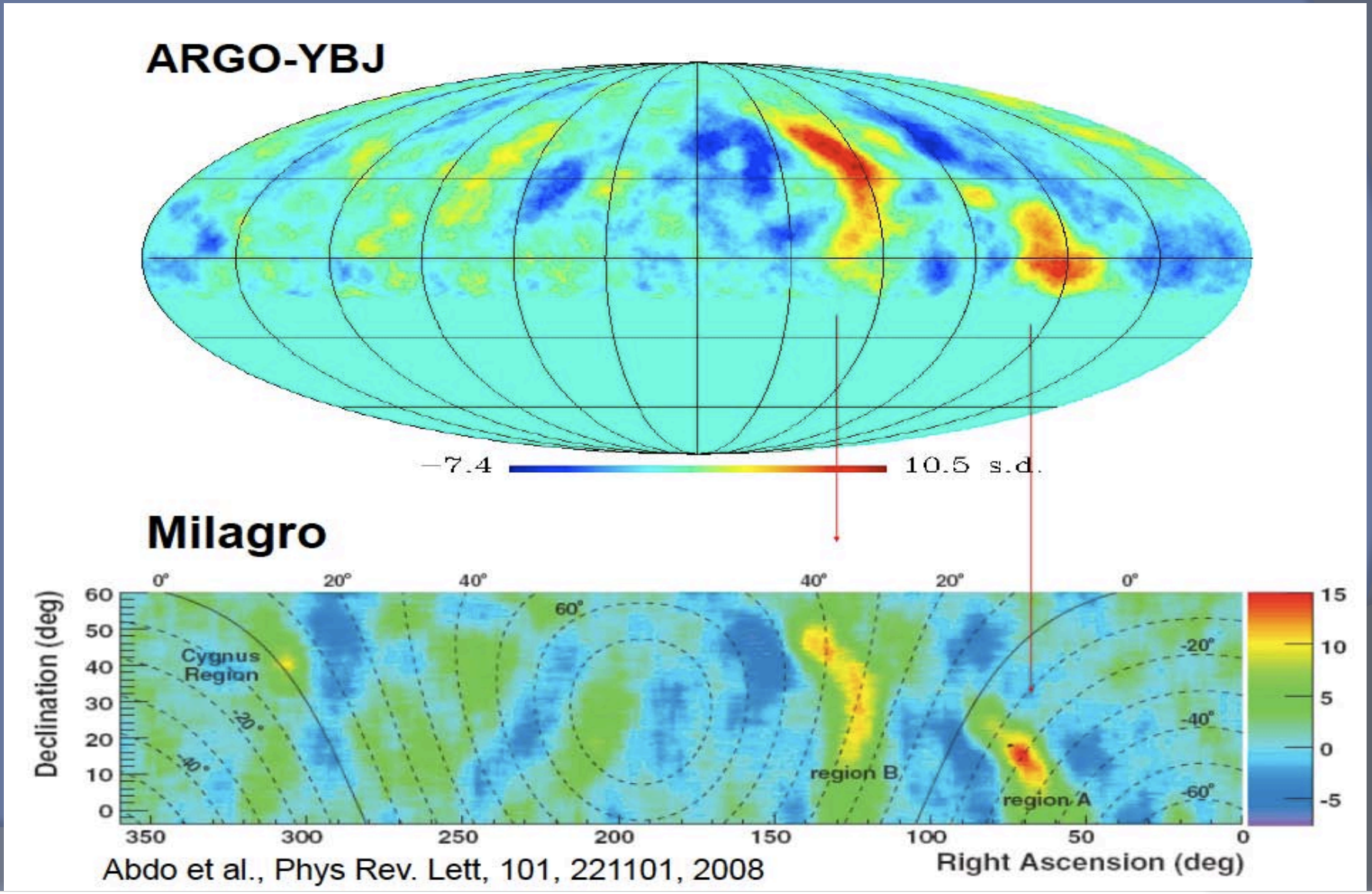
MILAGRO Galactic plane observation



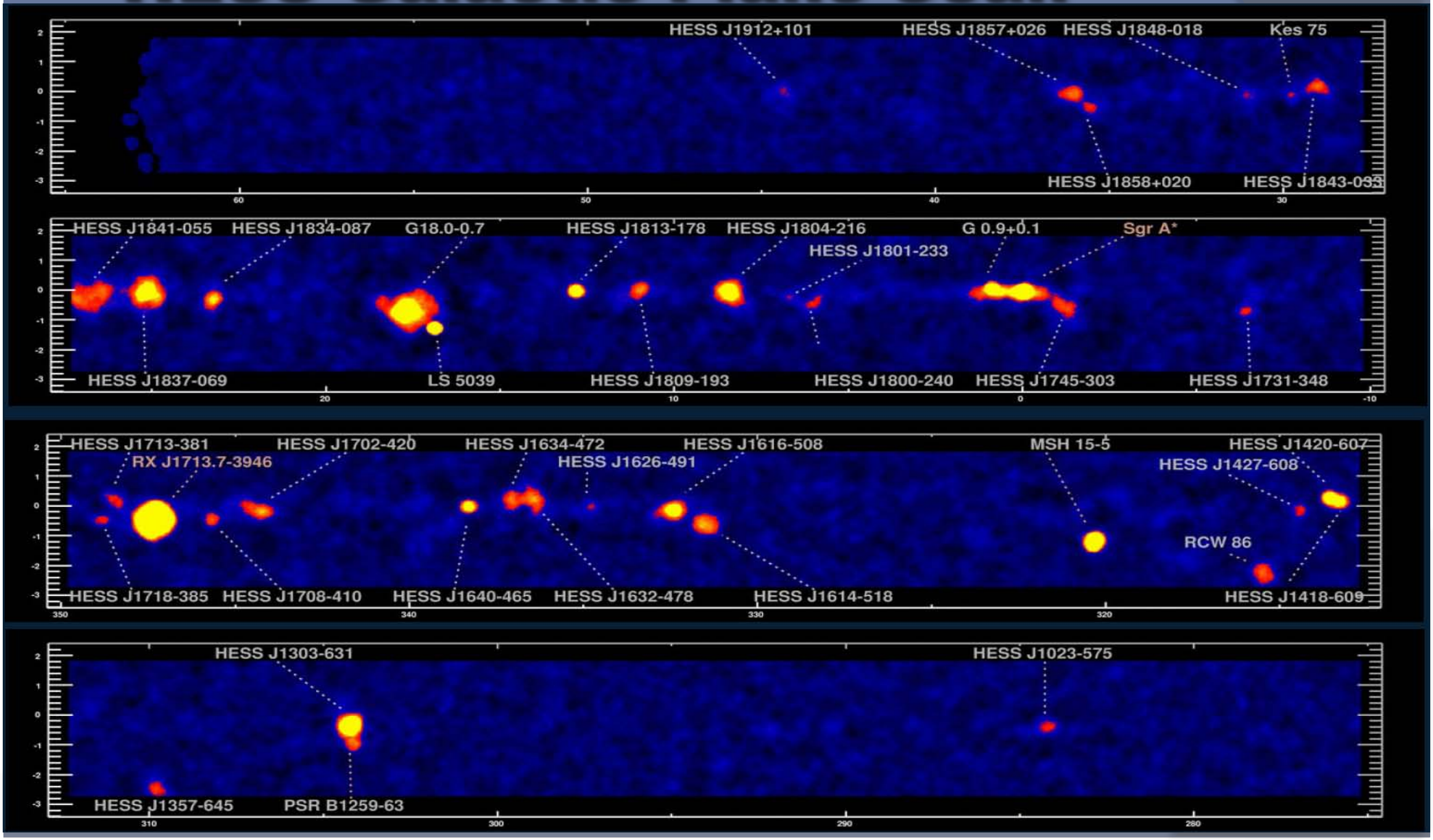
MILAGRO Observation in Galactic Coordinate



Anisotropy pattern (cosmic rays)

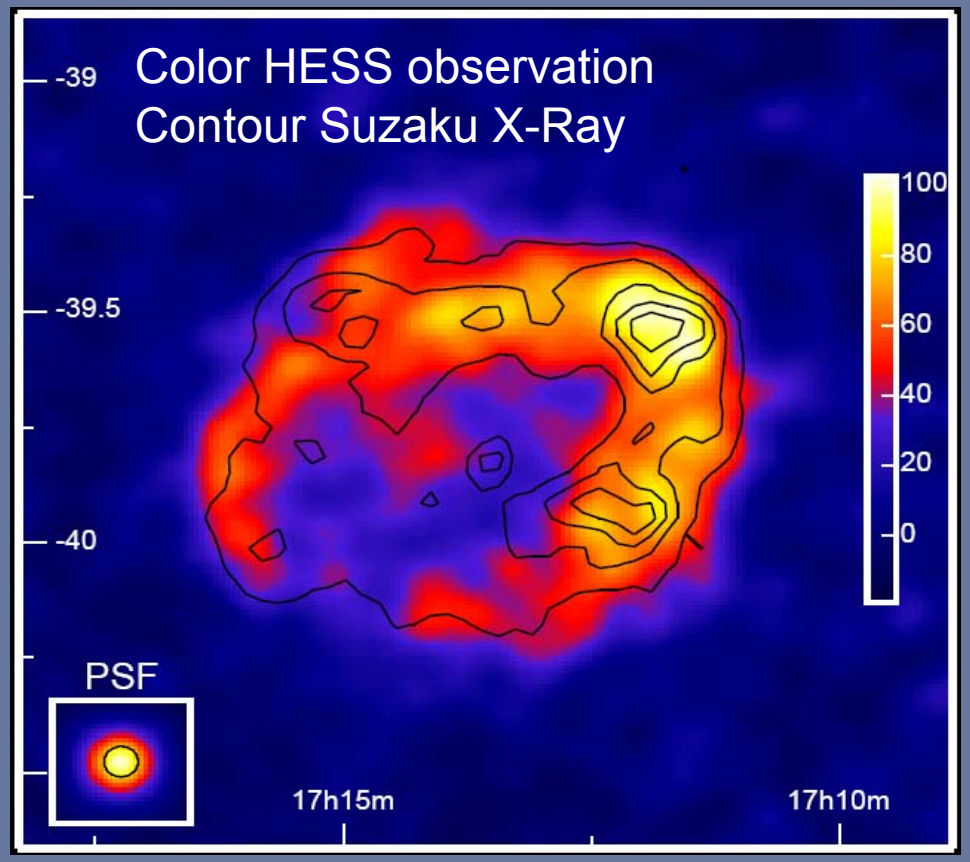


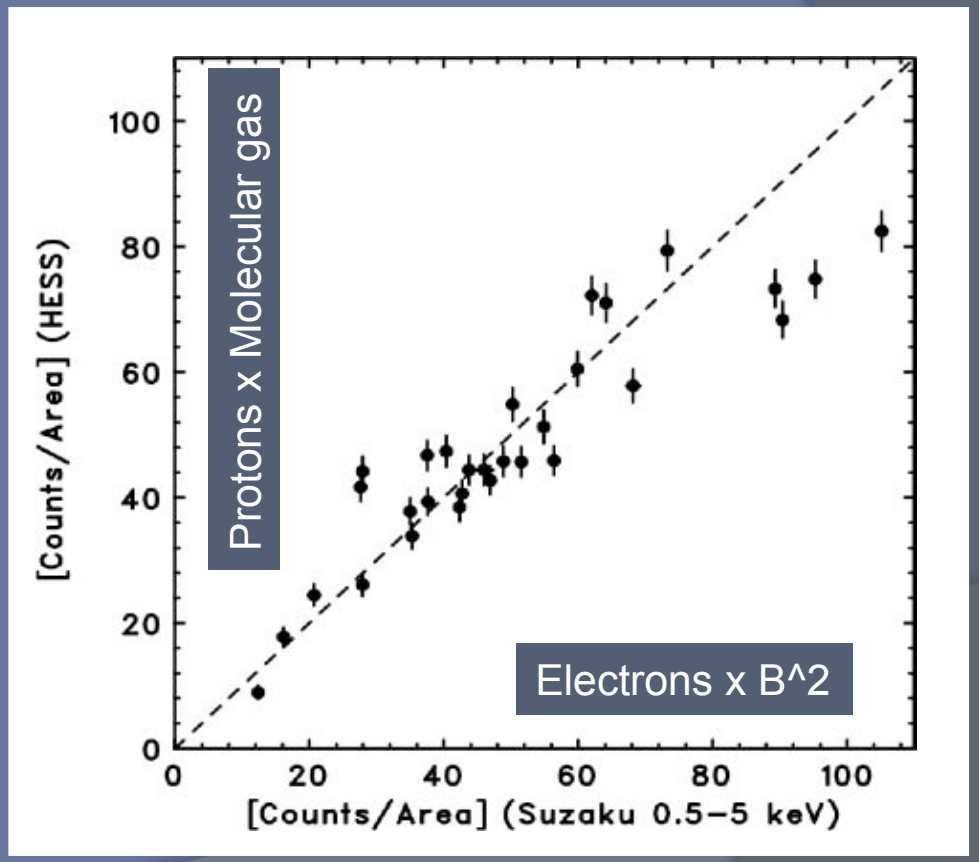
Great success!!
HESS Galactic Plane Scan



RX J1713
X-ray vs. Gamma-Rays

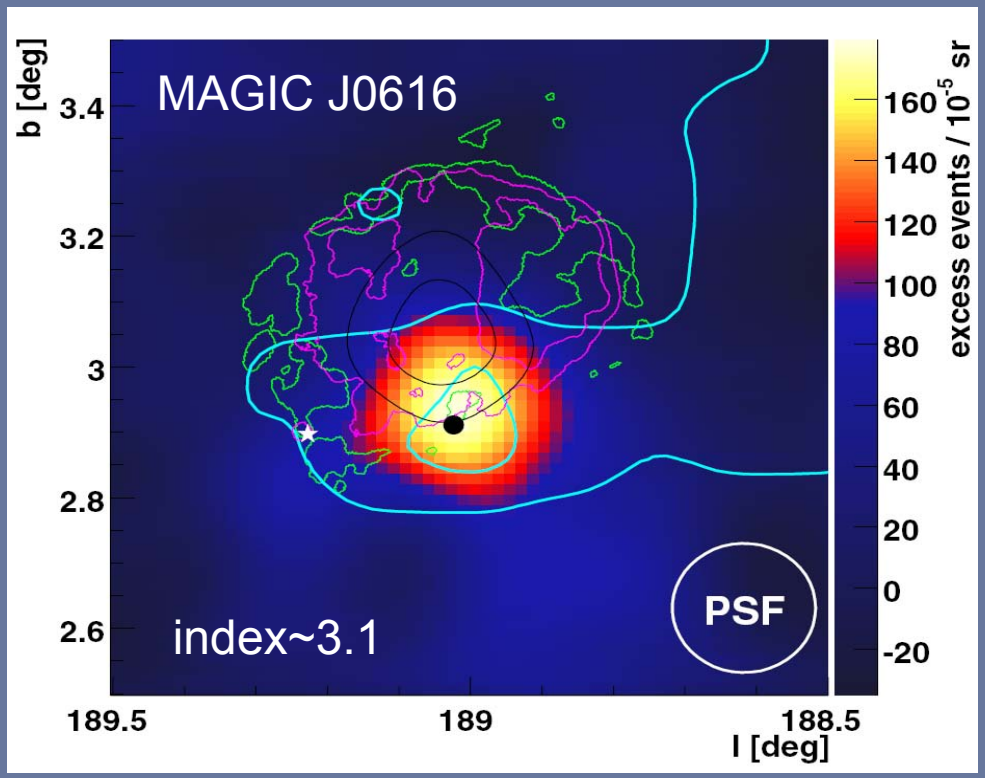
SED and Strong B in the shell suggest Hadronic origin of VHE gammas

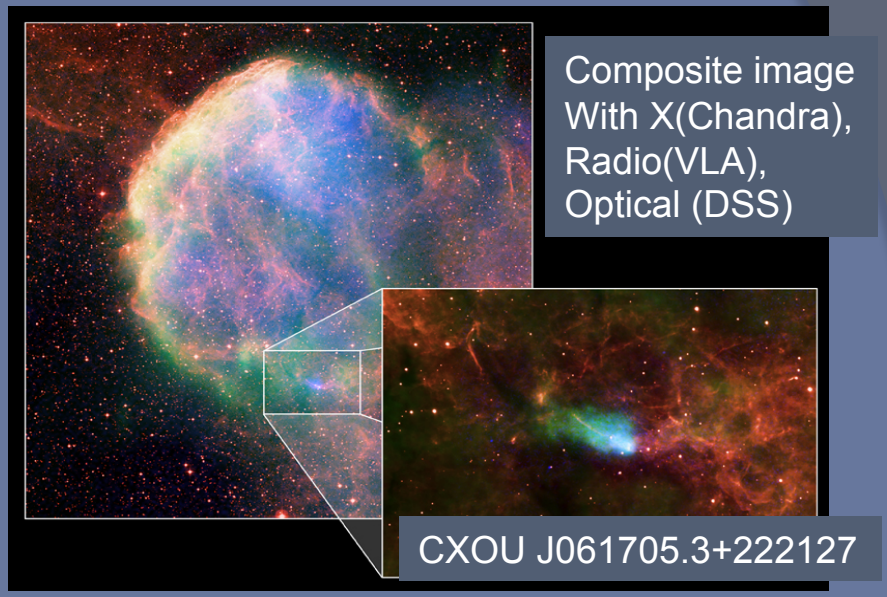




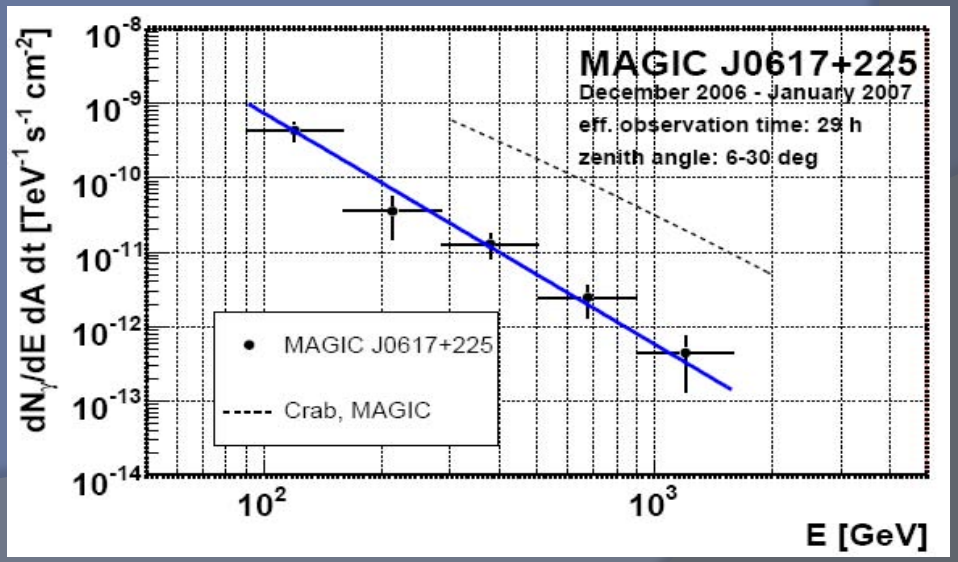
Y. Uchiyama, T. Takahashi
Texas Symp. 2006

Shell type SNRs
IC443(MAGIC J0616)



