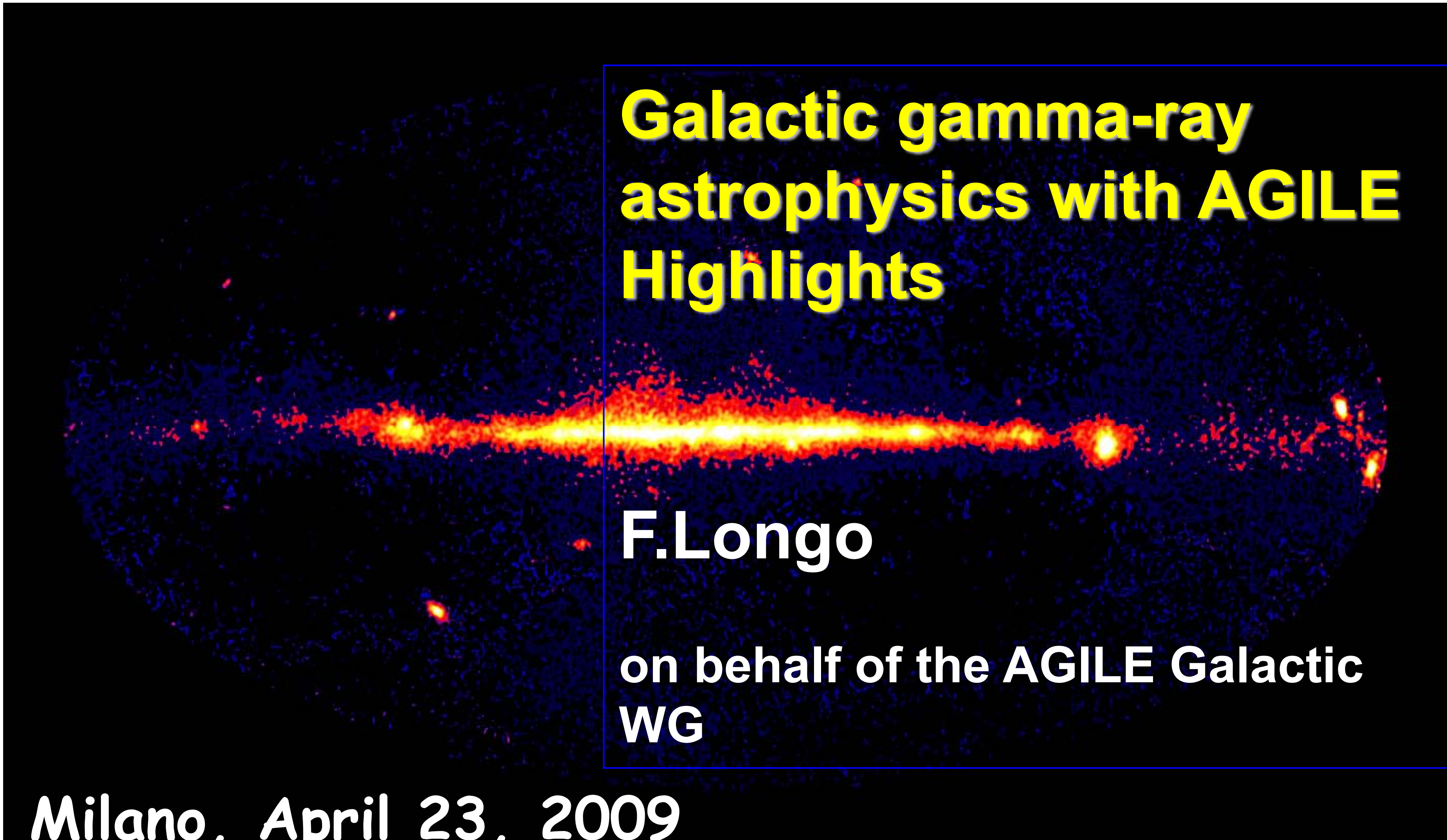


Galactic gamma-ray astrophysics with AGILE Highlights

F.Longo

on behalf of the AGILE Galactic WG

Milano, April 23, 2009

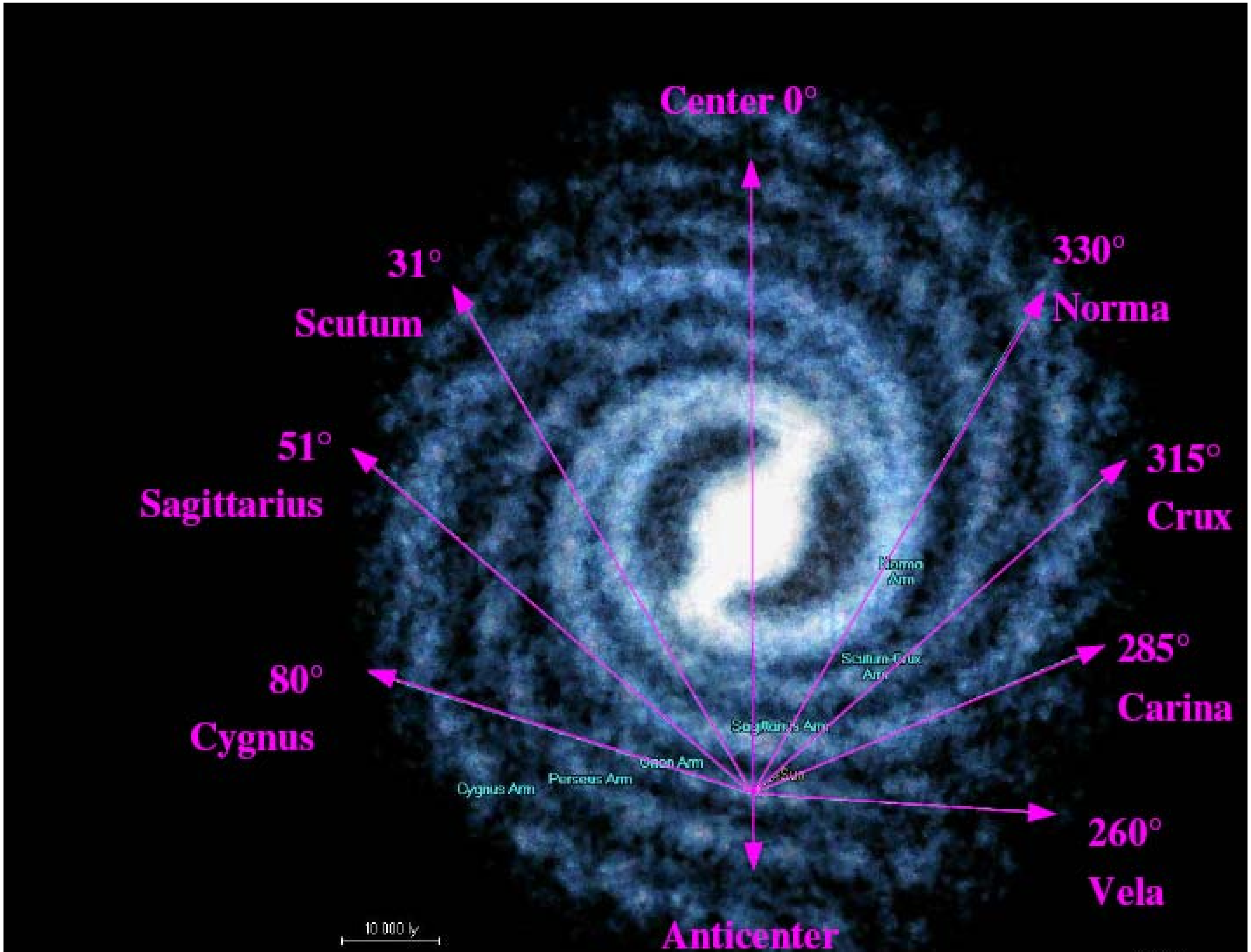
The Galactic WG

- A.Giuliani, A.Chen, A.Pellizzoni, S.Vercellone, P.Caraveo, M.Marelli, Y.Evangelista, E.Del Monte, M.Feroci, A.Bulgarelli, M. Marisaldi, G.Piano, F.Longo, S.Sabatini, M.Tavani, F.Boffelli, P.Cattaneo, A.Rappoldi, A.Morselli, P.Lipari, C.Pittori, F.Verrecchia
- SNR and TeV + Diffuse and DM + UnID WGs + X-ray Compact Sources
- Close connection with PSR WG

