High energy sources: counterparts, synergies

Alberto Carramiñana

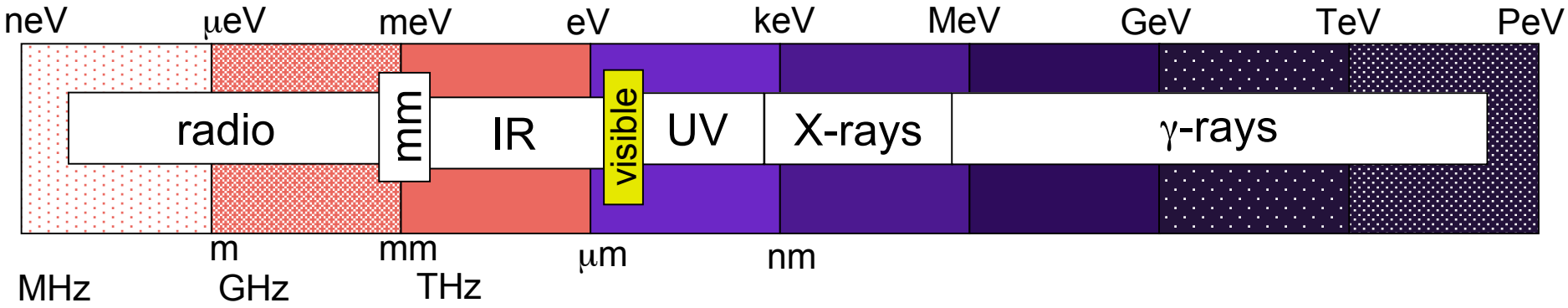
Instituto Nacional de Astrofísica, Óptica y Electrónica

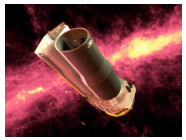
Tonantzintla, Puebla, México

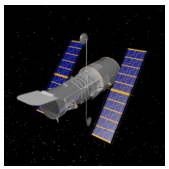
GH 2008, 15 August 2008

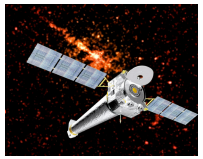
The high energy bands / sky

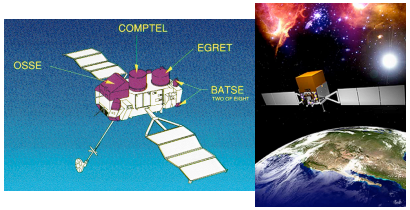
- All sky γ-ray surveys: CGRO (1991-2000)
  - Comptel: 0.7 - 30 MeV (not in this talk)
  - EGRET: 30 MeV - 30 GeV $\longrightarrow$ GLAST
- Half sky survey (2000-2008):
  - Milagro: > 1 TeV $\longrightarrow$ HAWC
- Cherenkov telescopes:
  - high sensitivity pointed observations + limited surveys (HESS-GP + Veritas-Cygnus)

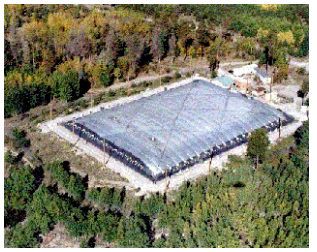












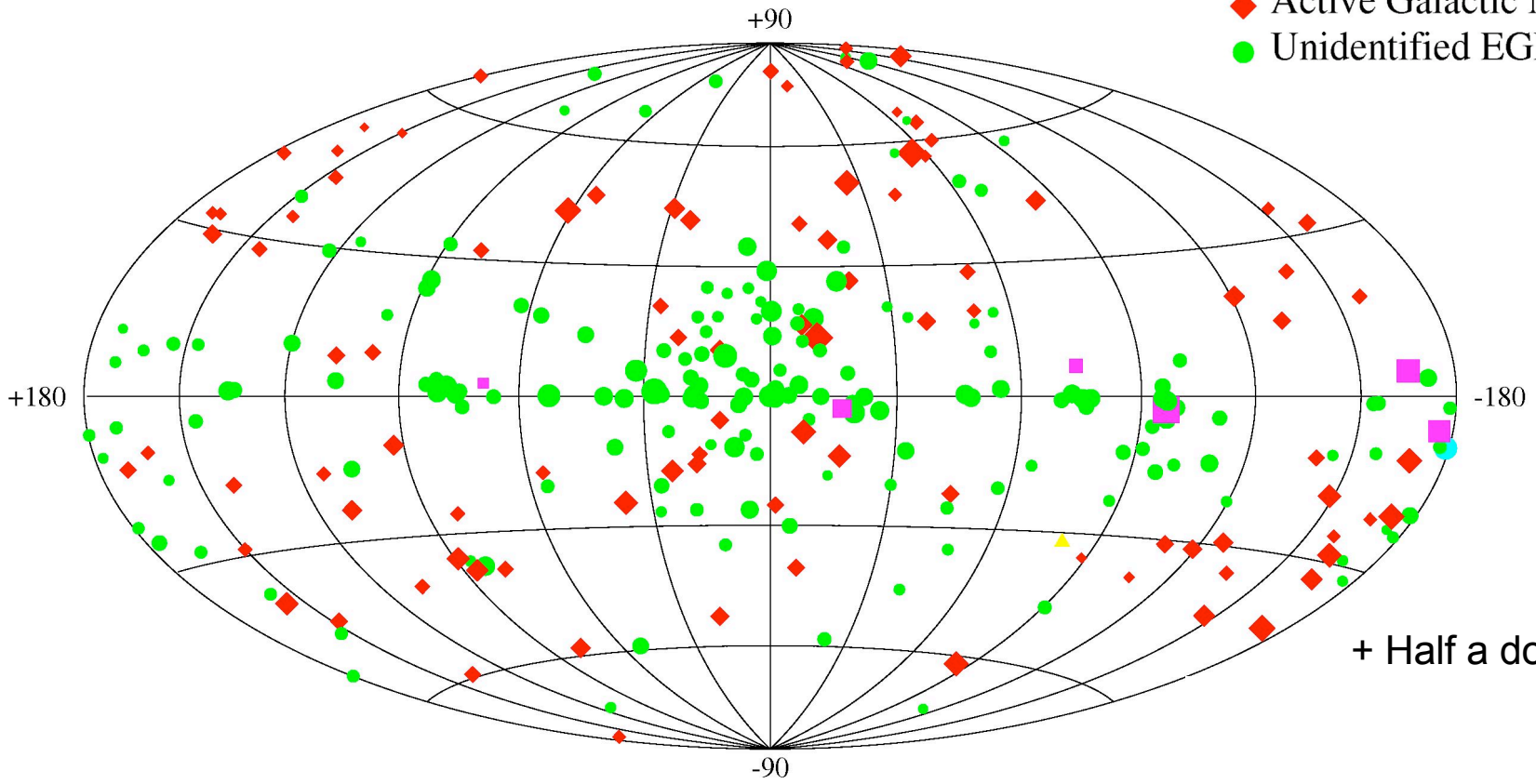
Thermal

3 K 3000 K 10^8 K

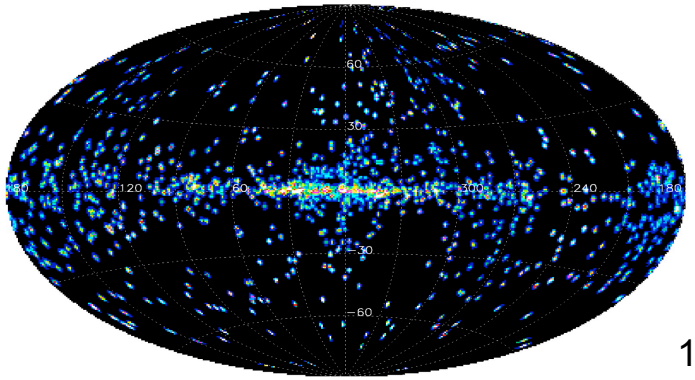
Third EGRET Catalog

E > 100 MeV

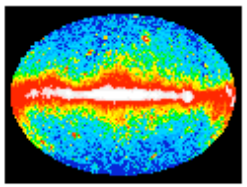
- Pulsars
- LMC
- Solar FLare
- Active Galactic Nuclei
- Unidentified EGRET Sources