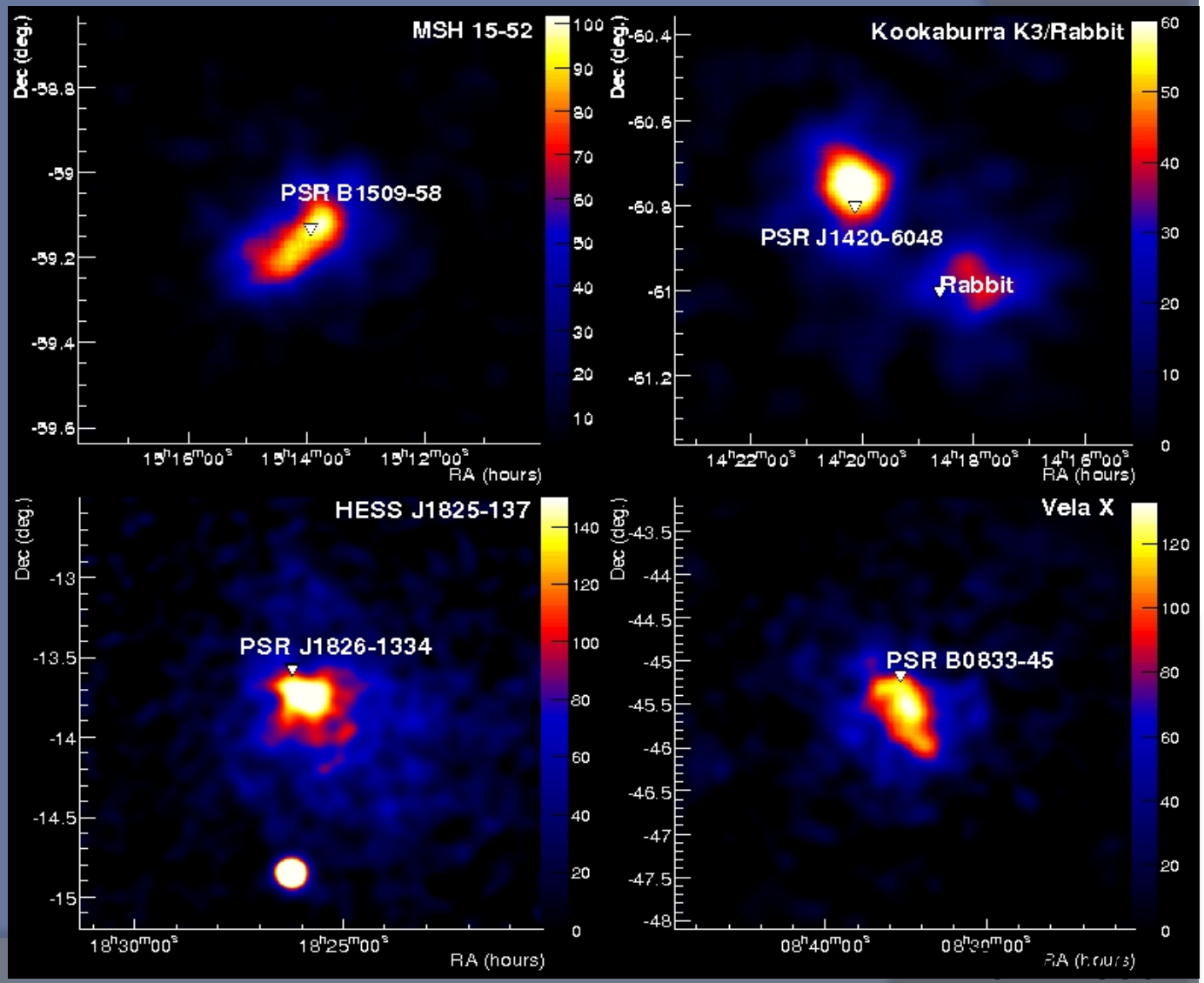


Molecular Cloud
Radio
X-ray
EGRET 3EG J0617+2238
Pulsar CXOU J061705.3+222127



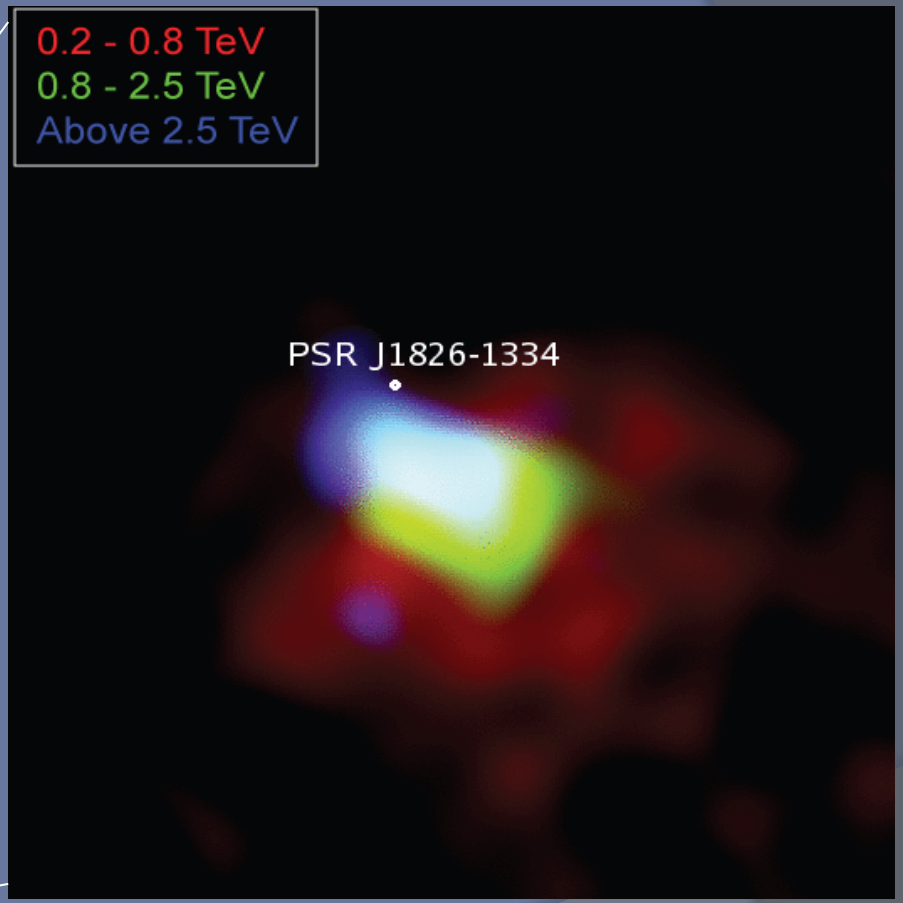
Pulsar Wind Nebulae observation by HESS

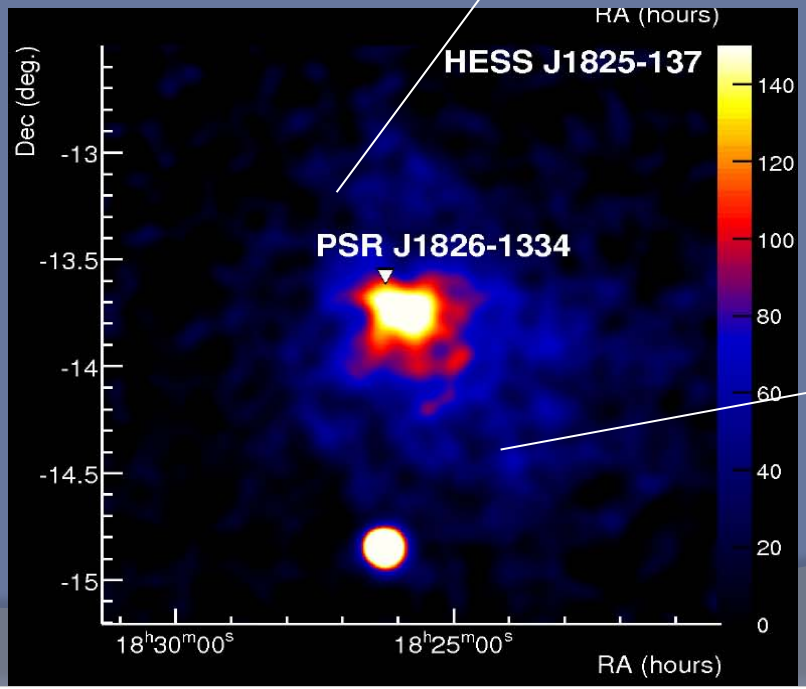
- Major galactic TeV source population
  - Associated with relatively young (<10^5 year old) and energetic pulsars
- Generally believed that we see inverse Compton emission of 1-100 TeV electrons
- 1% of Spin-down energy goes to VHE gamma rays



Pulsar Wind Nebula HESS J1825-137 Energy Dependent Morphology

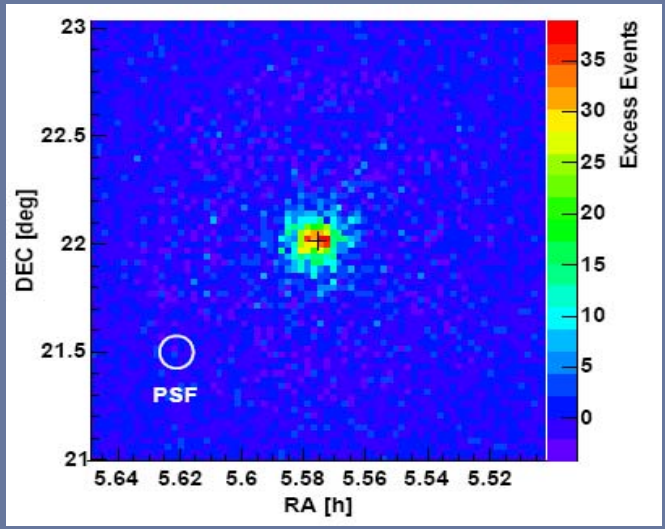
- HESS J1825-137 is energetic PWN
- Spectral steepening seen away from the pulsar
- Clear evidence for cooling of electrons in the Nebula

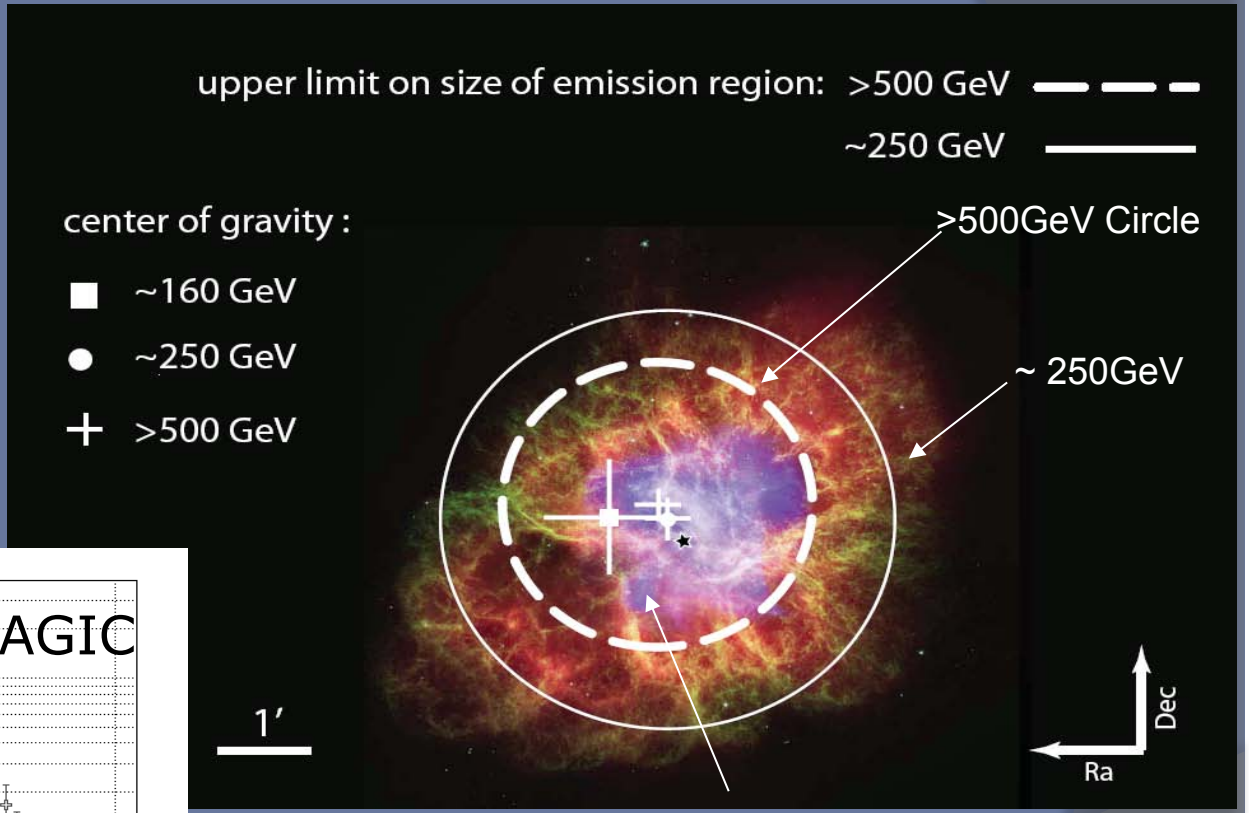


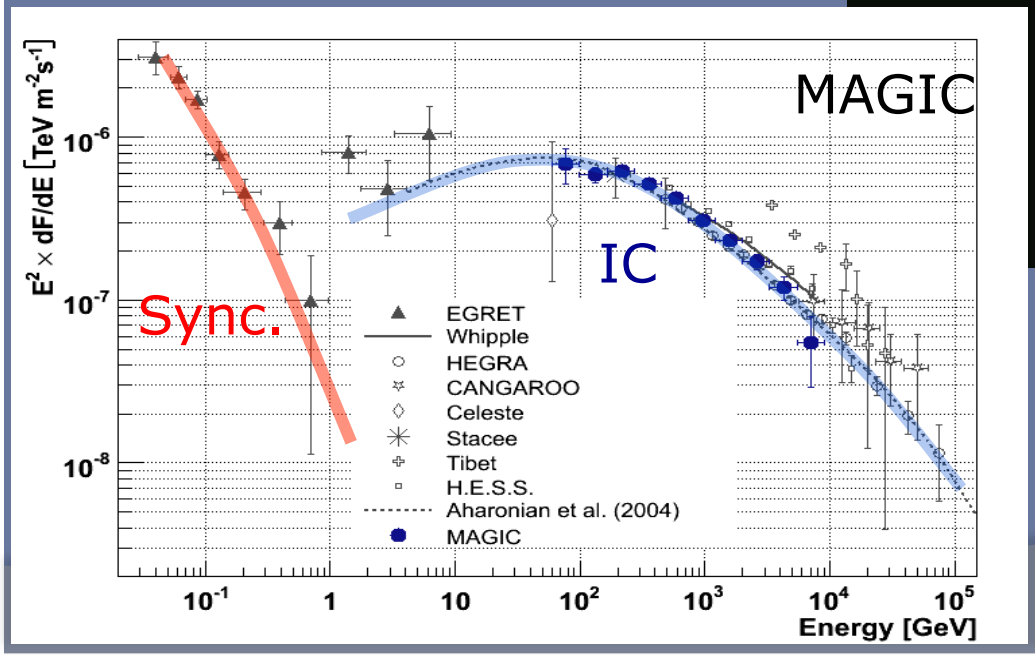


MAGIC Crab Nebula (PWN)

Gamma Ray Signals from Crab ~ 0.4Hz





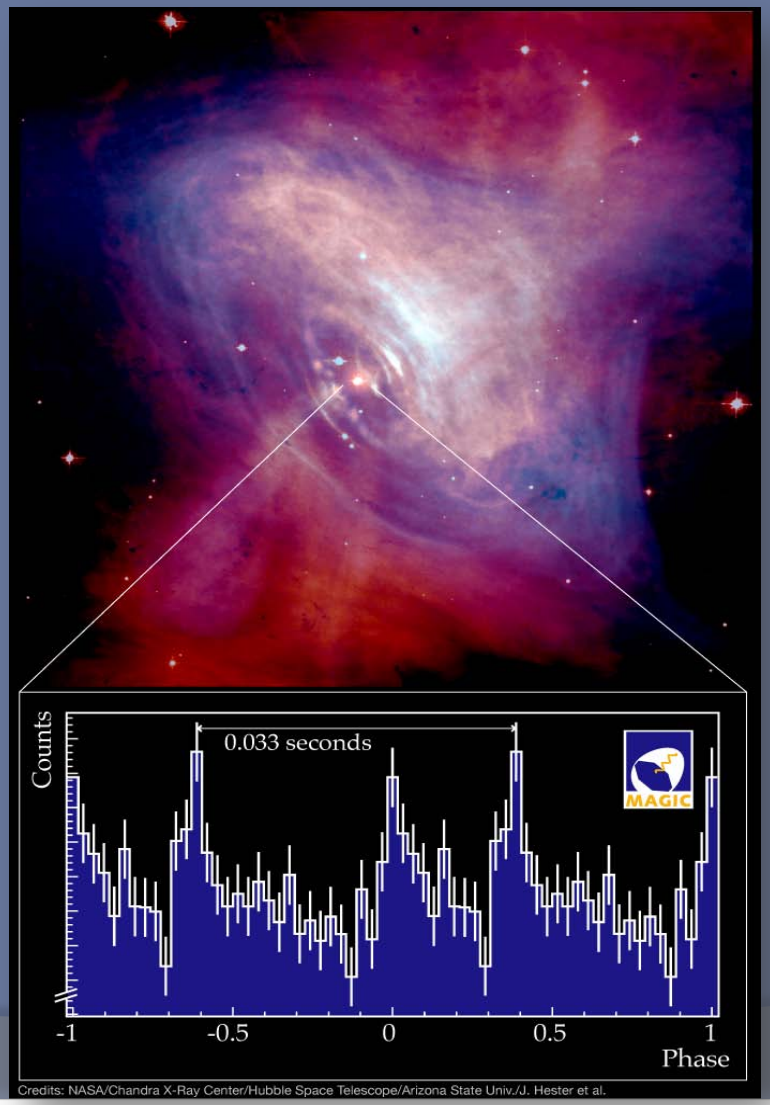


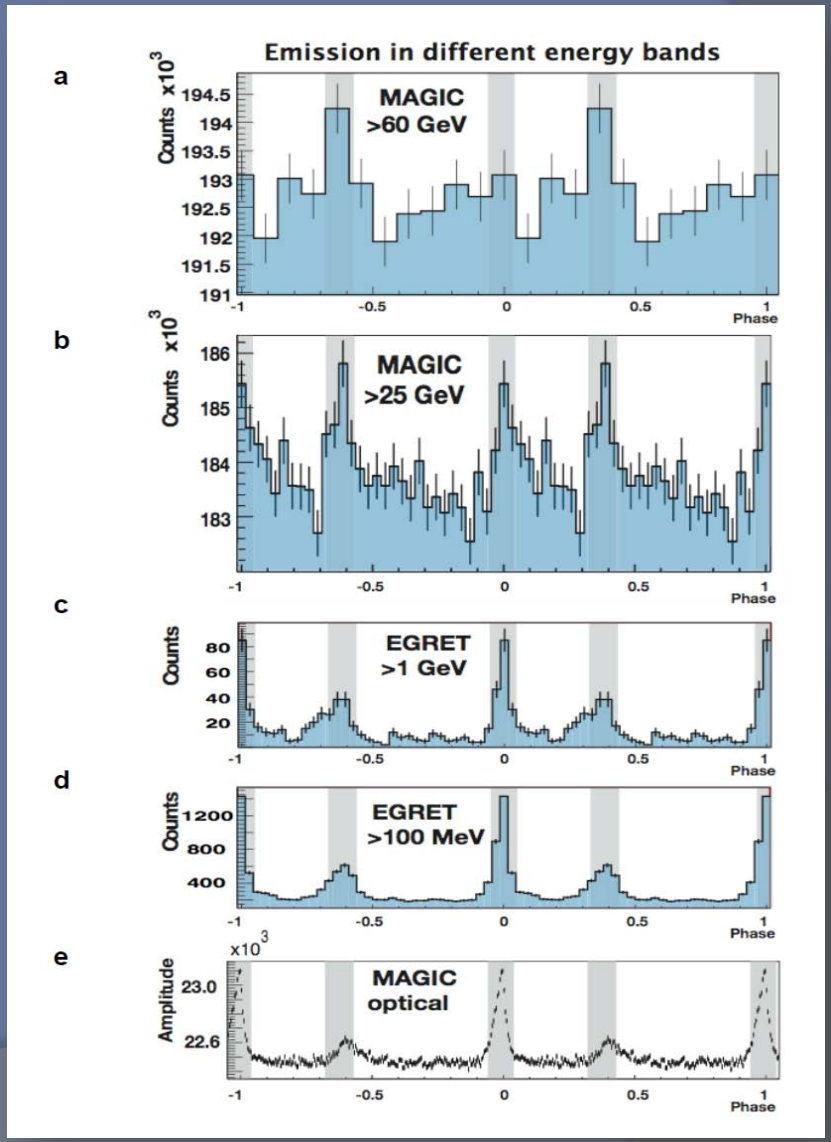
IC peak is estimated to be

IC_peak = 77 ± 35 GeV

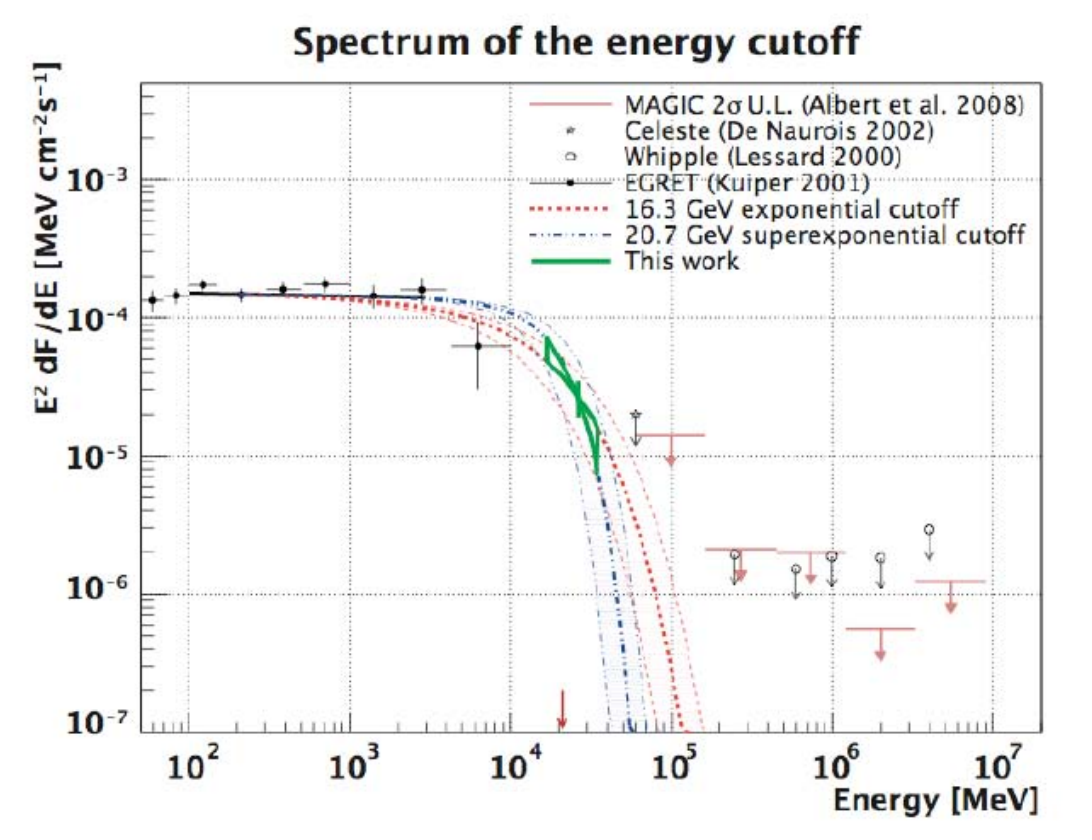
Detection of Crab Pulsar after 20 years long effort

