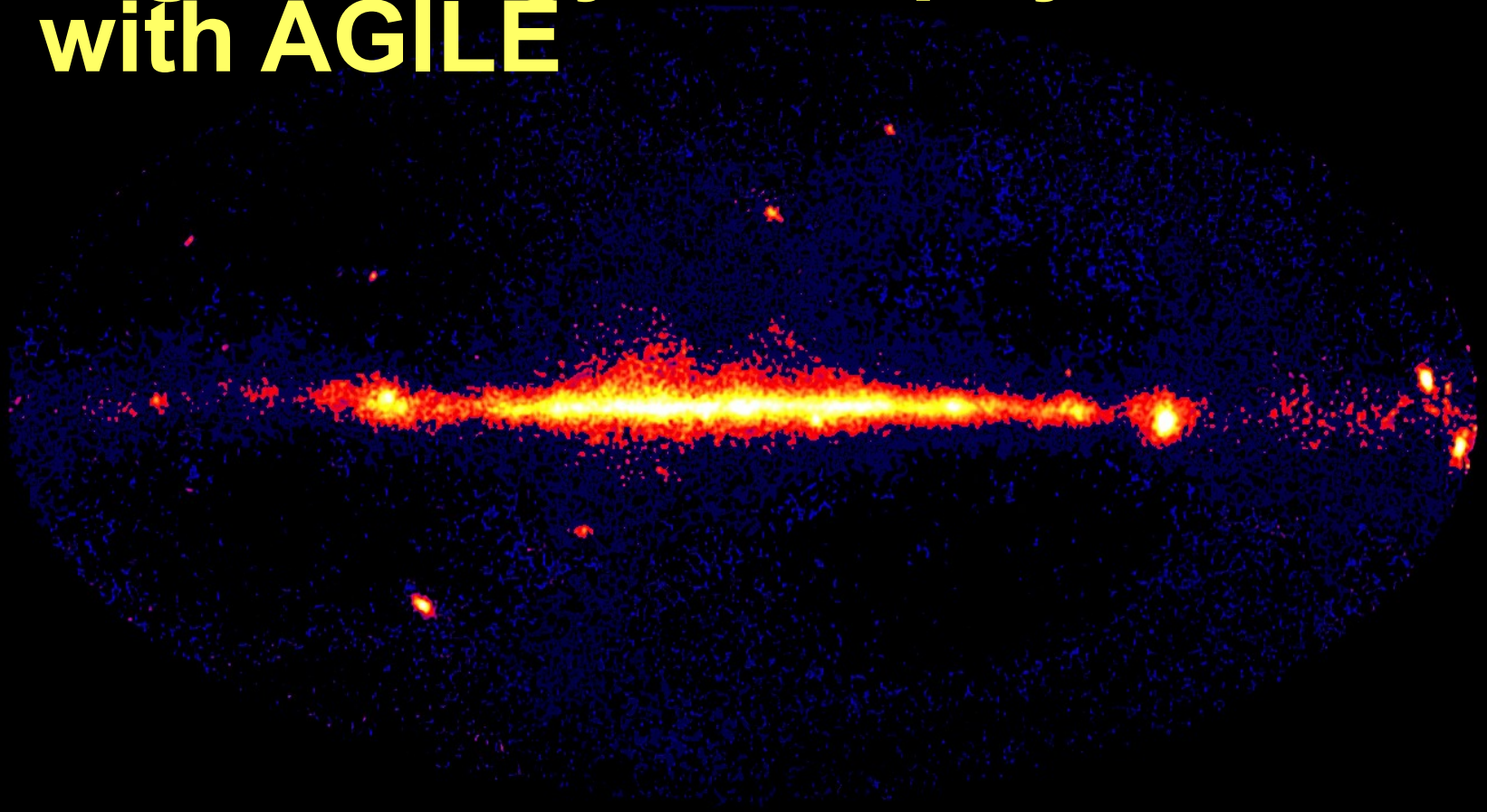
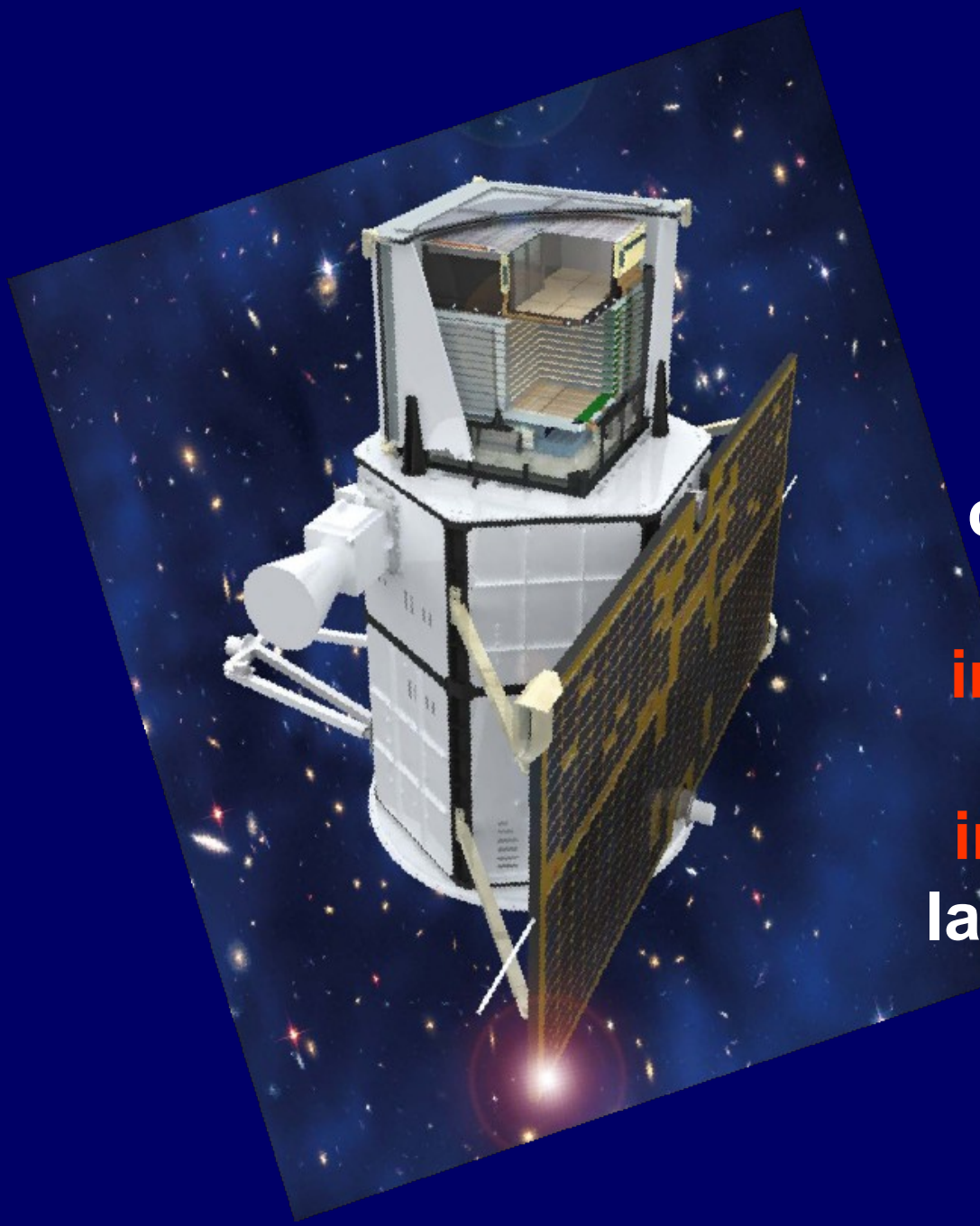
High-Energy Astrophysics with AGILE



La Thuile 2009



The AGILE Payload

combines for the first time a gamma-ray imager (30 MeV- 30 GeV) with a hard X-ray imager (18-60 keV) with large FOVs (1-2.5 sr) and optimal angular resolution

AGILE

agenzia spaziale italiana

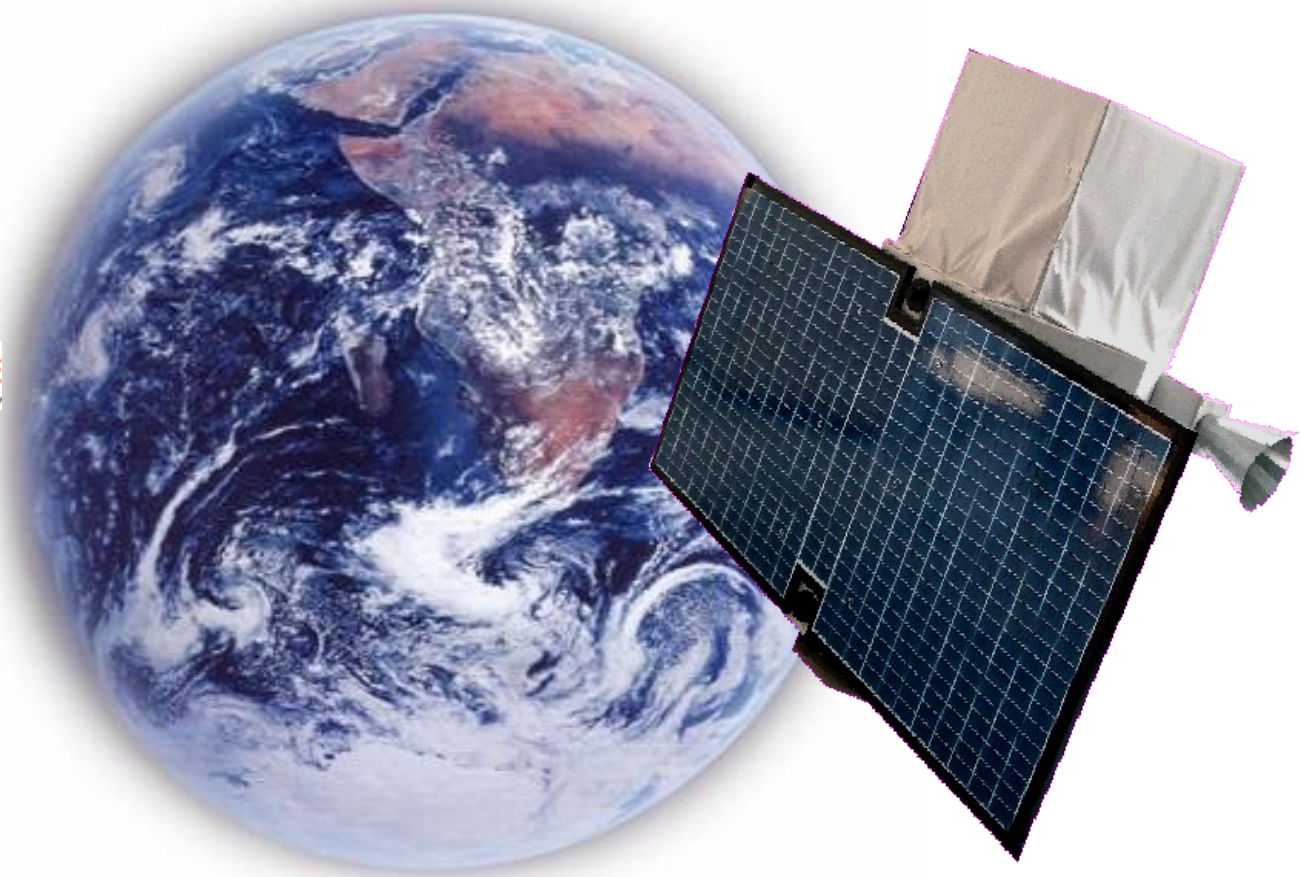
INAF

INFN

CARLO GAVAZZI

Carlo Gavazzi Space SpA

OERLIKON CONTRAVES



ALCATEL ALENIA SPACE

An Alcatel/Finmeccanica company

telespazio

A Finmeccanica/Alcatel company

Galileo Avionica

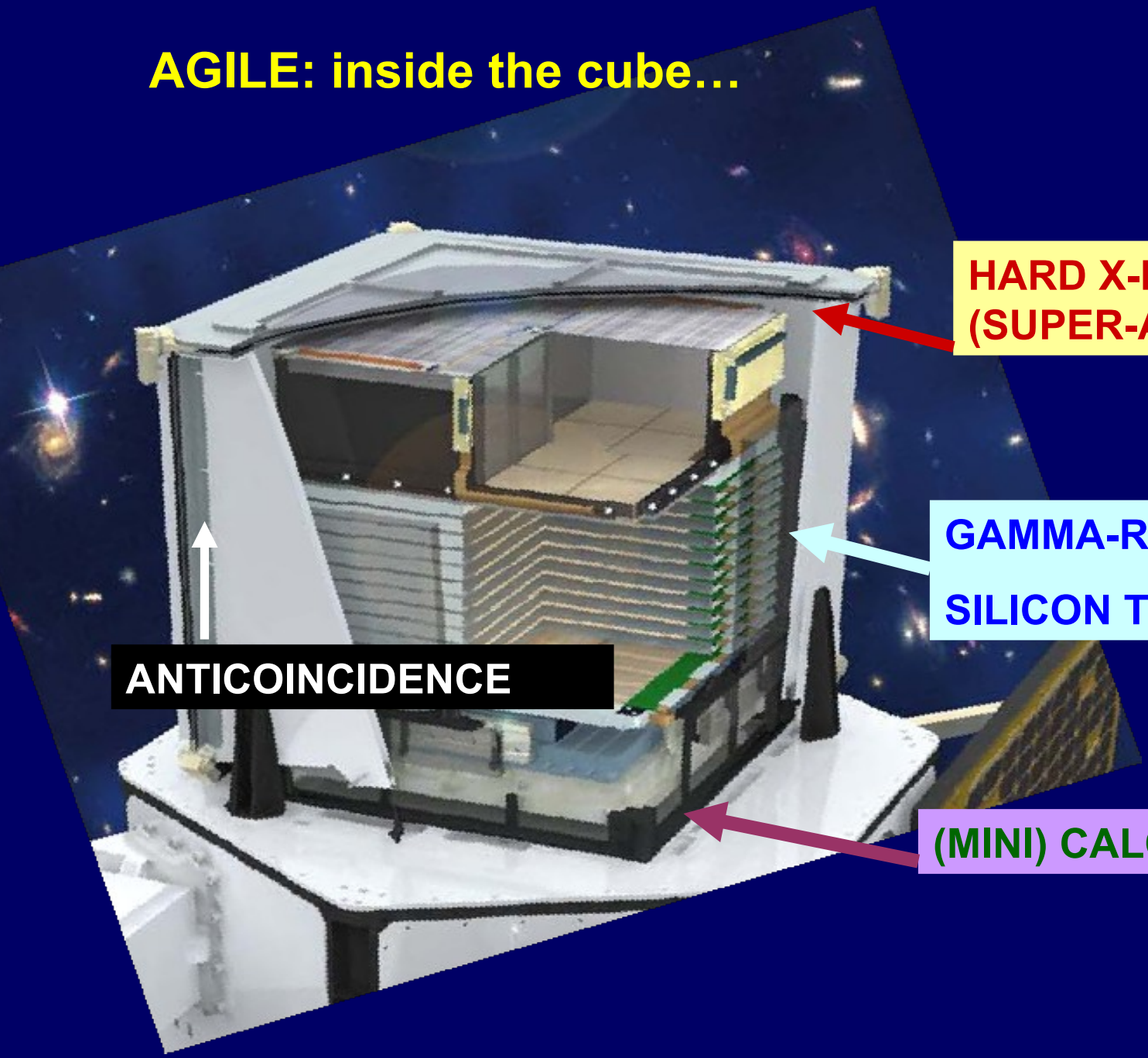
MIPOT

ENEA

AGILE challenge…

- only ~100 kg of Payload
- only ~100 W of PL absorbed power
- only 350 kg of satellite…
- Small Mission budget and resources