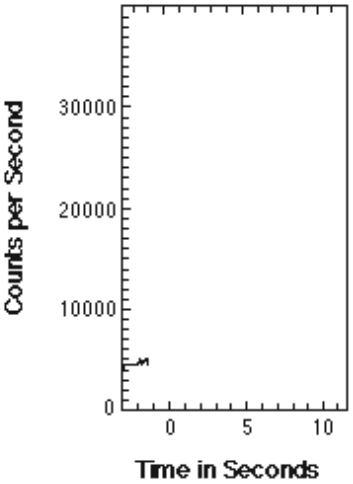


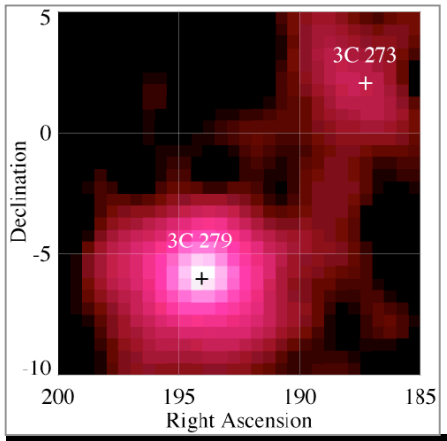
+ Half a dozen GRBs

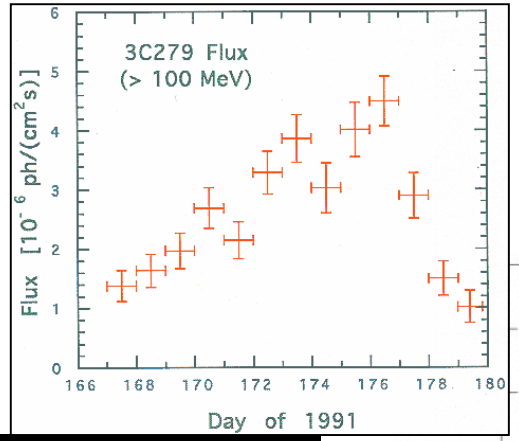


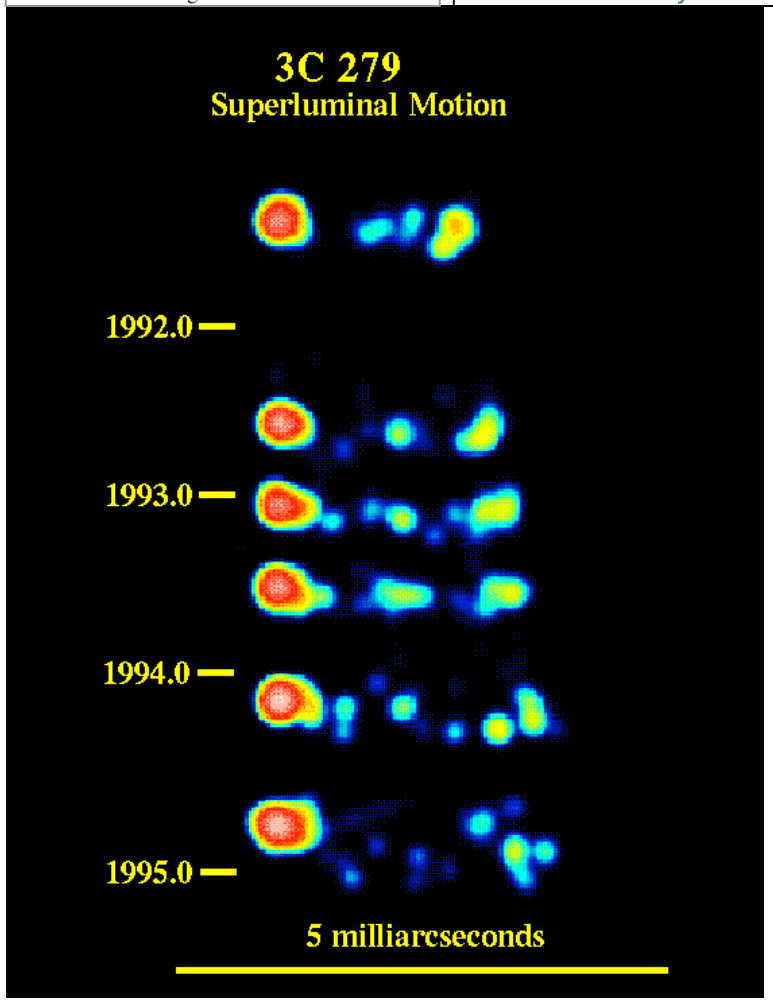
1509 photons >10 GeV

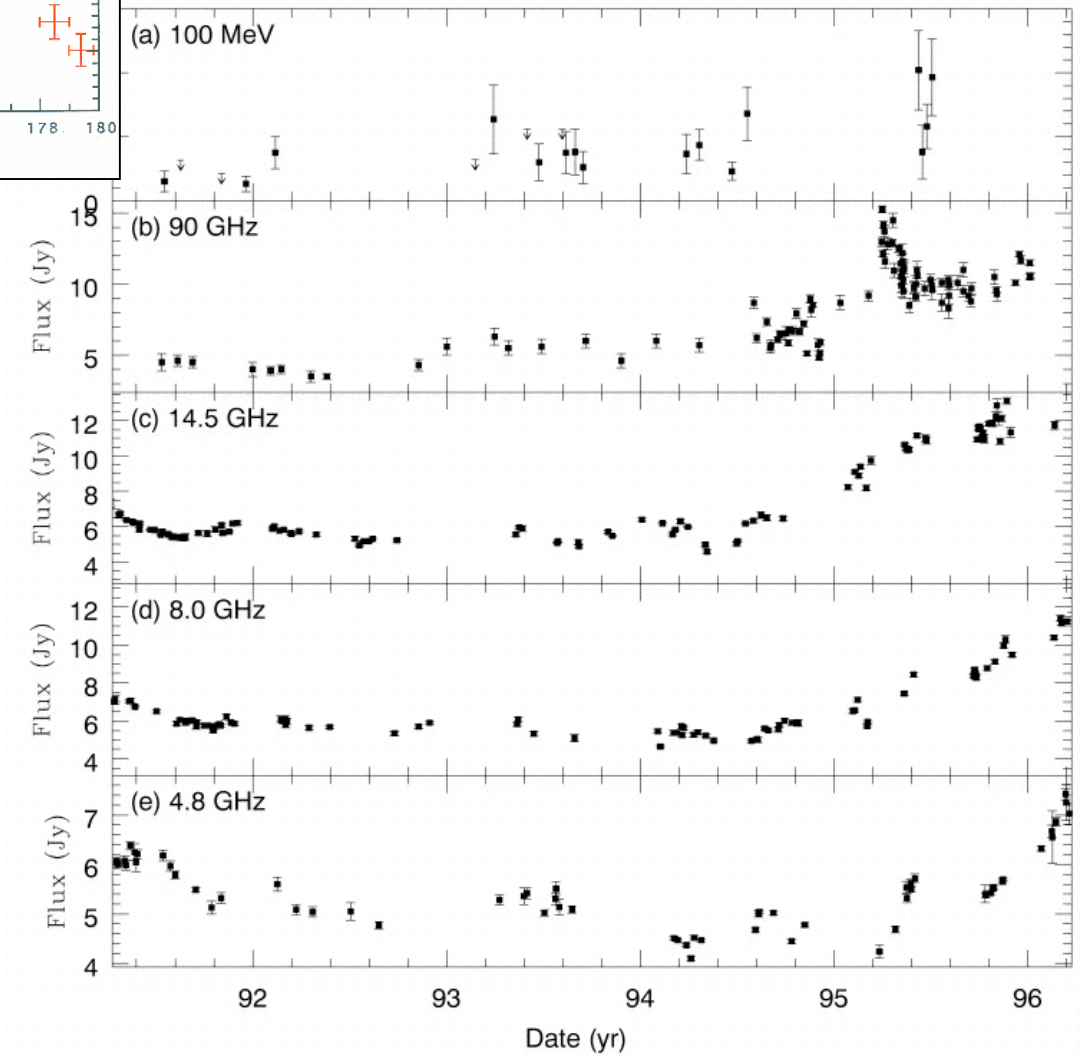





3C 273
3C 279
Declination
Right Ascension
5
0
-5
-10
200
195
190
185

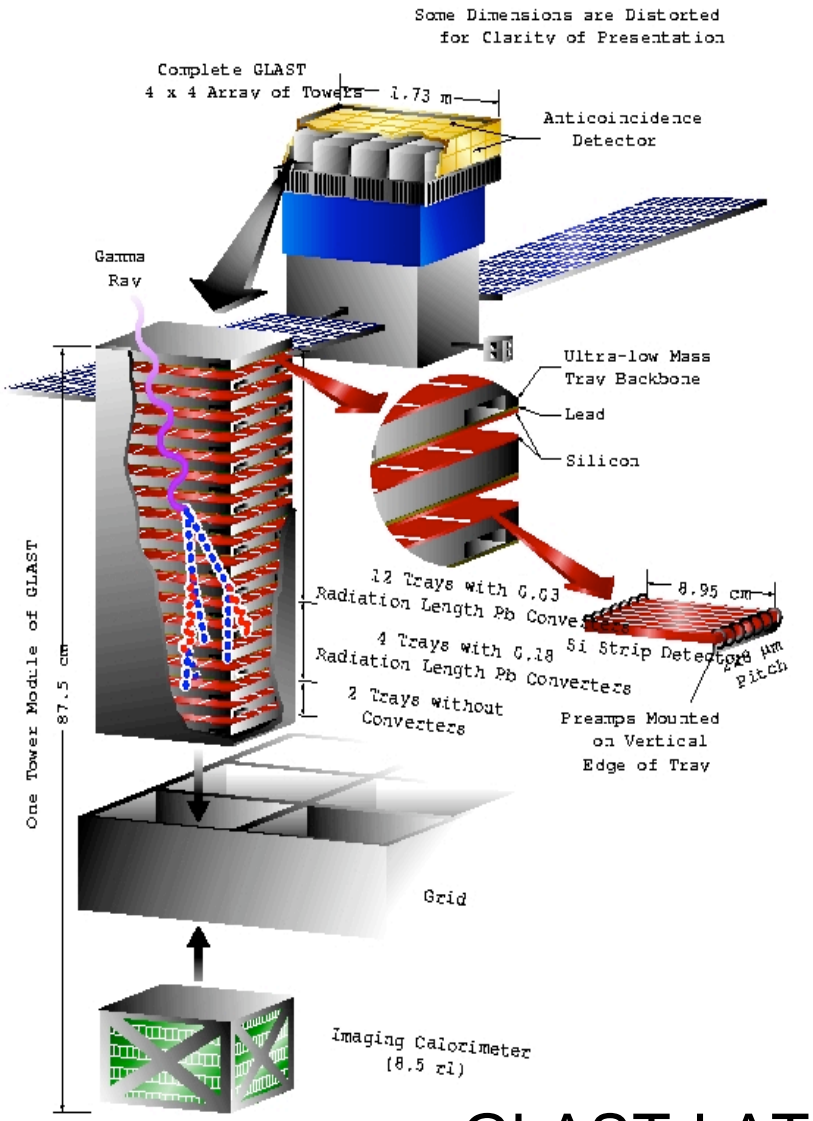

3C279 Flux
(> 100 MeV)
Flux [10⁻⁶ ph/(cm²s)]
Day of 1991
166
168
170
172
174
176
178
180