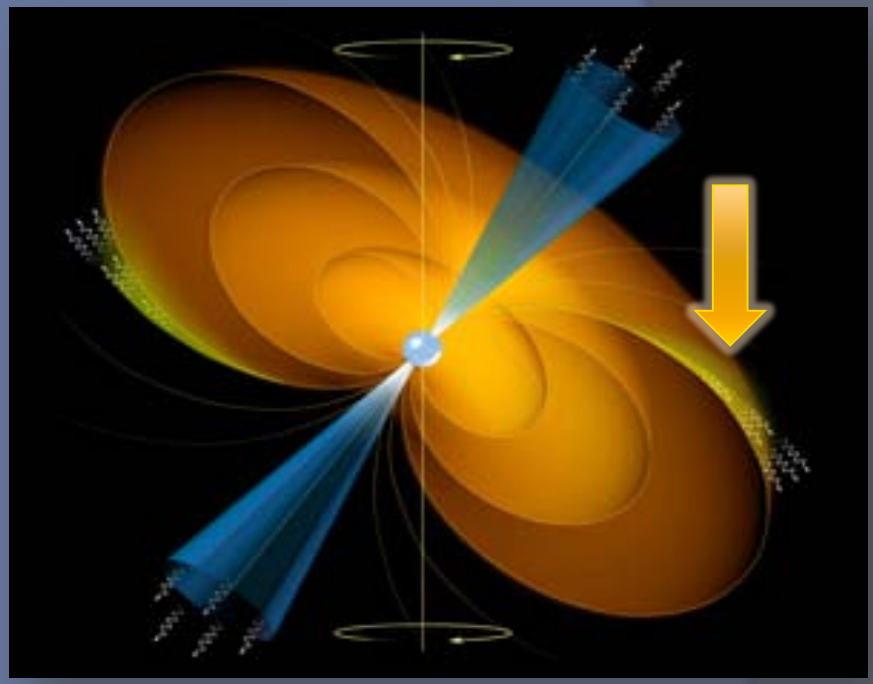
Published in Science in 2008

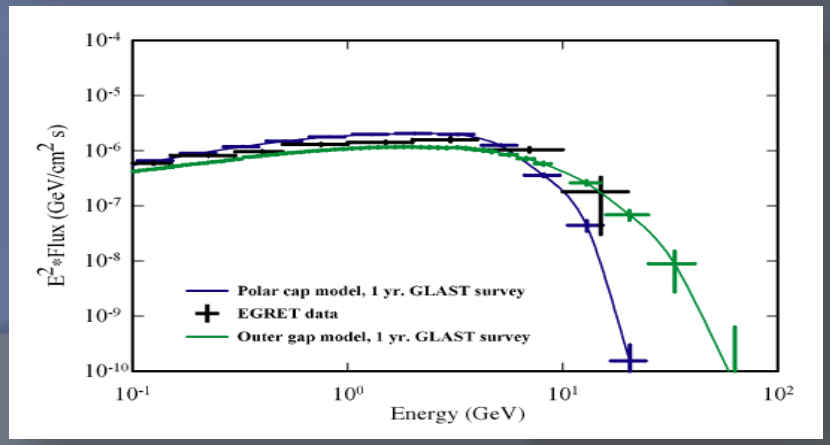




The MAGIC measurement clarified the emission mechanism



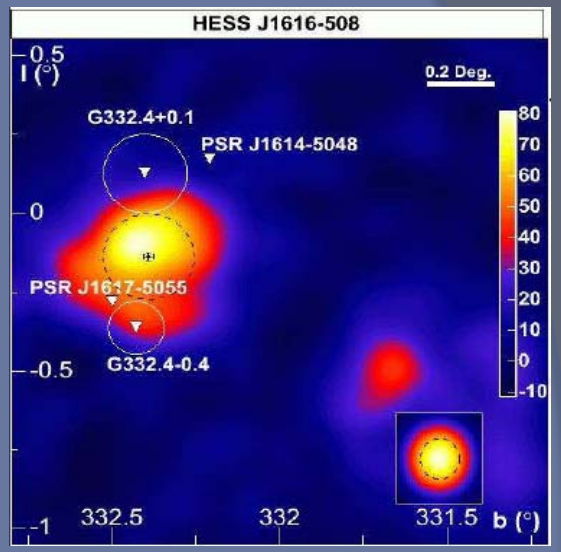




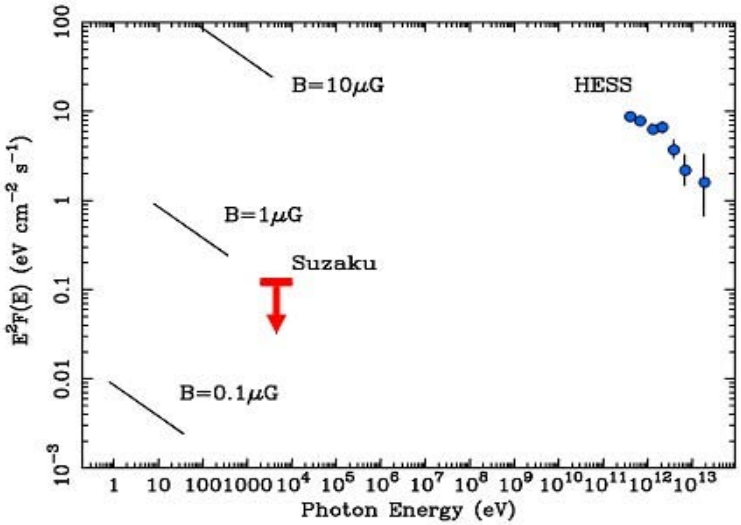
Un-IDs (Dark Sources)

?

Category	Source	Discovery	Observation
Un-ID	TeV J2032+4130	HEGRA	
Un-ID	HESS J1303-631	HESS	
Un-ID	HESS J1614-518	HESS	
Un-ID	HESS J1702-420	HESS	
Un-ID	HESS J1708-410	HESS	
Un-ID	3EG J1744-3011 ?	HESS J1745-303	



Name	Possible counterpart	Type[a]	Γ^b_{TeV}	f^c_{TeV}	N^d_H	Γ^e_X	f^f_X	f_{TeV}/f_X	Reference[g]
HESS J0852−463	RX J0852−4622	SNR	2.1	6.9	4	2.6	∼10	∼ 0.7	1, 2, 3
HESS J1303−631	—	?	2.4	1.0	20	2.0	<0.64	> 1.6	4, 5
HESS J1514−591	PSR B1509−58	PWN	2.3	1.6	8.6	2.0	3.2	0.5	6, 7
HESS J1632−478	AX J1631.9−4752	HMXB?	2.1	1.7	210	1.6	1.7	1.0	8, 9
HESS J1640−465	G338.3−0.0	SNR	2.4	0.71	96	3.0	0.30	2.4	8, 10
HESS J1713−397	RX J1713.7−3946	SNR	2.2	3.5	8	2.4	54	0.065	11, 12
HESS J1804−216	Suzaku J1804-2142	?	2.7	0.48	2	-0.3	0.025	19	8, 13
HESS J1804−216	Suzaku J1804-2140	?	2.7	0.48	110	1.7	0.043	11	8, 13
HESS J1813−178	AX J1813−178	?	2.1	0.89	110	1.8	0.70	1.3	8, 14
HESS J1837−069	AX J1838.0−0655	?	2.3	1.4	40	0.8	1.3	1.1	8, 15
TeV J2032+4130	—	?	1.9	0.20	?	?	<0.20	>1.0	16
HESS J1616−508	—	?	2.4	1.7	4.1	2.0	<0.031	>55	This work

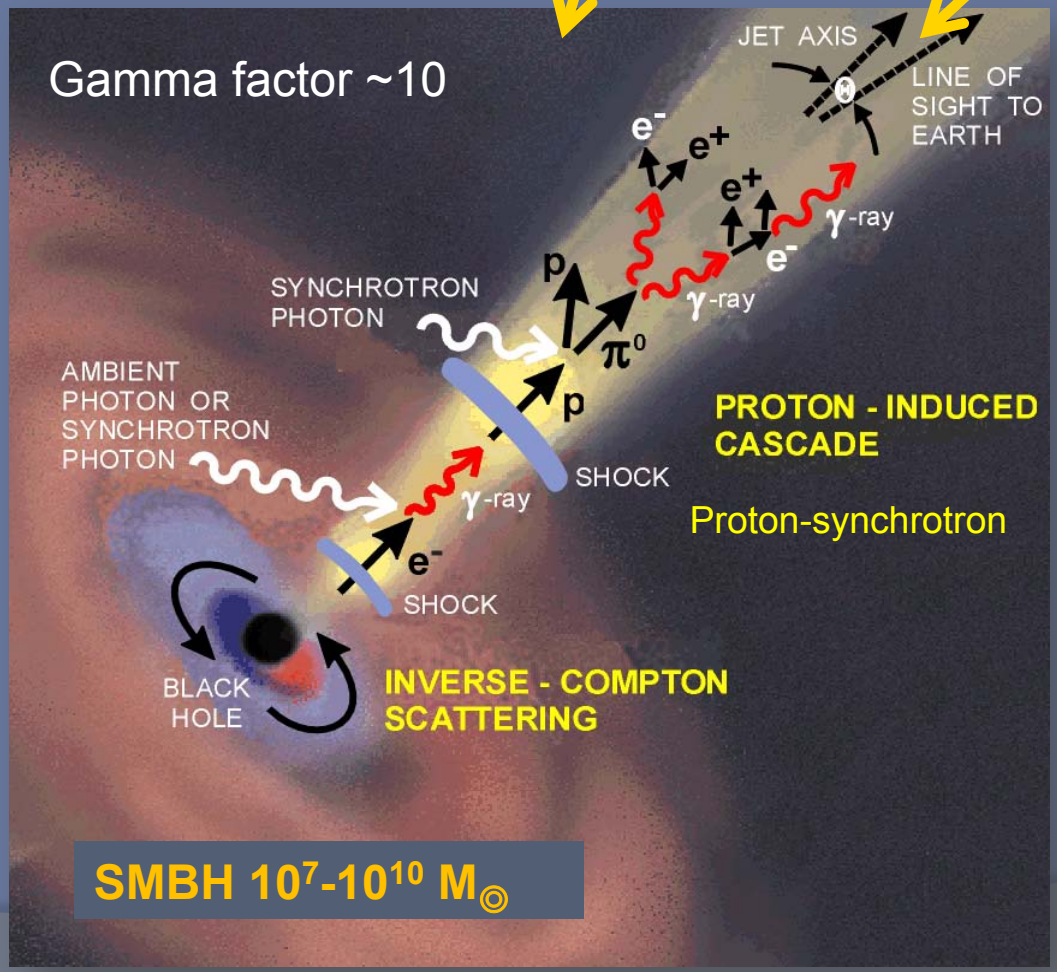


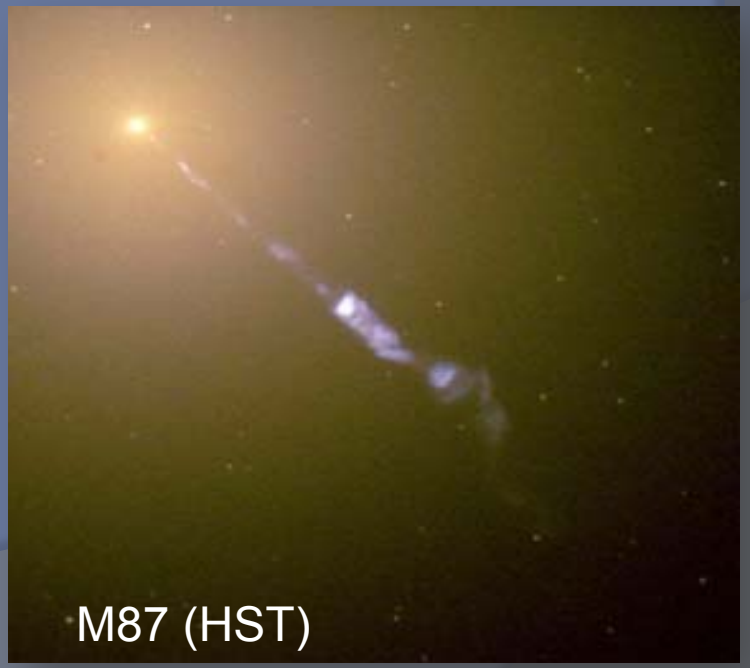
Suzaku (Matsumoto et al. 1996)