AGILE: inside the cube…

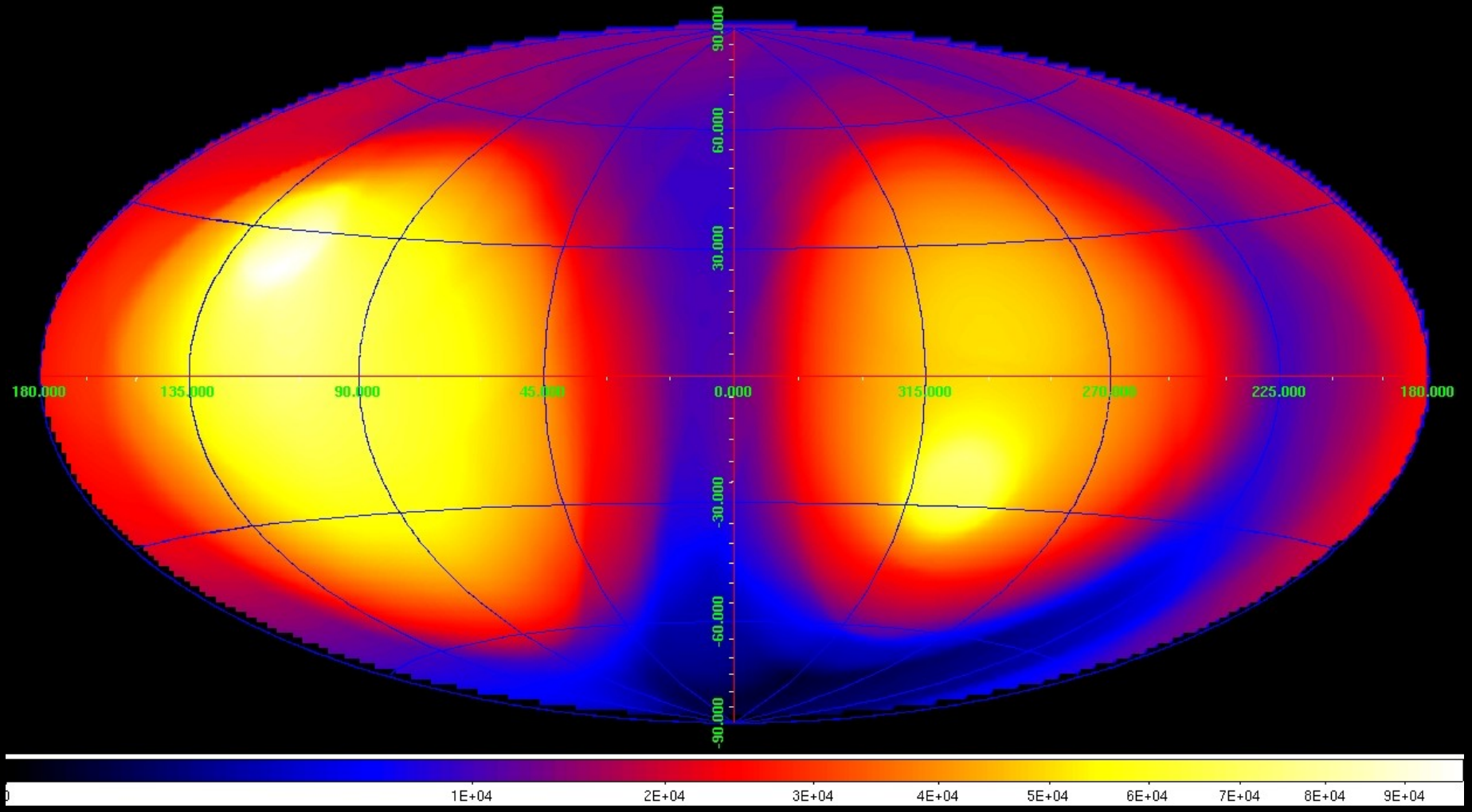


AGILE in orbit…

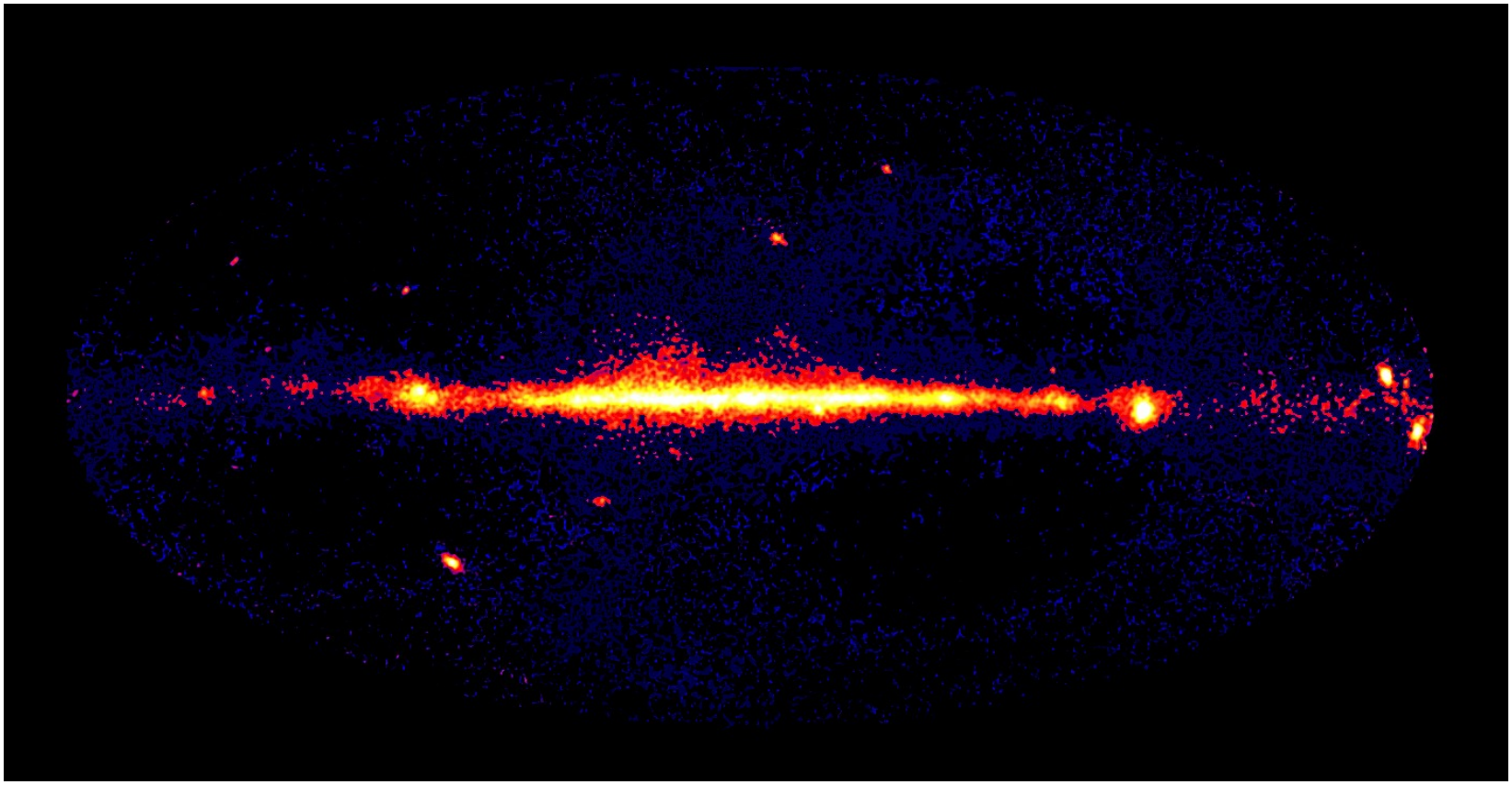
- ~9150 orbits, January 30, 2009.
- Healthy Scientific Instrument
- AGILE Cycle-2 on going
- Nominal scientific performance of all subsystems

The AGILE gamma-ray exposure (E > 100 MeV)

more than 1 yr. exposure: July 2007 – 15 Sept. 2008

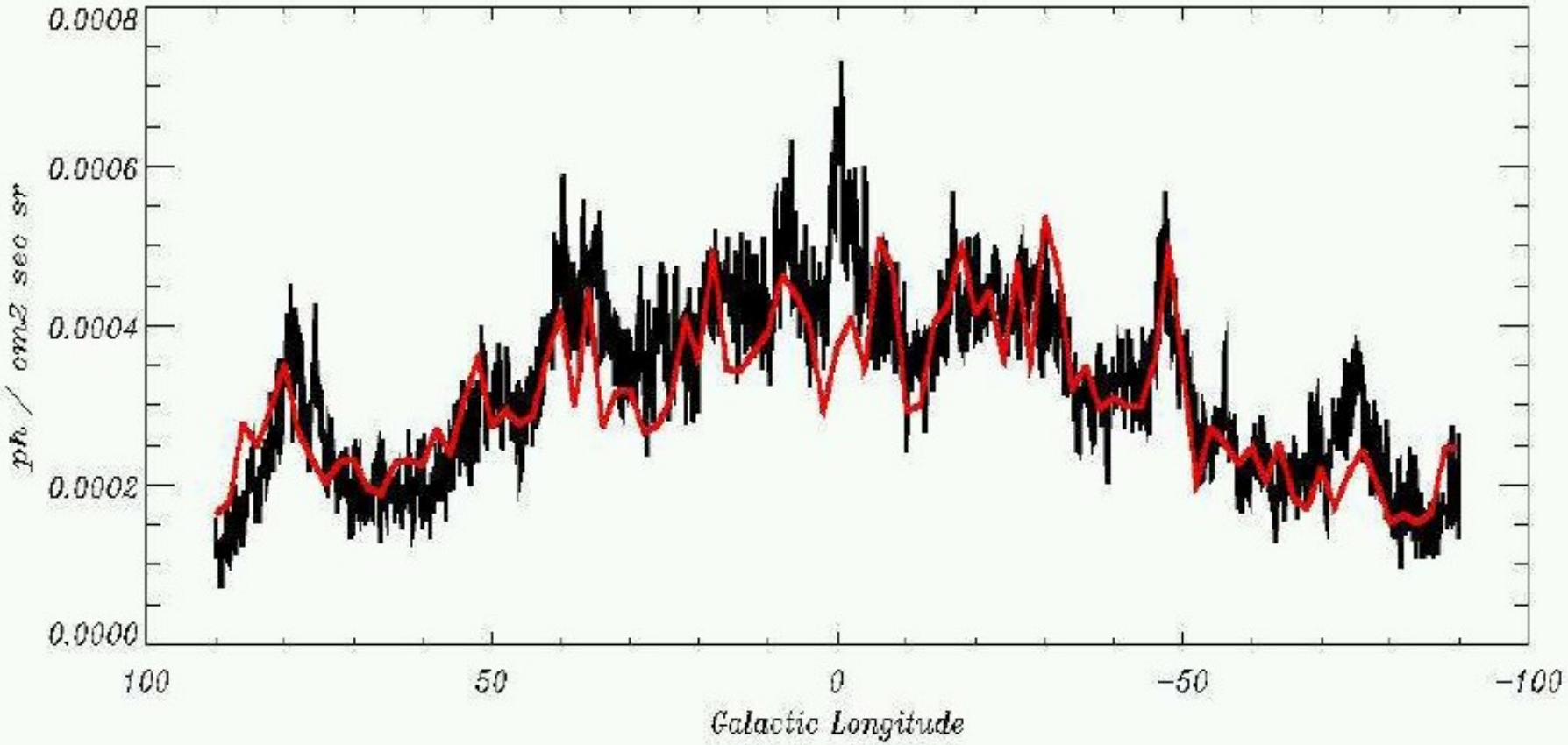


Gamma-ray sky after one year as seen by AGILE

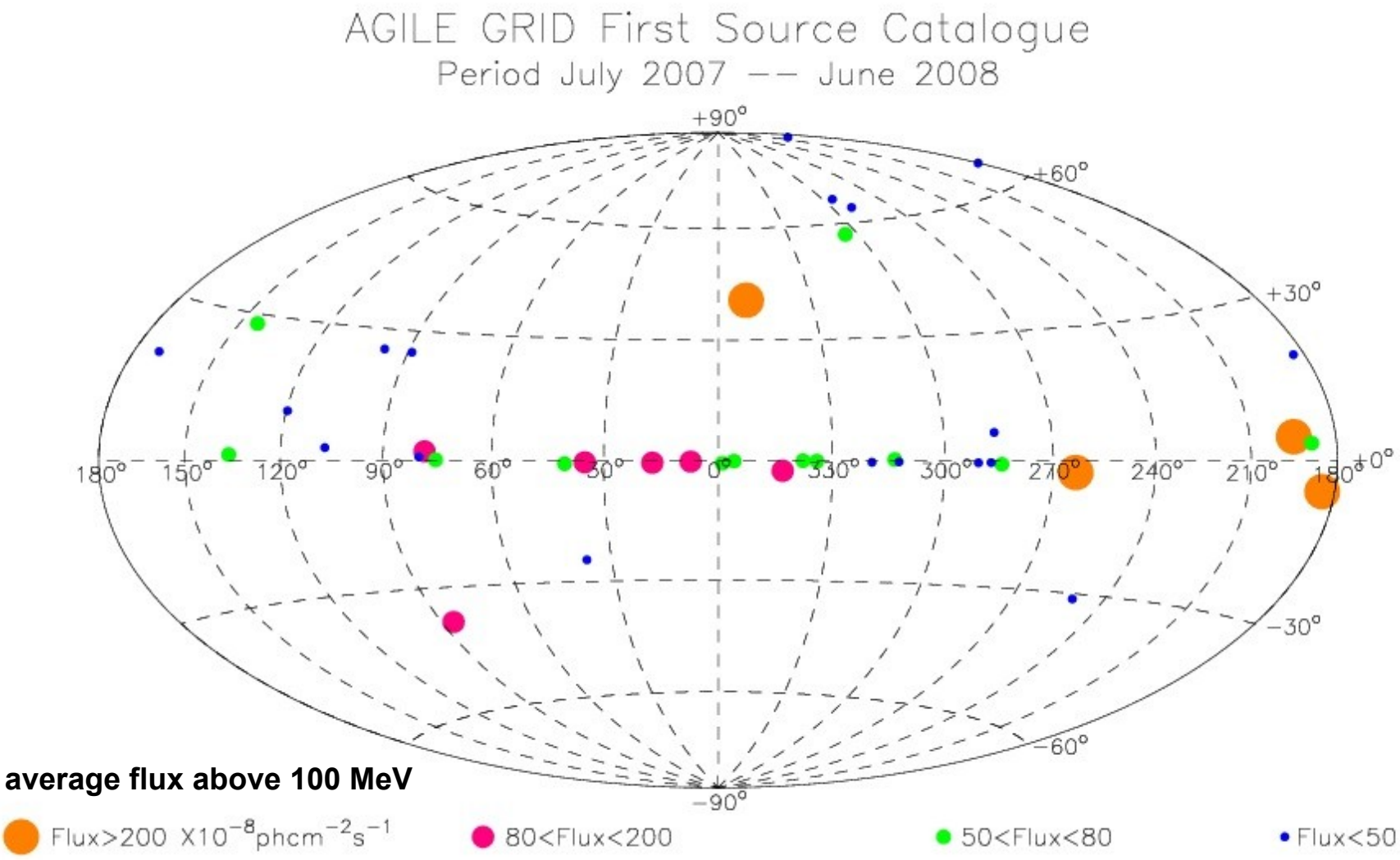


AGILE Observations vs Model

(-90 < l < 90)



AGILE First Catalog of high-significance gamma-ray sources (ASDC)



Pittori et al., 2009

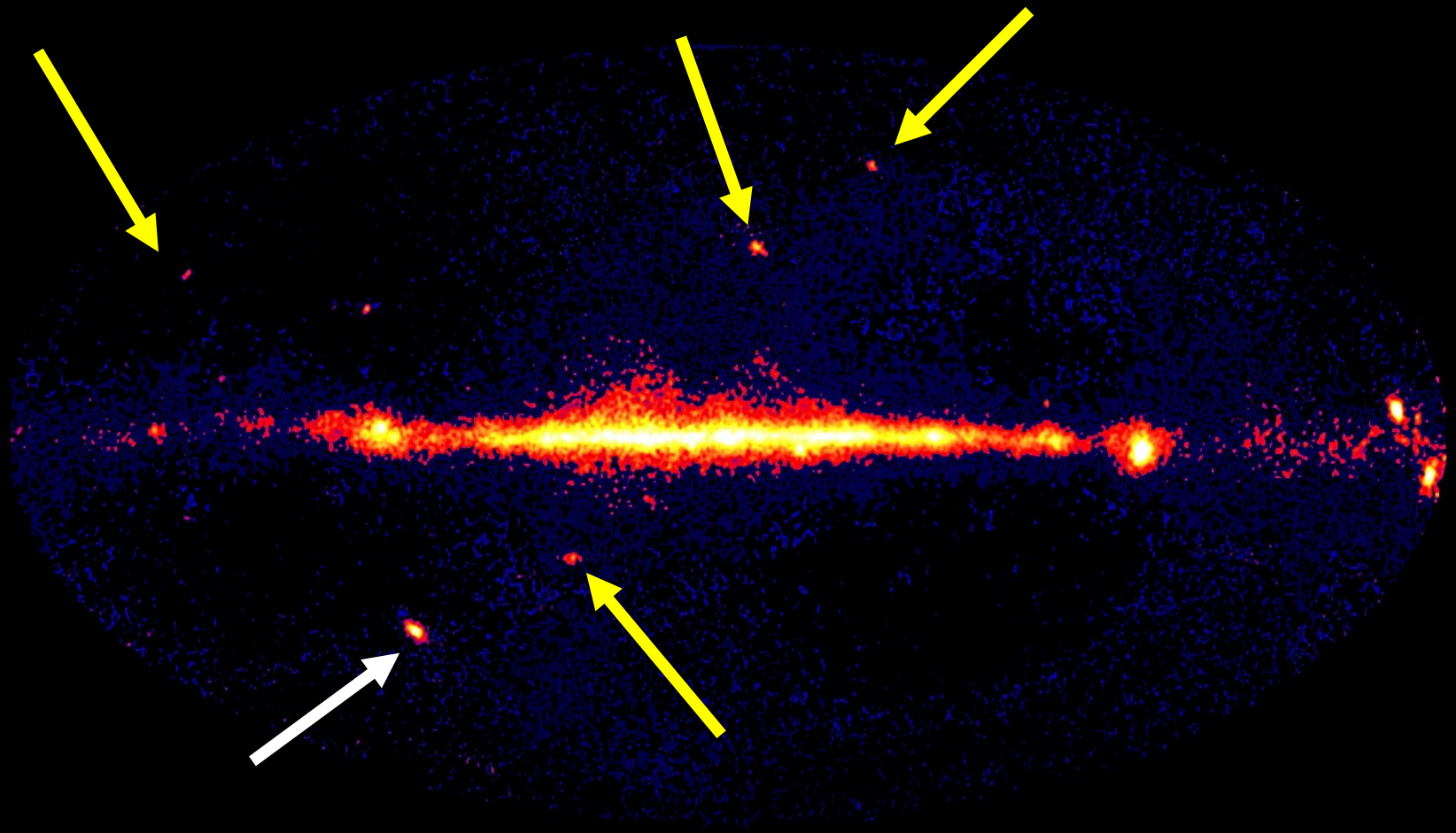
Main science topics

- Active Galactic Nuclei

- Pulsars
- SNRs and origin of cosmic rays
- VARIABLE Galactic sources
- Microquasars, Gal. compact objects

- Gamma-Ray Bursts
  (and Terrestrial Flashes)

Gamma-ray bright blazars detected by AGILE in 9 months



AGILE blazar main detections

- **Flat spectrum radio quasars**
  - **3C 454.3, 3C 273, 3C 279, PKS 1510-089**
  - **External Compton**
- **LBLs – PKS 0537-441**
- **IBLs**
  - **S5 0716+714 - near maximum power for spinning supermassive black hole, consistent with two-component SSC**
  - **W Comae**
- **HBLs – Mrk 421**
  - **Simultaneous hard-X, MeV, GeV, TeV**

AGILE blazar main detections

- Strong variability
  - from single day to several weeks
- Crucial multifrequency observations
  - Spitzer, Swift, INTEGRAL, RXTE, Suzaku, MAGIC, VERITAS, WEBT, REM

Known pulsars

In about 9 months of scientific life, AGILE reached EGRET exposure level in the Vela region.

(Pellizzoni et al. 2009, Ap.J. 691, 161)

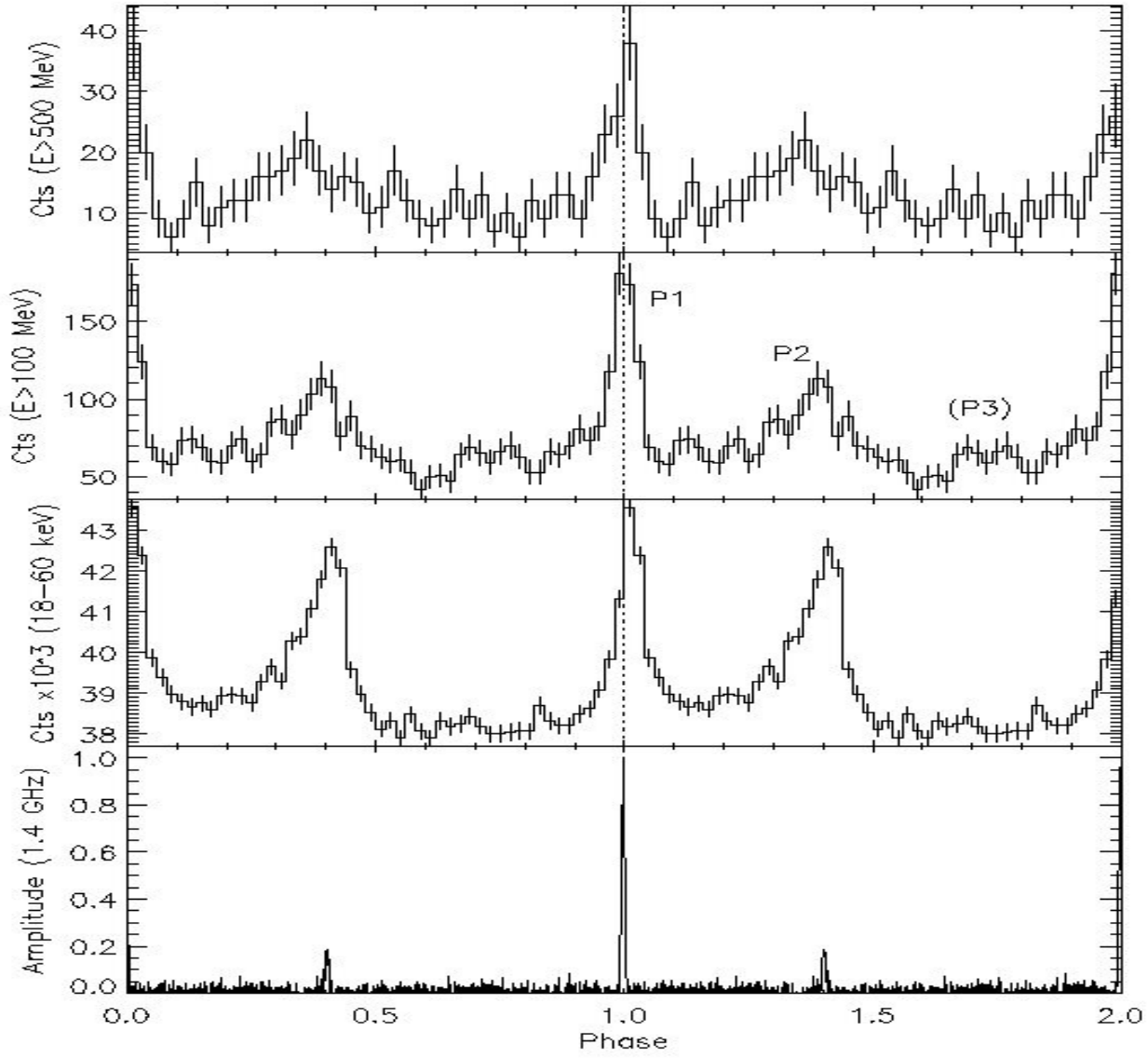
PSR	Pulsed Counts[a]	χ^2_r (d.o.f)	Exposure[b] (10^9 cm^{2}s)	Pulsed Flux[c] 10^{-8} ph cm^{-2} s^{-1}
Vela	9,170±580	225.51 (9)	1.24	930±60
Geminga	1,900±480	10.44 (9)	0.85	280±70
Crab	2,000±530	10.71 (9)	0.92	270±70
J1709-4429	2,370±720	9.11 (9)	1.56	190±60

[a]Pulsed counts (G+L event class) with E>100 MeV, 5 deg max from PSR position, 60 deg max from FOV center, 10 bins.