3C 279
Superluminal Motion
1992.0
1993.0
1994.0
1995.0
5 milliarcseconds


(a) 100 MeV
(b) 90 GHz
(c) 14.5 GHz
(d) 8.0 GHz
(e) 4.8 GHz
Flux (Jy)
Date (yr)
92
93
94
95
96

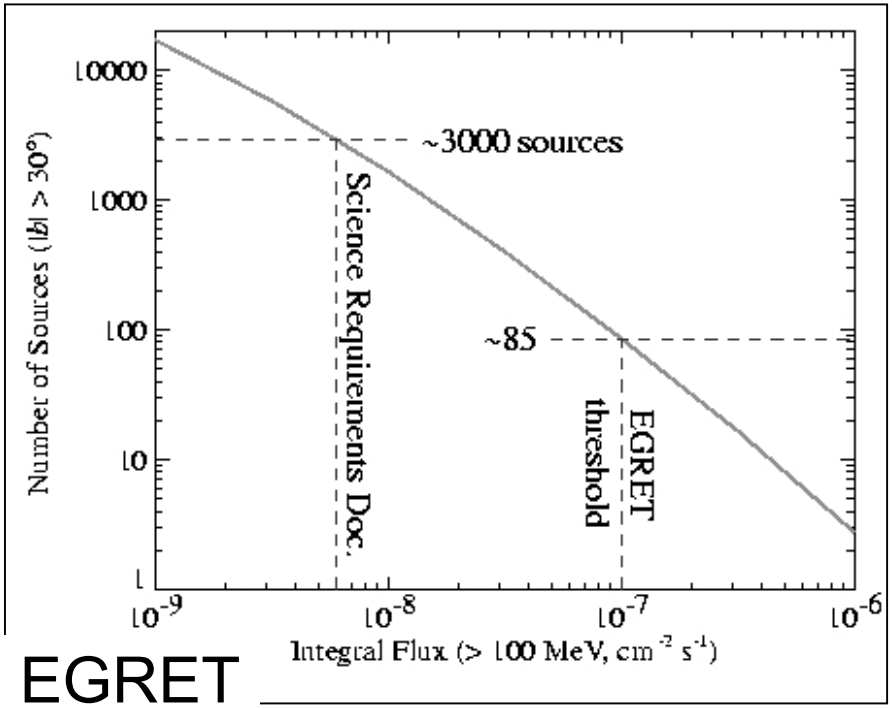
NRAO 530

GLAST



Gamma-ray Large Aperture Telescope

- larger detector efficiency ⇒ larger $\{A_e, \Omega\}$
  - $A_e \approx 1 m^2 \approx 10$ EGRETs
  - FOV ≈ 2.5 sr ≈ 3 EGRETs
- better tracking ⇒ better PSF
- better PSF + more photons ⇒ better locations (1 arcmin)