Cosmic Ray accelerator
Active Galactic Nuclei

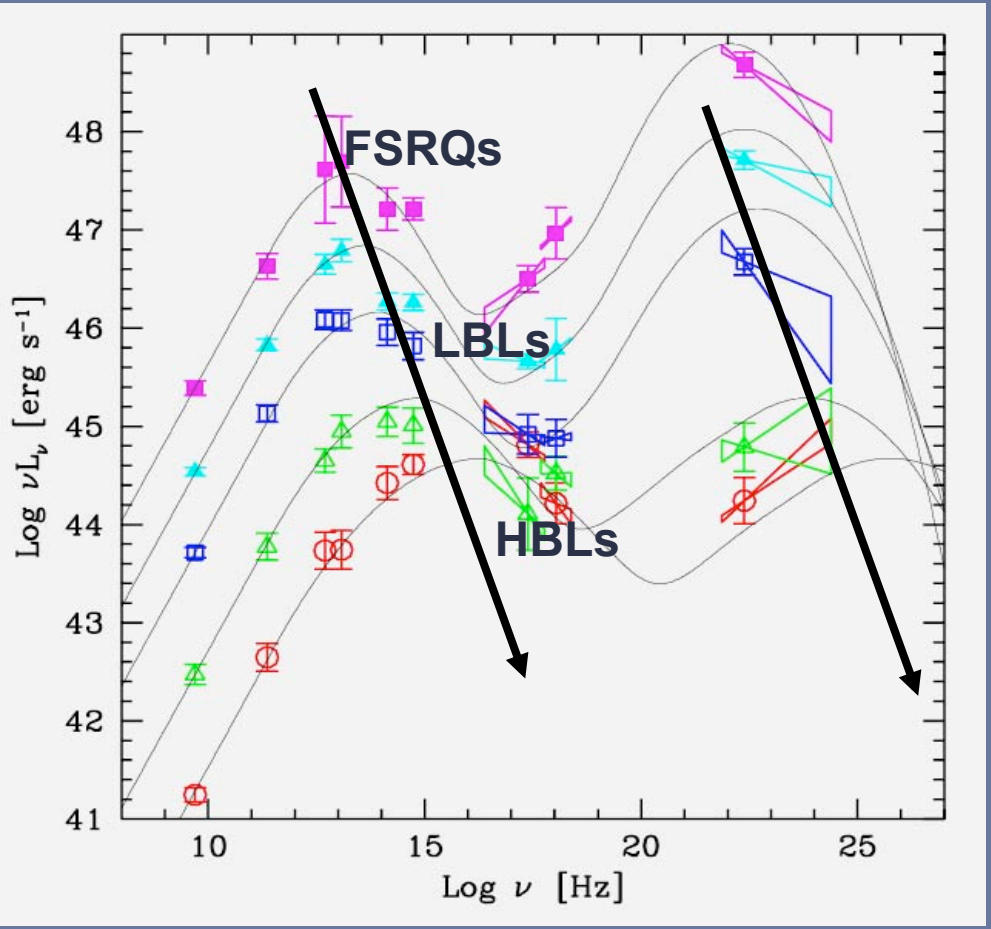
FRI, FRII

Blazars

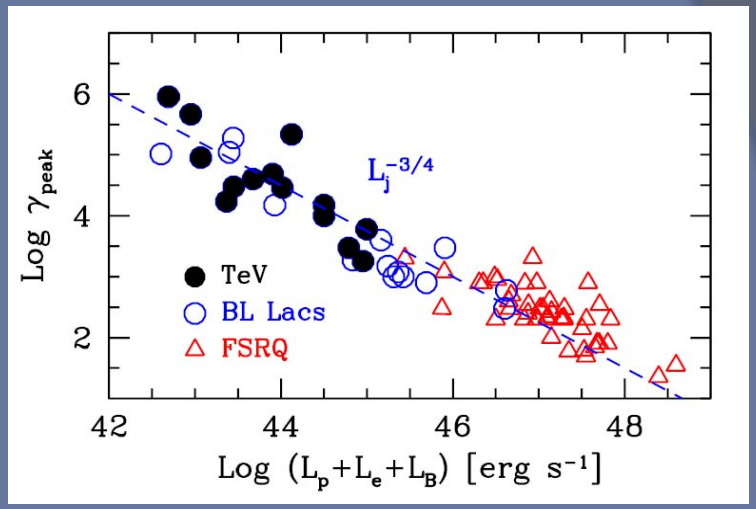




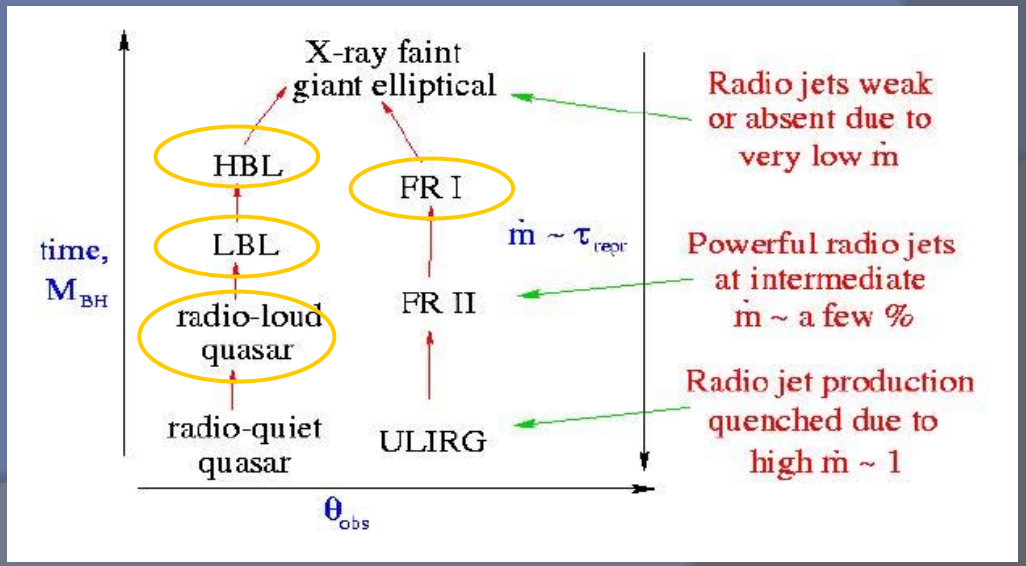
Blazar's Sequence



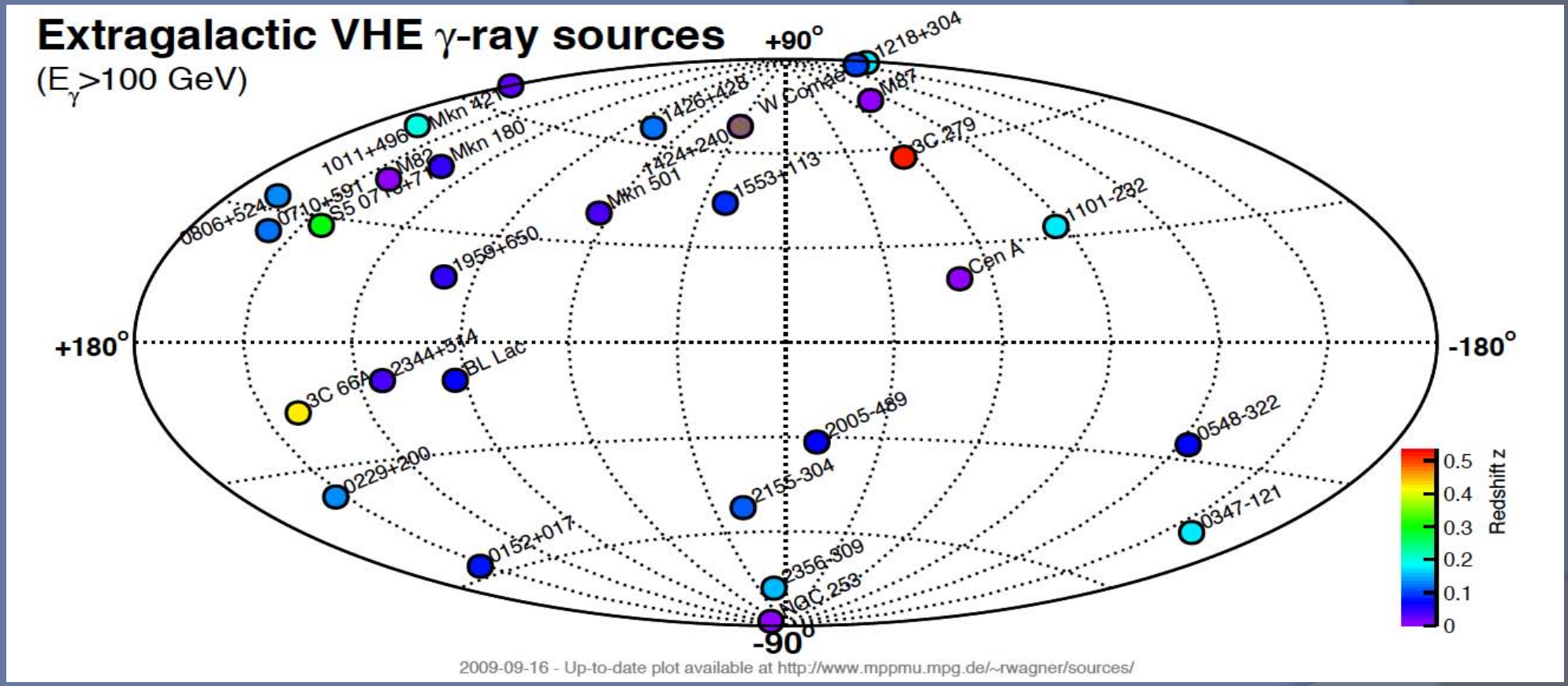
Fosatti et al. 1998



Celotti & Ghisellini 2007



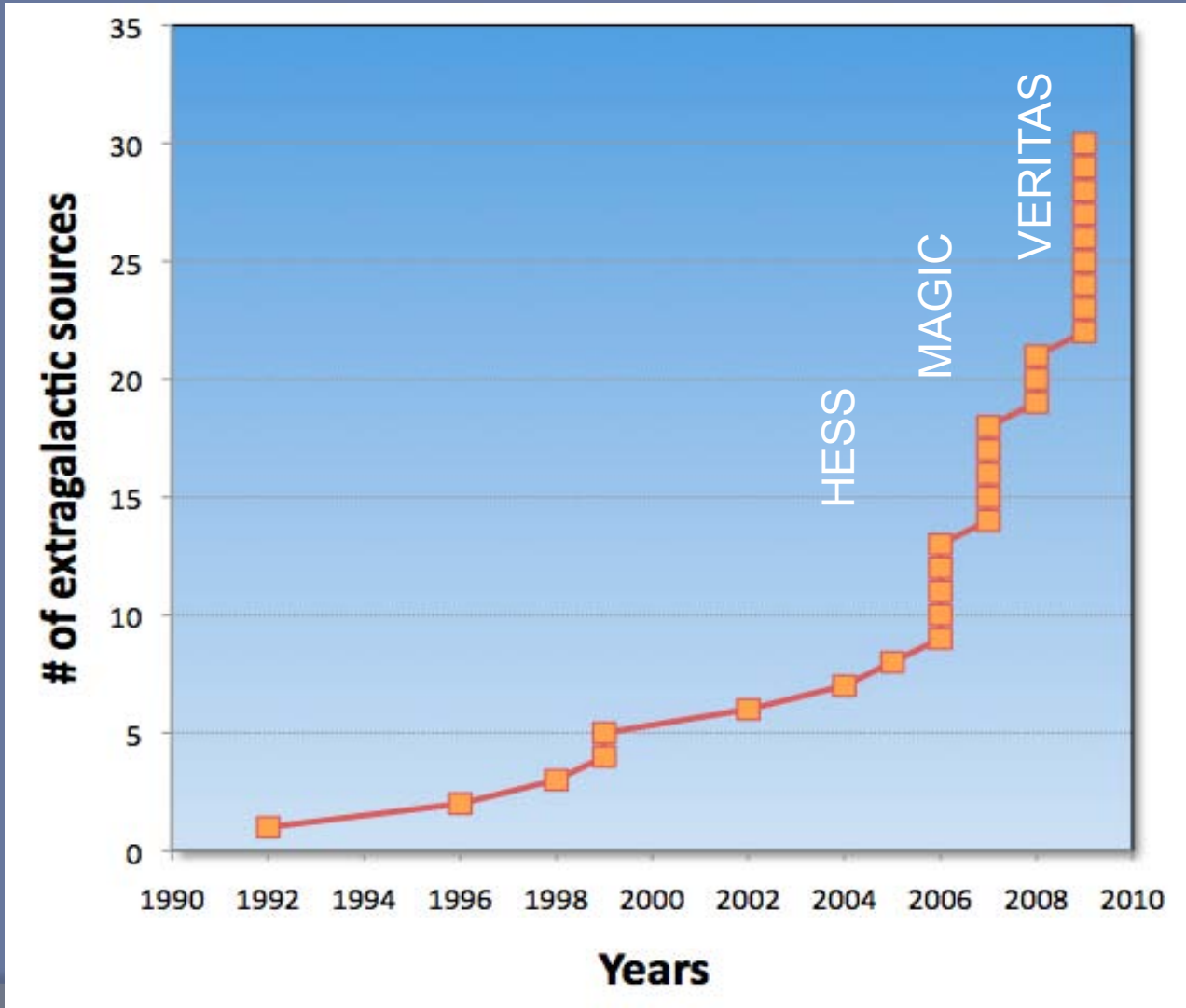
Extragalactic VHE sources



30 sources in 2009 Sep

24 x Blazars, 1 x FSRQ, 3 x FR-I, 2 x Star Burst Galaxies,

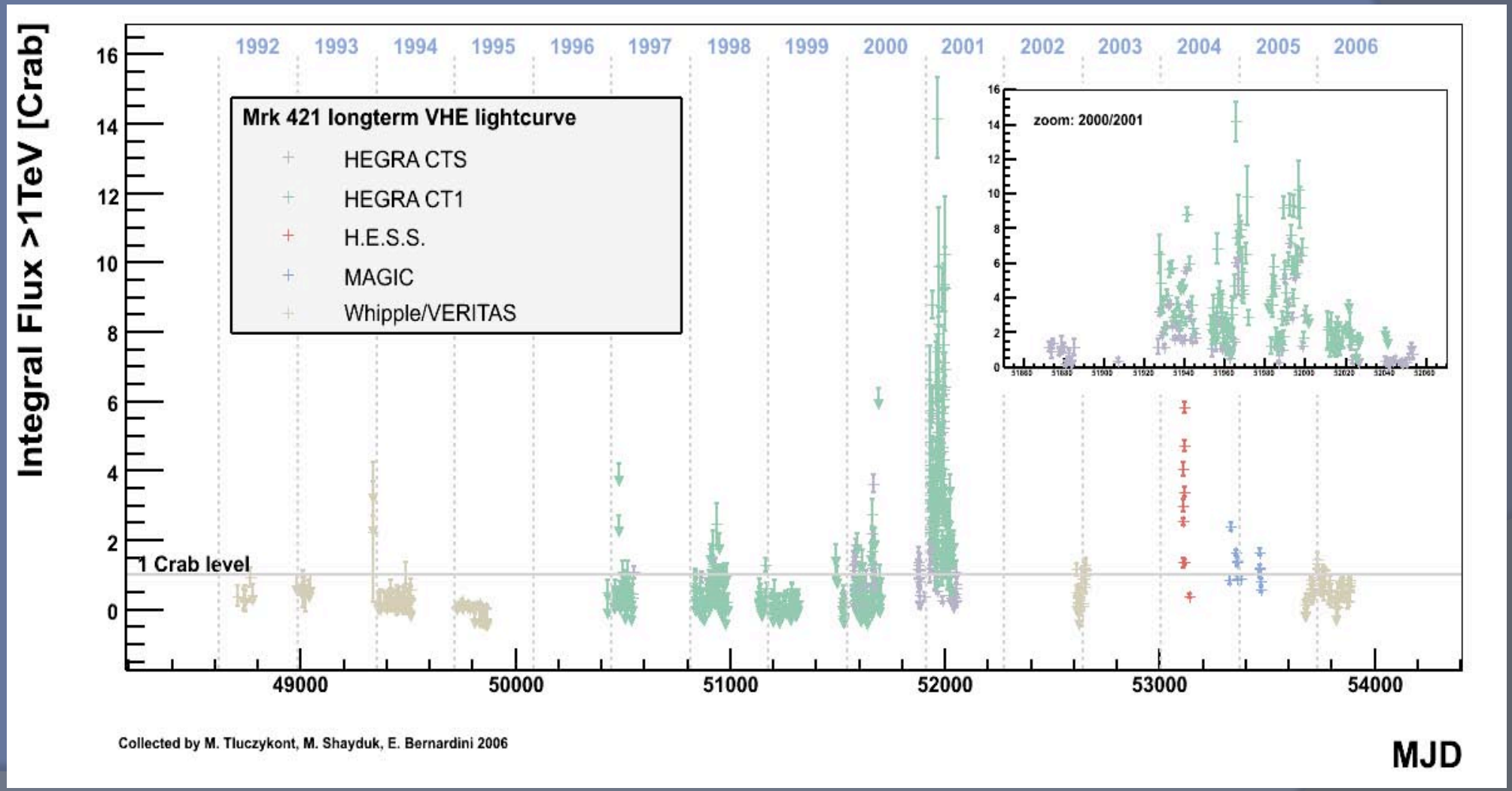
Number of extragalactic VHE Sources



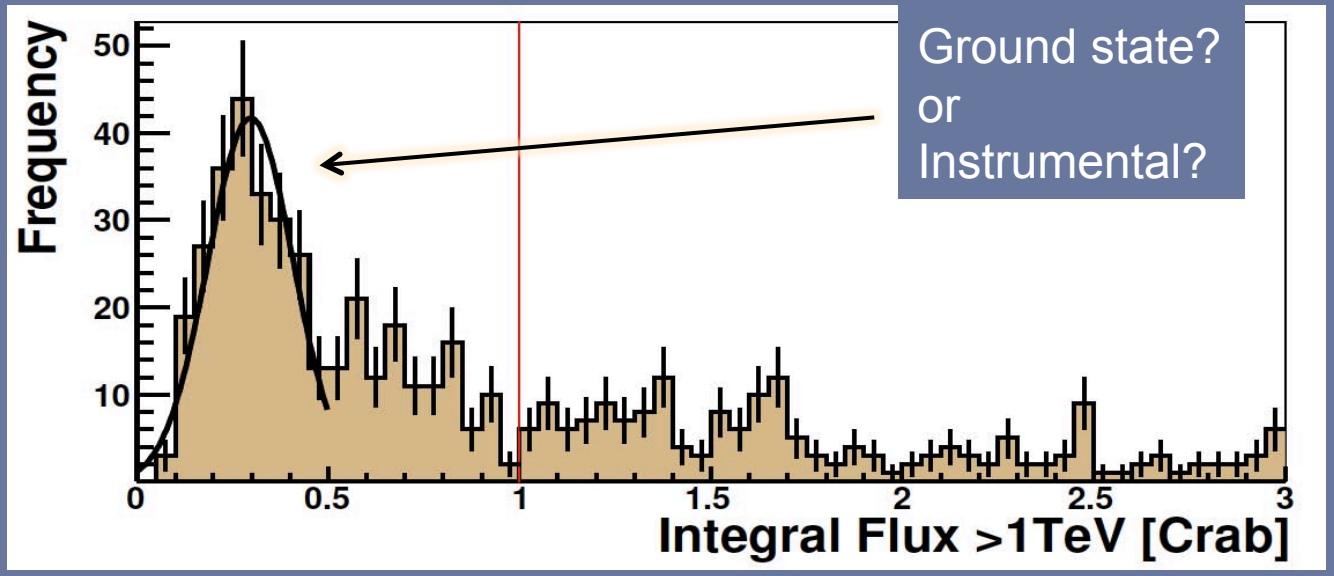

NEARBY
BLAZARS

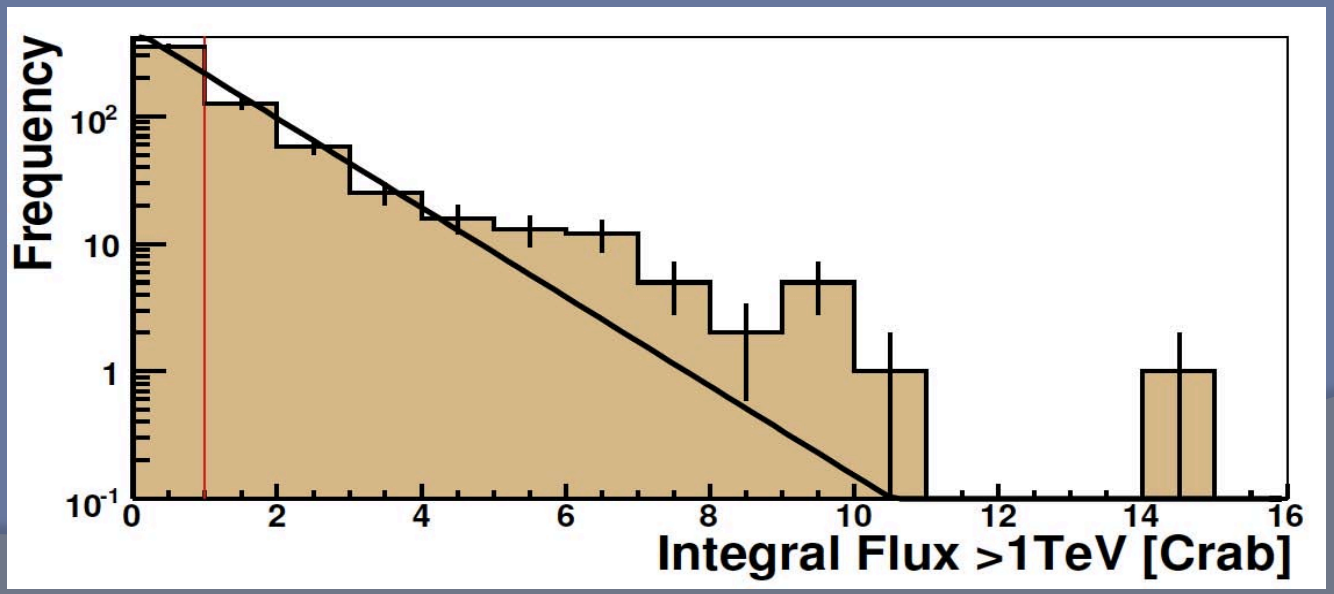
Mkn421 long term light curve

M.Tluchzykont
http://www-zeuthen.desy.de/multi-messenger/GammaRayData/



Mkn421 Flux levels





Intensity variation
X 50

Mrk421 2007-2008 light curve

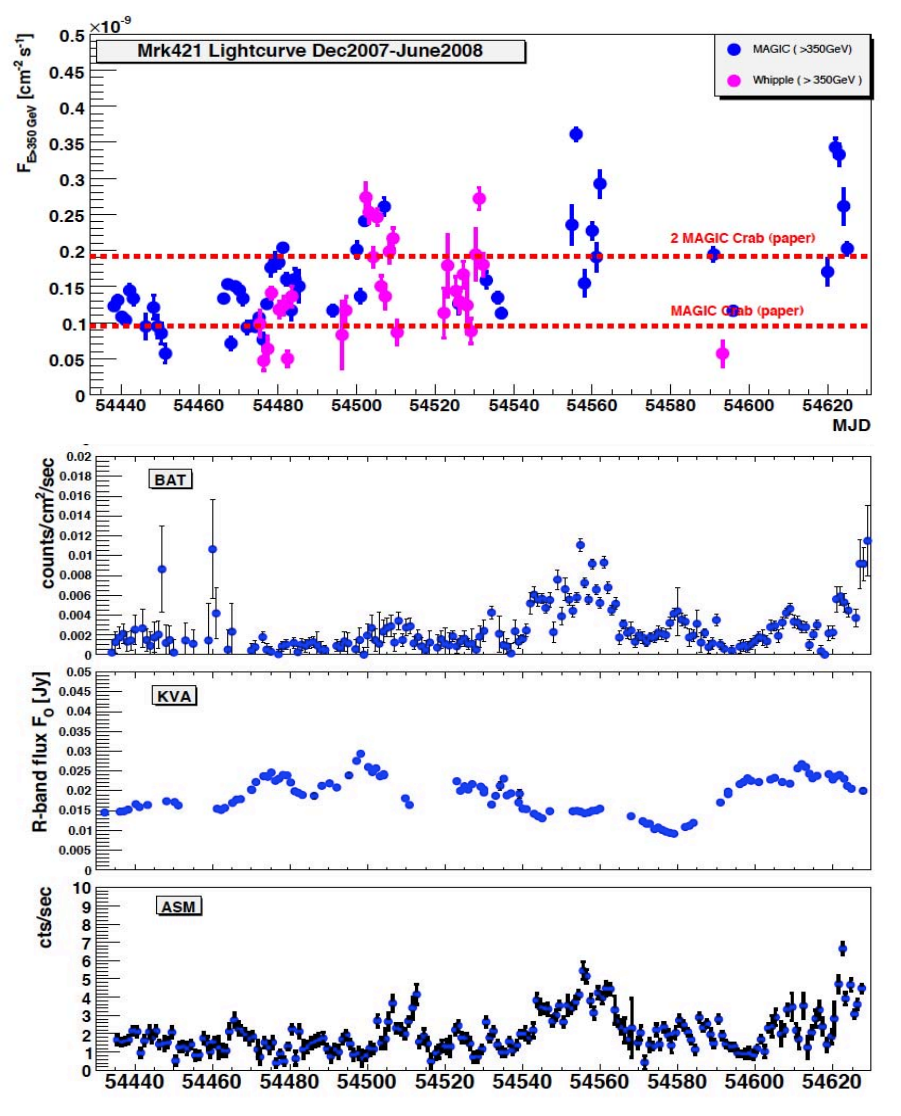
C.C.Hsu 2009

VHE (300GeV)

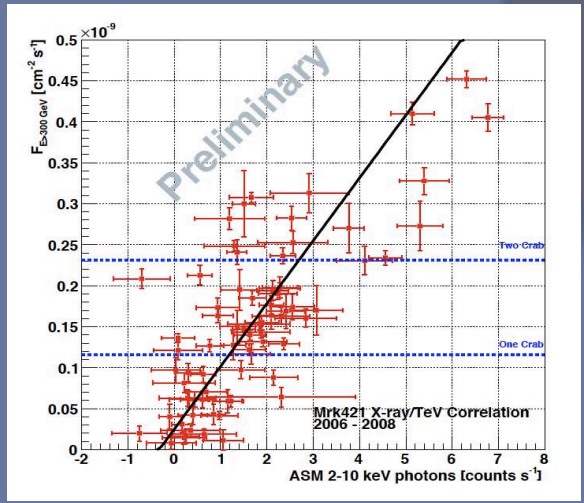
HX (BAT)

Optical (KVA)

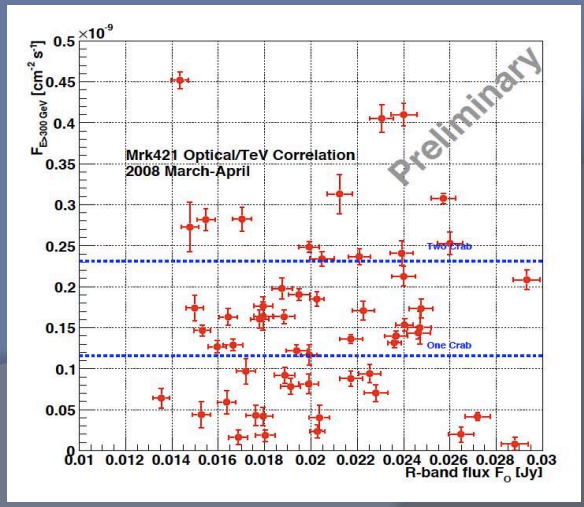
X (ASM)