Technical Activities by the Group

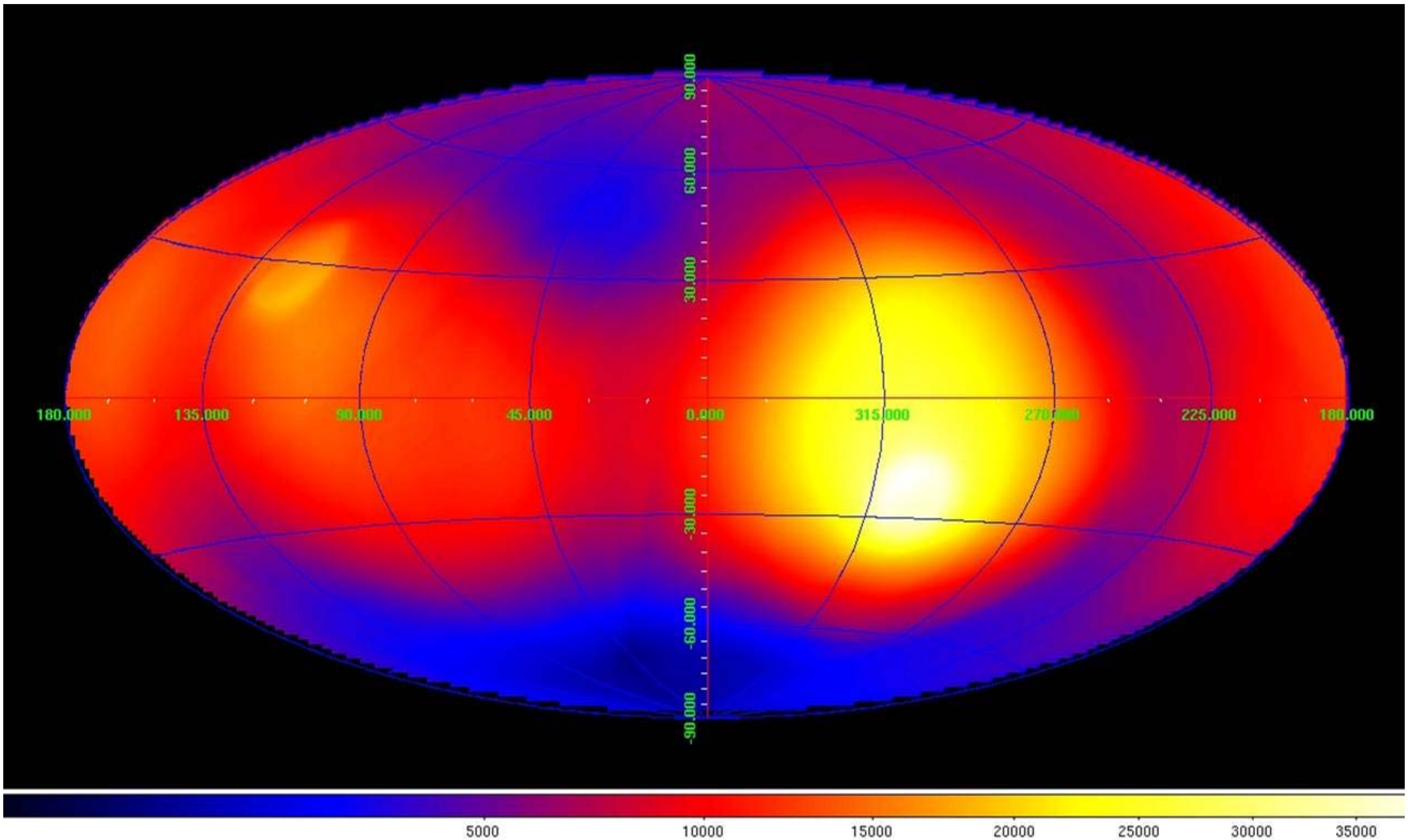
- Likelihood Multi Src Tool
- Galactic Diffuse emission model
- Search for Gamma-ray Transients
- X-Gamma analysis
- AGILE Catalog