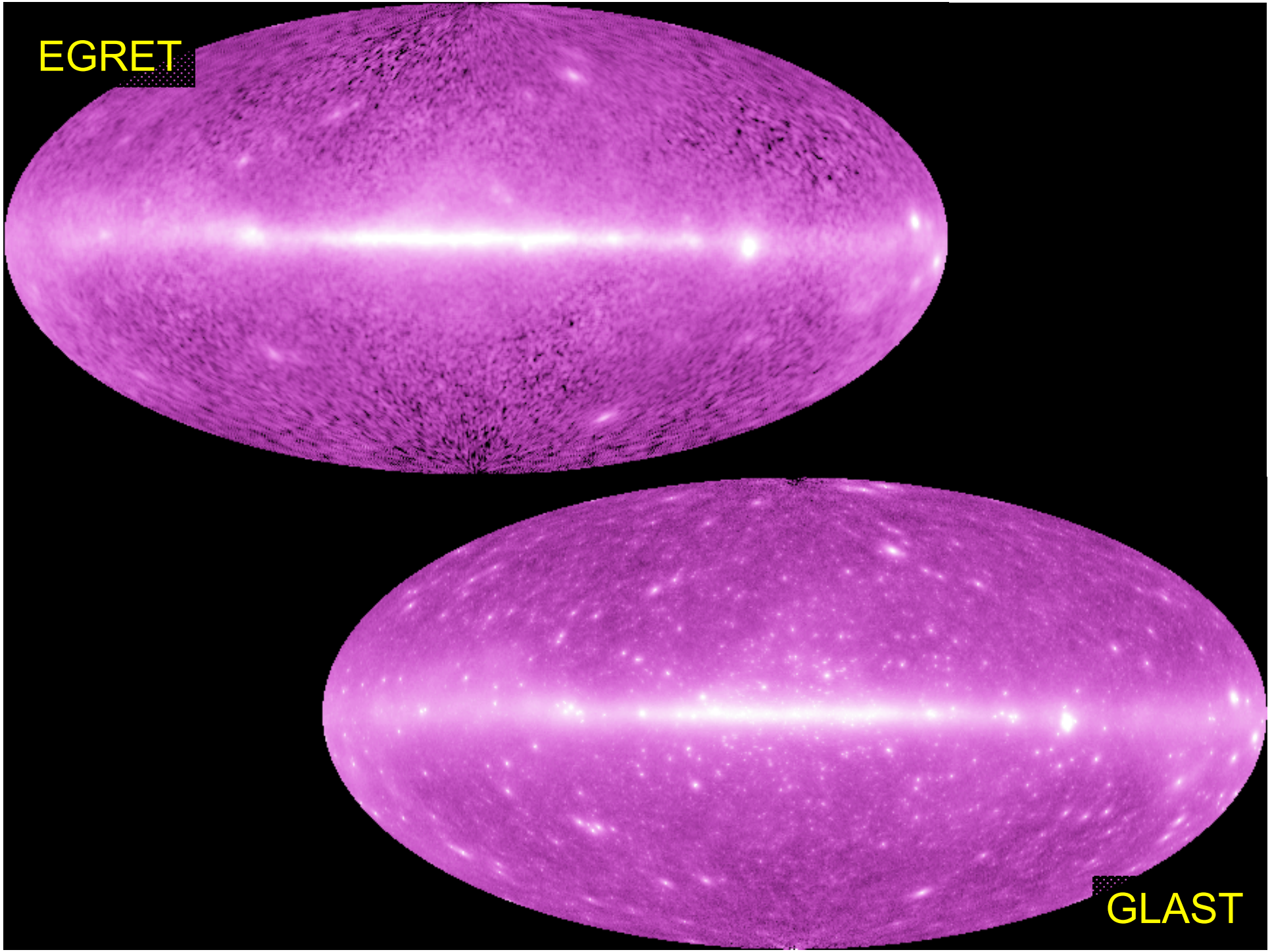


GLAST-LAT≈ 30 EGRET

GLAST - a formidable synoptic telescope

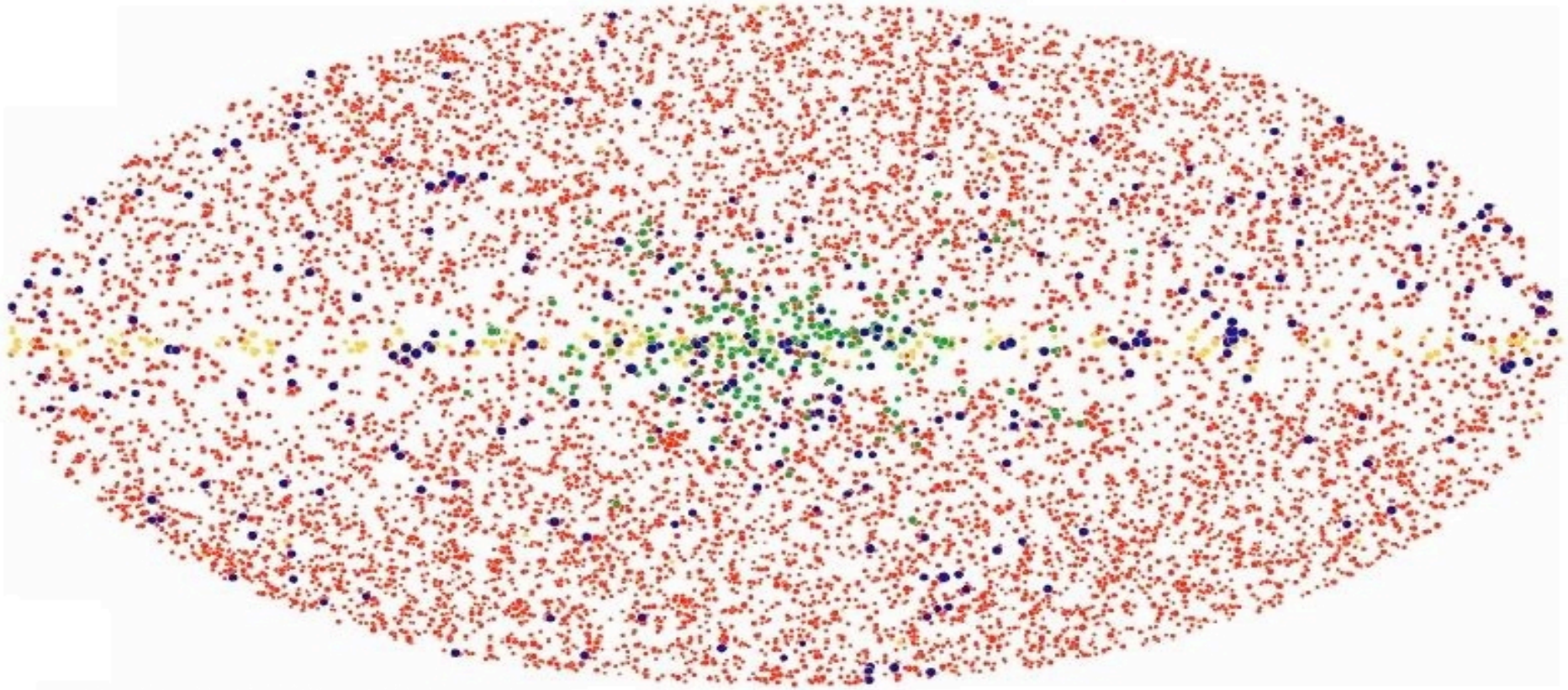
- All-sky surveys between 100 MeV and 100 GeV
- Instantaneous FOV ≈ 20% of the sky
- One sky survey every 3 hours (2 orbits)
- Source location = 1 arcmin

- To find up to 10,000 γ-ray sources


EGRET
GLAST

5σ Sources from Simulated One Year All-sky Survey

LIR galaxies?



Results of one-year all-sky survey.
(Total: 9900 sources)