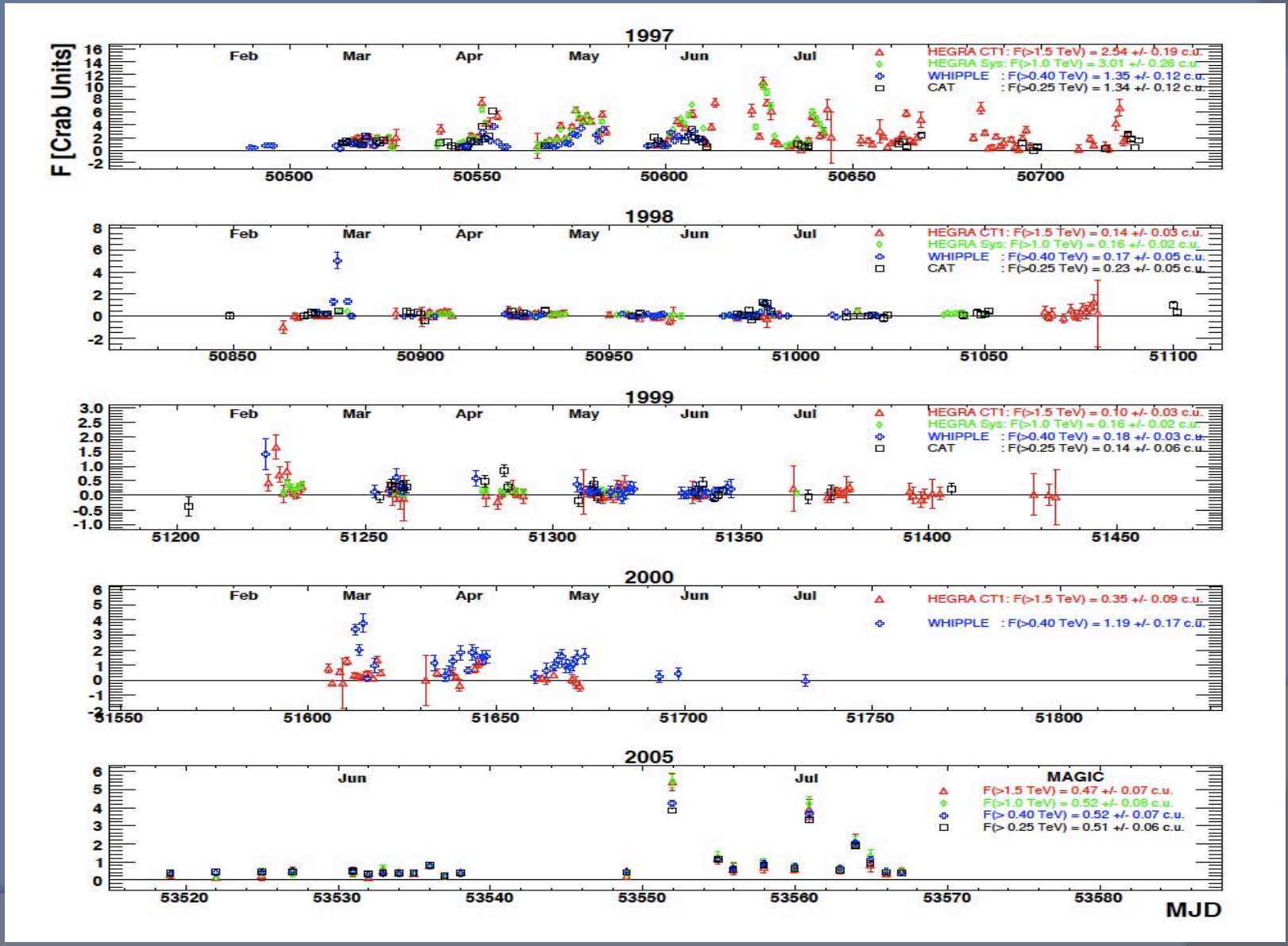
VHE - X



VHE - Optical

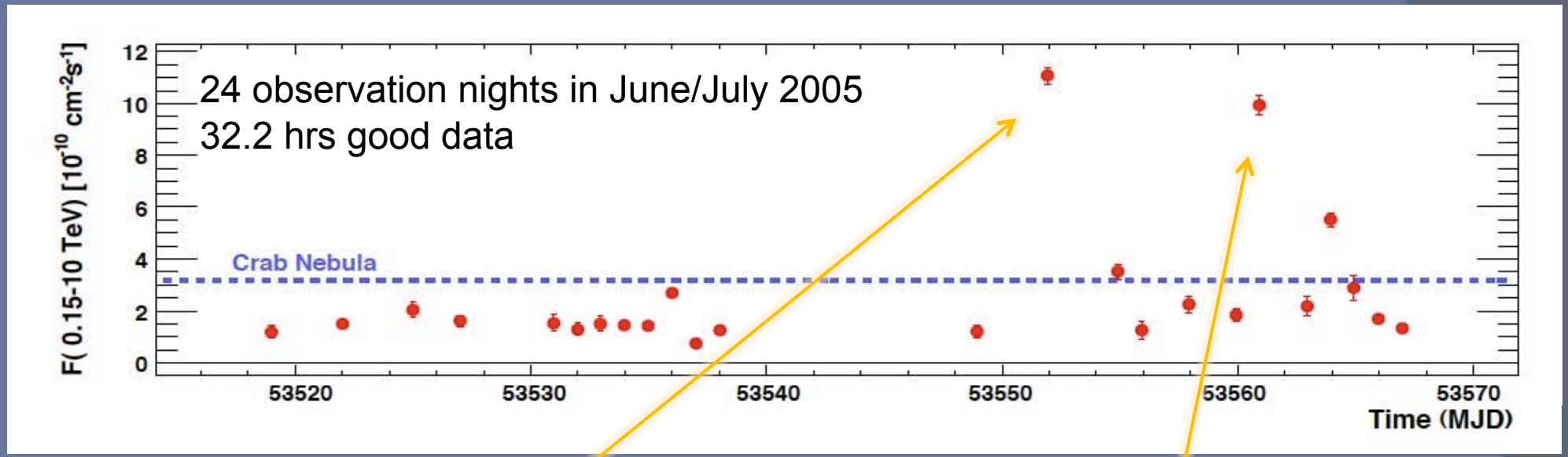


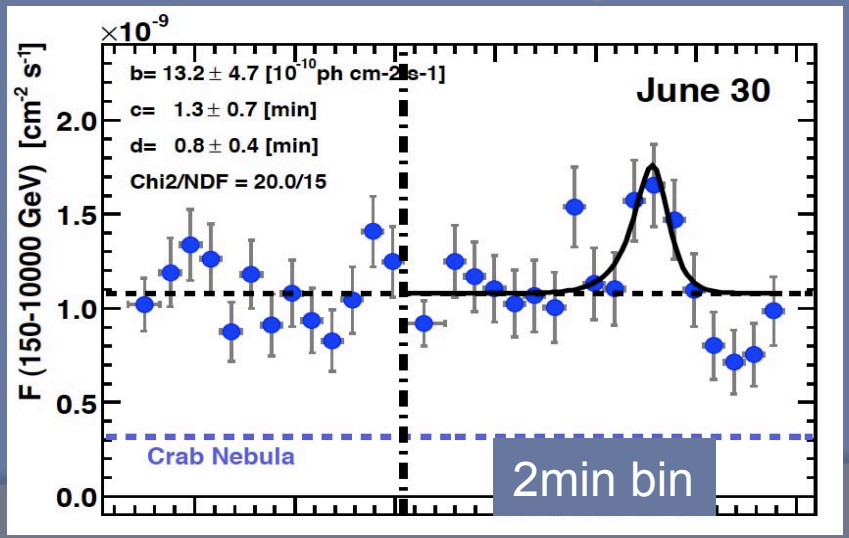
Mkn501 historical long term light curve

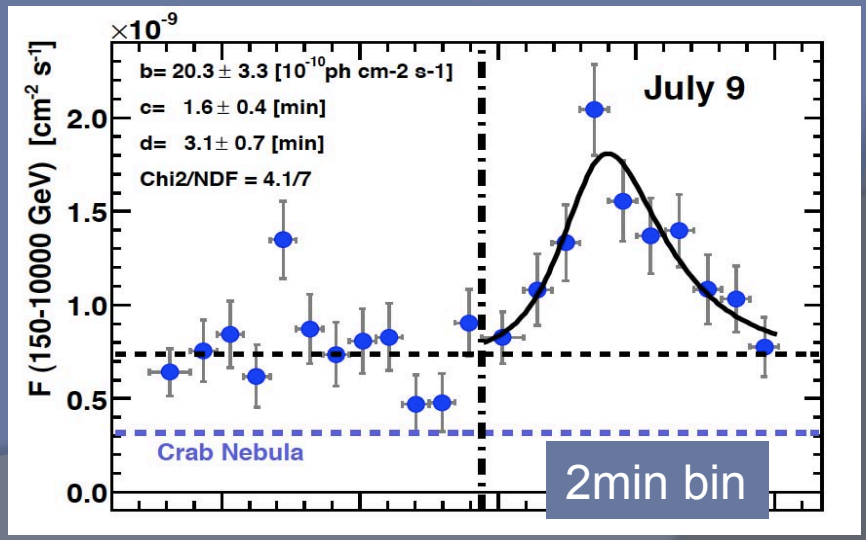


MAGIC: Mkn501 2005 flares

a few mins fast time variation



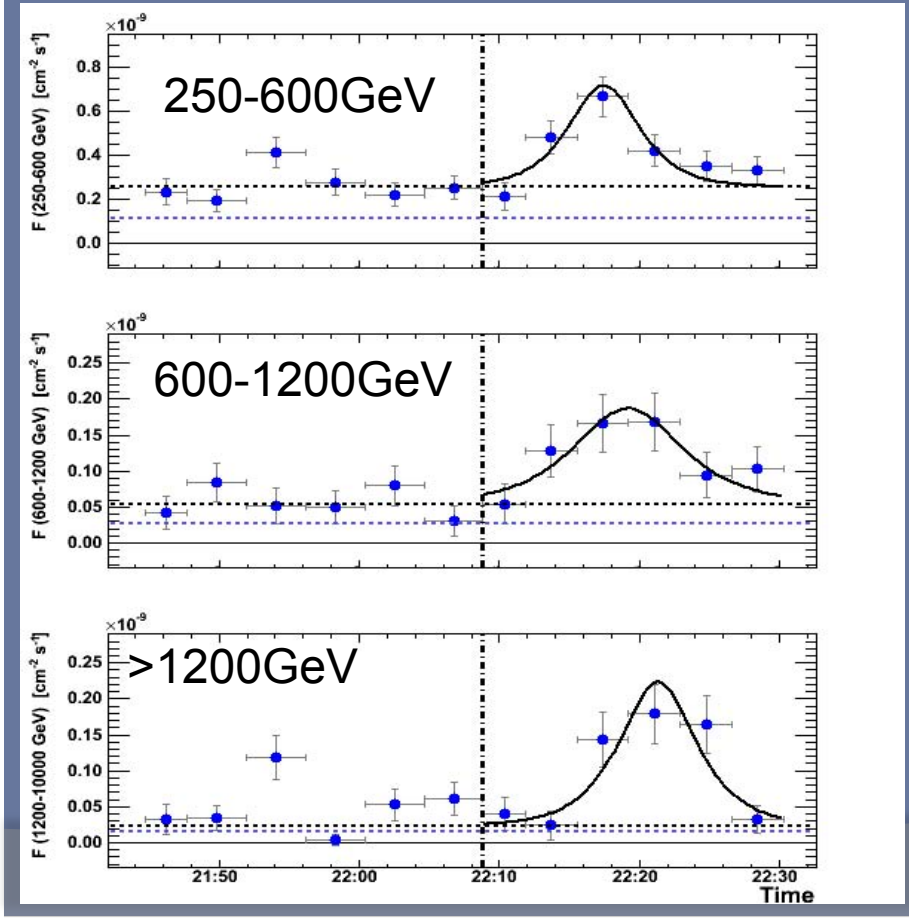




Very fast time variability
Mrk501 by MAGIC, PKS 2155 by HESS

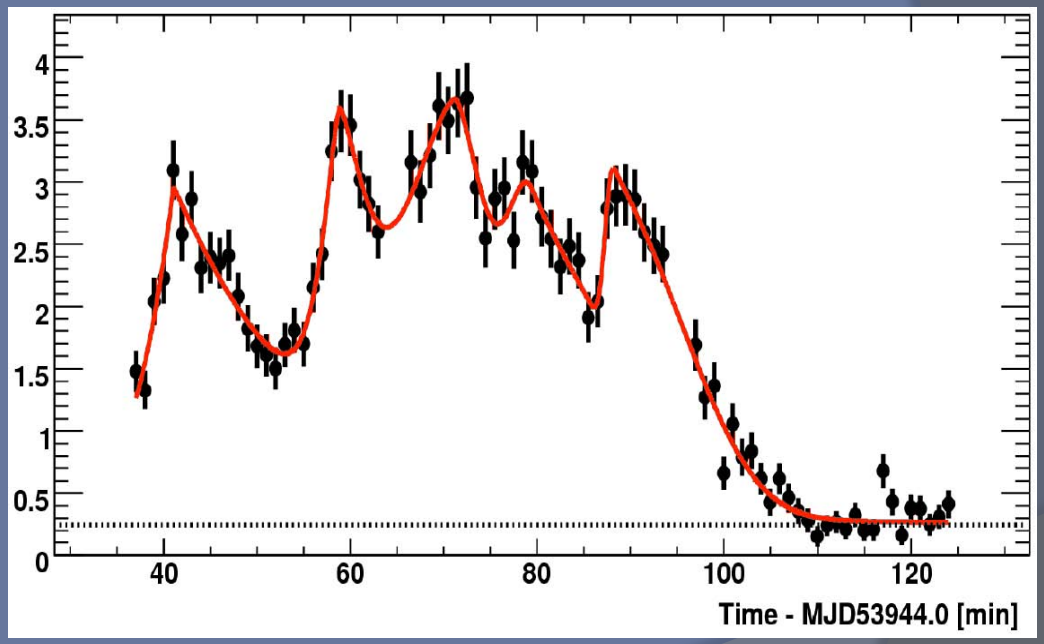
Mrk501(z=0.03) MAGIC observation

$M_{QG1} > 0.26 \times 10^{18}$GeV



PKS2155(z=0.116) HESS observation

$M_{QG1} > 0.72 \times 10^{18}$GeV

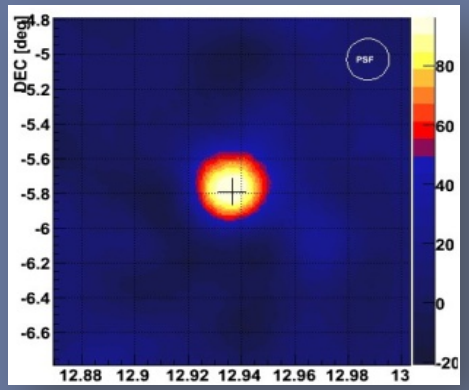


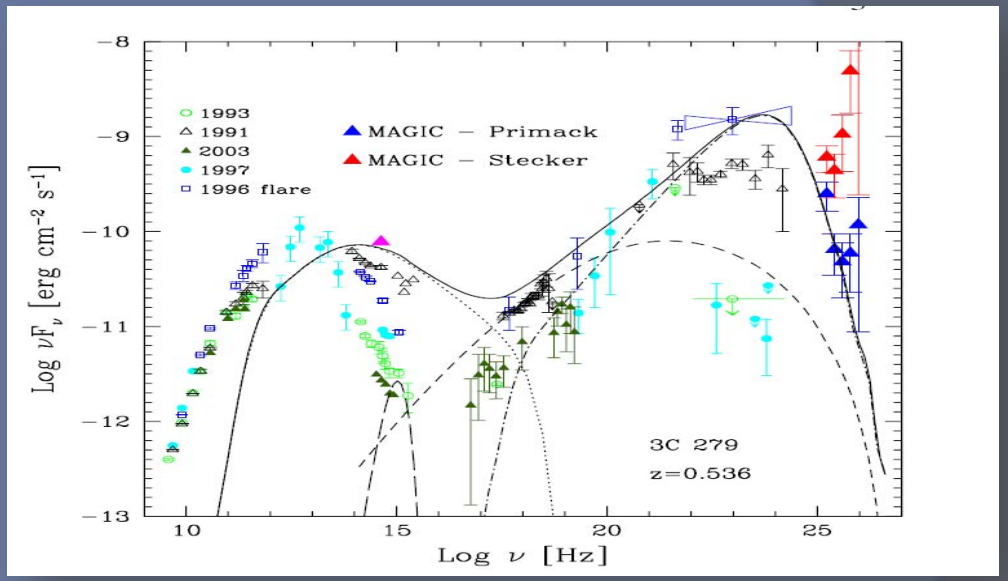
Fermi: GRB080916c, $M_{QG1} > 1.3 \times 10^{18}$GeV

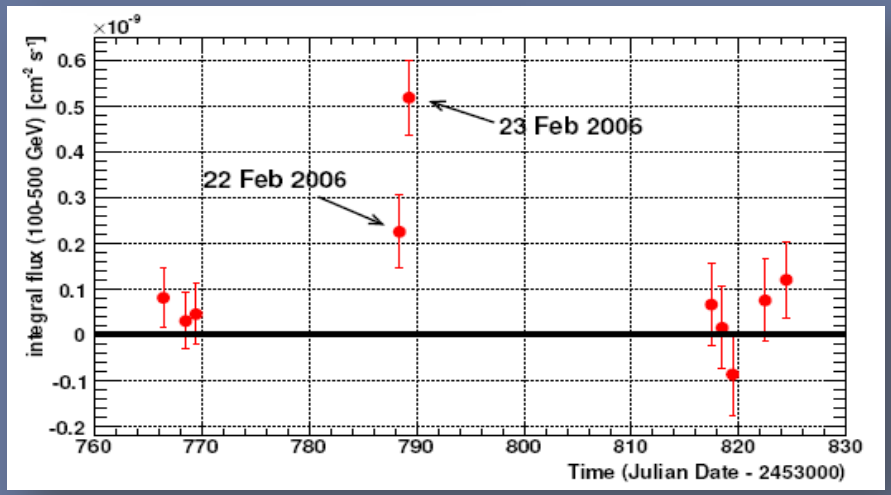
Fermi: GRB090510, $M_{QG1} > 14{,}5 \times 10^{18}$GeV

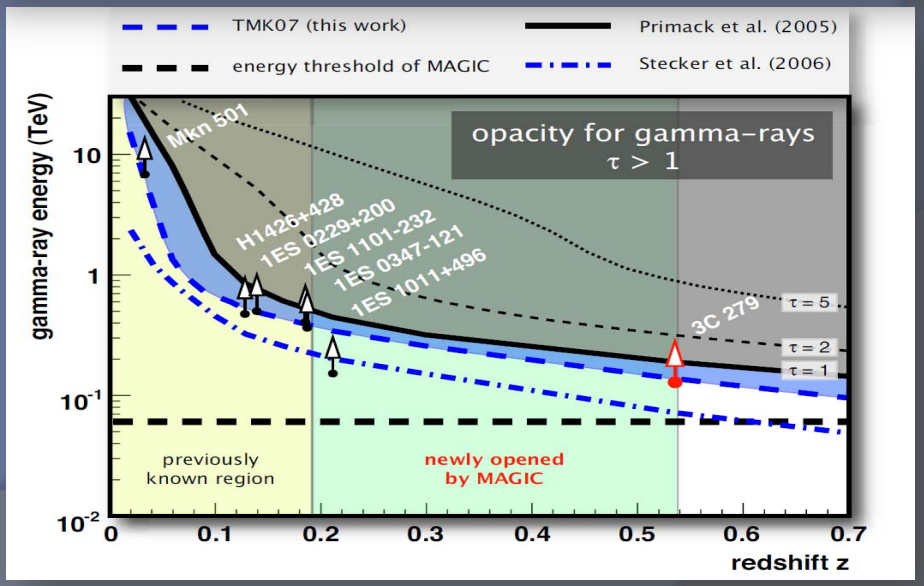

DISTANT
BLAZARS

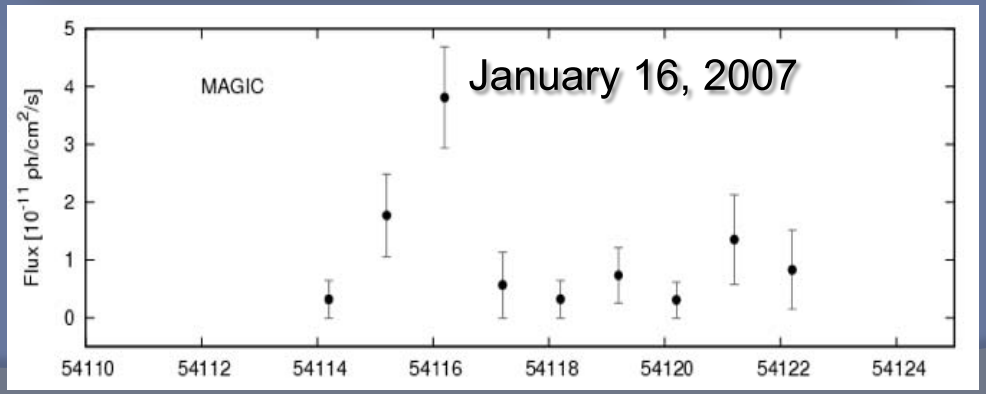
FSRQ 3C279 (z=0.536)
Most distant 100GeV AGN