[b]Good observing time after dead-time and occultation corrections.

[c]Calculated with the expression $C_P f/E$, where C_p=pulsed counts, E=exposure, f=factor accounting for source counts at angular distance > 5 deg from source position according to the point spread function (f∼1.3).

High resolution timing - Crab



0.5<E<30 GeV

AGILE

E>100 MeV

←0.7 ms bins

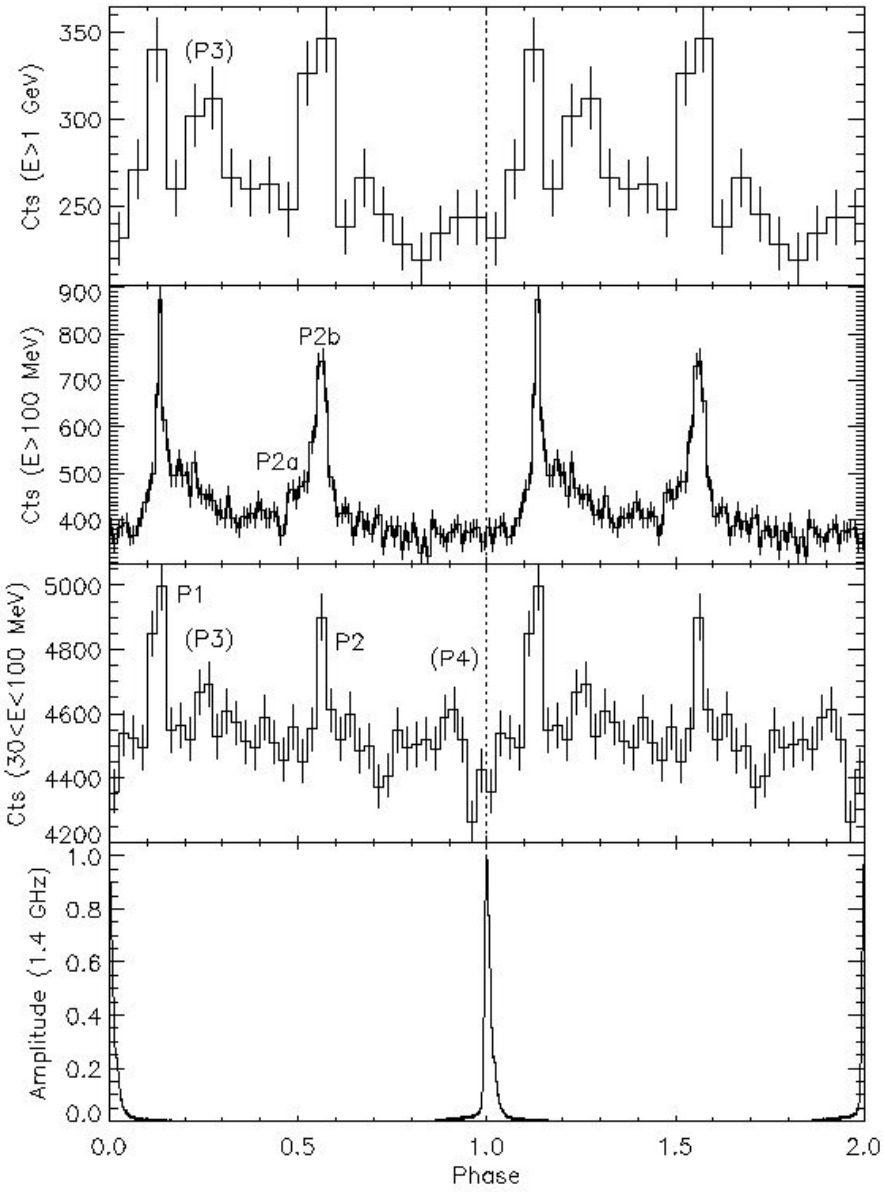
SuperAGILE

18-60 keV

Radio

High resolution timing - Vela

Vela pulsar



E > 1 GeV

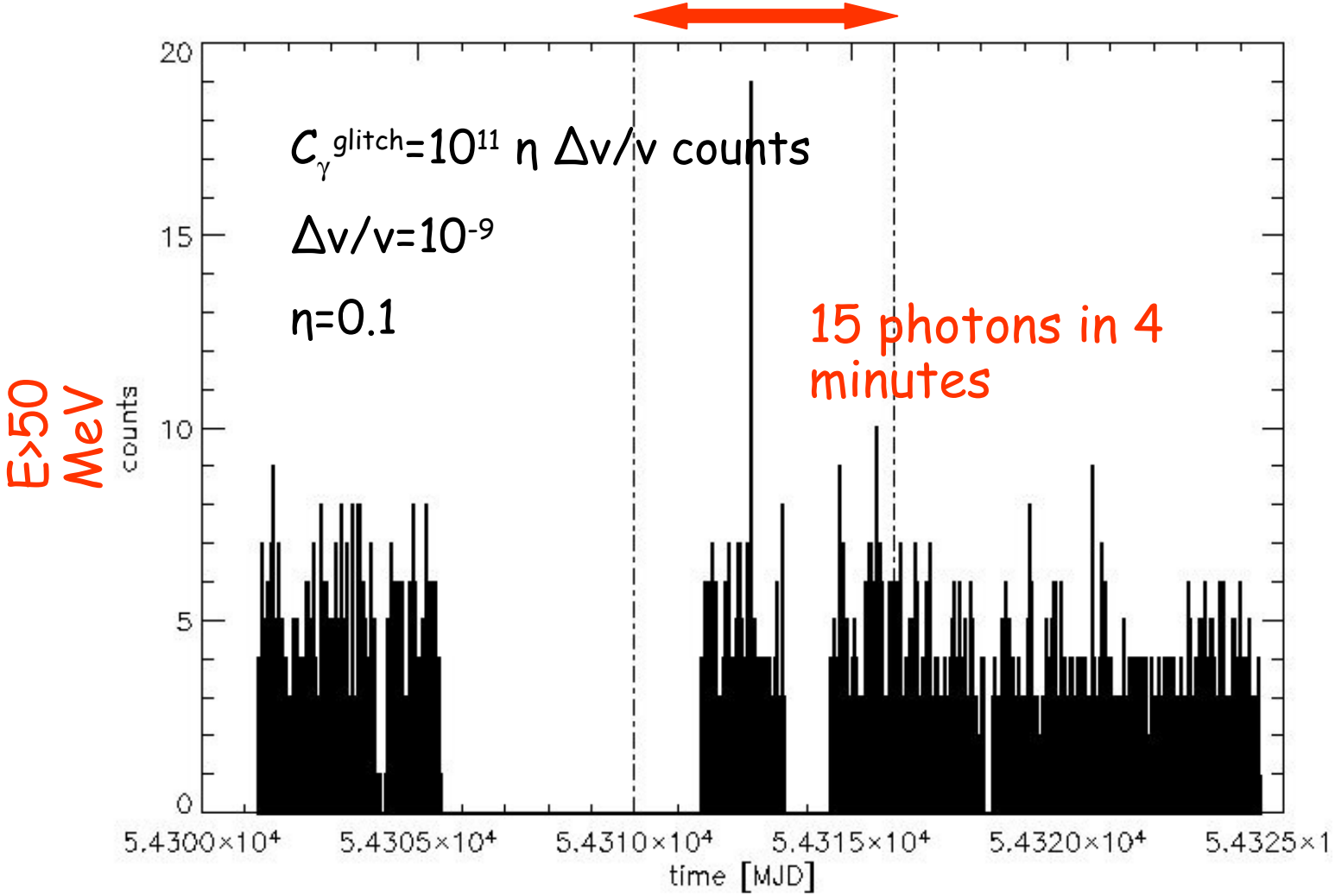
E > 100 MeV

30 - 100 MeV

radio

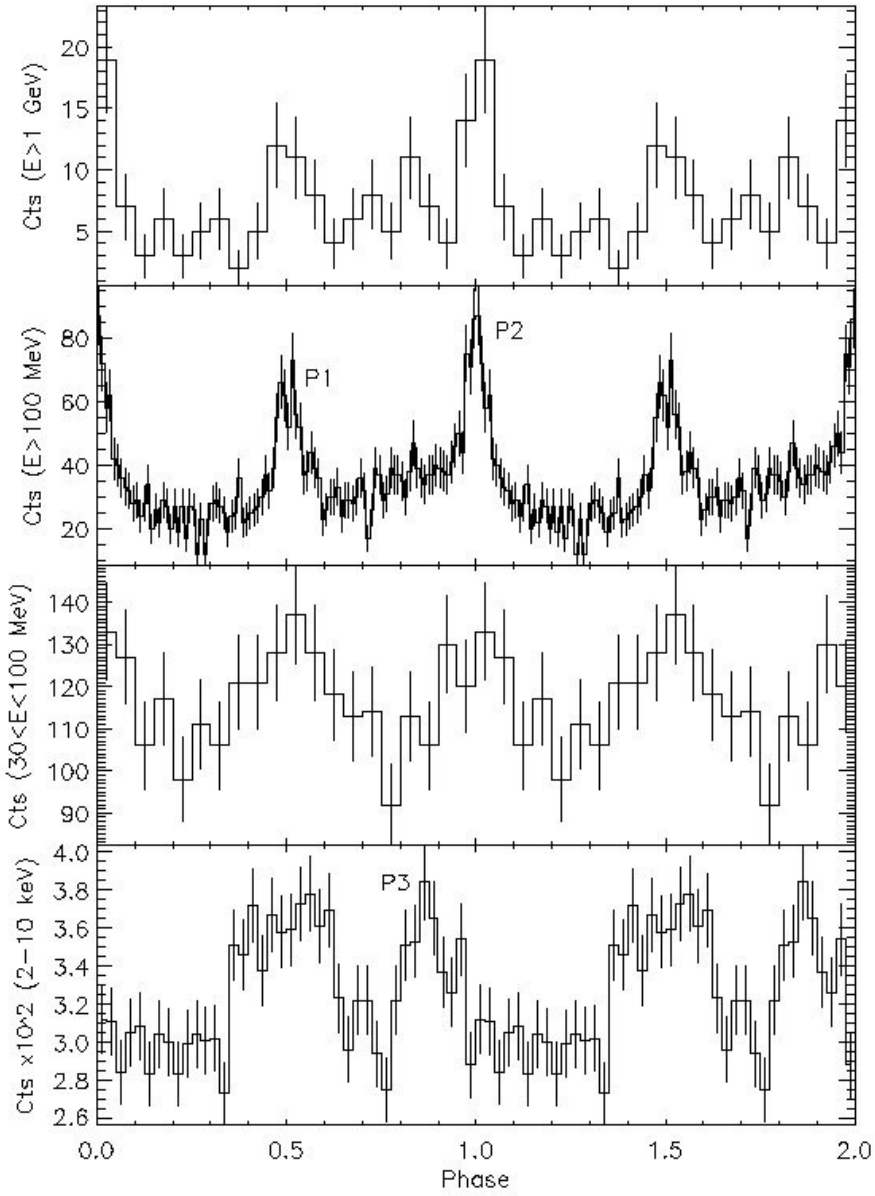
Vela glitch

Vela glitch=54,312.5+/-3 MJD



Small Vela glitch in August 2007: burst emission possibly detected by AGILE

High resolution timing - Geminga

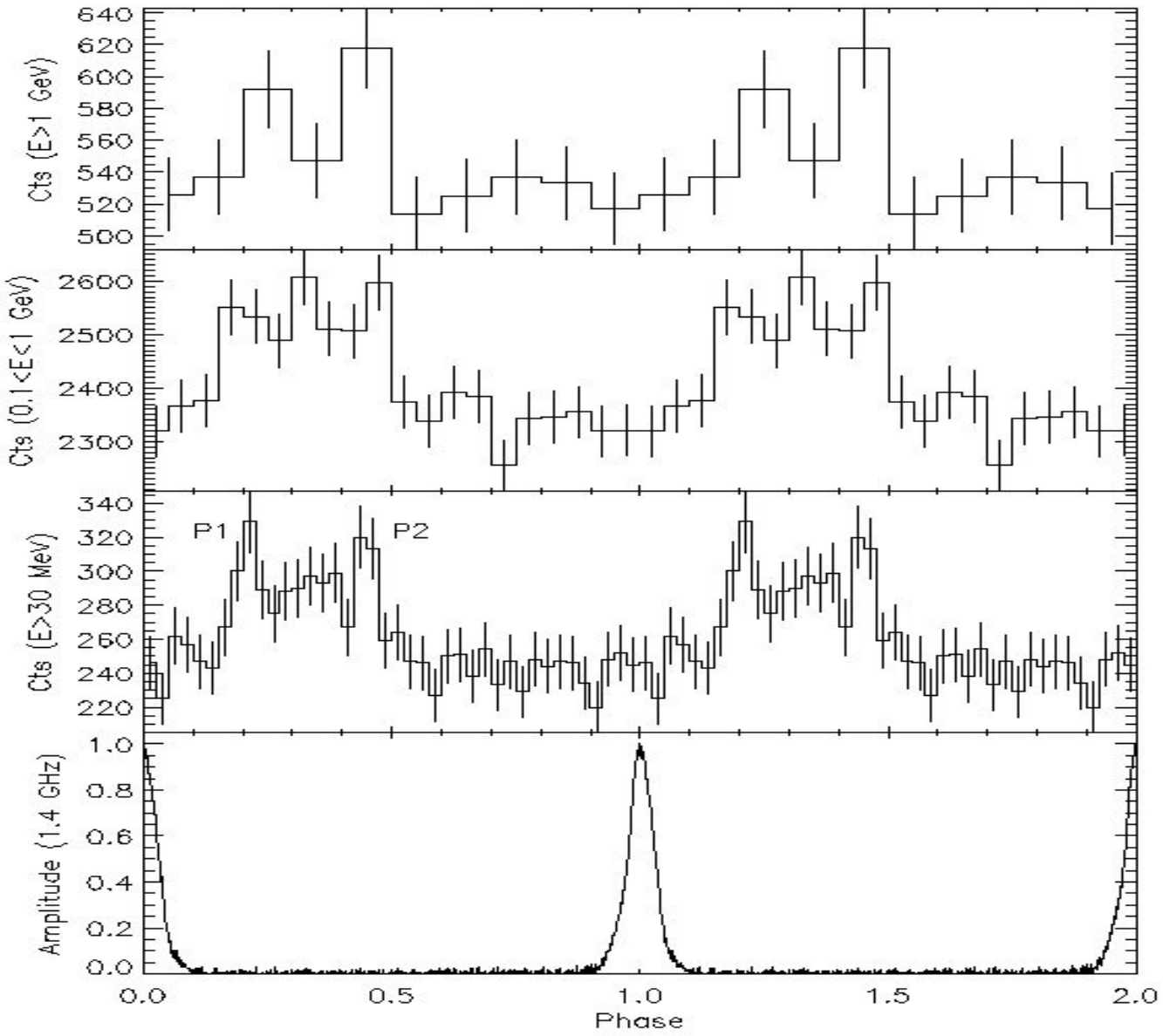


E > 1 GeV

E > 100 MeV

30 - 100 MeV

X-rays



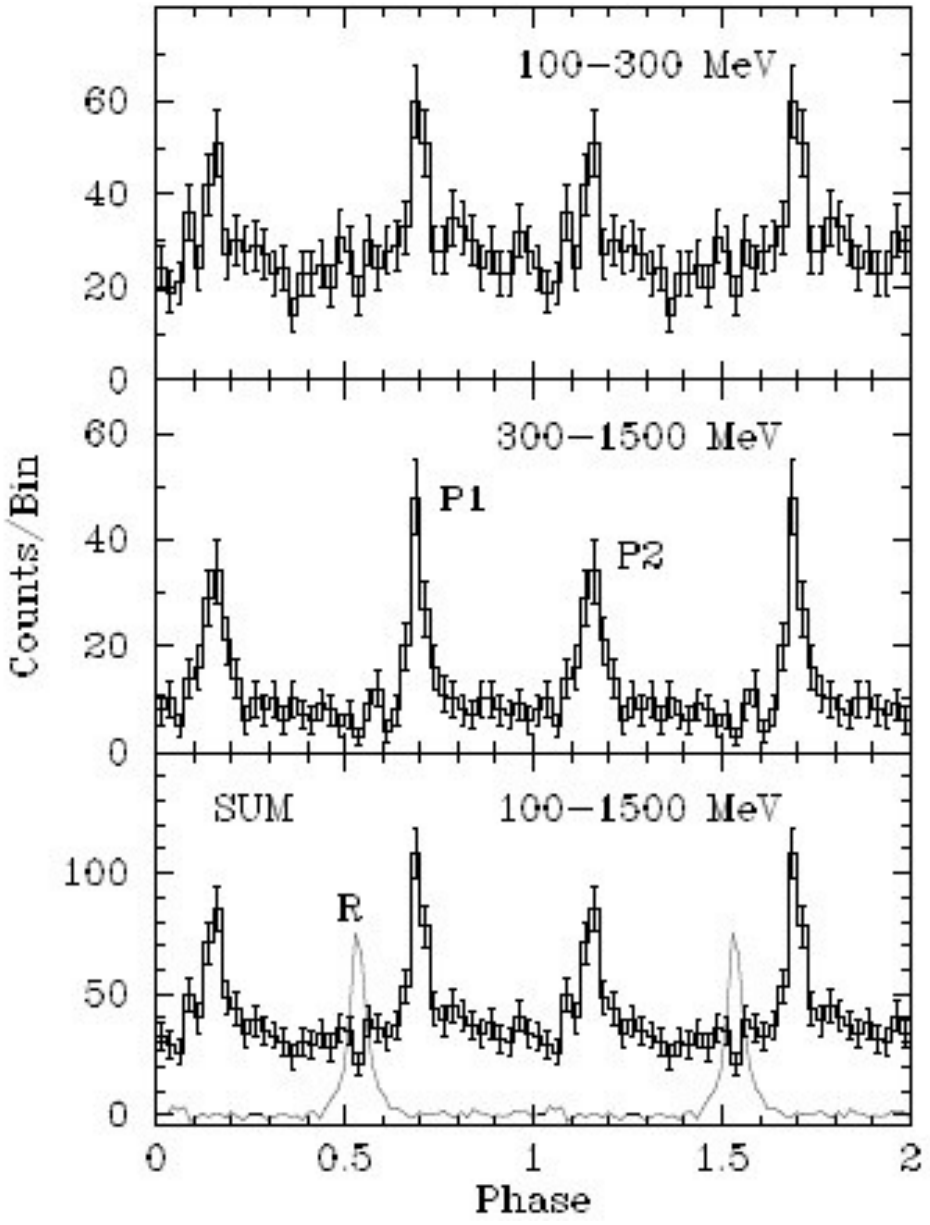
B1706-44

E>30 MeV

←2.6 ms

New gamma-ray pulsar !