AGN
3EG Catalog
Galactic Halo
Galactic Plane

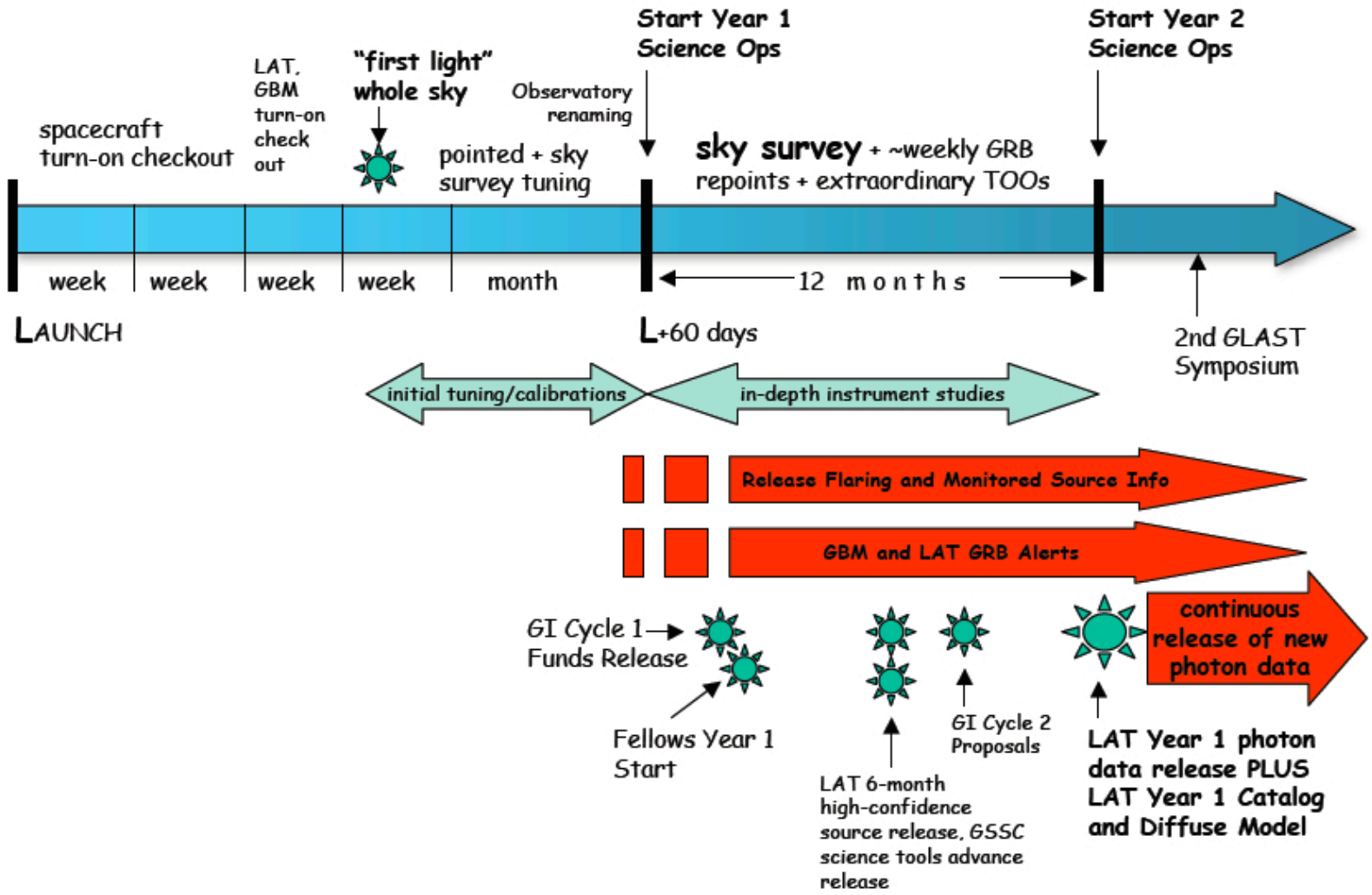
The GLAST era

Started

11th of June

11:05am

Year 1 Operations Timeline Overview



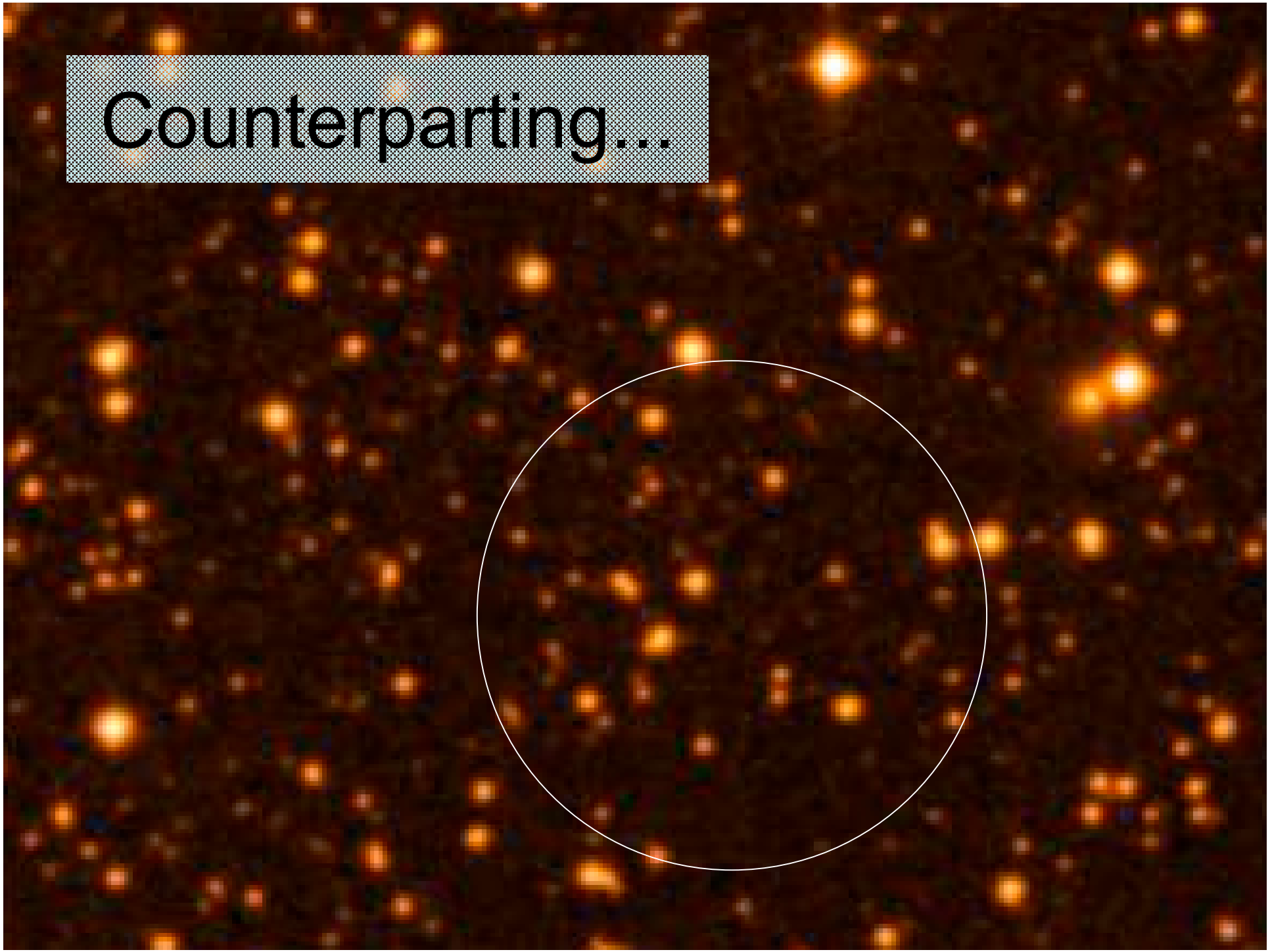
S. Ritz

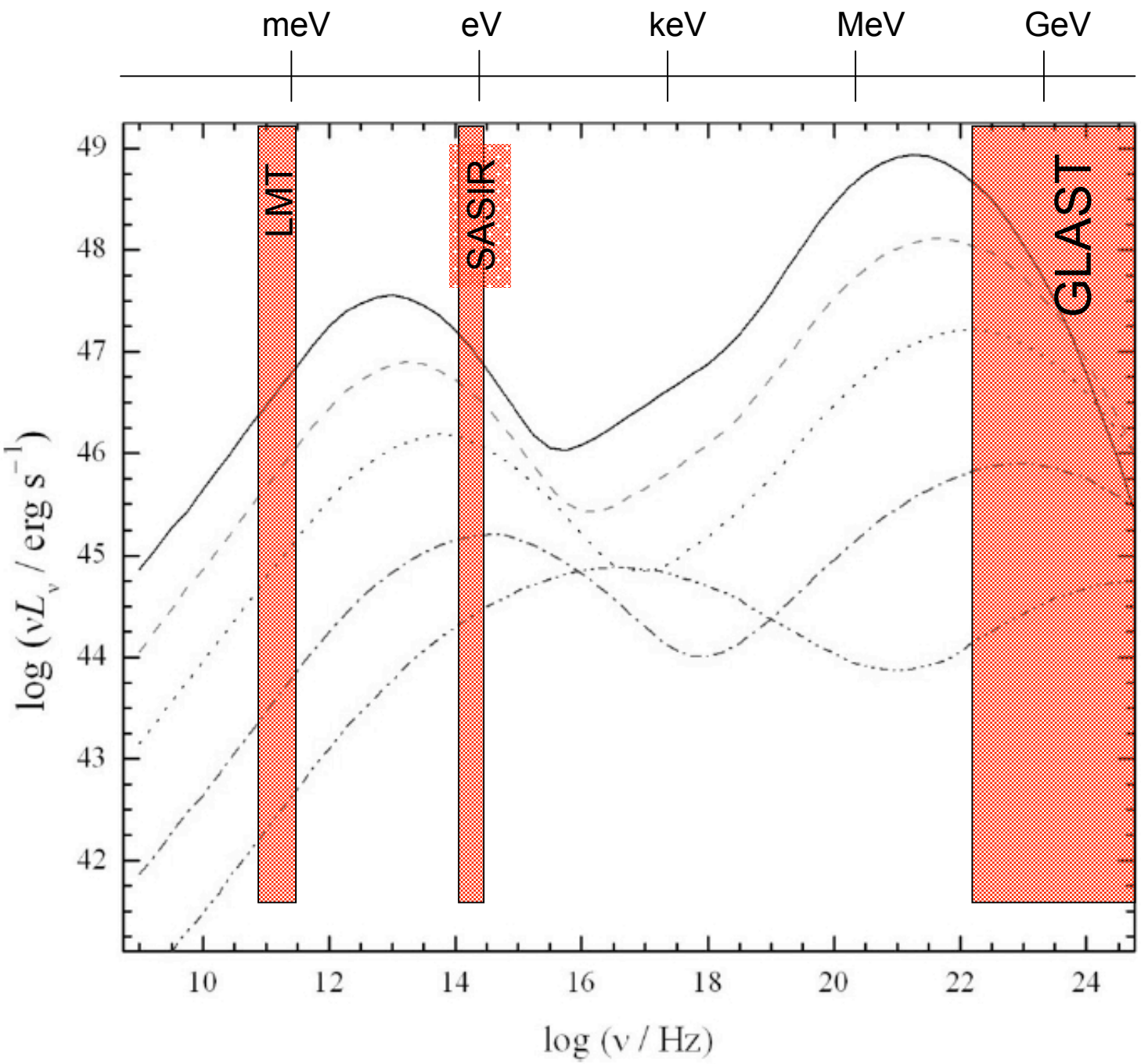
GLAST - LMT synergy

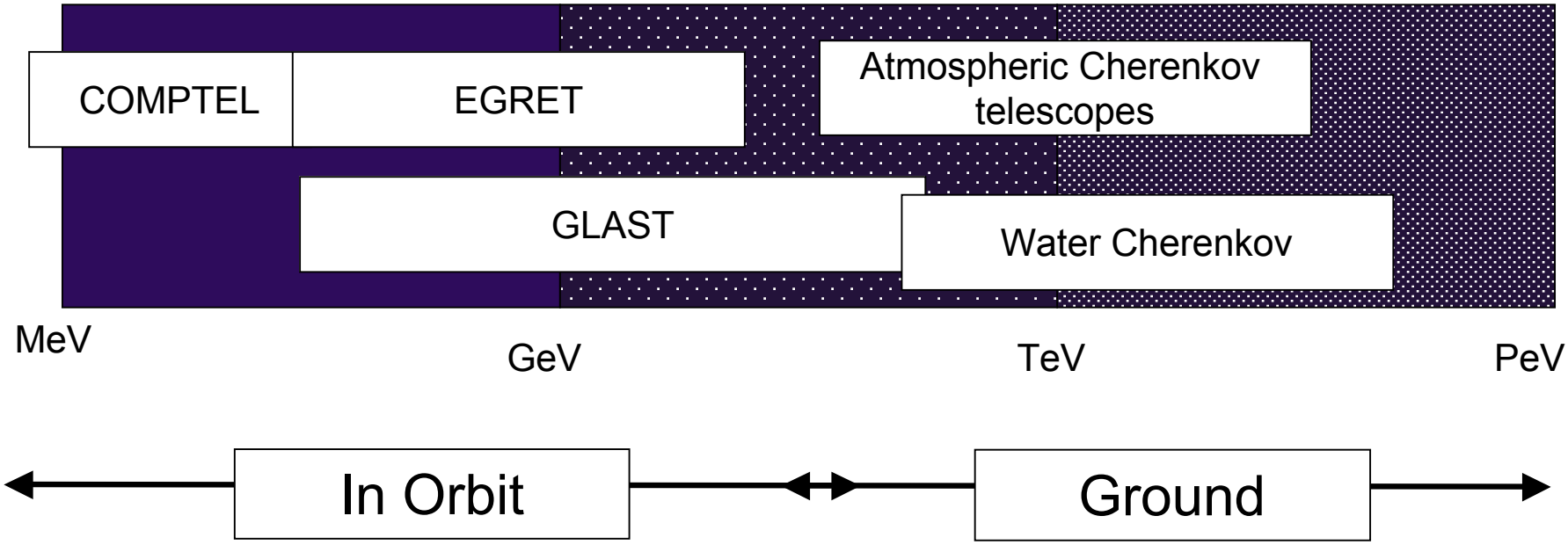
- γ-ray loud blazars:
  - EGRET - WMAP correspondence
  - EGRET reached $z \approx 3 \Rightarrow$ GLAST to $z \approx 7$
  - LMT can reach WMAP blazars @ $z \approx 30$
- GRBs:
  - thick-thin afterglow evolution
  - dust and SFR in GRBs hosts (Tanvir 2004)
- Unidentified GLAST sources:
  - LMT to test variability / spectra
  - ToO follow-ups including daytime

Adding SASIR?

	ν (Hz)	F_ν (Jy)	νF_ν (Hz Jy)
GLAST	2.4×10^{23}	6×10^{-14}	1.4×10^{10}
LMT	3×10^{11}	10^{-4}	3×10^{7}
SASIR	1.3×10^{14}	1×10^{-6}	1.3×10^{8}


Counterparting...


meV
eV
keV
MeV
GeV
LMT
SASIR
GLAST
49
48
47
46
45
44
43
42
10
12
14
16
18
20
22
24
log (νL_ν / erg s^-1)
log (ν / Hz)


COMPTEL
EGRET
Atmospheric Cherenkov telescopes
GLAST
Water Cherenkov
MeV
GeV
TeV
PeV
In Orbit
Ground

TeV ground based detectors (include the atmosphere)