The Galaxy

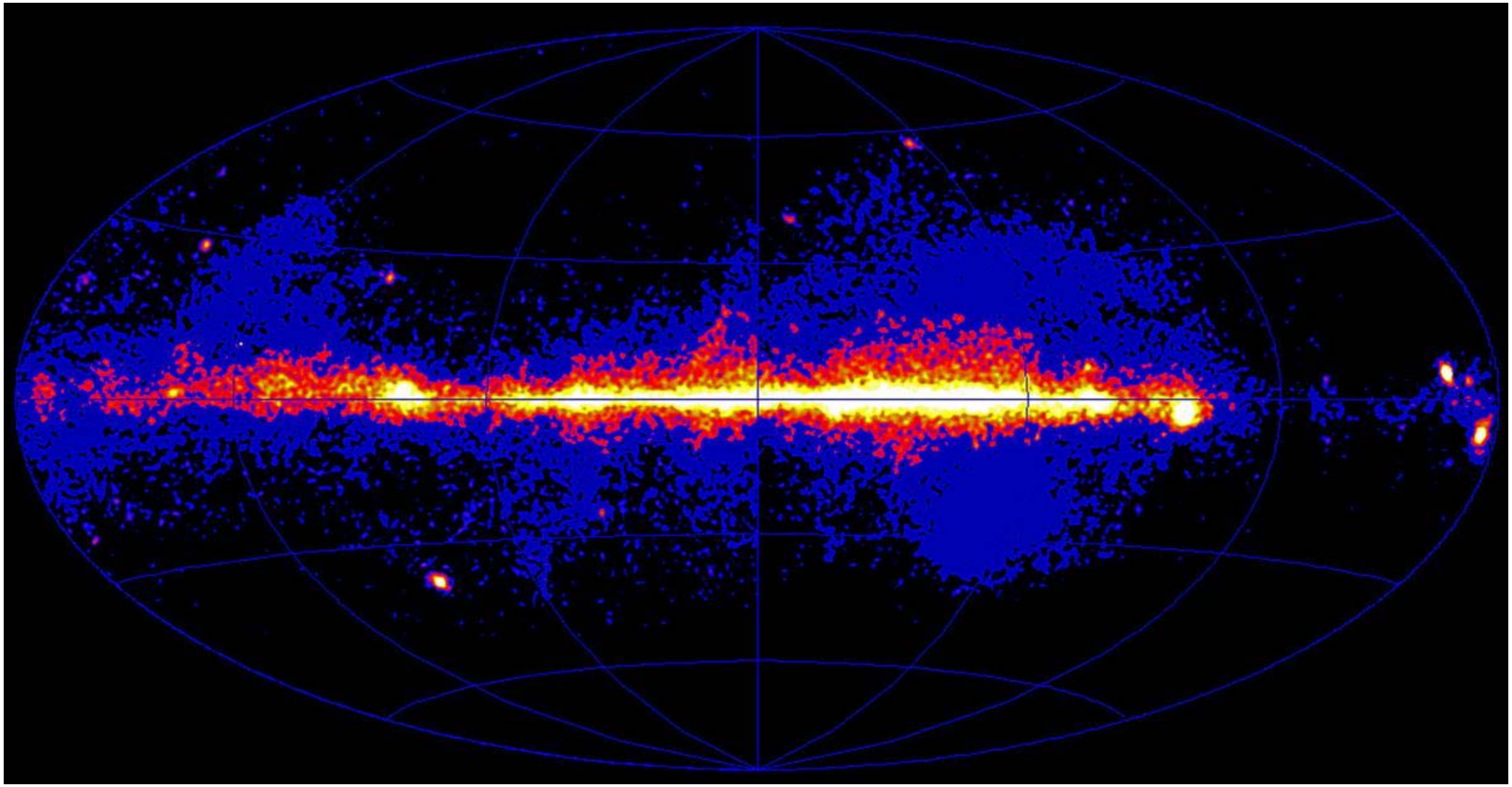


Center 0°
31°
Scutum
330°
Norma
51°
Sagittarius
315°
Crux
Norma Arm
Scutum-Crux Arm
80°
Cygnus
285°
Carina
Sagittarius Arm
Orion Arm
Perseus Arm
Cygnus Arm
Sun
260°
Vela
10 000 ly
Anticenter