PSR J2021-3651



100-300 MeV

300-1500 MeV

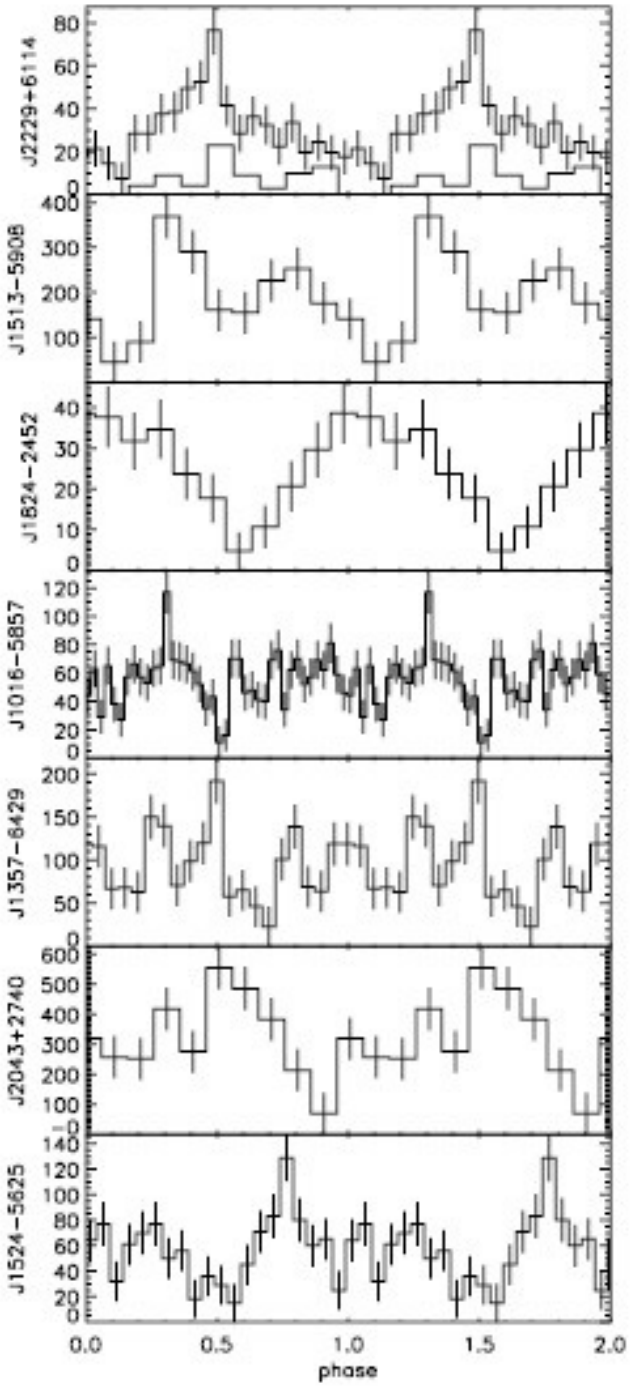
100 - 1500 MeV

Halpern et al., 2008

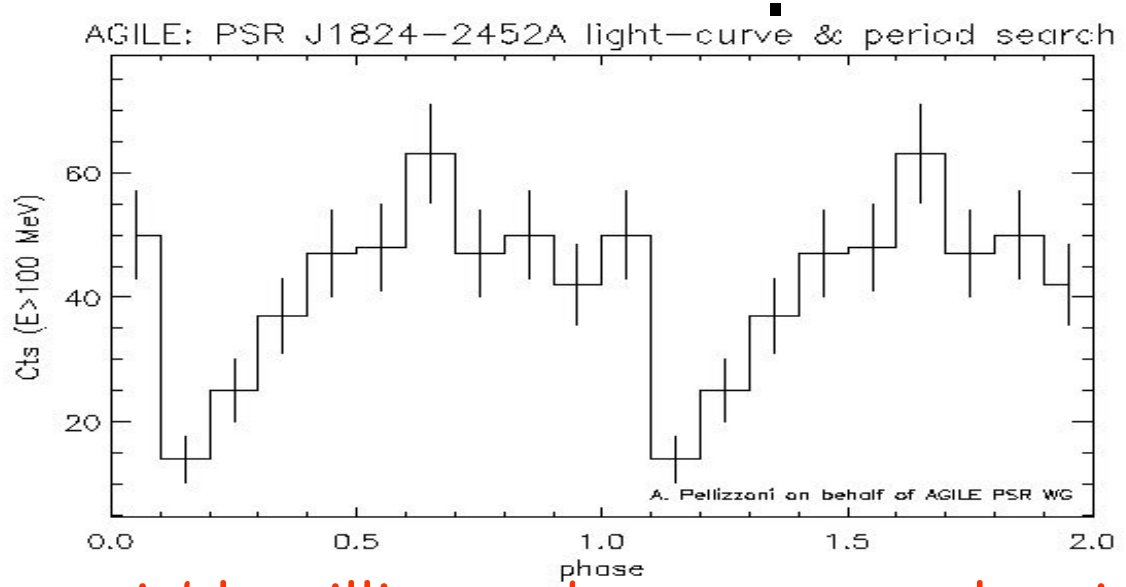
AGILE's new gamma-ray pulsars

PSR Name	G.Lon. deg	G.Lat. deg	P ms	τ[a] yr	D[a] kpc	$\log \dot{E}$ erg s^{-1}	$\chi^2_{red}(N_{st})$[b]	σ_{time}[c]	σ_{space}[d]	F_γ[d]	$\log L_\gamma$[e] erg s^{-1}	$L_\gamma/\dot{E}$
J2229+6114	106.65	2.95	51.6	1.0×10^4	12.0	37.35	6.0(36)	5.0	7.5	26±4	35.36	0.01
J1513−5908	320.32	-1.16	150.7	1.6×10^3	5.8	37.25	4.2(3)	4.0	6.4	34±6[f]	35.04	0.006
J1016−5857	284.08	-1.88	107.4	2.1×10^4	9.3	36.41	6.0(69)	4.8	12.3	62±6[f]	35.71	0.2
J1824−2452	7.80	-5.58	3.0	3.0×10^7	4.9	36.35	4.2(1)	4.2	3.6	18±5	34.62	0.02
J1357−6429	309.92	-2.51	166.1	7.3×10^3	4.1	36.49	5.2(7)	4.7	1.8	<14	<34.35	<0.007
J2043+2740	70.61	-9.15	96.1	1.2×10^6	1.1	34.75	4.1(1)	4.2	0.6	<6	<32.84	<0.01
J1524−5625	323.00	0.35	78.2	3.2×10^4	3.8	36.51	4.6(4)	4.3	1.0	<16	<34.34	<0.007

New pulsars


J2229+6114
J1513−5908
J1824−2452
J1016−5857
J1357−6429
J2043+2740
J1524−5625
phase