Atmospheric Cherenkov telescopes

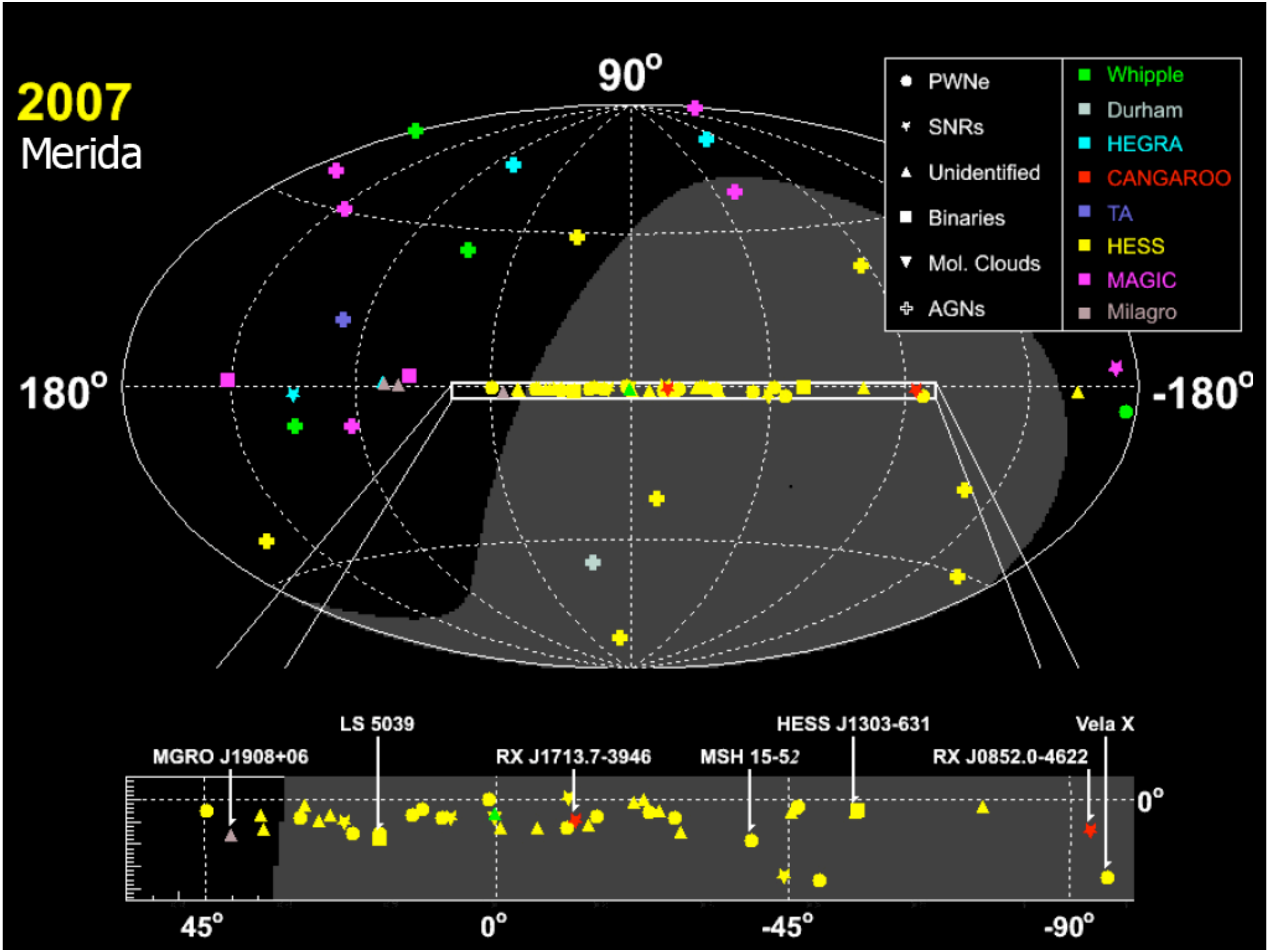
Rango de energía 0.05-50 TeV
Área > 10^4 m^2
Eliminación de hadrones > 99%
Resolución angular 0.05º
Resolución en energía ~15%
Apertura 0.003 sr
Funcionamiento (Duty Cycle) 10%

Espectros con alta resolución
Estudios detallados de fuentes conocidas
Ubicación y morfología
Mapeo profundo de regiones limitadas del cielo

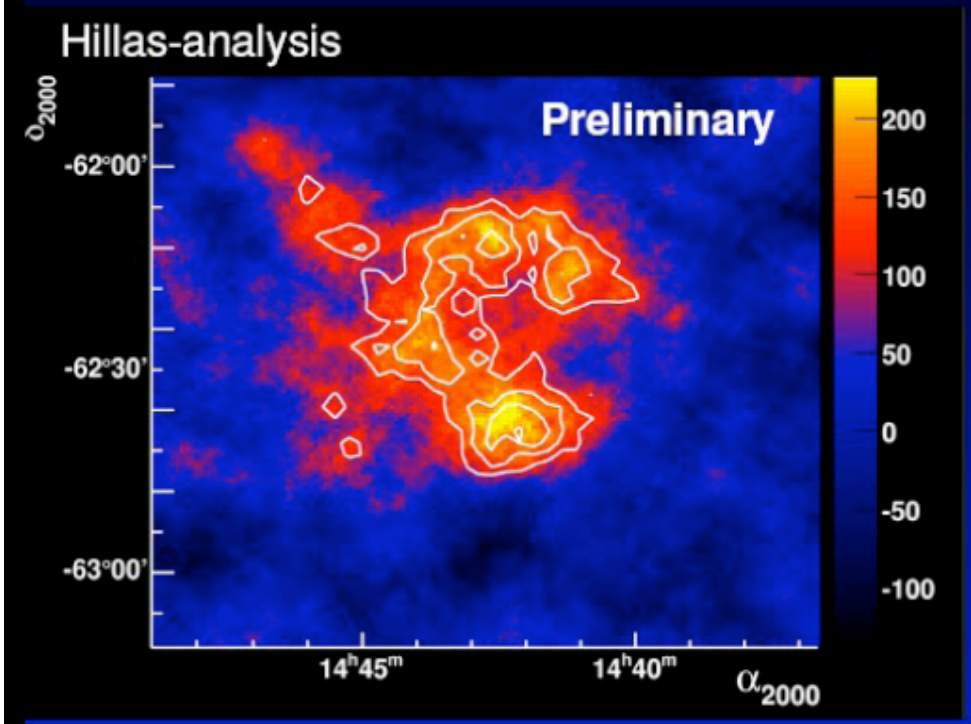
Surface detectors

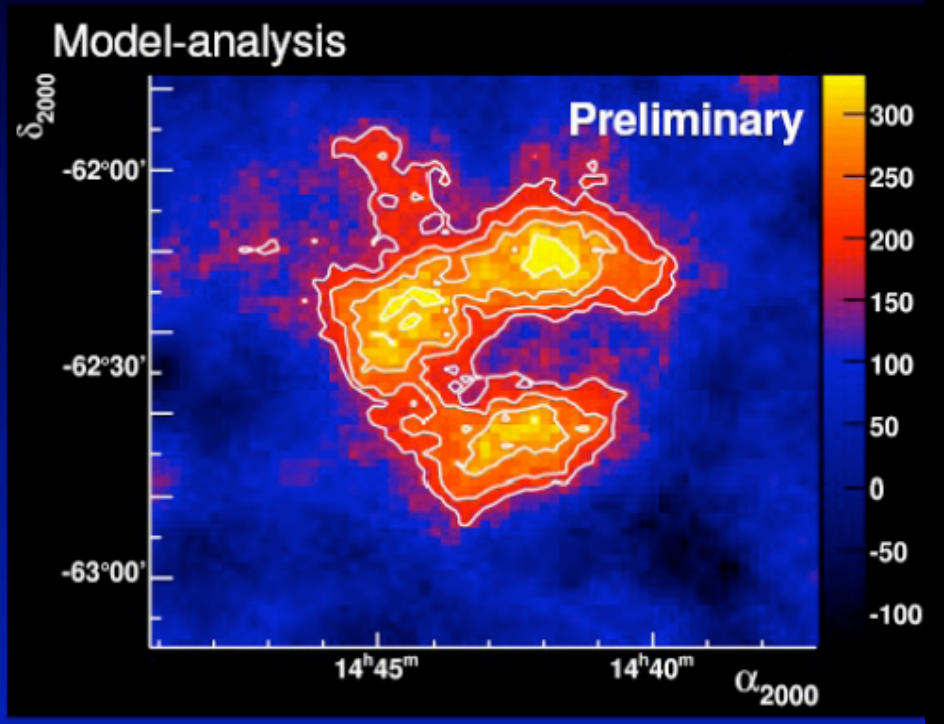
Rango de energía 0.1-100 TeV
Área > 10^4 m^2
Eliminación de hadrones > 95%
Resolución angular 0.3º - 0.7º
Resolución energía ~50%
Apertura > 2 sr
Funcionamiento (Duty Cycle) > 90%

Mapeo homogéneo y completo
Fuentes extendidas
Objetos eruptivos (GRBs blazares)
Observaciones multifrecuencia


2007
Merida
90°
180°
-180°
PWNe
SNRs
Unidentified
Binaries
Mol. Clouds
AGNs
Whipple
Durham
HEGRA
CANGAROO
TA
HESS
MAGIC
Milagro
LS 5039
HESS J1303-631
Vela X
MGRO J1908+06
RX J1713.7-3946
MSH 15-52
RX J0852.0-4622
0°
45°
0°
-45°
-90°