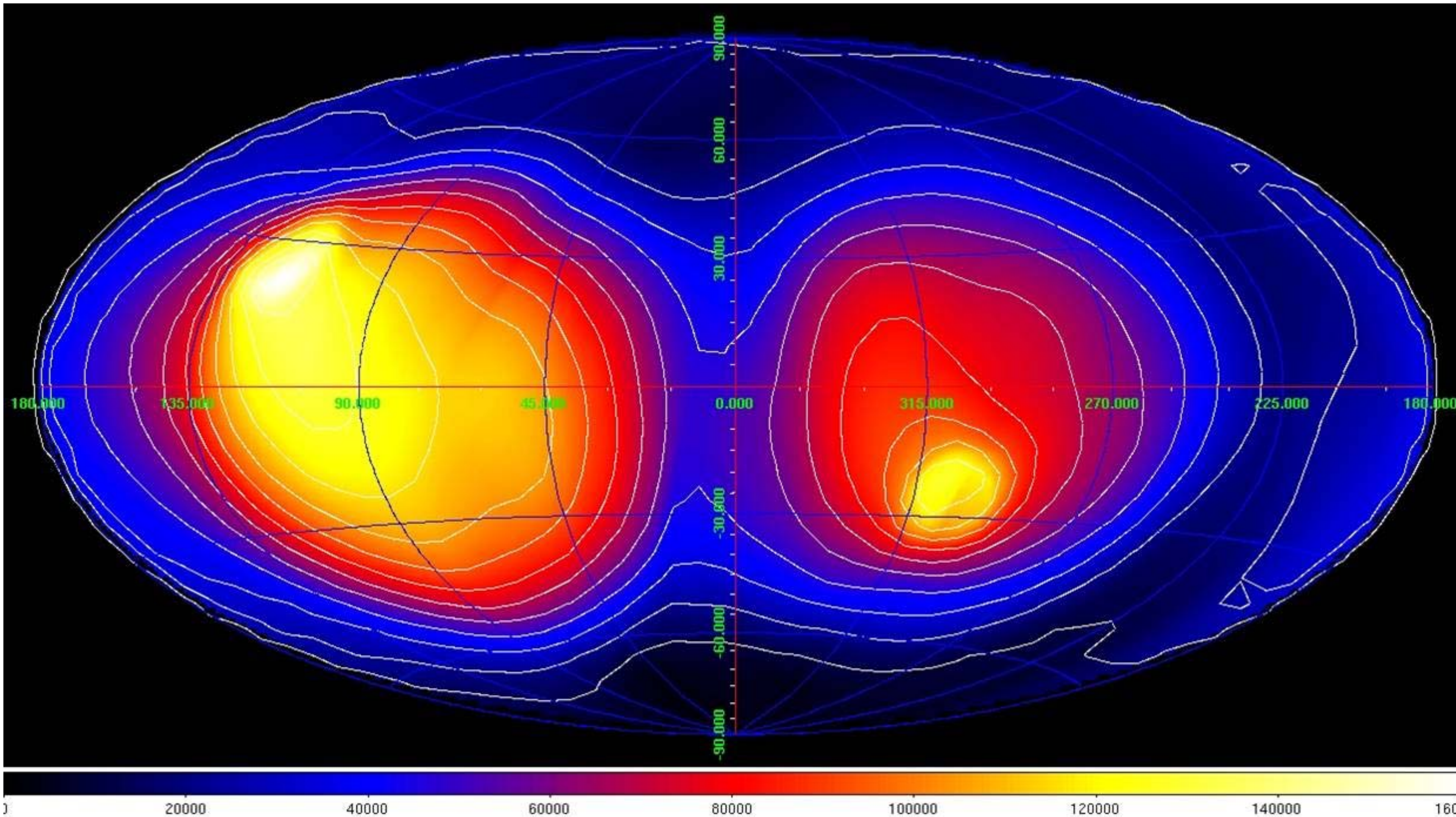
1yr Exposure