PSR J1824-2452A – new ms

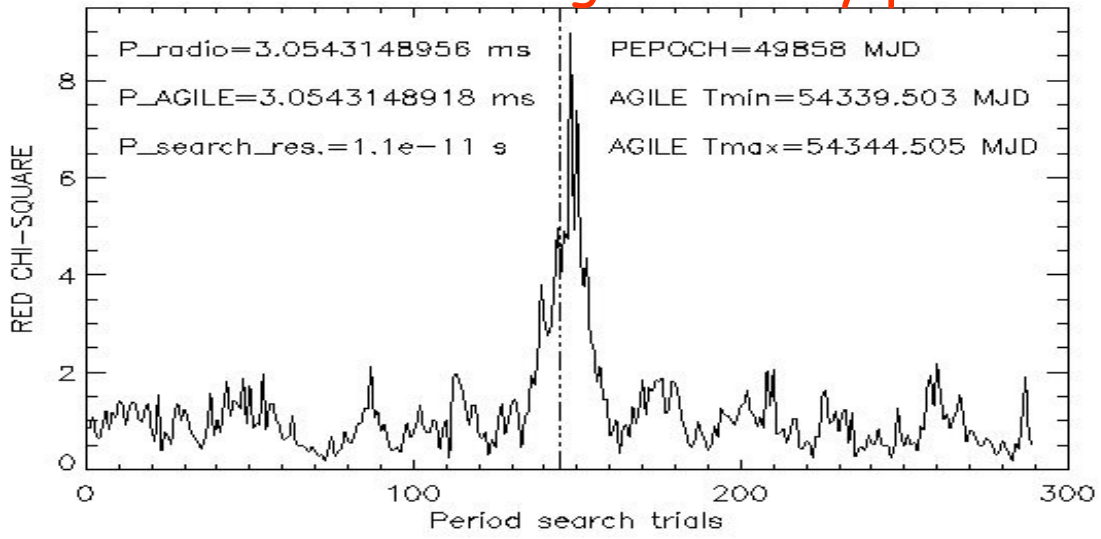


E_{ROT}= 2.2x10^{36} erg/s

P = 3 ms

d = 4.9 kpc

A new variable millisecond gamma-ray pulsar in a globular cluster



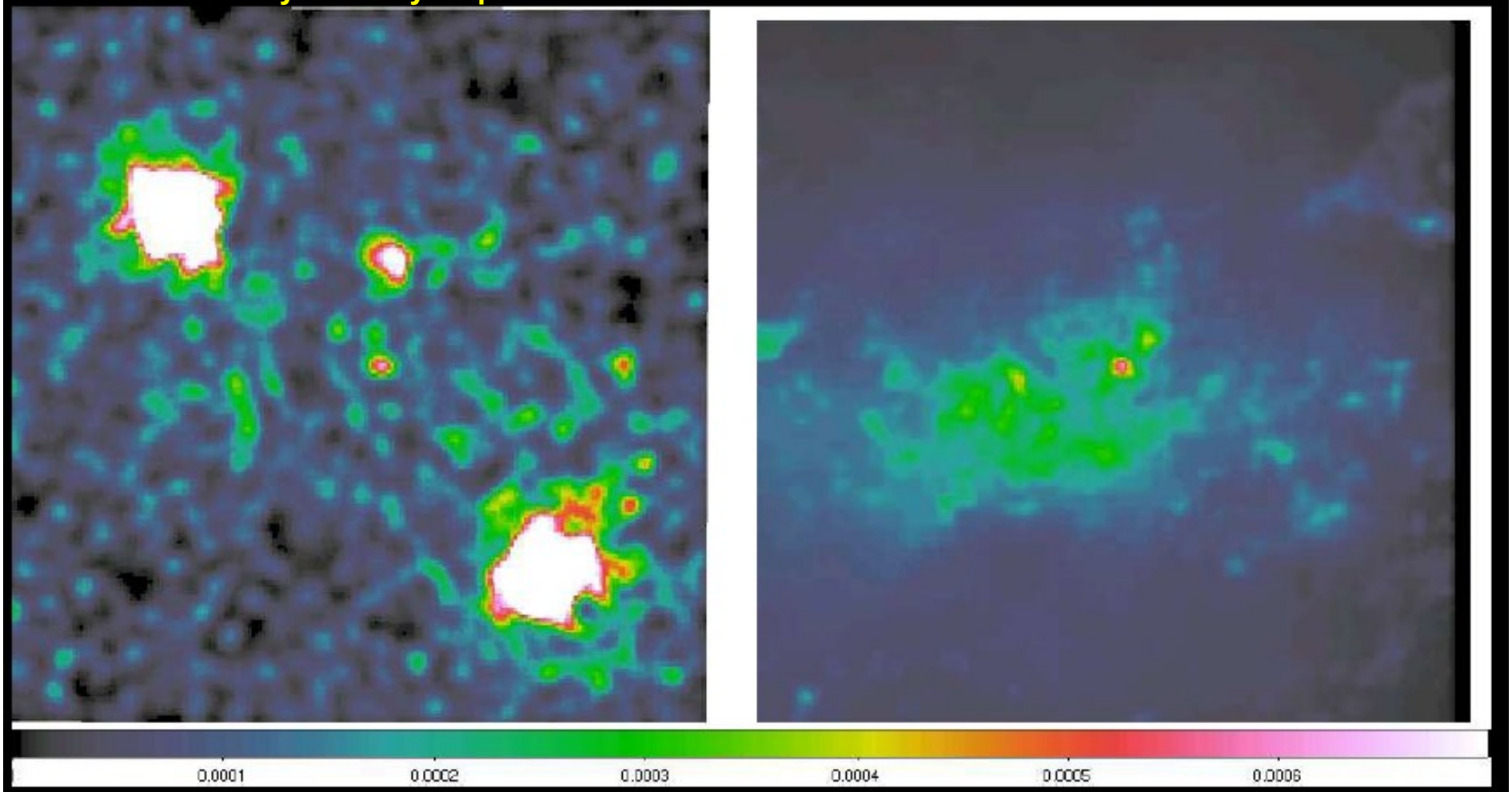
AFTER the pulsars…

SNRs

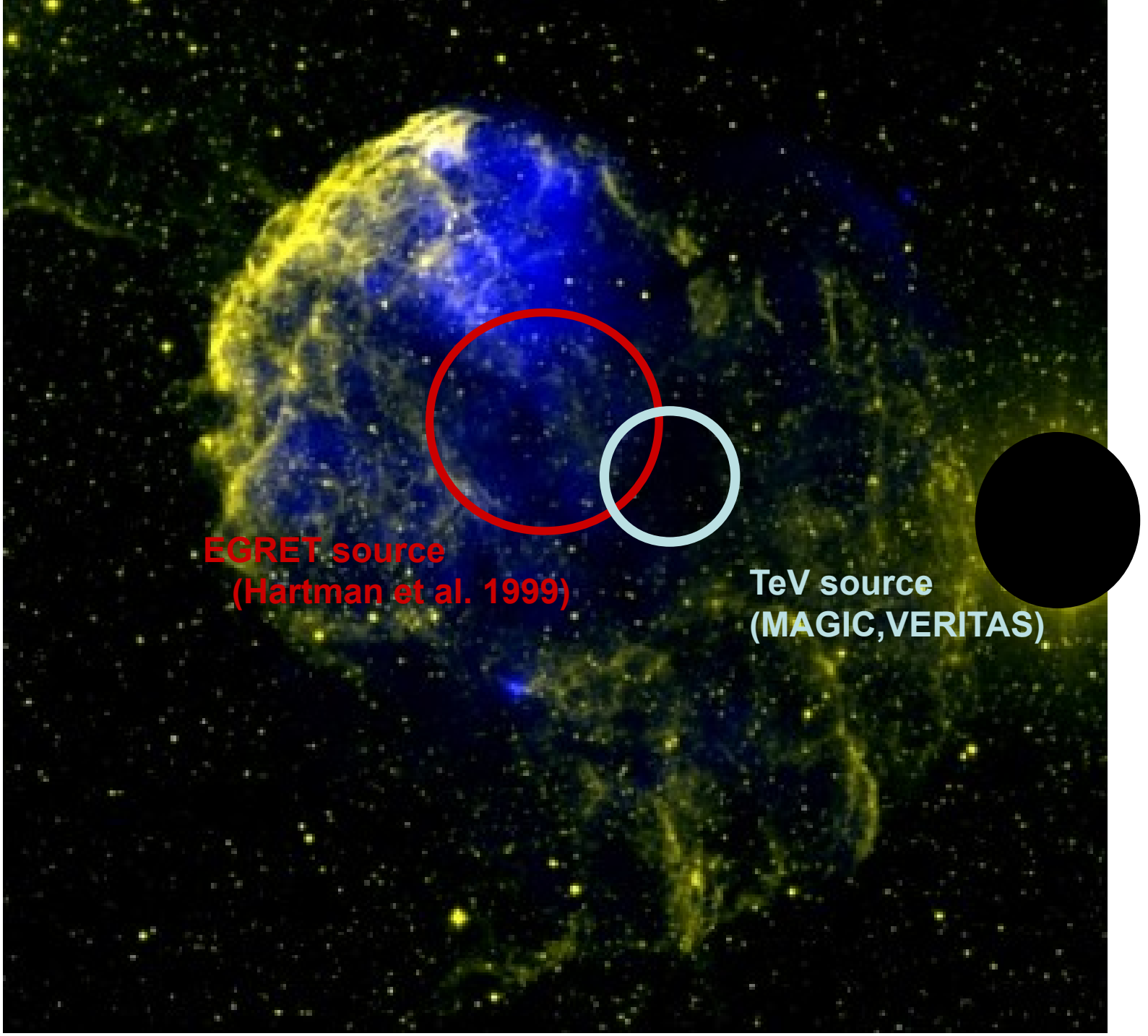
Anticenter – Molecular Clouds Complex

Gamma-ray intensity map

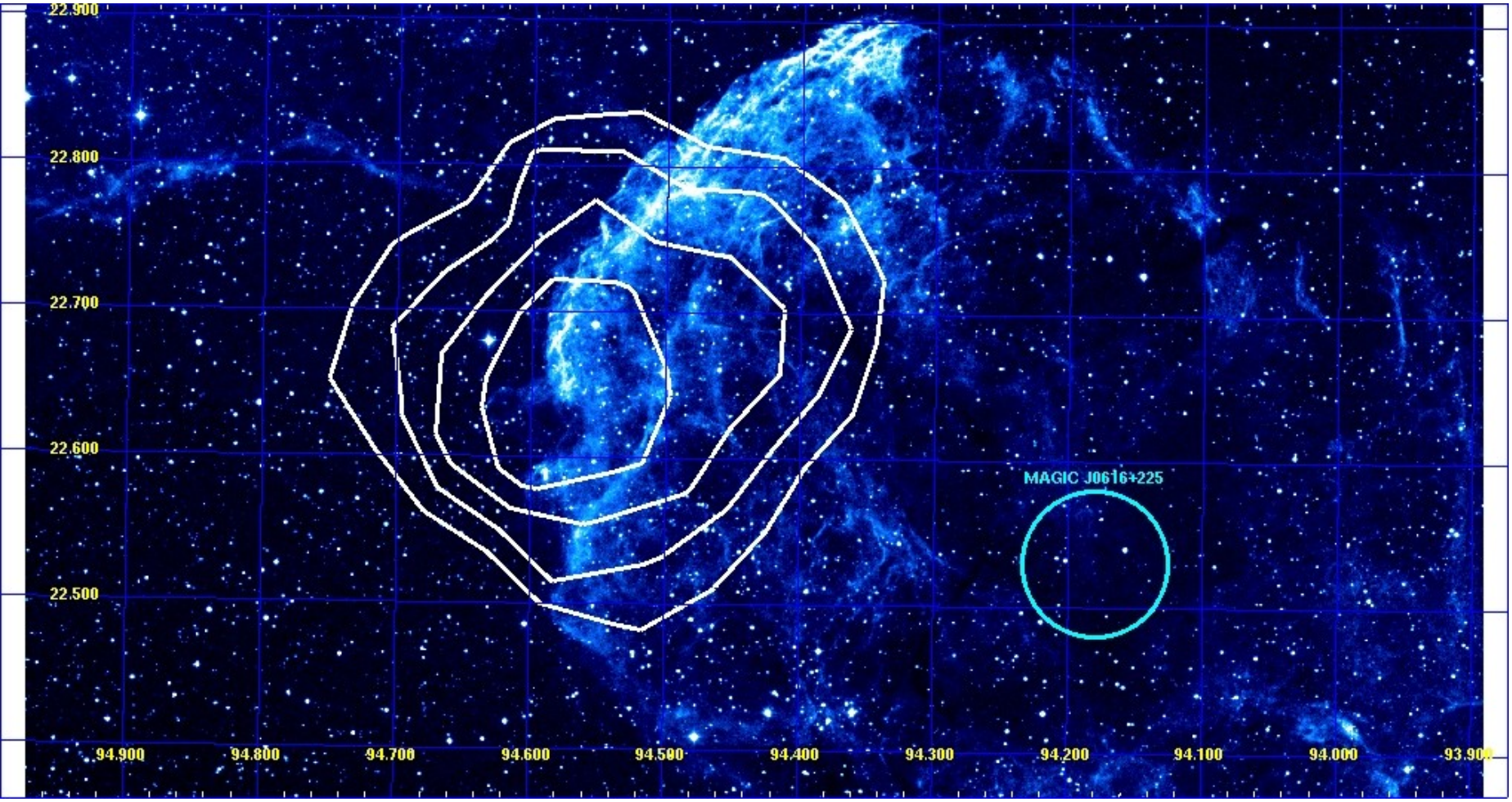
Gamma-ray model based on CO maps



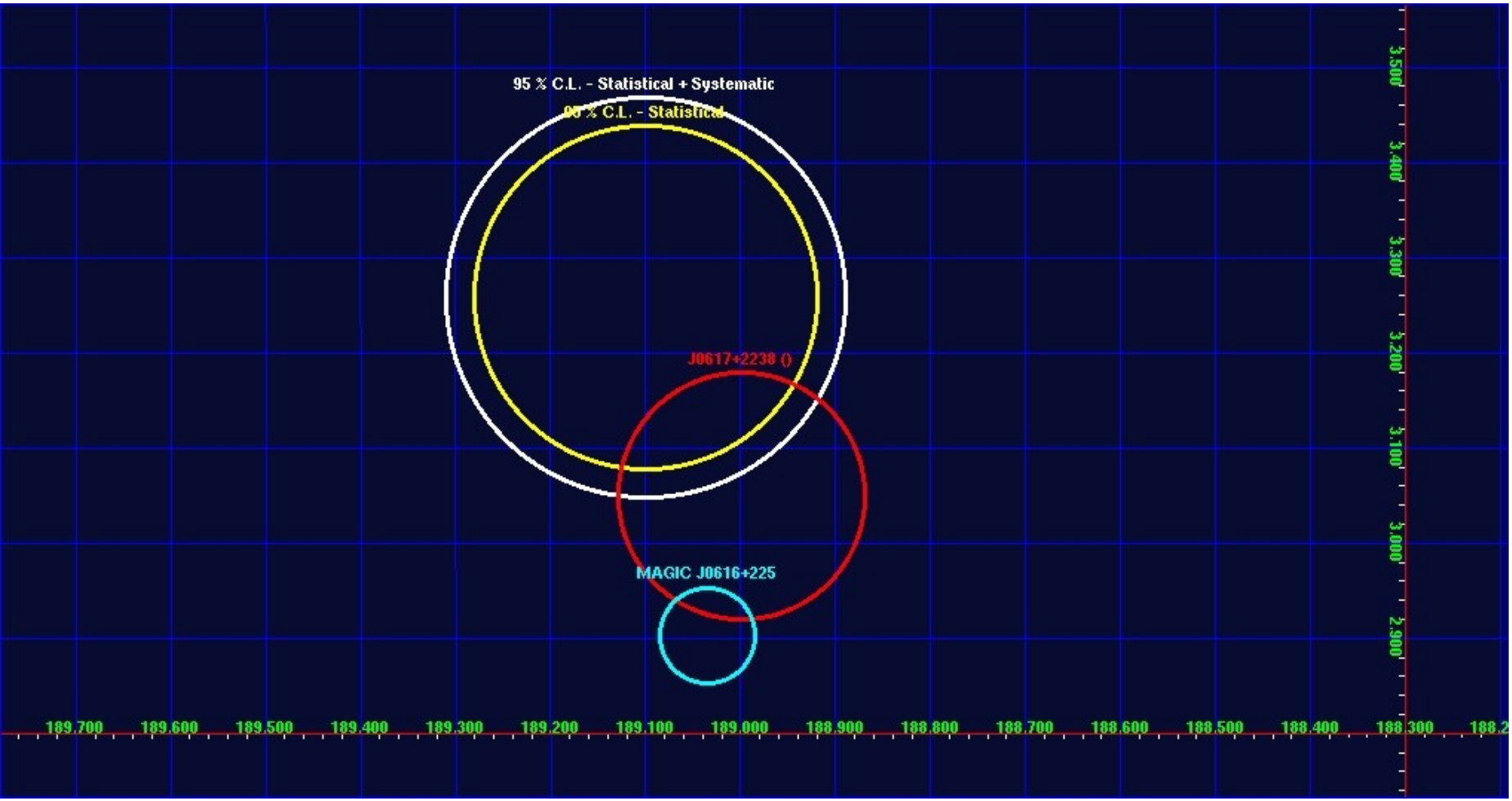
Intensity map – ph/cm^2 sec sr


EGRET source
(Hartman et al. 1999)
TeV source
(MAGIC,VERITAS)

Anticenter – IC 443



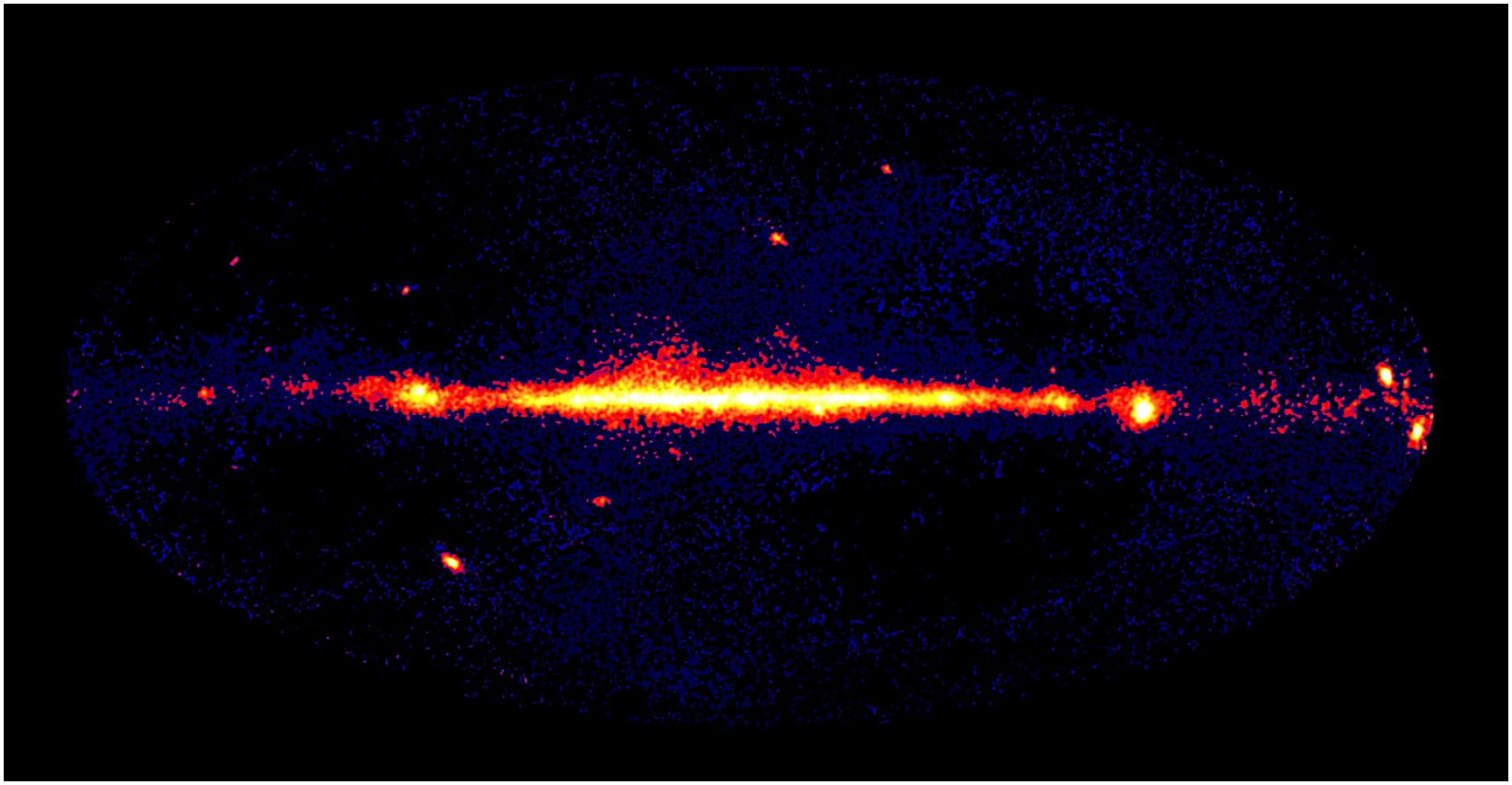
Anticenter – IC 443



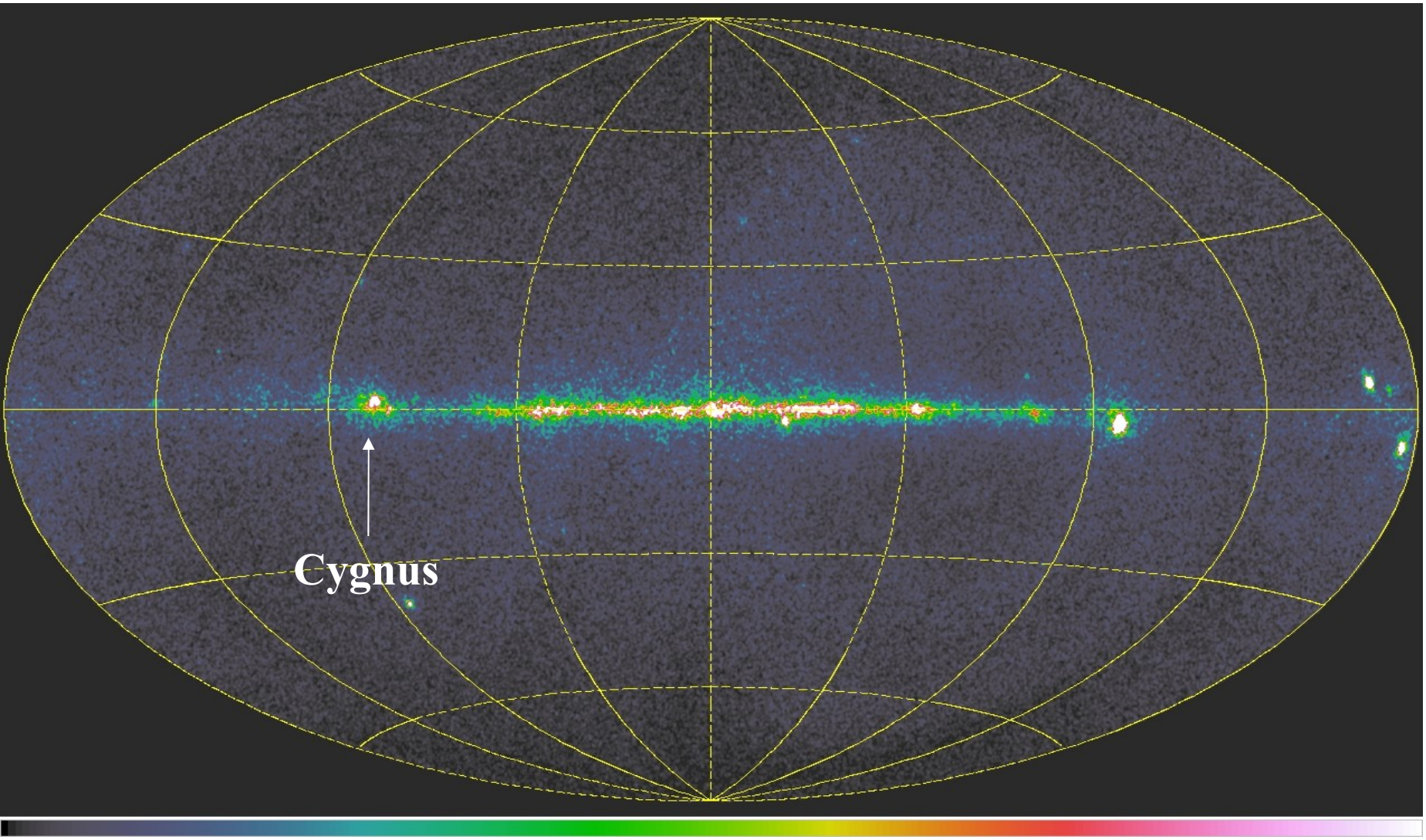
AGILE facts: direct evidence for proton acceleration in IC 443

- **100 MeV source and TeV source are non coincident !**
- **Absence of IC emission above 10-100 GeV at the gamma-ray peak:**
  - **electron/proton ratio ~10^{-2} (see also Gaisser et al. 1998)**
- **absence of prominent TeV emission along the SN shock front (and of non-thermal X-ray emission):**
  - **electron contribution subdominant**
- **The Northeastern SNR shock environment provides the target for proton-proton interaction and pion production/decay**
  - **Hadronic model at the NE shock is the only viable**