RCW 86



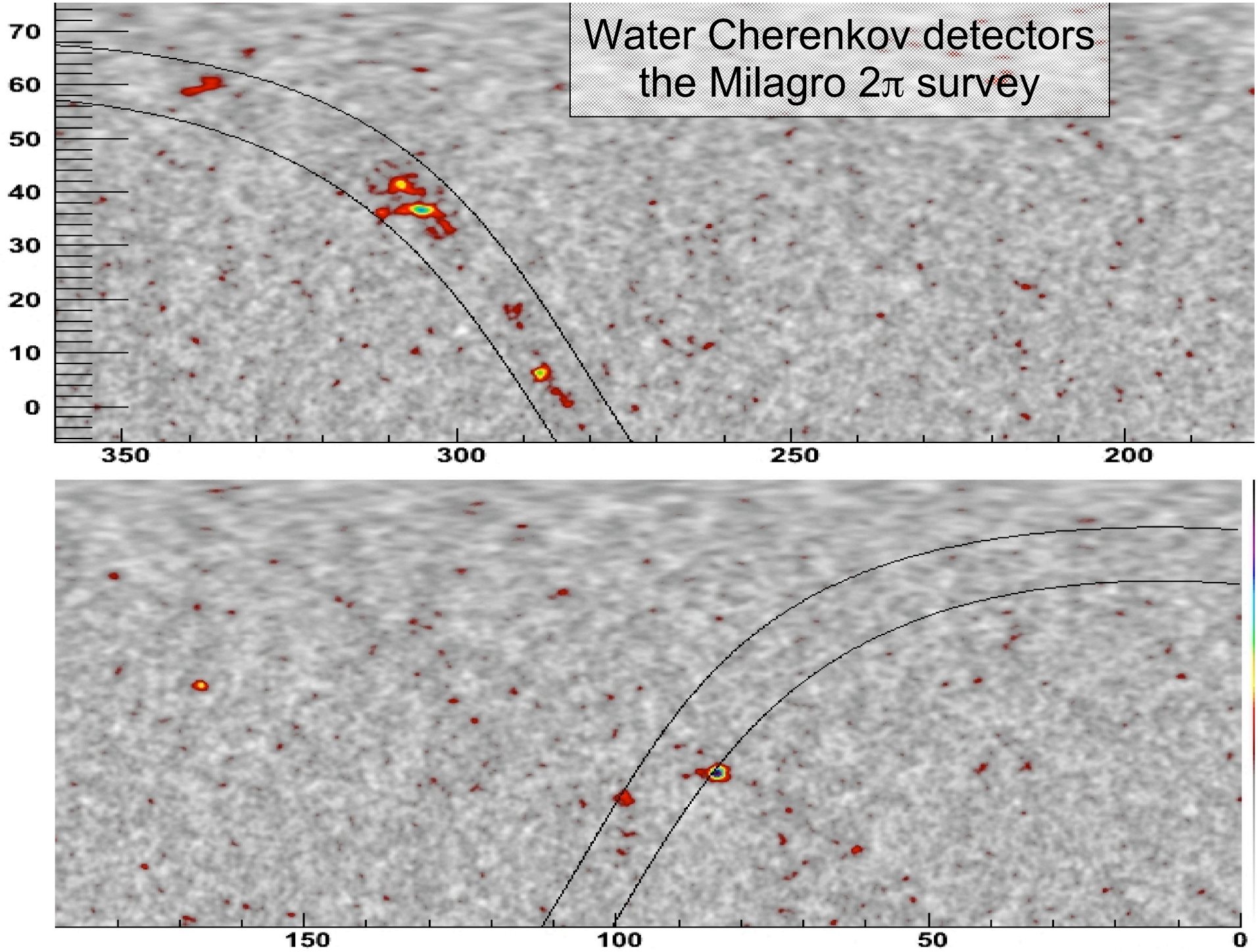


Hoppe 280

Small correlation radius: 0.11°
Contours: 3,4,5,6 σ

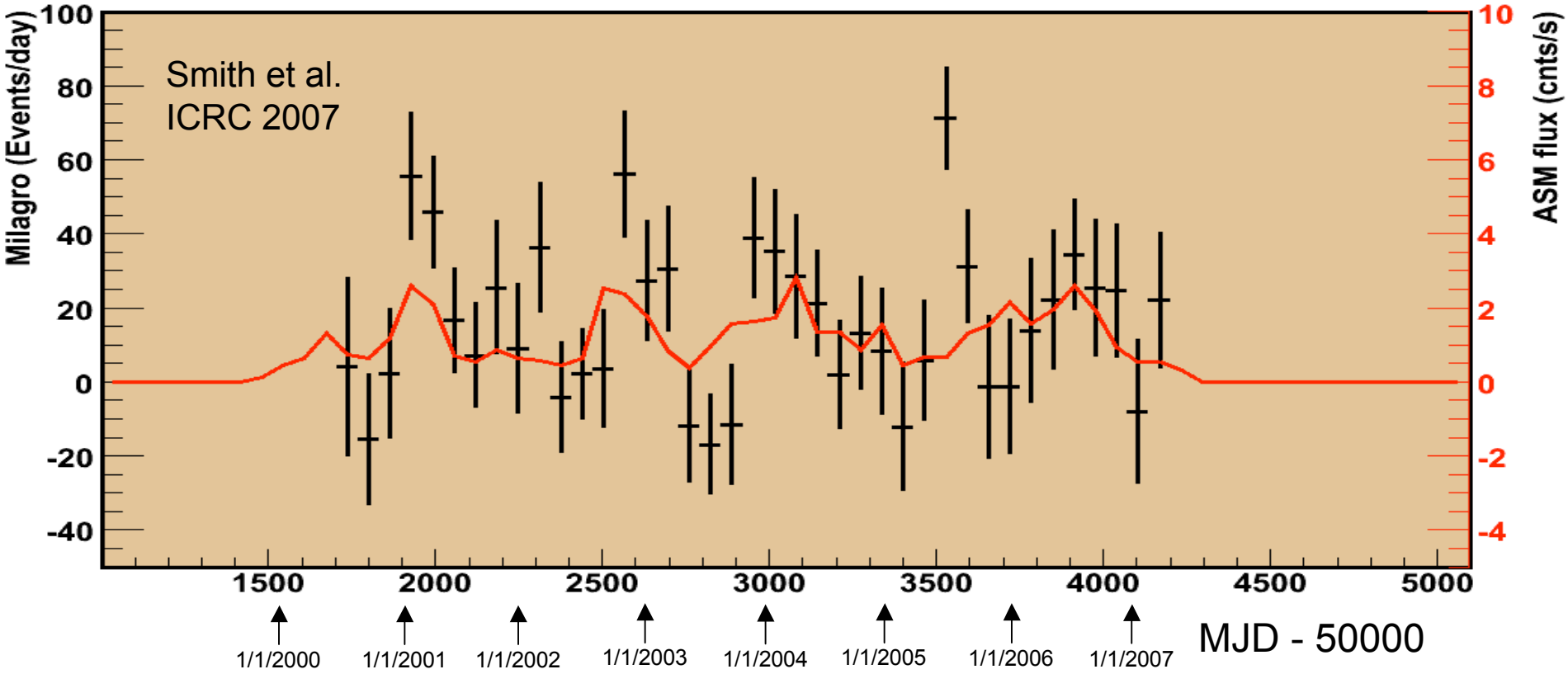
- **9.4 σ in 30 hours, $E^{-2.5 \pm 0.1}$ spectrum**
- **Probably the third TeV SNR *shell***

Hinton, rapporteur ICRC 2007


Water Cherenkov detectors
the Milagro 2π survey
70
60
50
40
30
20
10
0
350
300
250
200
150
100
50
0

Milagro AGN monitoring

- 7 year daily monitoring
- 64 day bins
- Mean flux ≈ 2/3 Crab



HAWC

- 2.7π survey instrument between 100 GeV and 100 TeV
- Instantaneous FOV $\approx$ 15% of the sky
- One 2/3-sky survey every 3 hours (2 orbits)
- Source location $\approx$ 0.3º
- Two Cherenkov telescopes on site
- Synergy with GLAST, IACT, IceCube + LMT

The HAWC collaboration

HAWC-MX

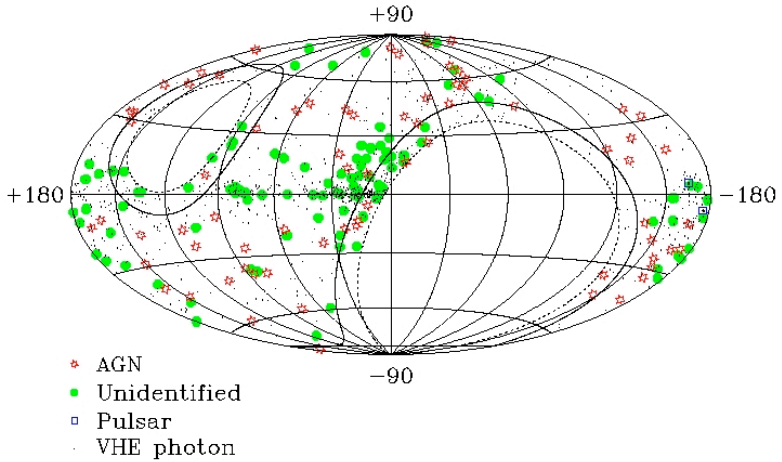
- INAOE
- UNAM:
  - Instituto de Astronomía
  - Instituto de Física
  - Instituto de Geofísica
  - Instituto de Ciencias Nucleares
  - Centro Geociencias (*)
  - DGSCA
- Benemérita Univ. Autónoma Puebla
- Universidad de Guanajuato
- CINVESTAV
- Universidad Michoacana SNH
- UAM Iztapalapa (*)
- Universidad Autónoma de Chiapas
- [Universidad de Guadalajara]