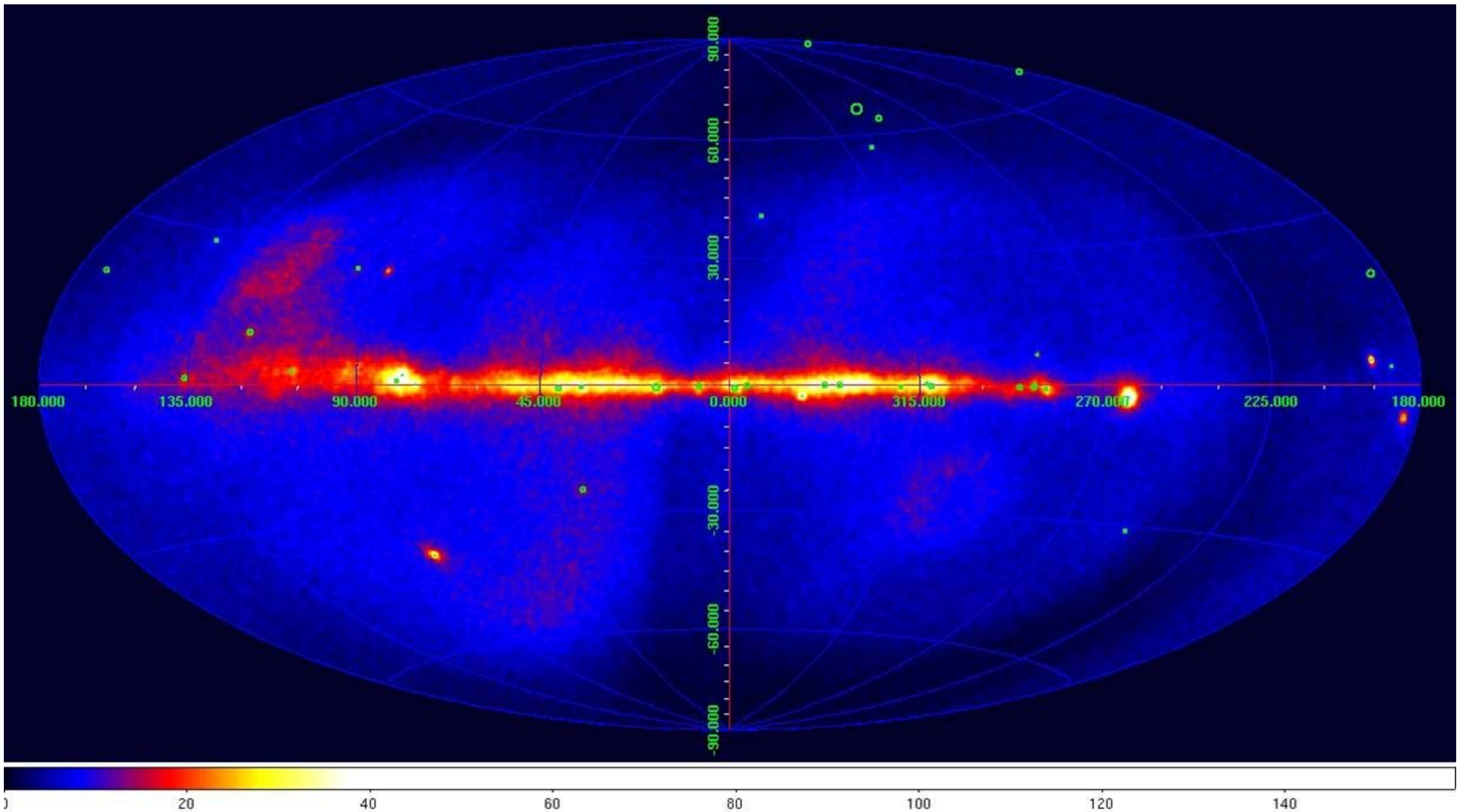
1 yr Gamma-ray sky by AGILE