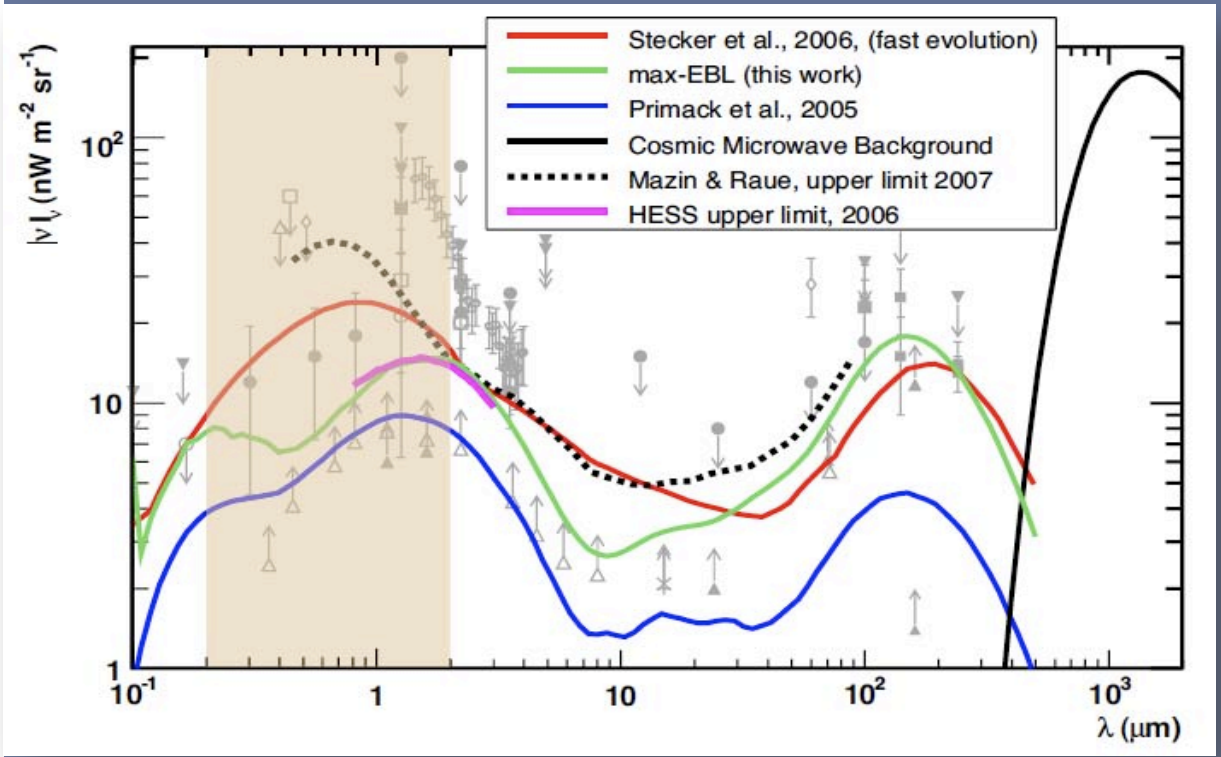




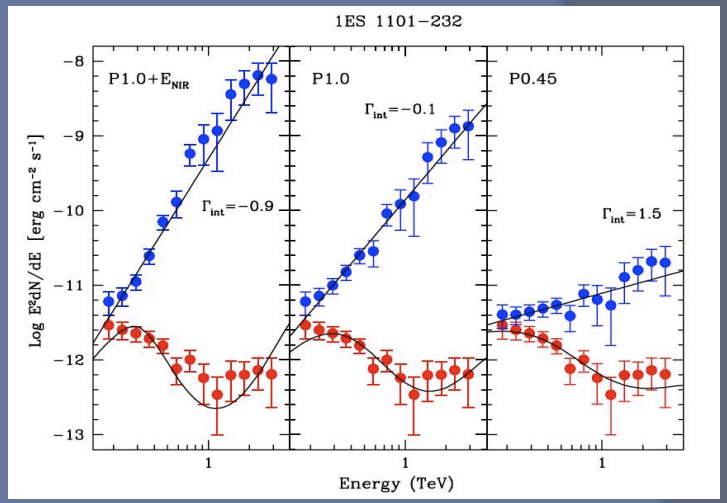




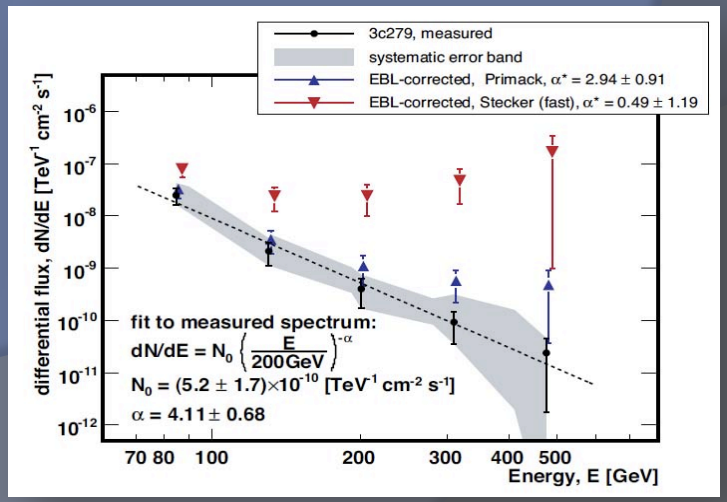
Limit on EBL spectrum



HESS 1ES 1101

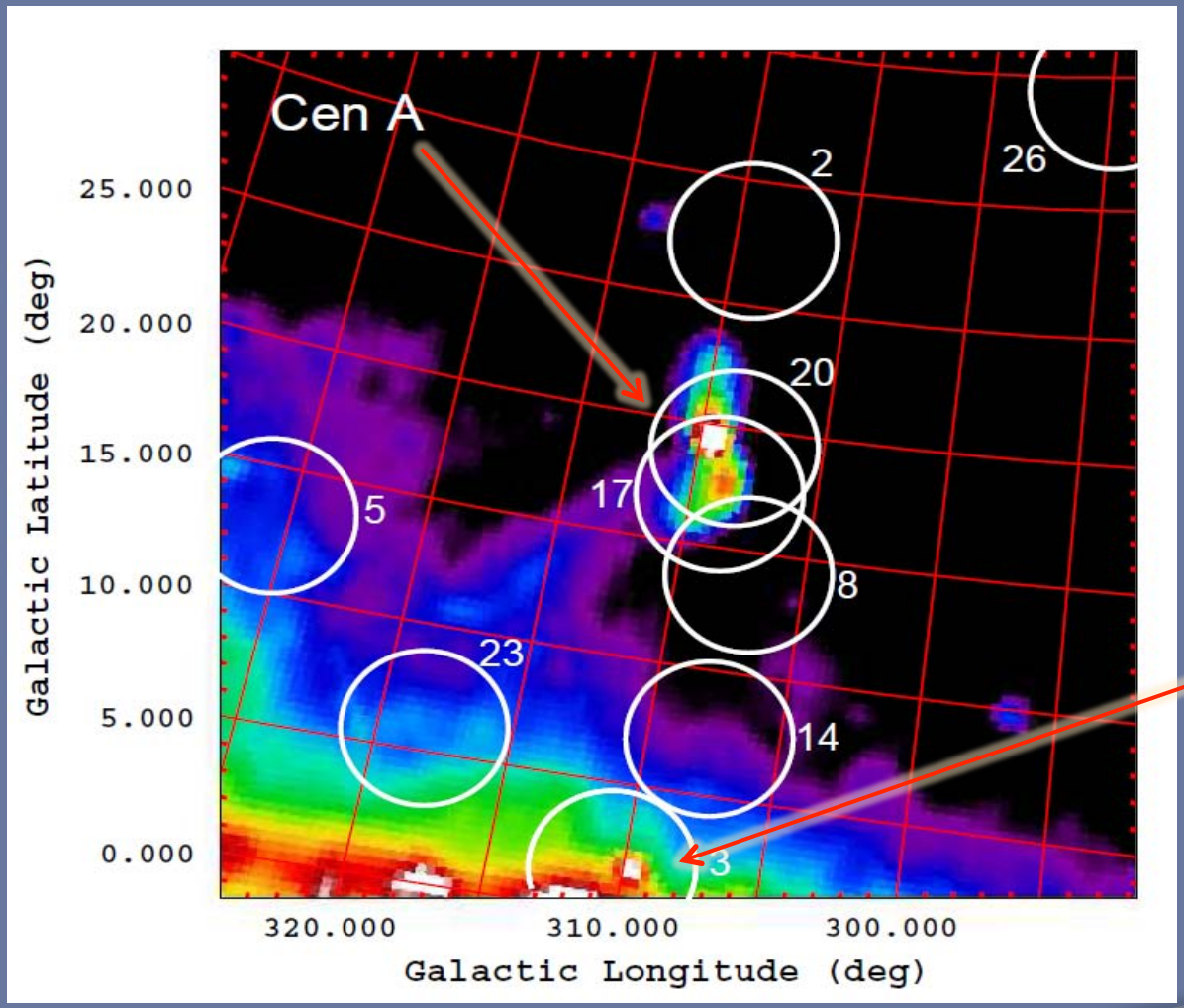


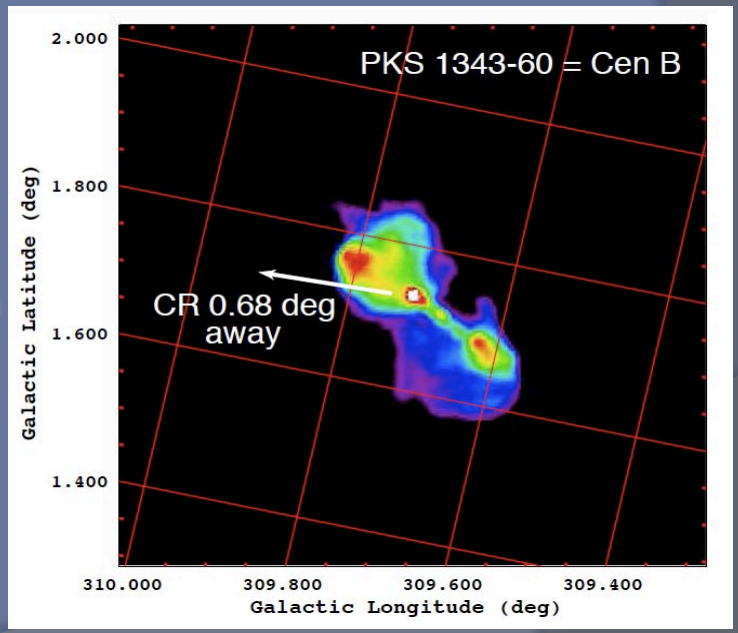
MAGIC 3C279



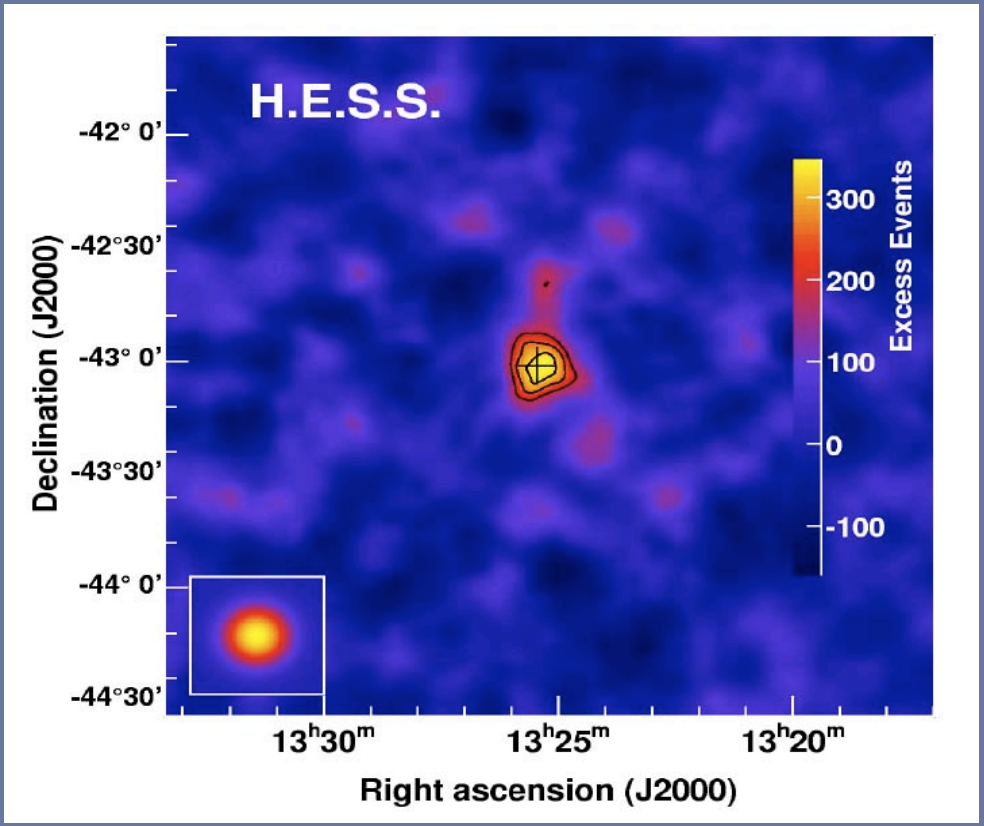

FR-I &
STARBURST

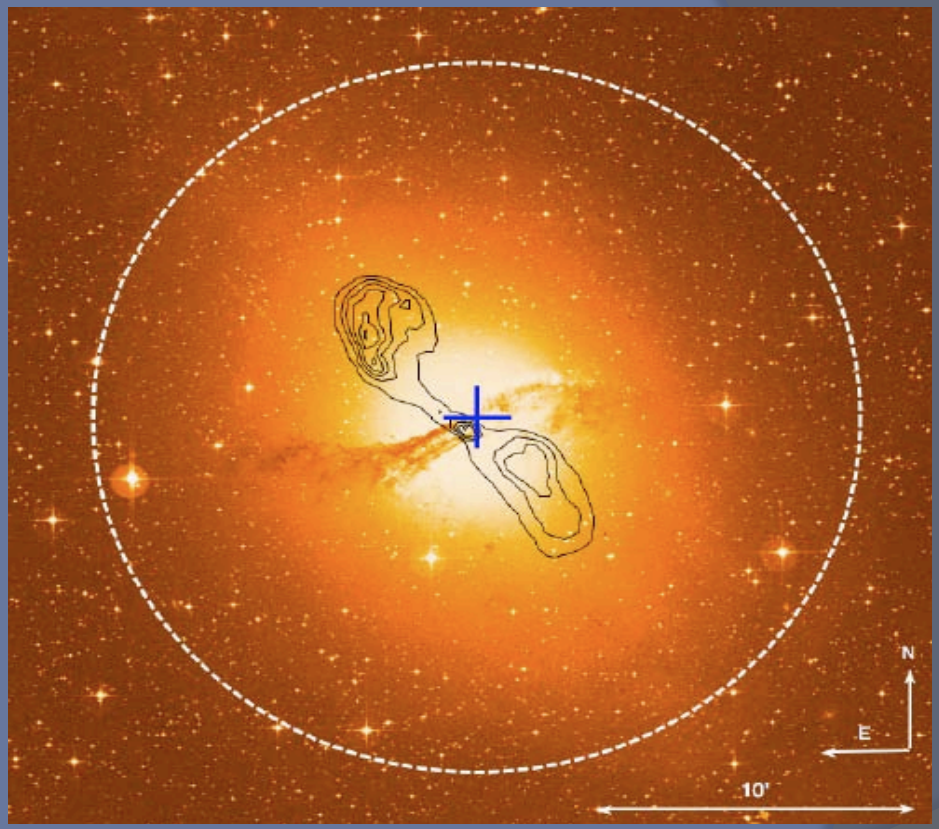
Morphological studies of potential sources
Cen A (3.4Mpc) & Cen B (56Mpc)
Moskalenko et al. 0805.1260v1





Cen A: HESS detection



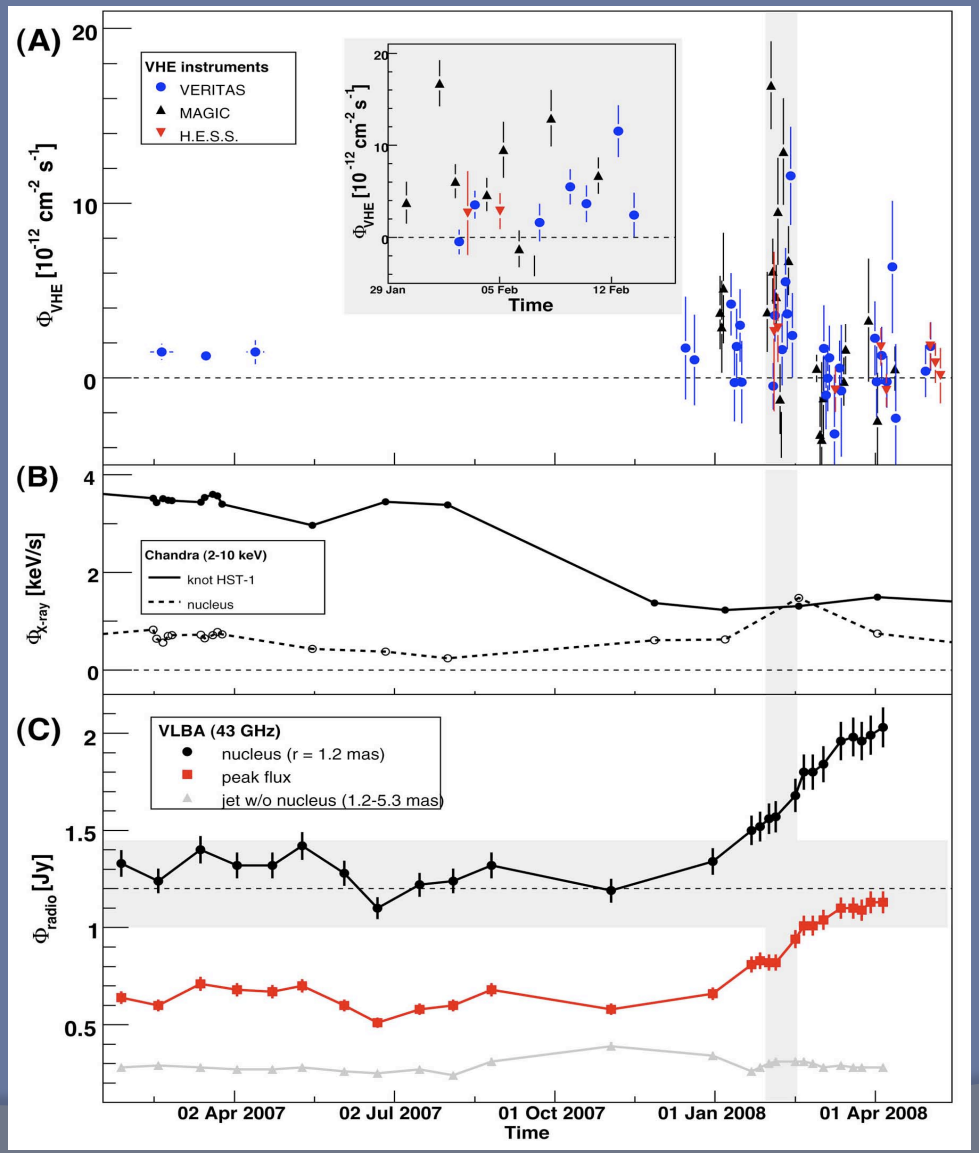


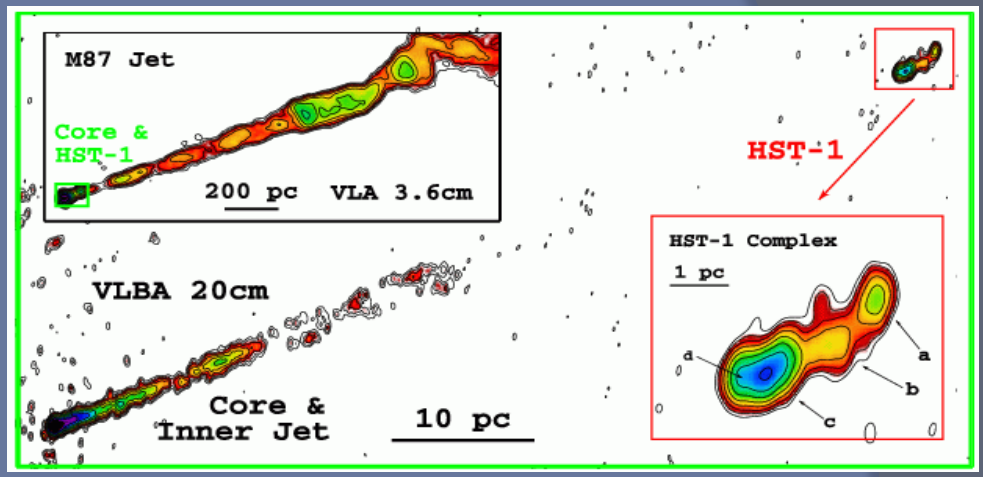
Distance: 3.8Mpc
Flux: 0.8% in Crab Unit
Spectral Index: -2.7

Cross: the best location (COG)
Circle: 95% C.L. VHE extension limit

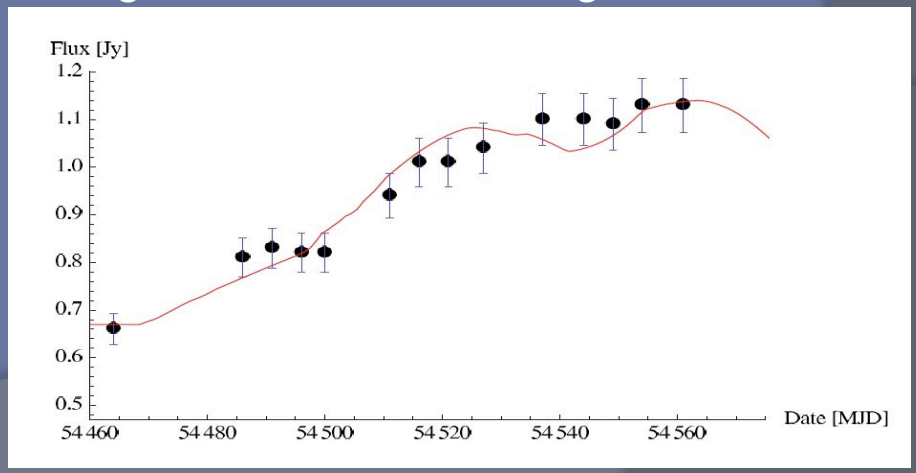
$L_{VHE} \sim 2.6 \times 10^{39}$ erg s-1
$L_{UHECR} \sim 10^{40}$ erg s-1

M87 flare in 2008: VERITAS, MAGIC, HESS, VLBA

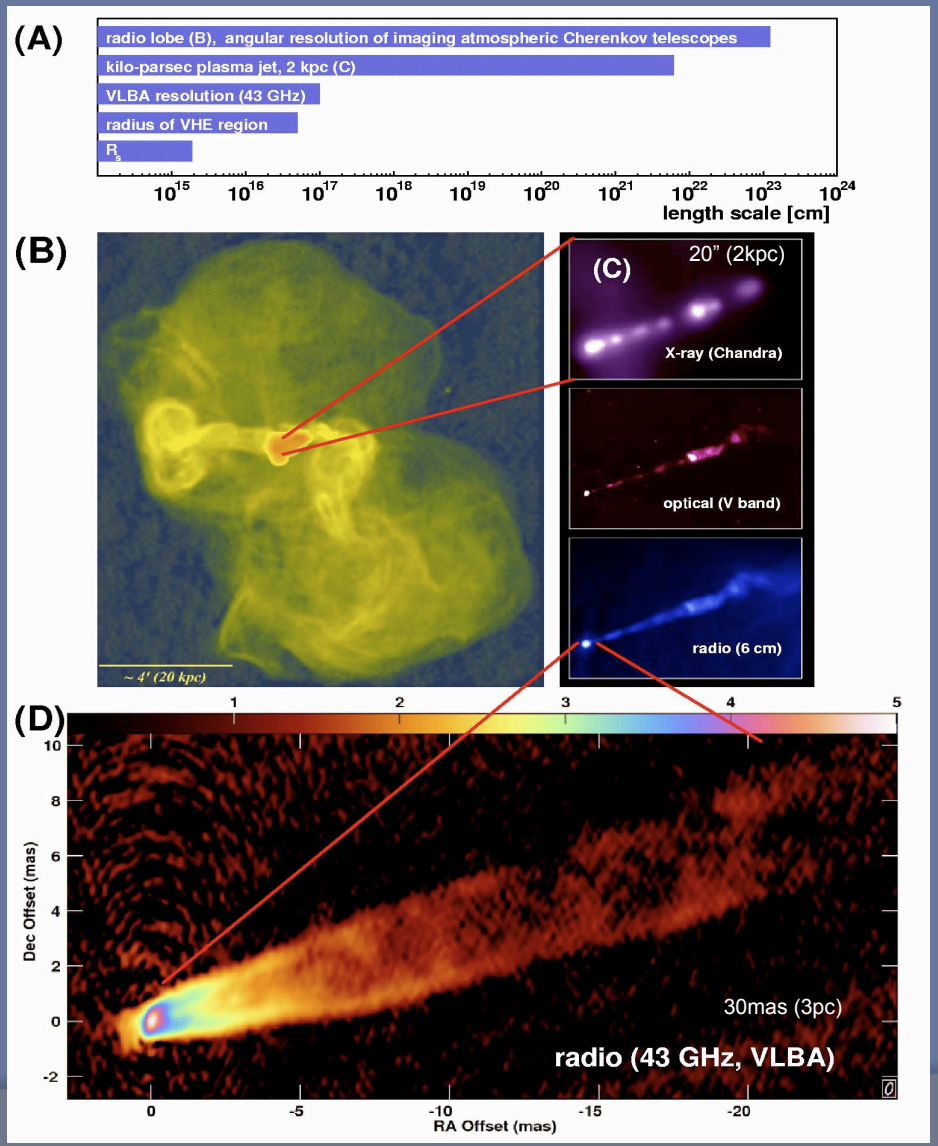


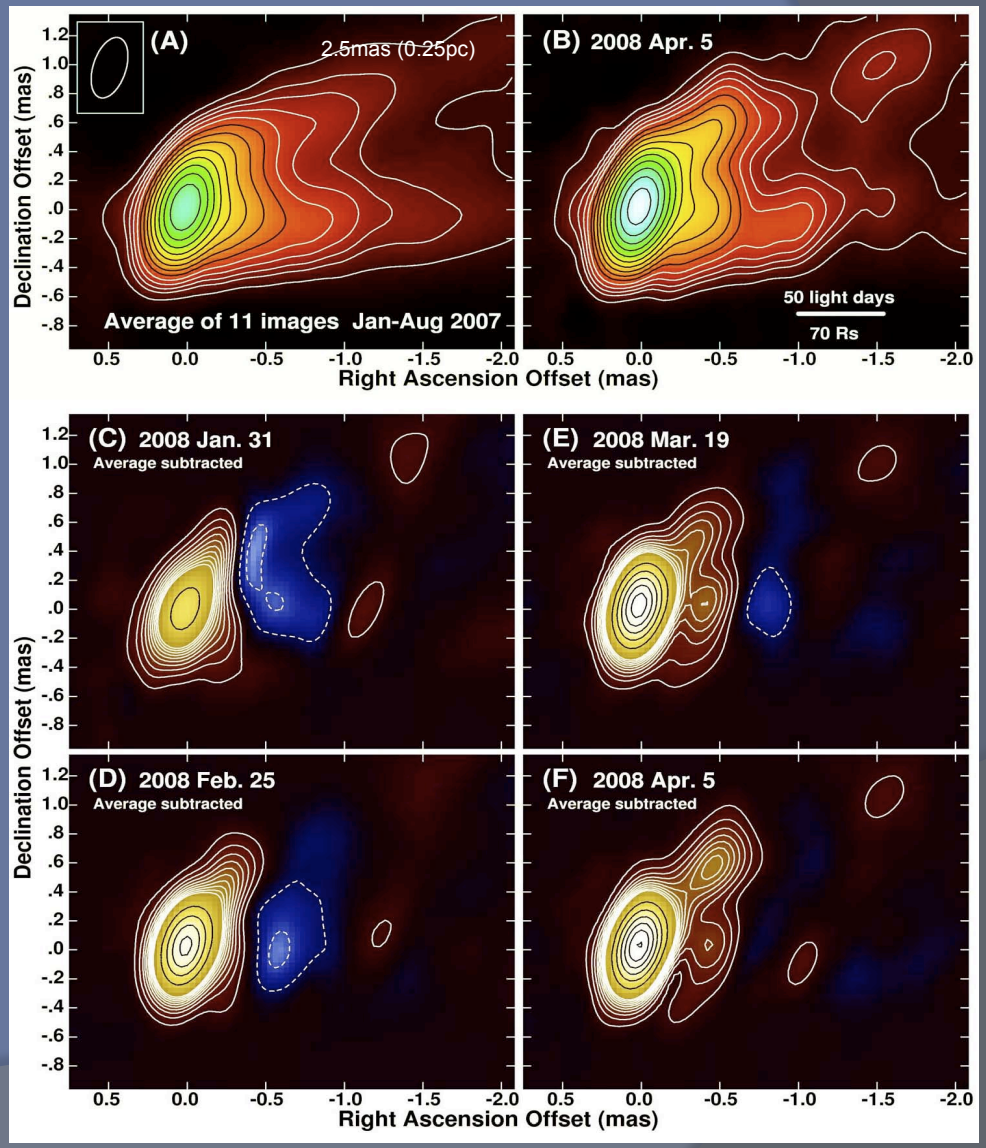


Model of 43GHz Radio flux
using the measured VHE gamma flux

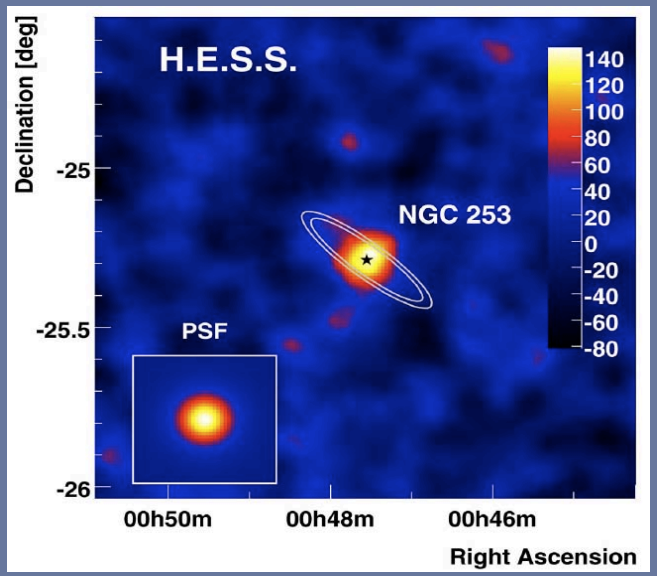


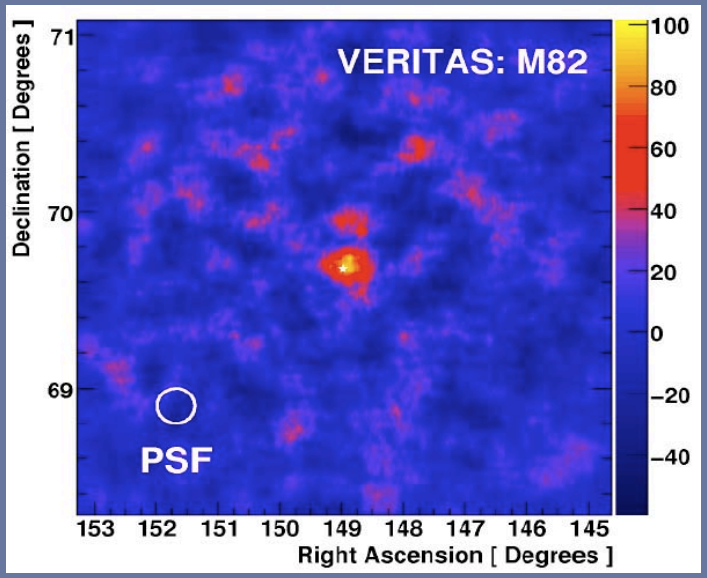
M87 flare in 2008:
VERITA, MAGIC, HESS, and VLBA