Variable galactic sources as seen by AGILE

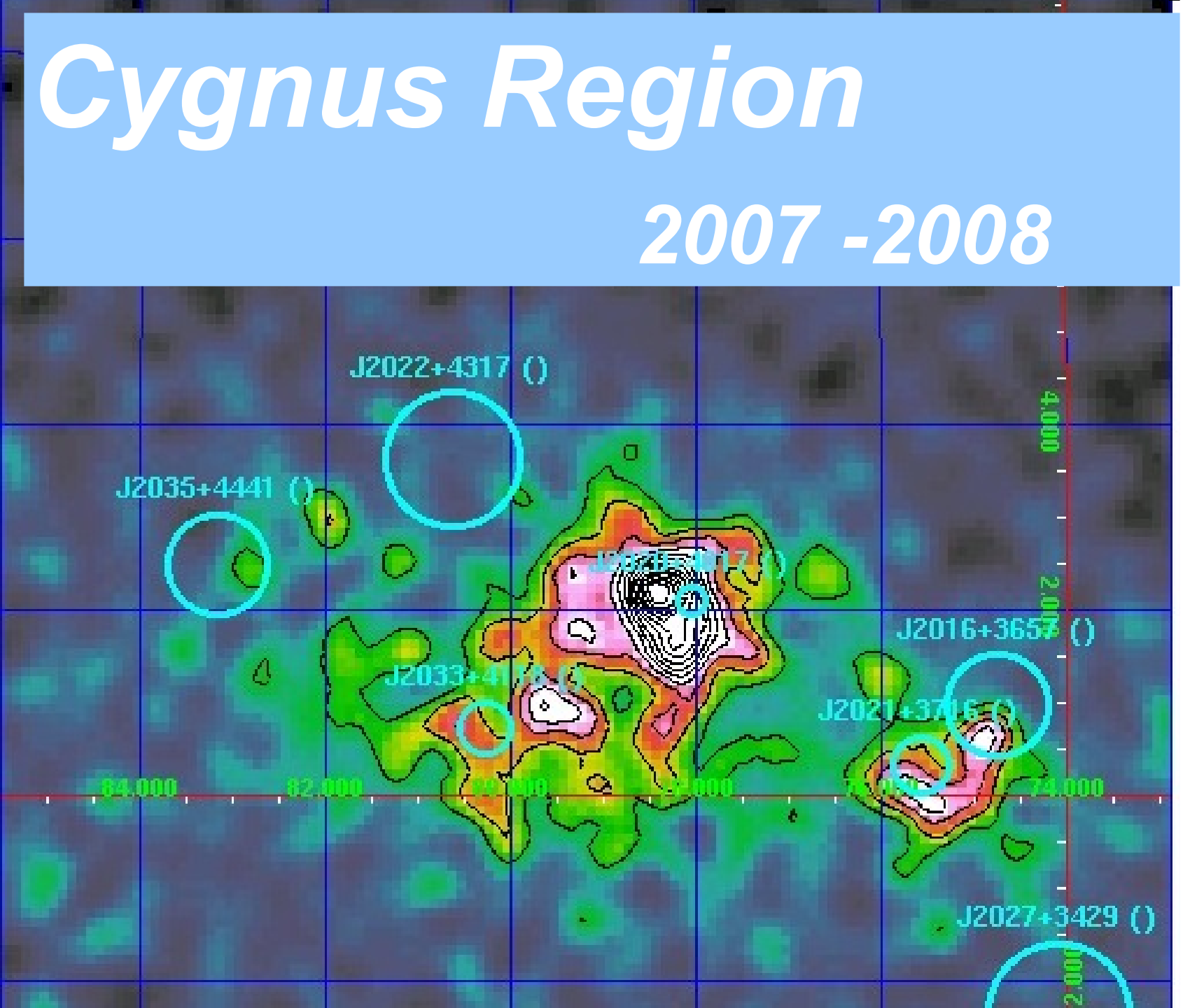


Cygnus region



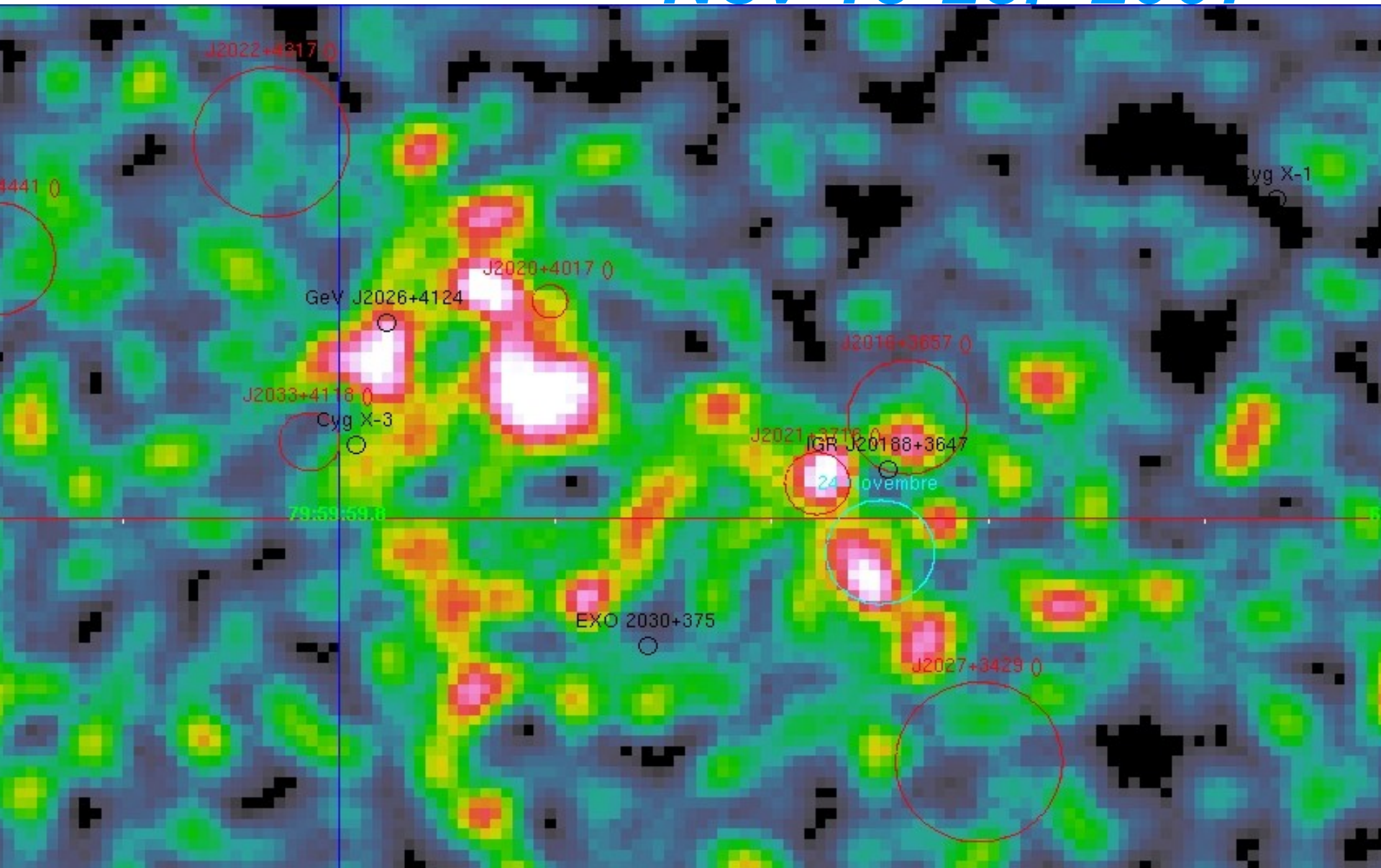
Cygnus Region

2007 -2008



Cygnus Region

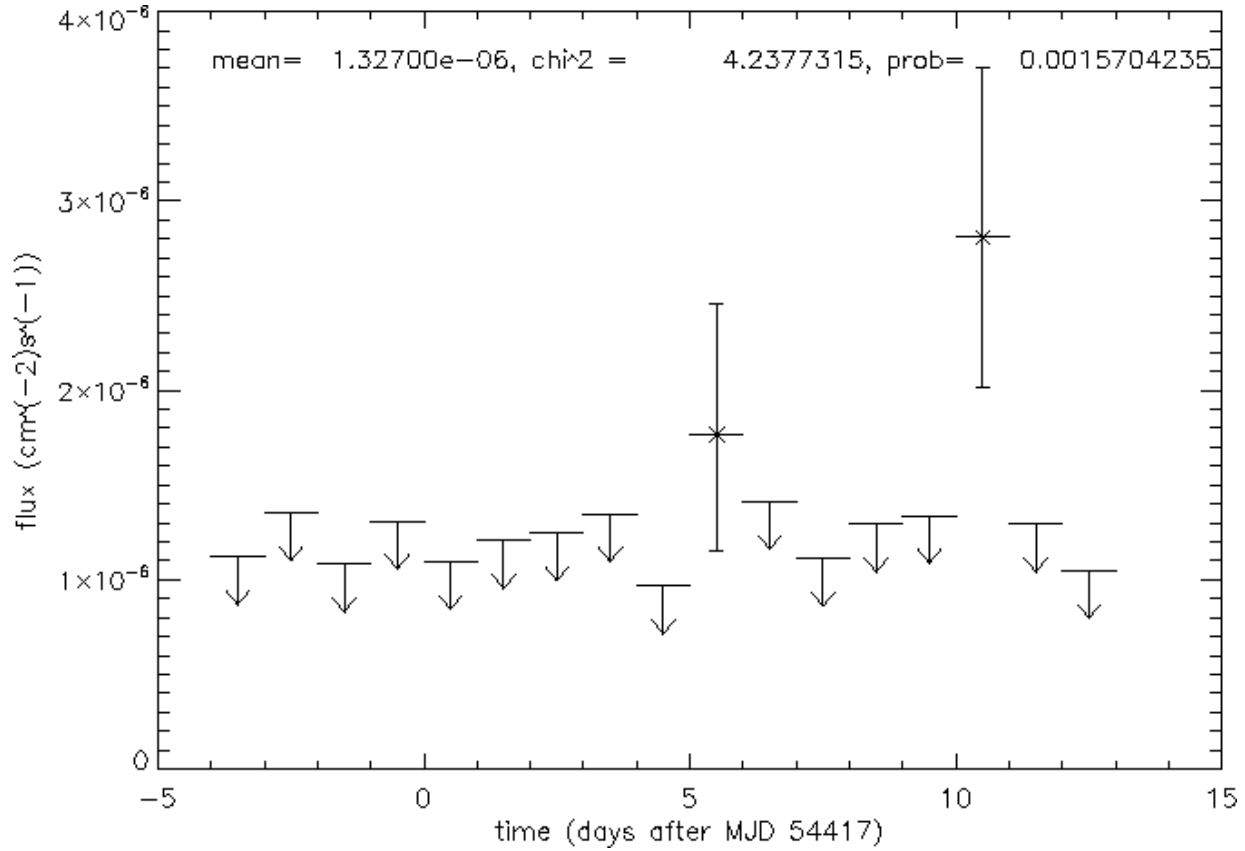
Nov 18-28, 2007



AGLJ2022+3622

- ATEL #1308 Chen et al.
  - AGILE gamma-ray detection of a strongly variable source in the Cygnus region
- Observed November 9-25, 2007
- 1-day flare on November 23-24, 2007
- Significance and flux
  - 3 days: $(1.2 \pm 0.3) \times 10^{-6}$ cm^{-2} s^{-1} at 4.9 σ
  - 1 day: $(2.6 \pm 1.0) \times 10^{-6}$ cm^{-2} s^{-1} at 3.8 □
- Position (l,b)=(74.4,-0.5)°, error ~ 0.8°

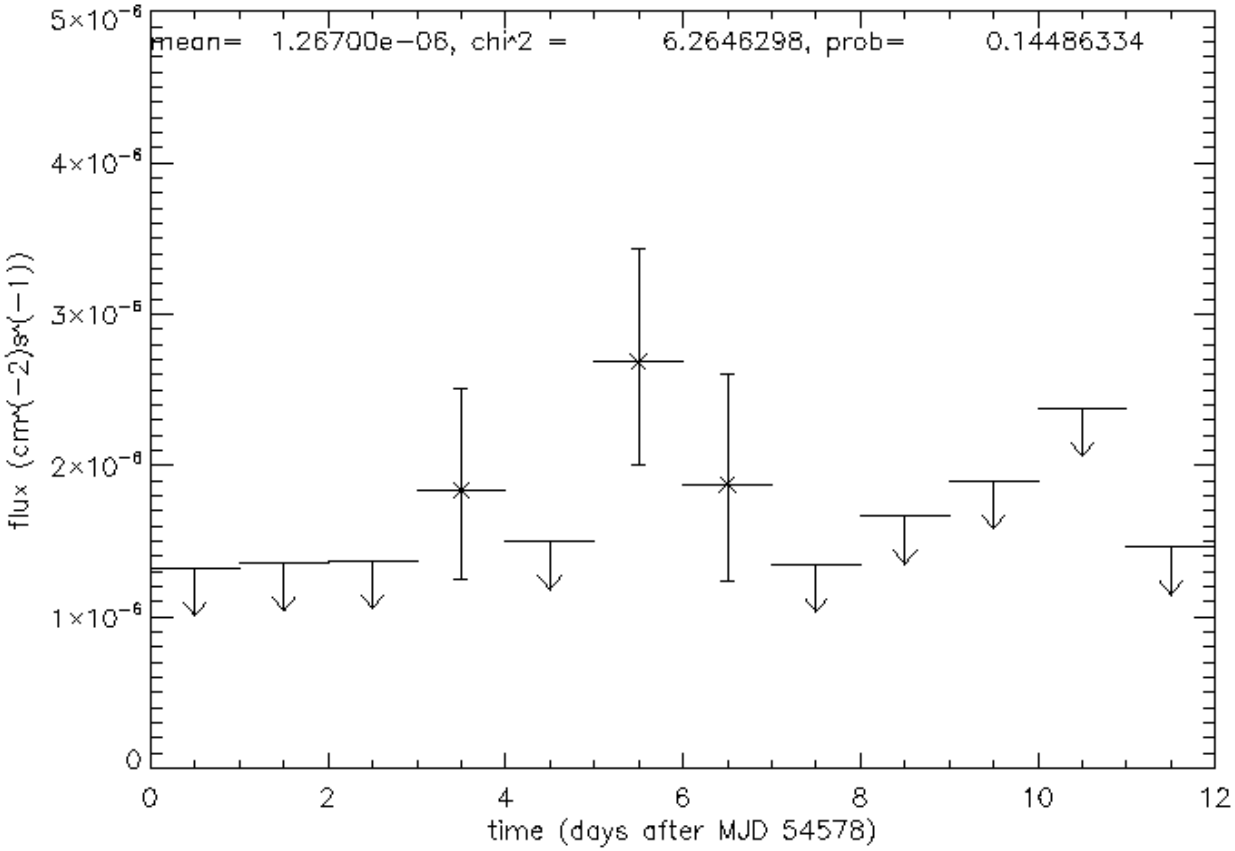
AGLJ2022+3622 -- Light Curve



AGLJ2020+4019

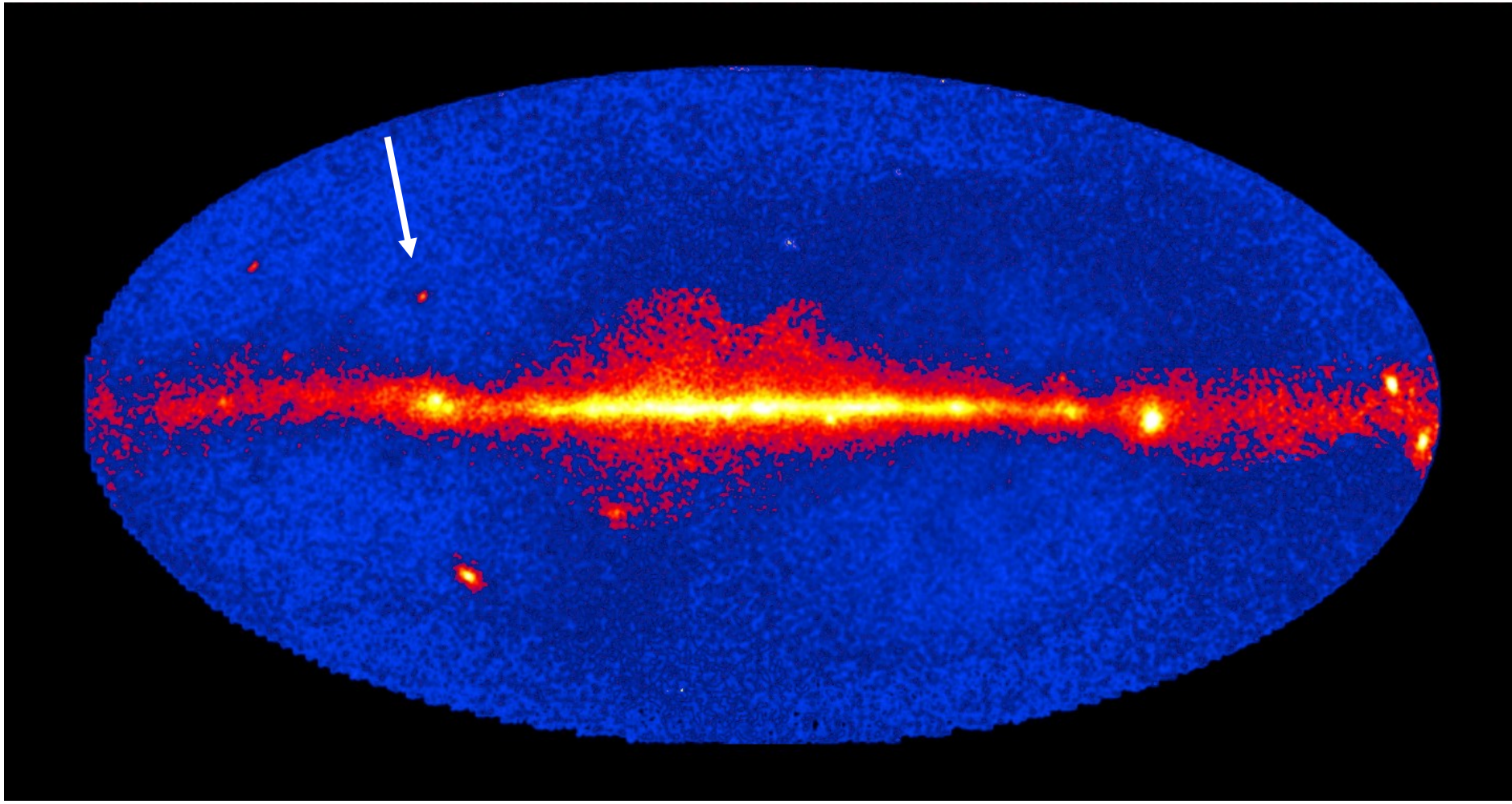
- Cygnus Region
  - Persistent Emission
  - $(1.19 \pm 0.08) \times 10^{-6}$ cm^{-2} s^{-1} at 25.9 □
- Position: (l,b) = (78.35, 2.08)°, error ~ 0.11°
- 1-day flare on April 27-28, 2008
  - (2.9 ± 0.8) × 10-6 cm-2 s-1 at 3.7 σ
  - Position: (l,b) = (78.1, 2.0)°, error ~ 0.8°
- 1-day flare on June 20-21, 2008
  - $(2.5 \pm 0.7) \times 10^{-6}$ cm^{-2} s^{-1} at 4.9 σ
  - Position (*l,b*) = (78.6, 1.6)°, error ~ 0.7°
- 3EGJ2020+4017

AGLJ2020+4019 -- April 27-28, 2008 Light Curve

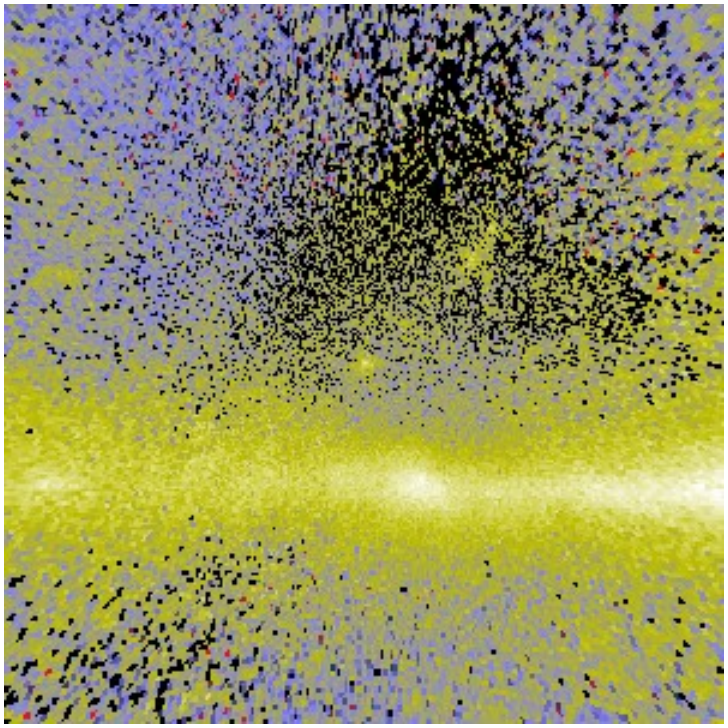


Very difficult to react in such a short time

A different kind of variability



3EG 1835+5918



The Next Geminga

even more difficult than the original one

In γ rays *5 times fainter than Geminga*

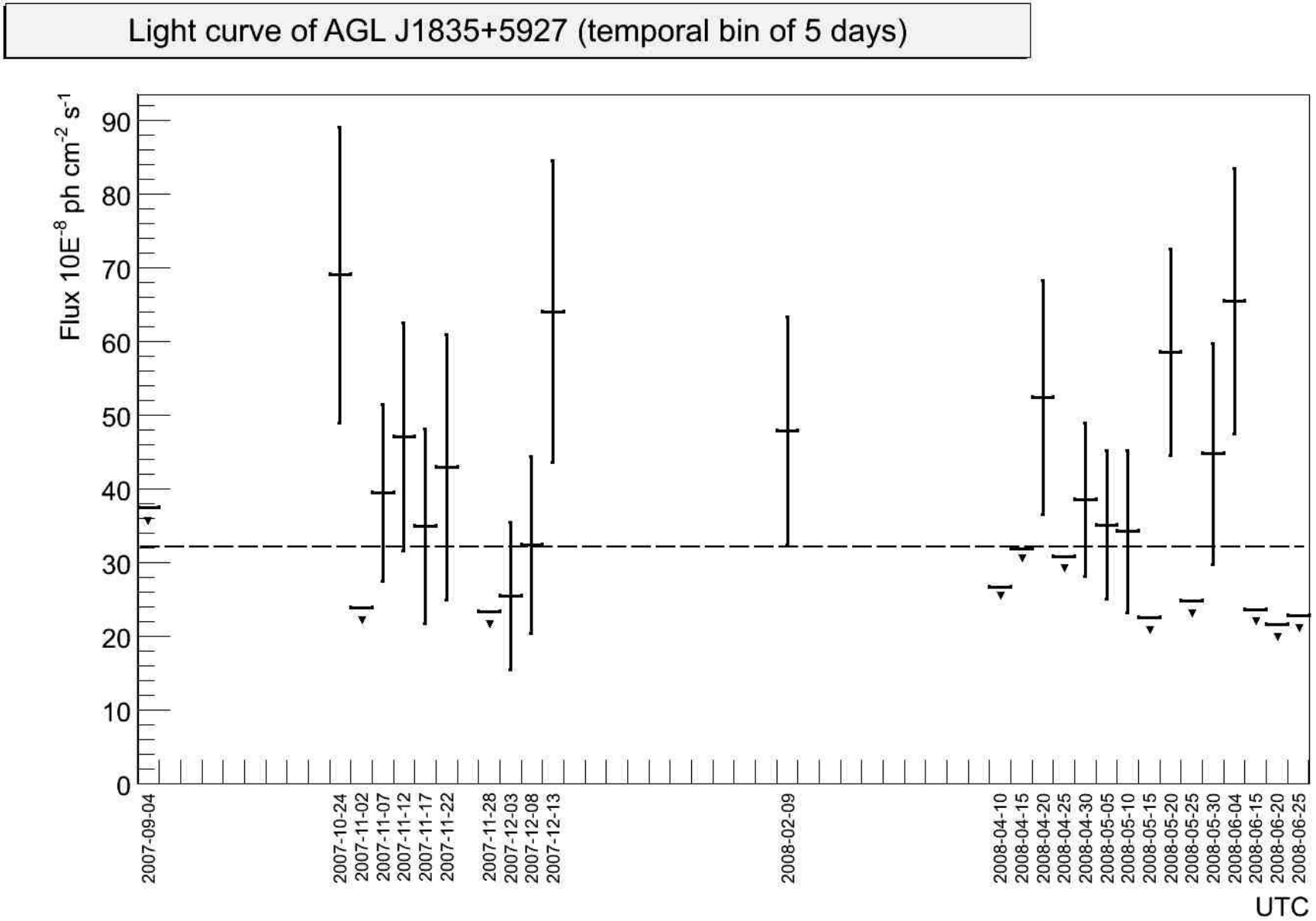
In X-rays *10 times fainter than Geminga*