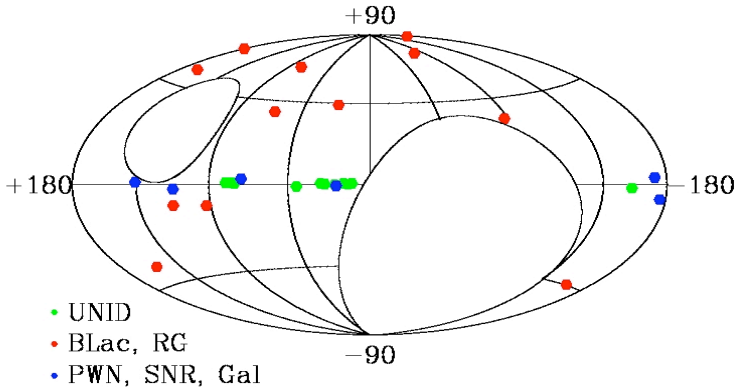
HAWC-US

- Maryland University
- U. California, Irvine
- U. California, Santa Cruz
- Michigan State University
- George Mason Univ.
- Los Alamos National Laboratory
- University of New Hampshire
- Penn. State University
- University of Utah
- University of New Mexico
- NASA/GSFC

+ Universita di Torino, Italia
+ IAFE & Balseiro Bariloche, Argentina

Ubicación geográfica de HAWC





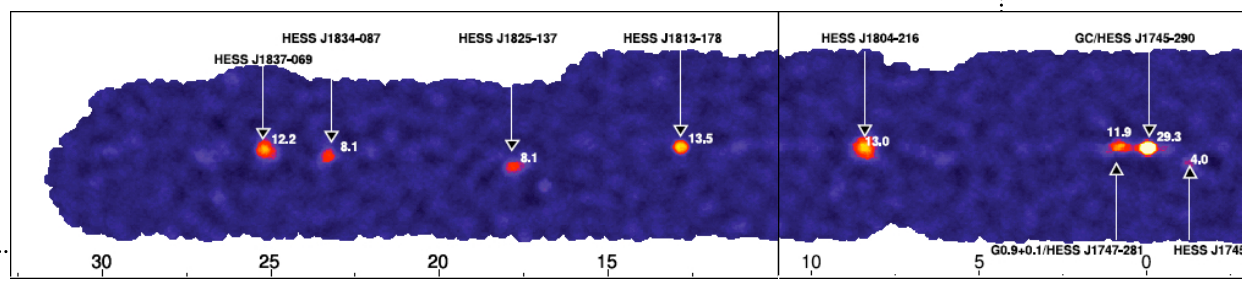
Cerca del ecuador: $\Omega_{sur} = 4\pi \cos(lat) \sin(\theta) \approx 4\pi(2/3)$

- 10% mayor cobertura que a 30º
- 40% traslape con el censo HESS del plano Galáctico
- 90% traslape con IceCube
- 100% traslape con el Whipple Strip Survey + VERITAS Cygnus Survey

Crab @ 3º del cenit

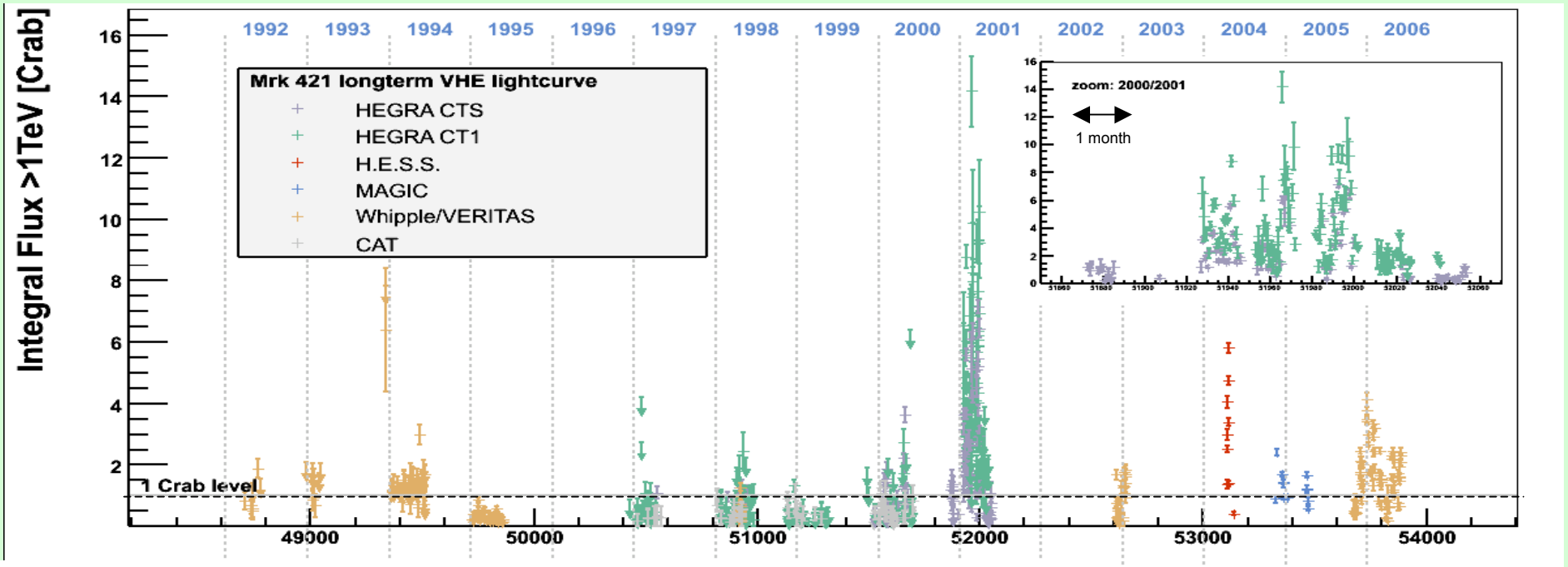
Centro Galáctico @ 48º

Sincrono con observatorios de EU y América Latina



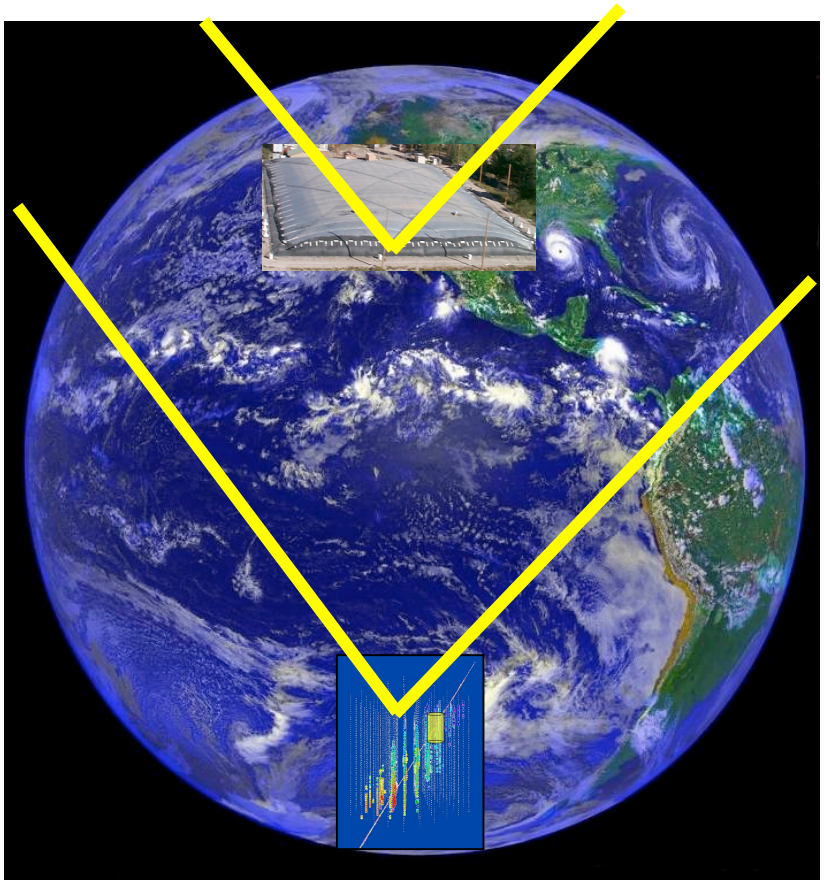
Monitoreo de blazares

- HAWC puede medir los ciclos de actividad de AGNs y notificar en tiempo real observadores acerca de eventos episódicos.
- AGN dentro de ~8 sr serán observados cada día por ~ 5 hrs.
- Las observaciones de HAWC serán continuas, sin interrupciones por clima, luna o sol.
  - Sensitividad 5σ de HAWC es (10,1,0.1) Crab en (3 min, 5 hr, 1/3 año)



Observaciones de Mrk421 con telescopios Cherenkov

HAWC & IceCube



- HAWC and IceCube to observe in similar energy ranges (100.
- Hadronic production of photons gives similar number of neutrinos → TeV HAWC sources as prime candidates for IceCube.
- HAWC can indicate IceCube *where y when* to search for neutrinos.
- HAWC boosts up IceCube.

Time frame

SASIR timeline ≥ 8 years (say survey 2017-2021)

- GLAST: 9 years after launch; 8 years after data becomes public; database established; GLAST functional? (simultaneity!)
- HAWC: 6 years into full array operation - coincident with last 4 years of operation - simultaneity with SASIR - HAWC / IceCube / SASIR?
- IceCube: 6 years into full detector operation
- AGIS / CTA: operational?

<u>Which will be the HE questions in 2017??</u>