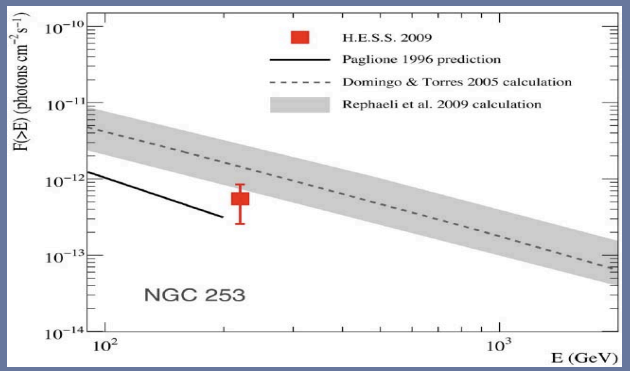


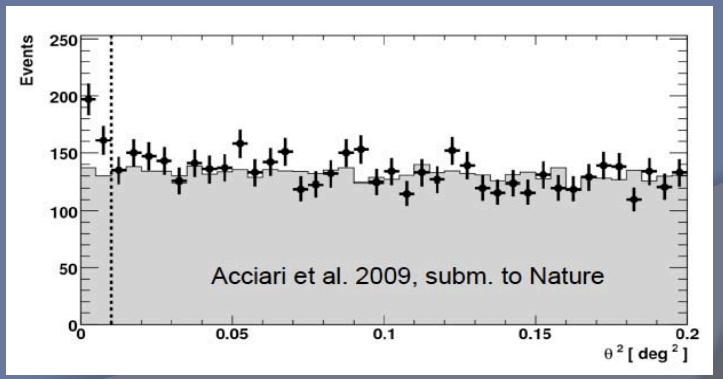


Starburst galaxies
NGC253 (by HESS), M82 (VERITAS)







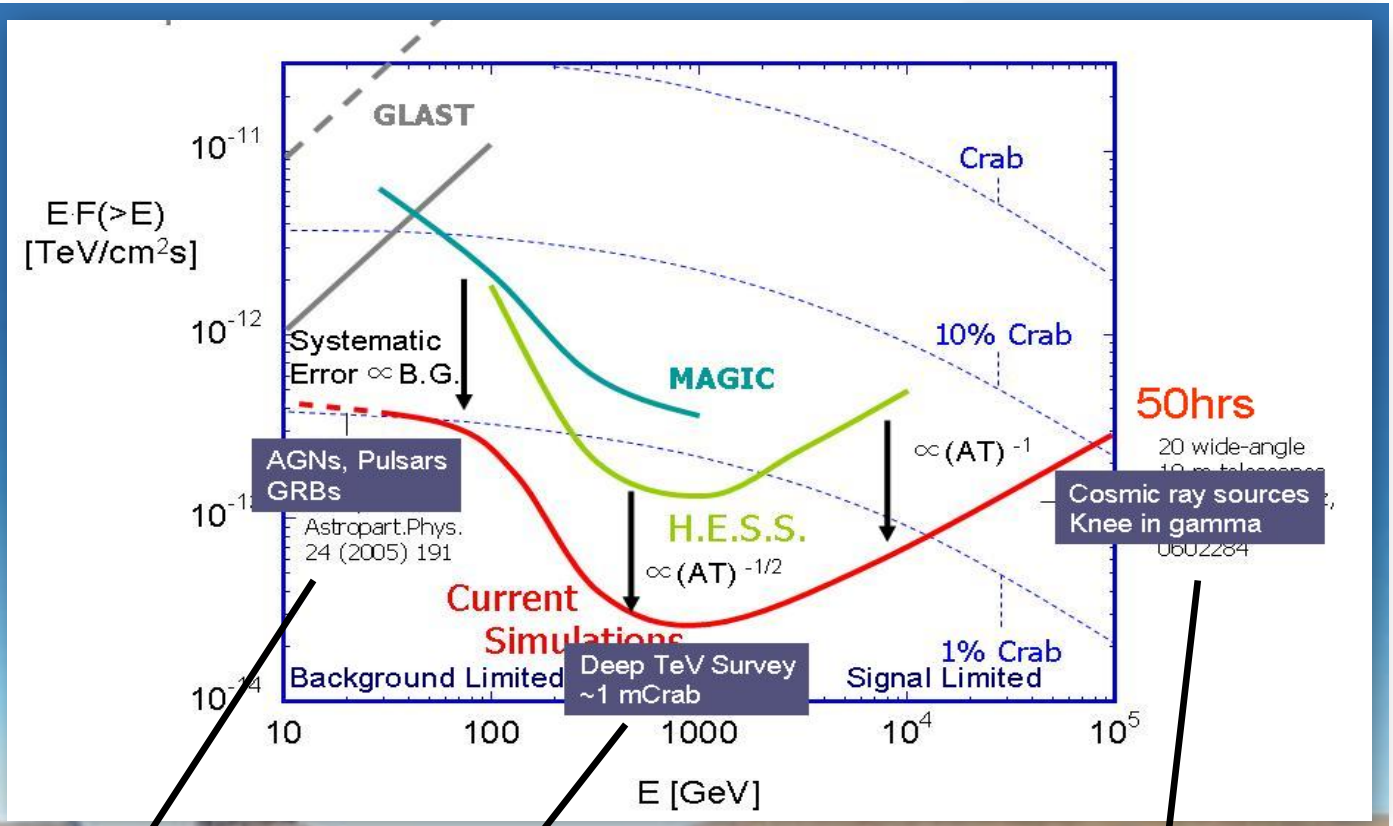


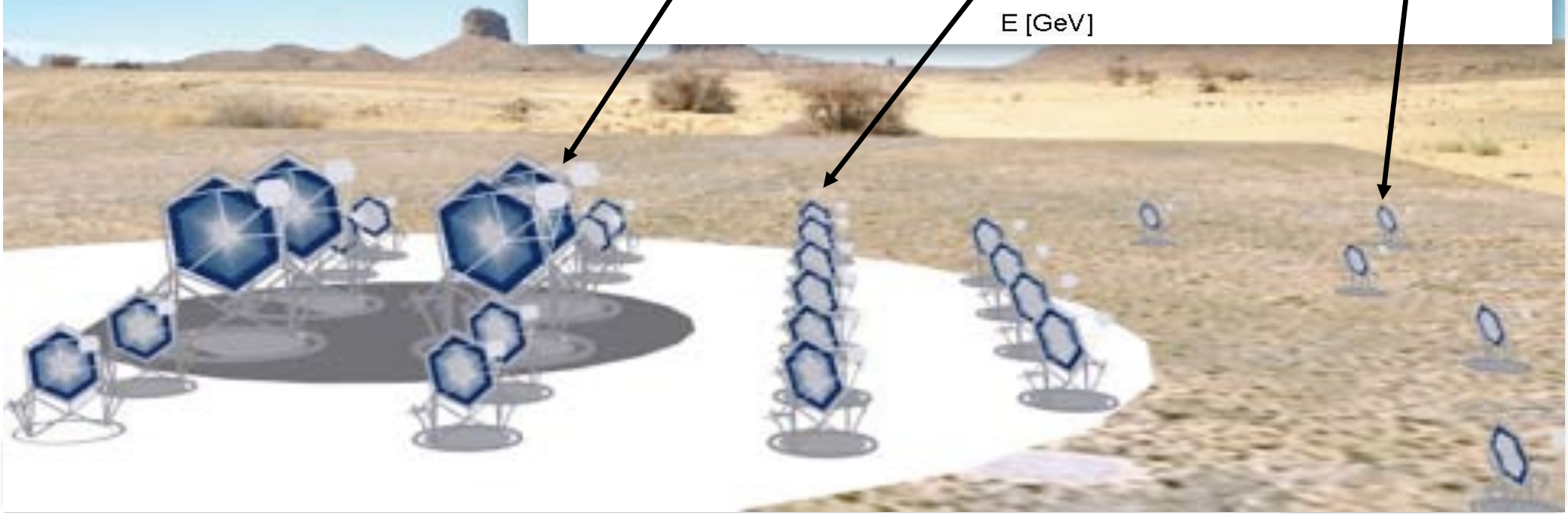
119hrs, >220GeV, 247 photons, 0.3% Crab

137hr, >700GeV, 91photons, 0.9 % Crab

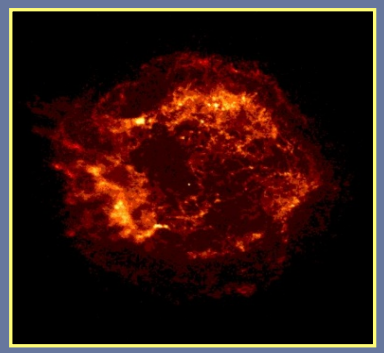

Toward Bright
Future

CTA

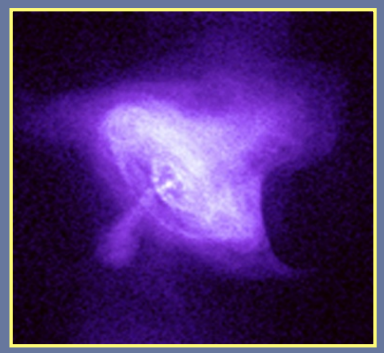

GLAST
Crab
10% Crab
1% Crab
MAGIC
H.E.S.S.
Systematic
Error ∝ B.G.
∝ (AT) -1
∝ (AT) -1/2
50hrs
20 wide-angle
AGNs, Pulsars
GRBs
Astropart.Phys.
24 (2005) 191
Cosmic ray sources
Knee in gamma
Current
Simulations
Deep TeV Survey
~1 mCrab
Background Limited
Signal Limited
E·F(>E)
[TeV/cm²s]
E [GeV]
10
100
1000
10⁴
10⁵
10⁻¹¹
10⁻¹²



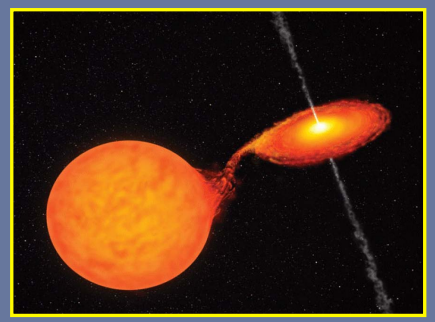
Guaranteed sources
Galactic sources



SNRs

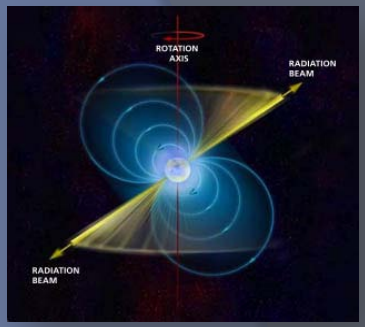


PWNe

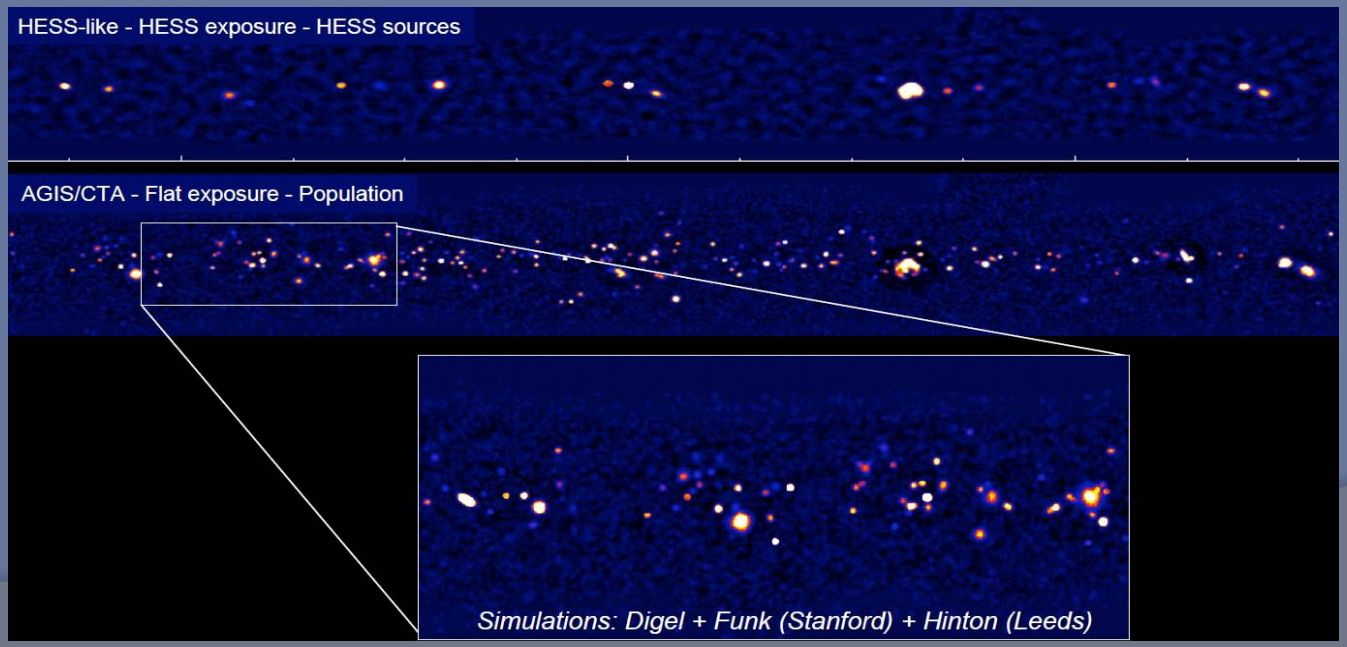


Micro quasars
X-ray binaries

Un-ID sources
Dark Sources



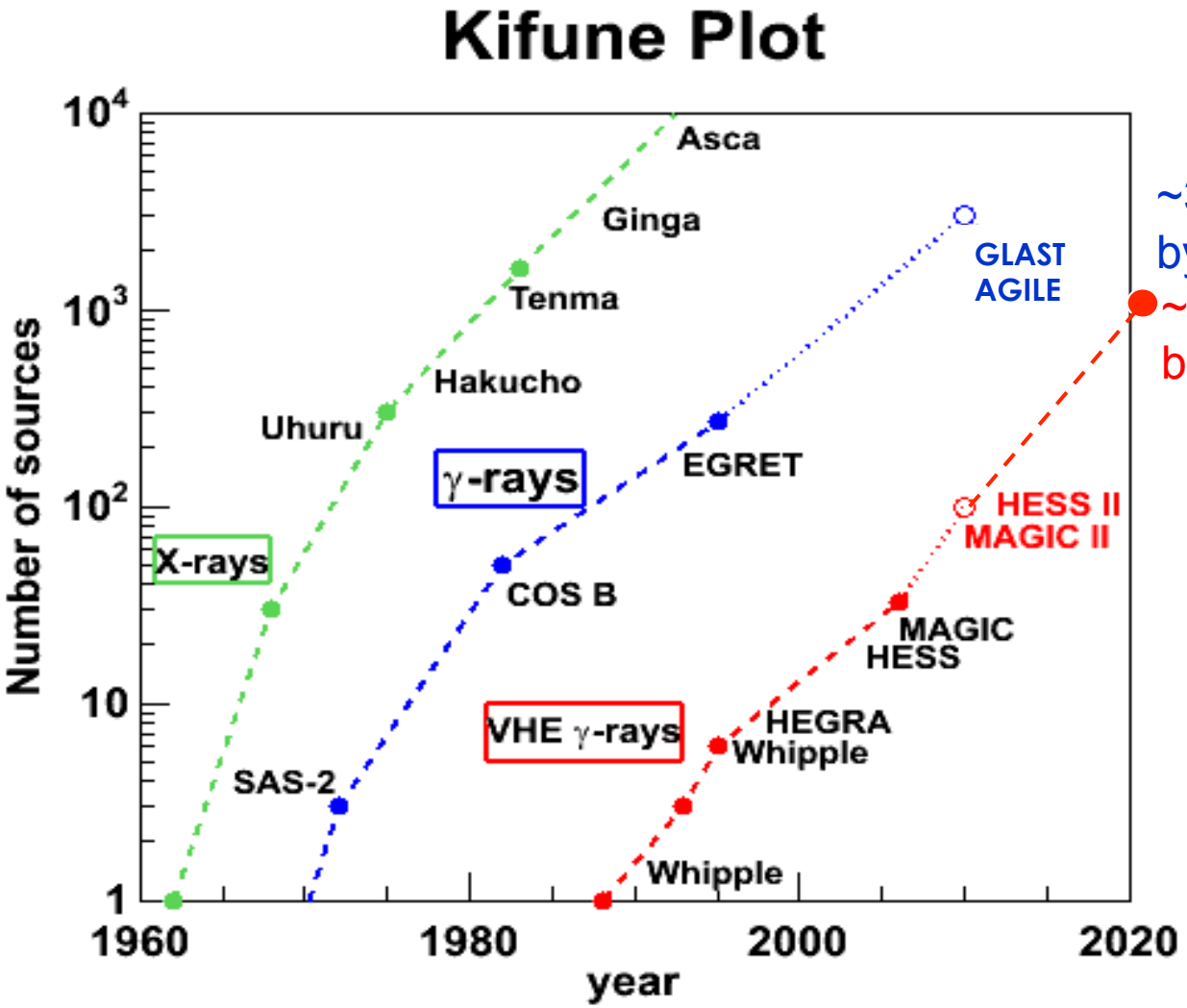
Pulsars



Galactic sources
200~400 sources with CTA

Where is PEVATRON???