In the optical *20 times fainter than Geminga*

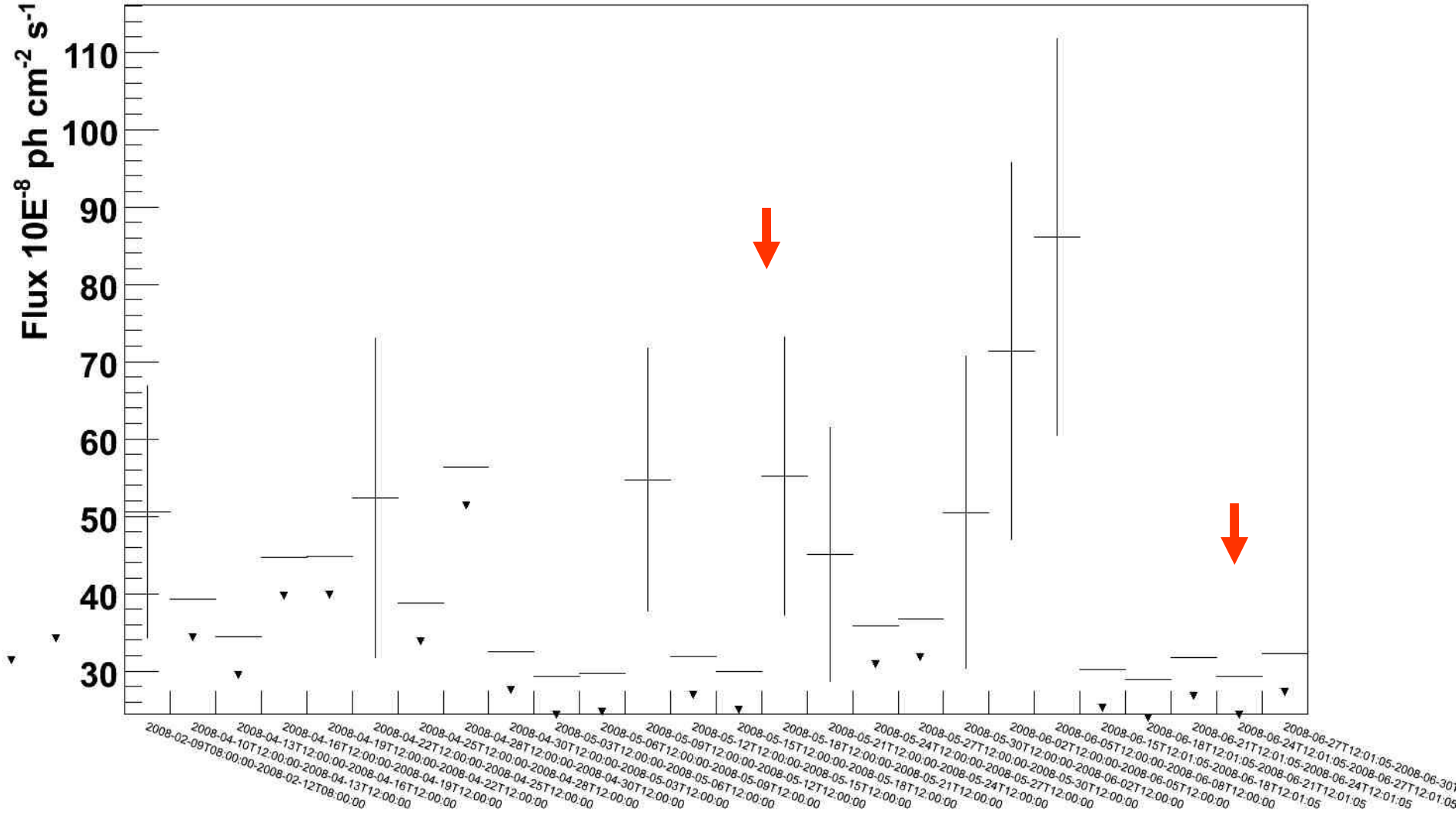
No radio detection, no X-ray pulsation

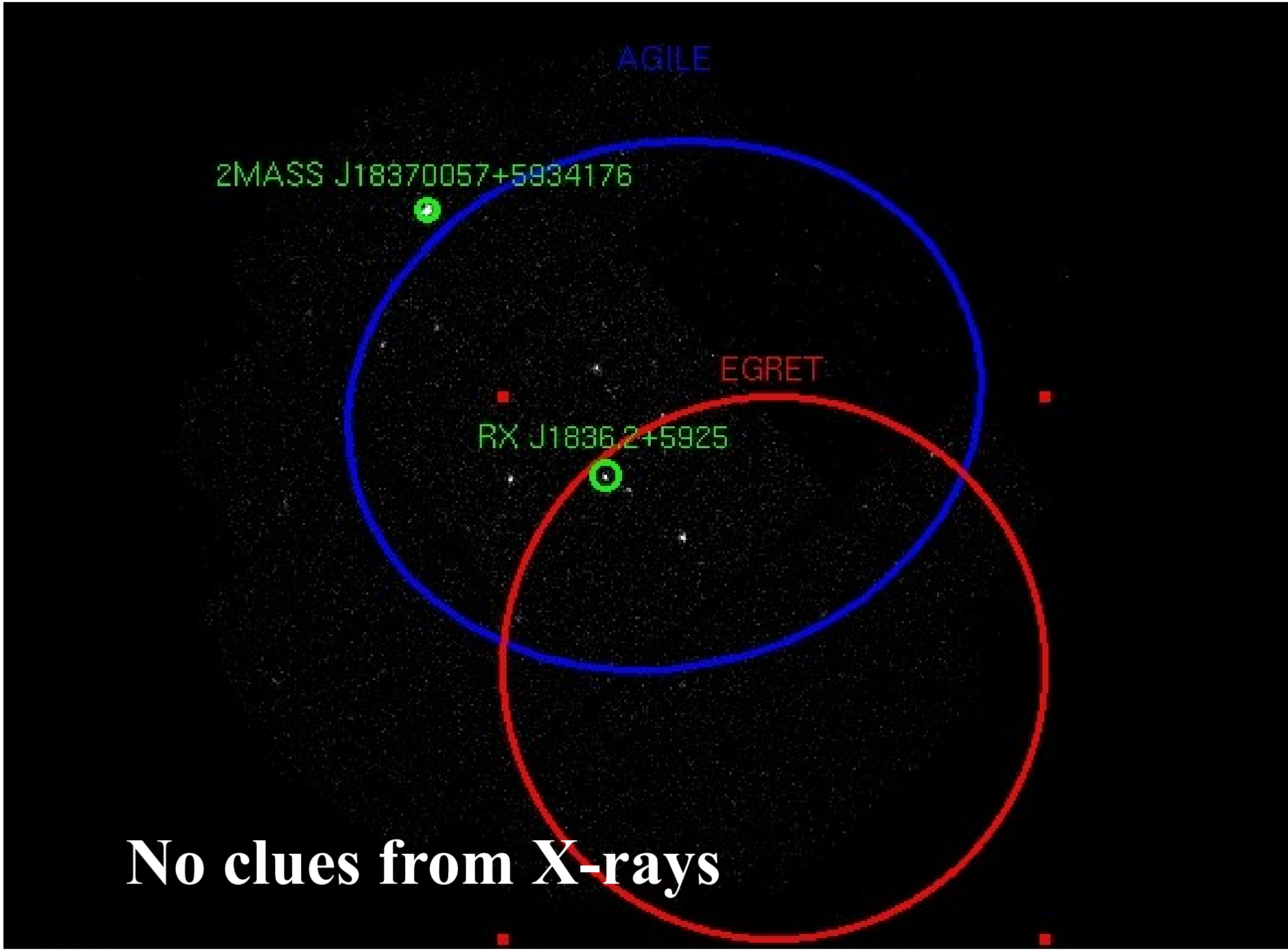
Agile View of Next Geminga

Bulgarelli et al 2008



Light curve of AGL J1835+5927 (bin size 3 days)





No clues from X-rays

Old (variable?) friends

Cygnus X-3

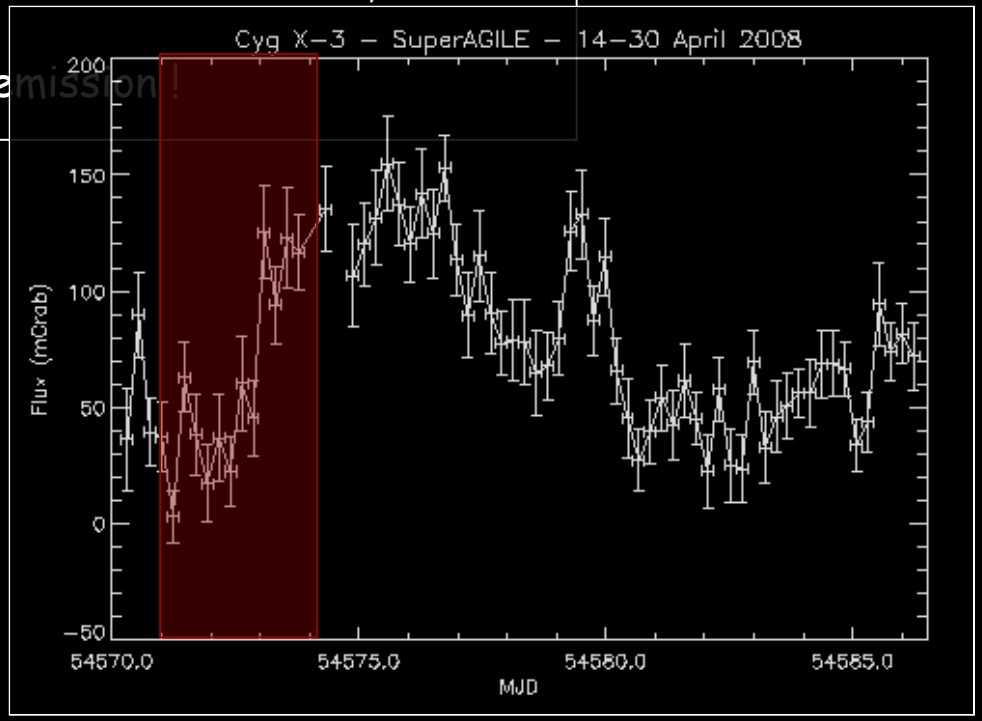
15 - 18 April 2008

Giant radio flare of Cygnus X-3 detected by RATAN-600 radio telescope

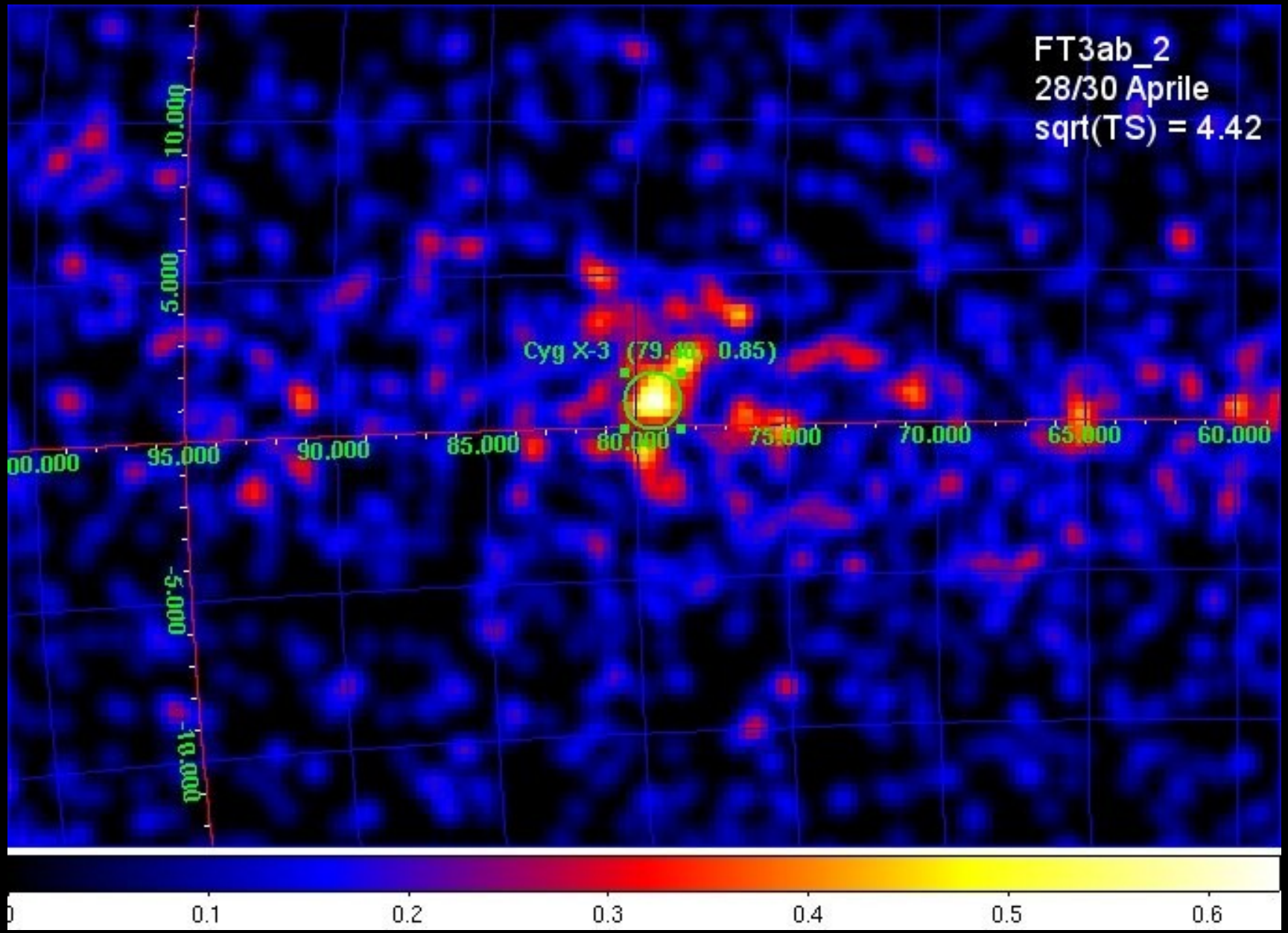
Radio flux increasing of a factor ~10^3, from ~10 mJy to ~10 Jy

S.A.Trushkin et al., ATel #1483

10 Jy is typical flux for plasmoids emission !



In the same period SuperAGILE revealed an X-ray flare


FT3ab_2
28/30 Aprile
sqrt(TS) = 4.42
Cyg X-3 (79.48, 0.85)
10.000
5.000
-5.000
-10.000
95.000
90.000
85.000
80.000
75.000
70.000
65.000
60.000
0.1
0.2
0.3
0.4
0.5
0.6

LSI +61°303

GRID Galactic anticenter observation

Future prospects for AGILE…

- **Erratic variability of accreting micro-QSOs**
- **Need simultaneous and well-sampled X-ray and gamma-ray coverage !**
- **Gamma-ray emission rare, if any.**

Summary of the AGILE results for GRBs

15 GRBs localized by SuperAGILE since July 2007 => ~1 GRB/month;

The uncertainty on the localization is 3 arcmin and the minimum detected fluence is ~5 10^{-7} erg cm^{-2};

11 follow-ups by Swift/XRT and the X-ray afterglow was always found;

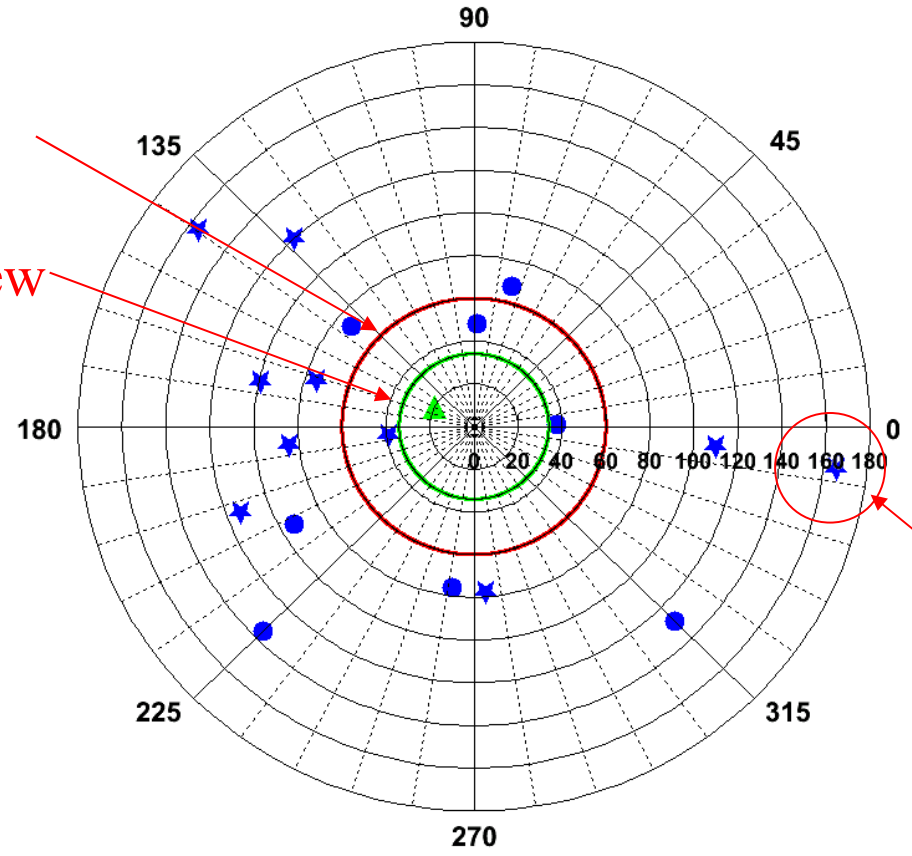
About 1 GRB/week detected by MCAL and 1 - 2 GRBs/month detected by SuperAGILE (outside FoV) and provided to IPN for triangulation;

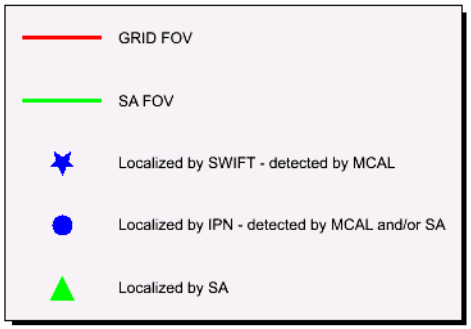
One firm detection in gamma rays (GRB 080514B, Giuliani et al., 2008, A&A) and two less significant detections (GRB 080721 and GRB 081001);

Localized AGILE GRBs

GRID field of view

SA field of view

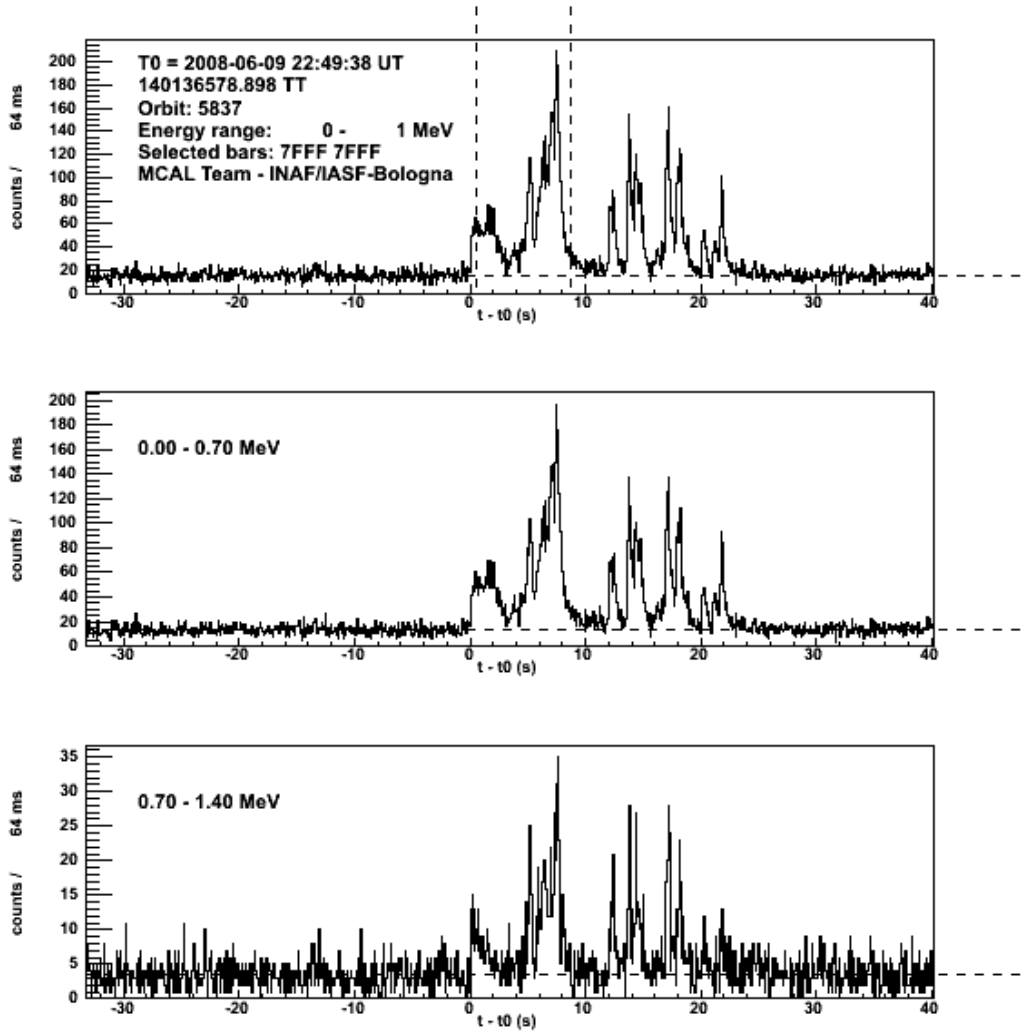




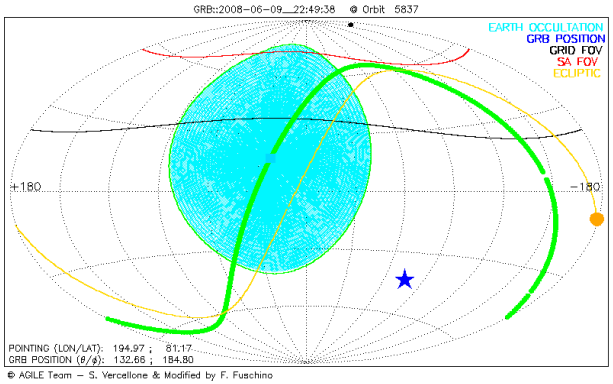
The most off-axis: 166 deg!

In the period July '07 – August '08: 64 GRBs detected (~1 GRB / week)
10 localized by SWIFT
8 localized by IPN (many more expected)
1 localized by SuperAGILE (other 4 SuperAGILE localizations without MCAL detection)

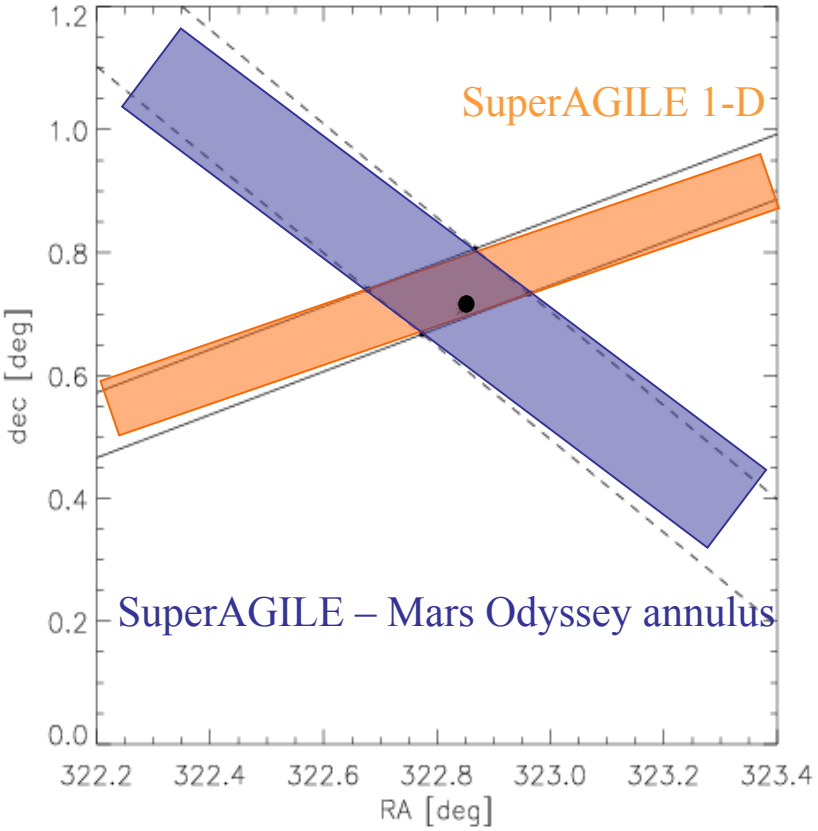
GRB 080609



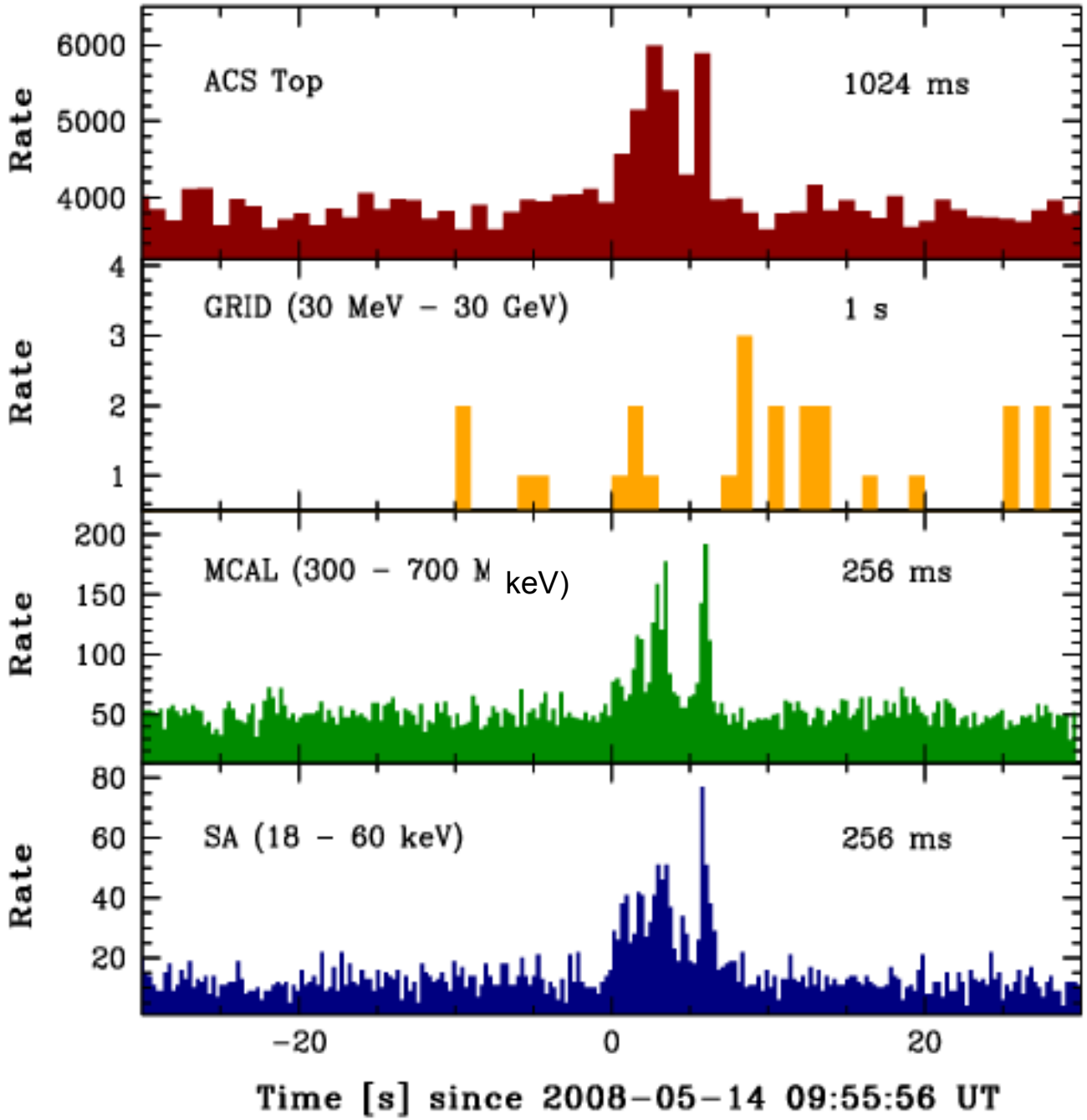
long
bright
multipeaked
out of GRID FOV



AGILE first gamma-ray detection of a GRB:
GRB 080514B (Giuliani et al., A&A 2008)



GRB 080514B has been localized jointly by SuperAGILE and IPN.
Follow-up by Swift provided the afterglow in X-rays.
Many telescopes participated in the observation of the optical afterglow yielding the redshift

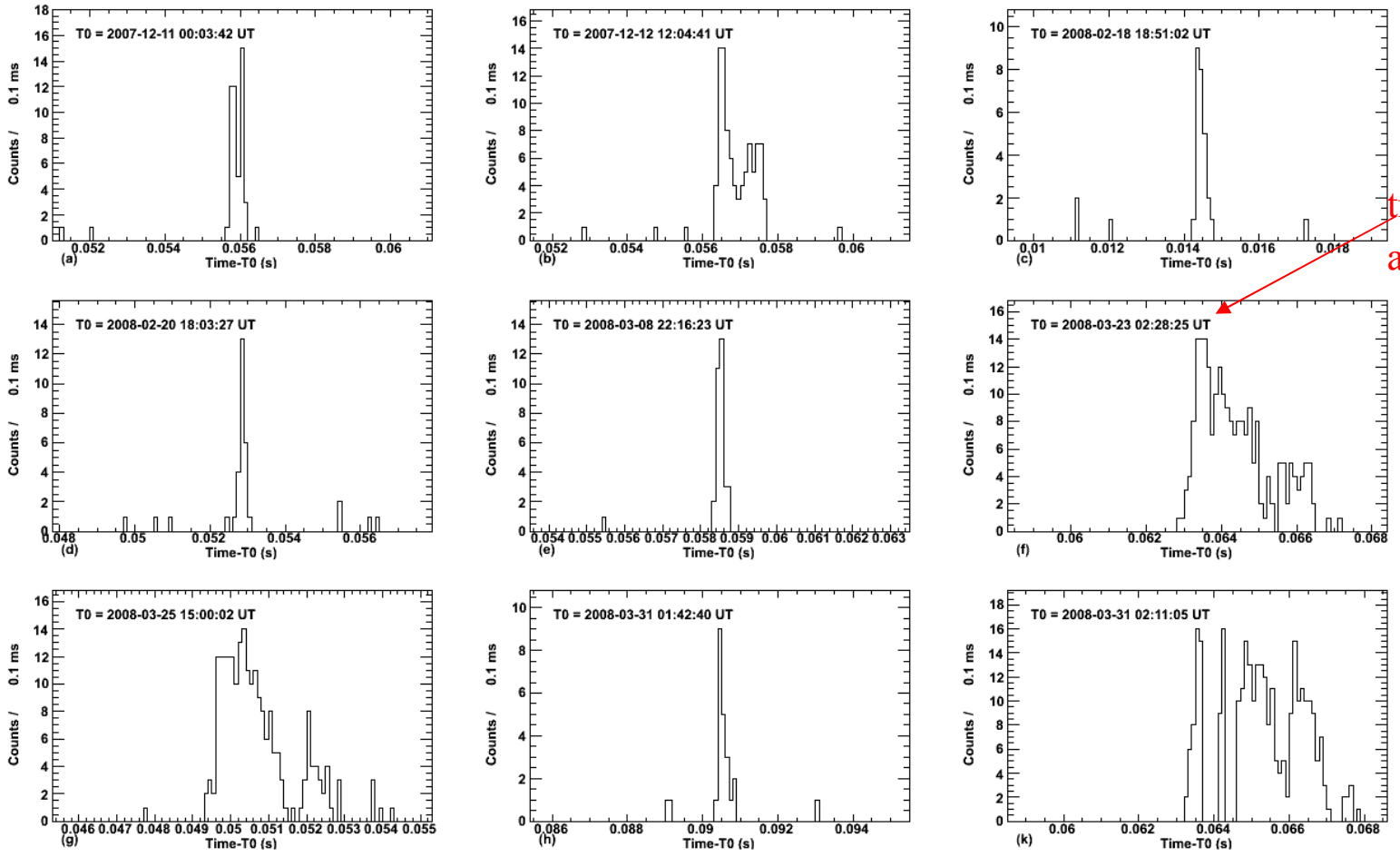


GRB 080514B

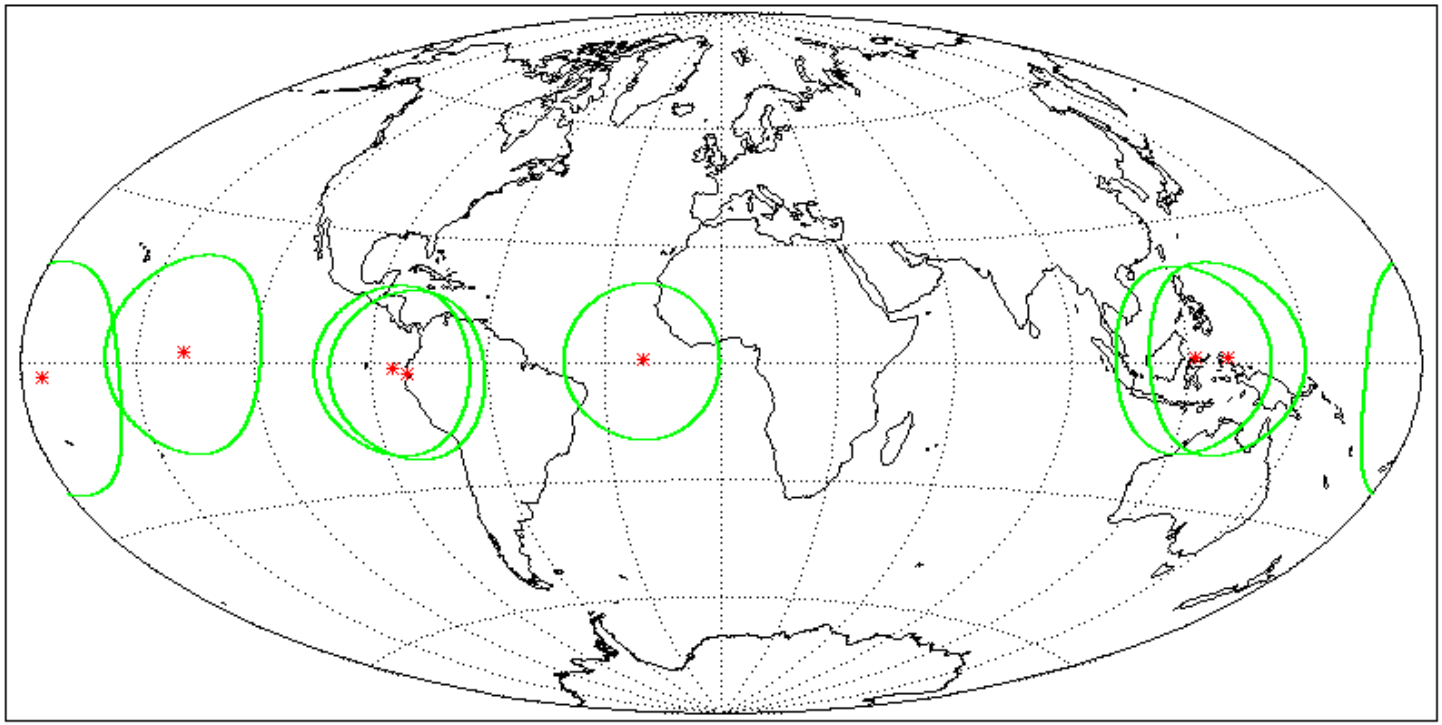
Giuliani et al. 2008)

MCAL candidate TGF

trigger on 64ms timescale



Candidate TGF geographical distribution



Conclusions

- **Very exciting time for gamma-ray and VHE astrophysics**
- **AGILE and Fermi LAT will provide a wealth of data on a variety of sources**
- **Multifrequency approach is crucial**

	AGILE	FERMI/LAT
A_{eff} (100 MeV) (cm^2)	~400	~ 2000-2500
A_{eff} (10 GeV) (cm^2)	500	~ 8000-10000
FOV (sr)	2.5	2.5
sky coverage	1/5	whole sky
Energy resolution (~ 400 MeV)	50 %	10 %
PSF (68 % cont. radius) 100 MeV 1 GeV	 3° - 4° < 1°	 3° - 4° < 1°

	AGILE (GRID)	FERMI (LAT)
FOV (sr)	2.5	2.5
sky coverage	1/5	whole sky
Average source livetime fraction per day	~ 0.4	~ 0.16
Attitude	fixed	variable

History of space astrophysics above 20 keV or so…