Kifune Plot
(expectation from log S - log N)



~3000 sources
by GLAST, AGILE
~1000 sources
by CTA

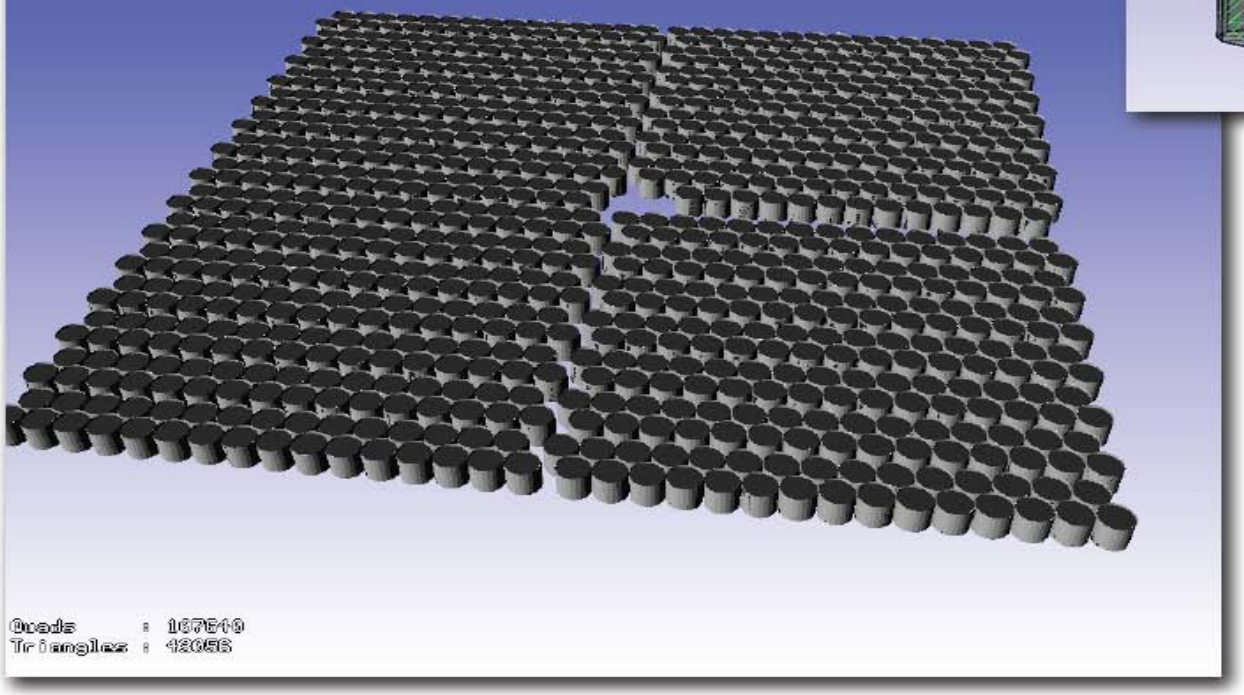
AGIS

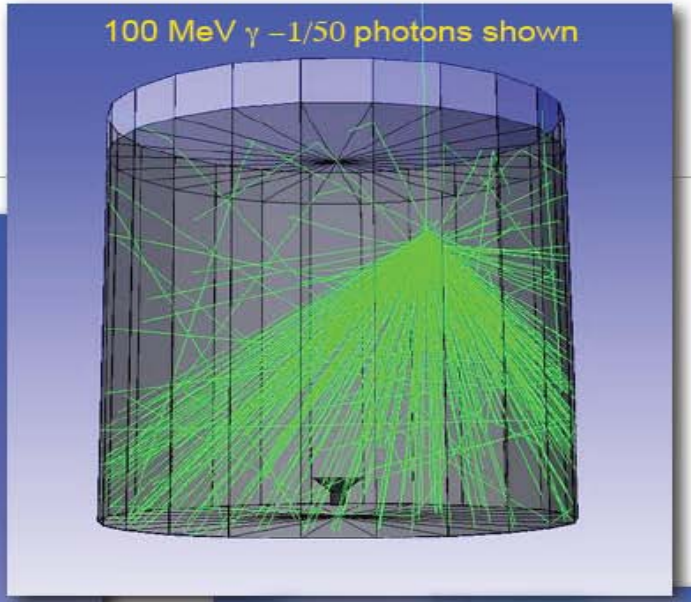
Advanced Gamma Imaging System

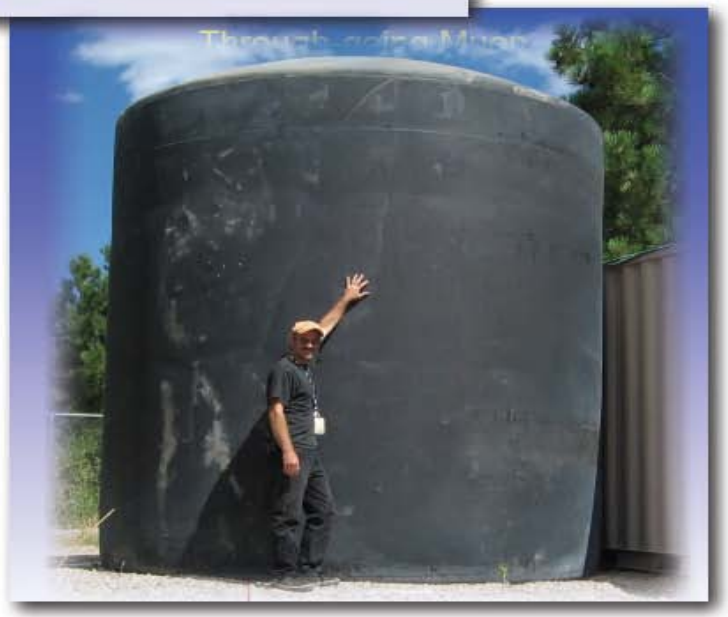
HAWC

HAWC Design

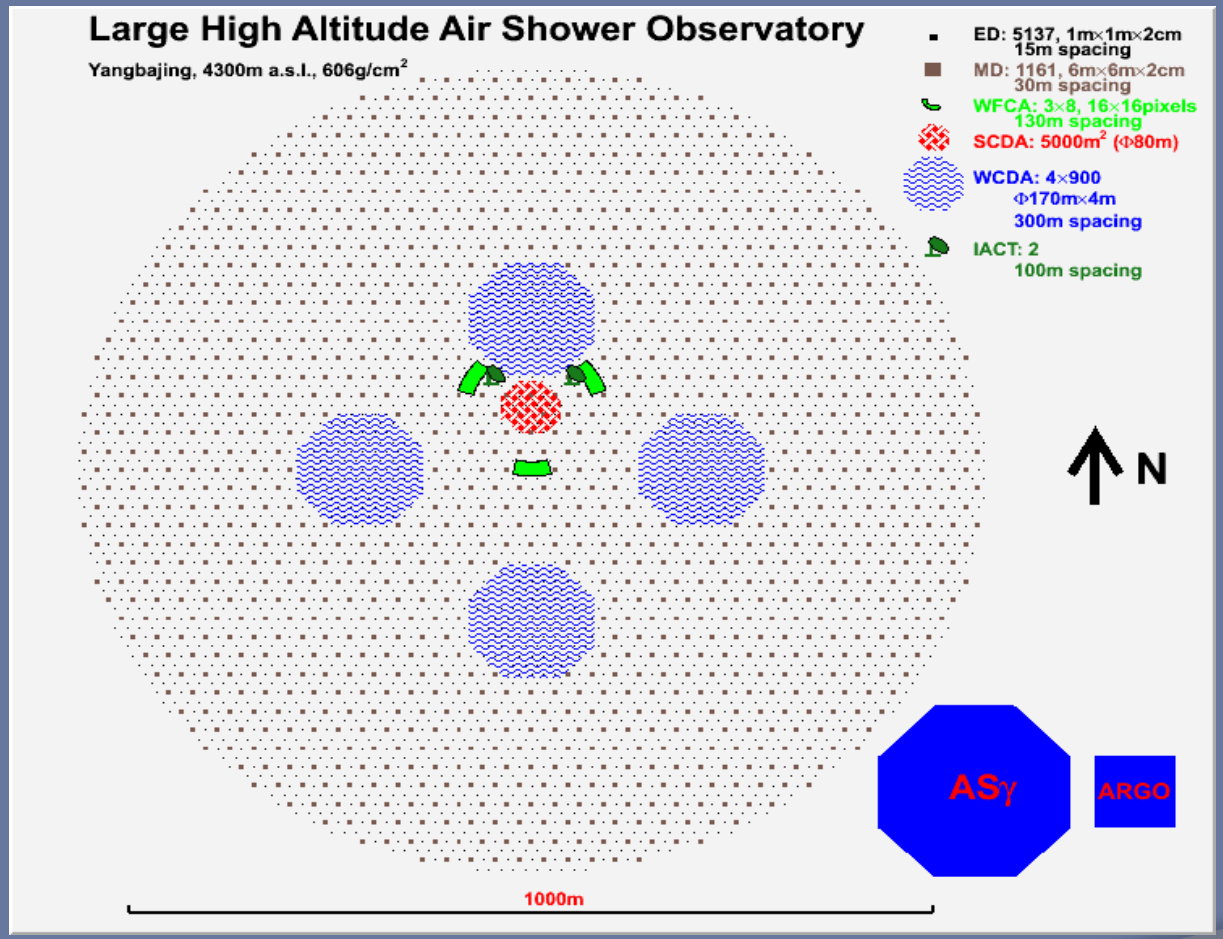
Array of 900 water tanks
5 m diameter x 4 m deep

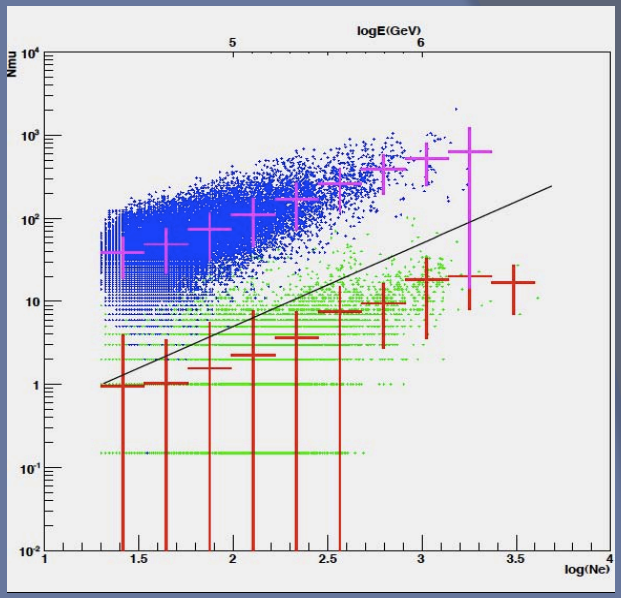


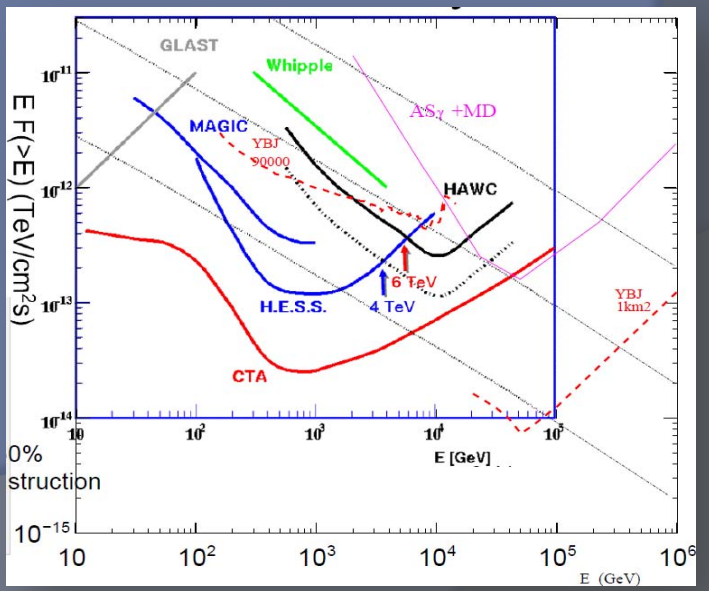




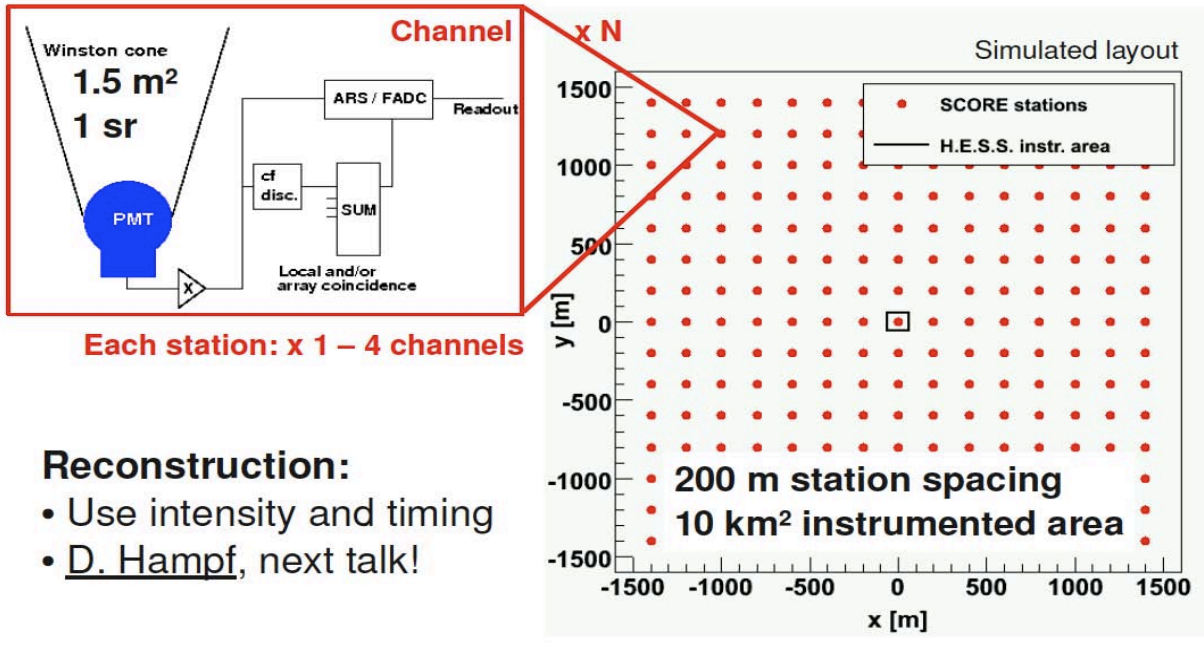
LHAASO


Large High Altitude Air Shower Observatory
Yangbajing, 4300m a.s.l., 606g/cm²
ED: 5137, 1m×1m×2cm
15m spacing
MD: 1161, 6m×6m×2cm
30m spacing
WFCA: 3×8, 16×16pixels
130m spacing
SCDA: 5000m² (Φ80m)
WCDA: 4×900
Φ170m×4m
300m spacing
IACT: 2
100m spacing
N
ASγ
ARGO
1000m


logE(GeV)
Nmu
log(Ne)

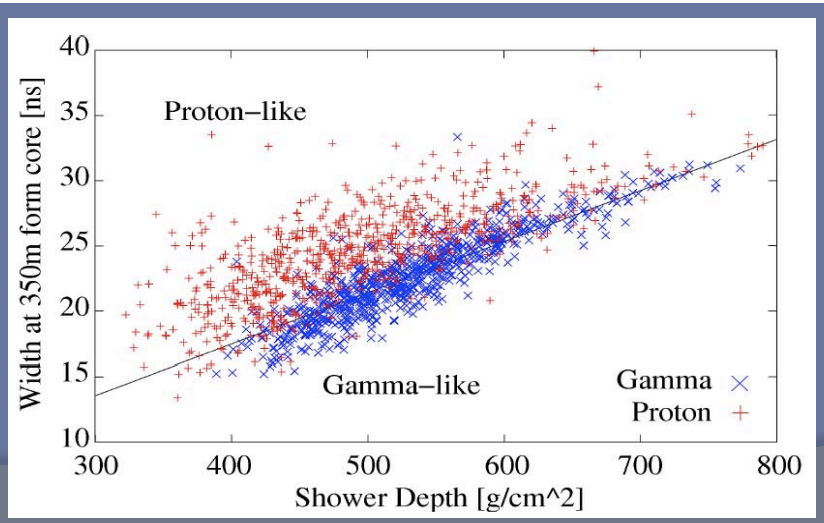

GLAST
Whipple
ASγ +MD
MAGIC
YBJ
90000
HAWC
6 TeV
H.E.S.S.
4 TeV
YBJ
1km2
CTA
E F(>E) (TeV/cm²s)
E [GeV]
0%
struction
E (GeV)

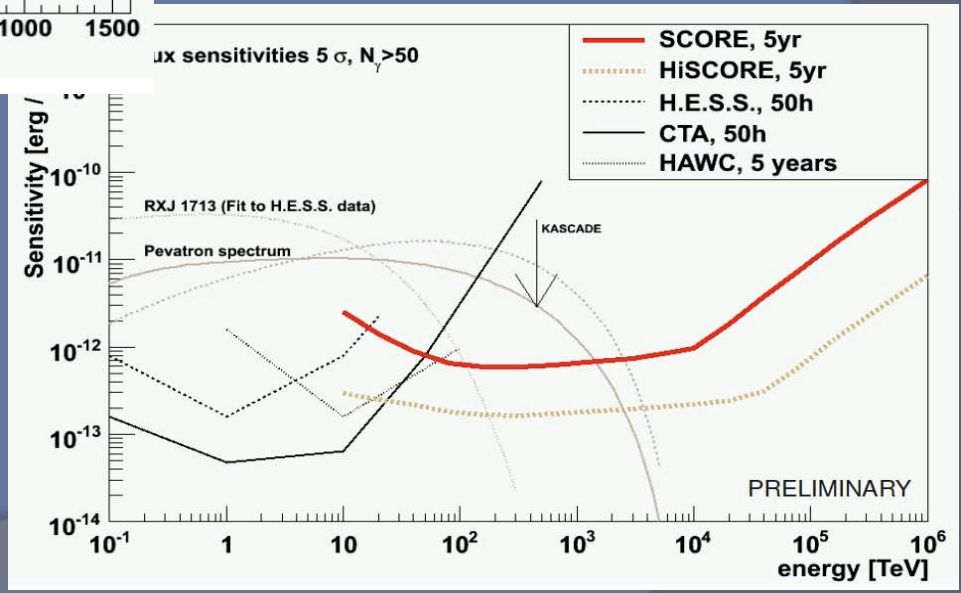
SCORE / HISCORE



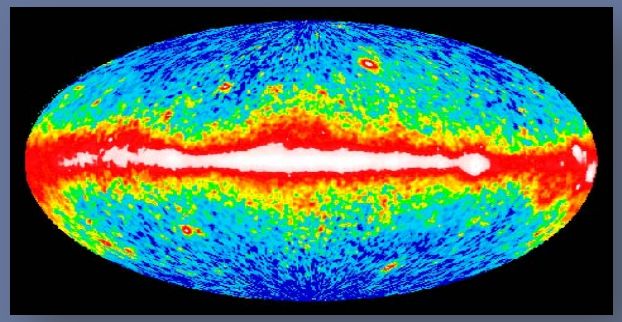
Reconstruction:

- Use intensity and timing
- D. Hampf, next talk!

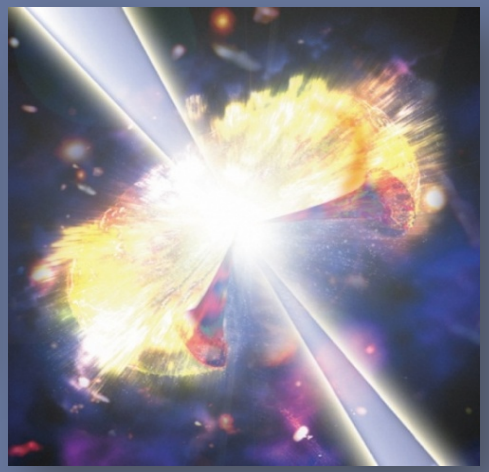




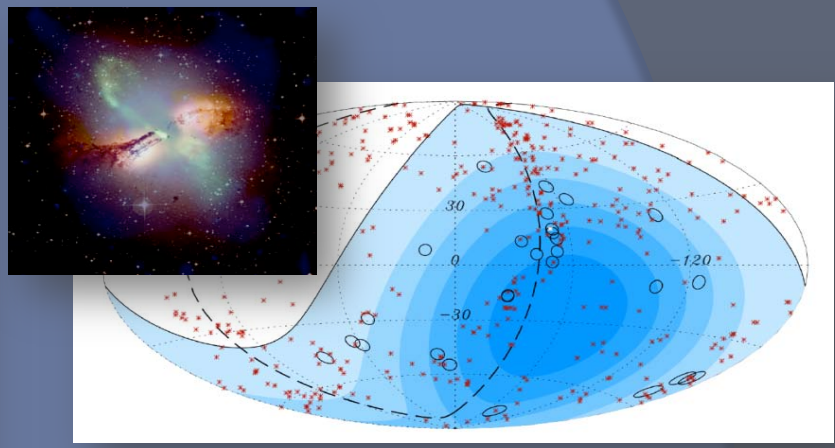
Possible New Classes of Sources



Galactic Diffuse

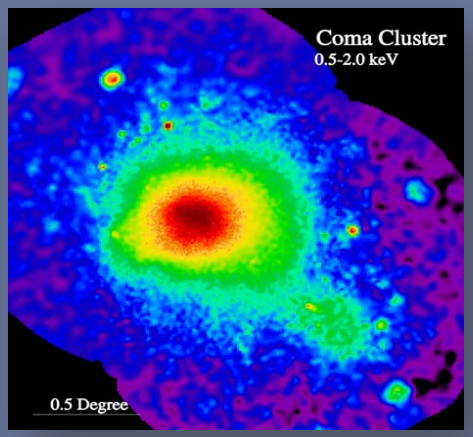


GRBs

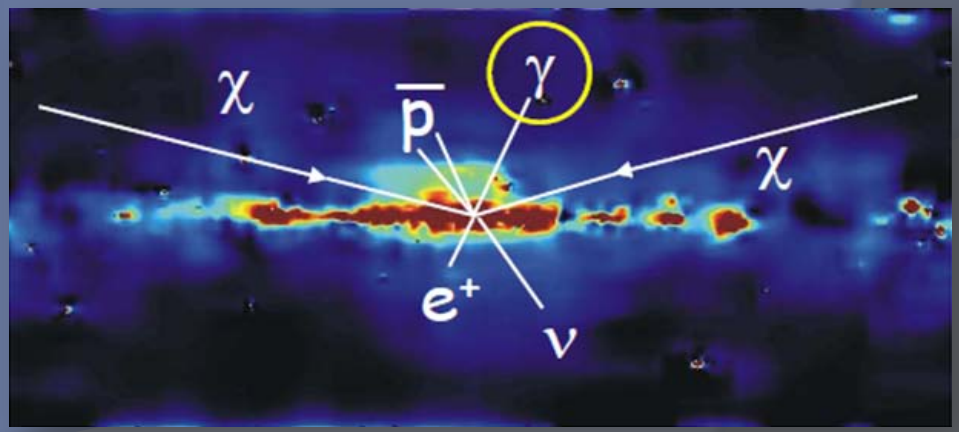


UHECR Sources

Starburst galaxies
Galaxy mergers



Clusters of galaxies



Dark Matter Annihilation

Summary

- The number of VHE sources is rapidly increasing
- Types of sources
  - SNR, Pulsar, PWN, HBL, IBL, LBL, FSRQ,, FR-I, Starburst Galaxies

- Very fast time variation – a few minutes
  - Mkn501, PKS2155
- Nearby bright sources, Intensity variation x 50
  - Mkn421, Mkn501, PKS2155
- Distant sources
  - Room for the extra component (Pop-III) in EBL is now very small
- Very strong limit on the linear term of LIV → search for second term
- LAT GRBs show >30GeV photons ← at the source >60-90GeV

- Prospects
  - There are several promising future projects
  - Wide energy coverage in gamma ray (several decades) → source
  - High time resolution → source, fundamental physics
  - High quality data (good S/N) → DM search


THANKS