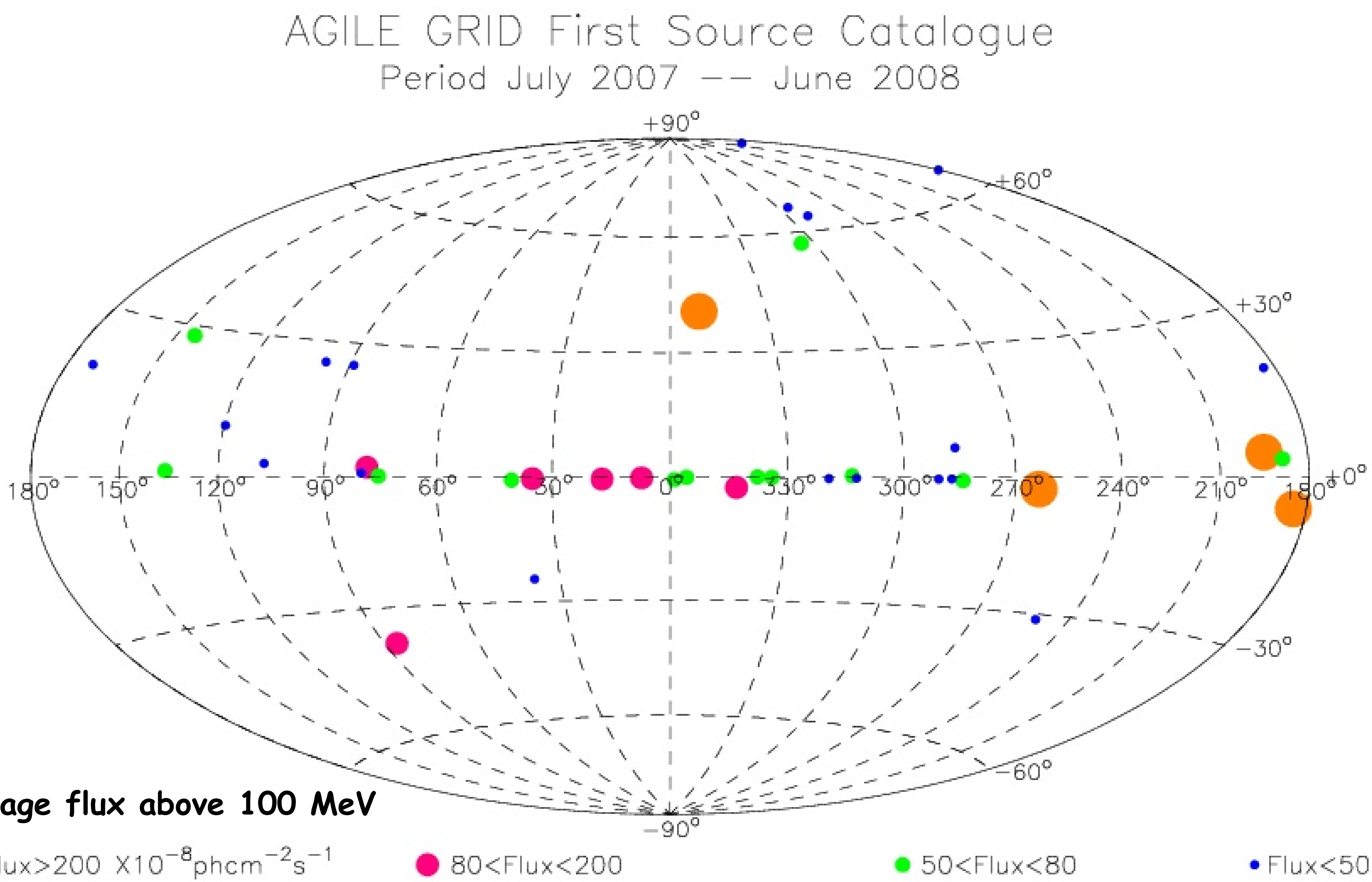
2yr Exposure



2 yr Gamma-ray sky by AGILE



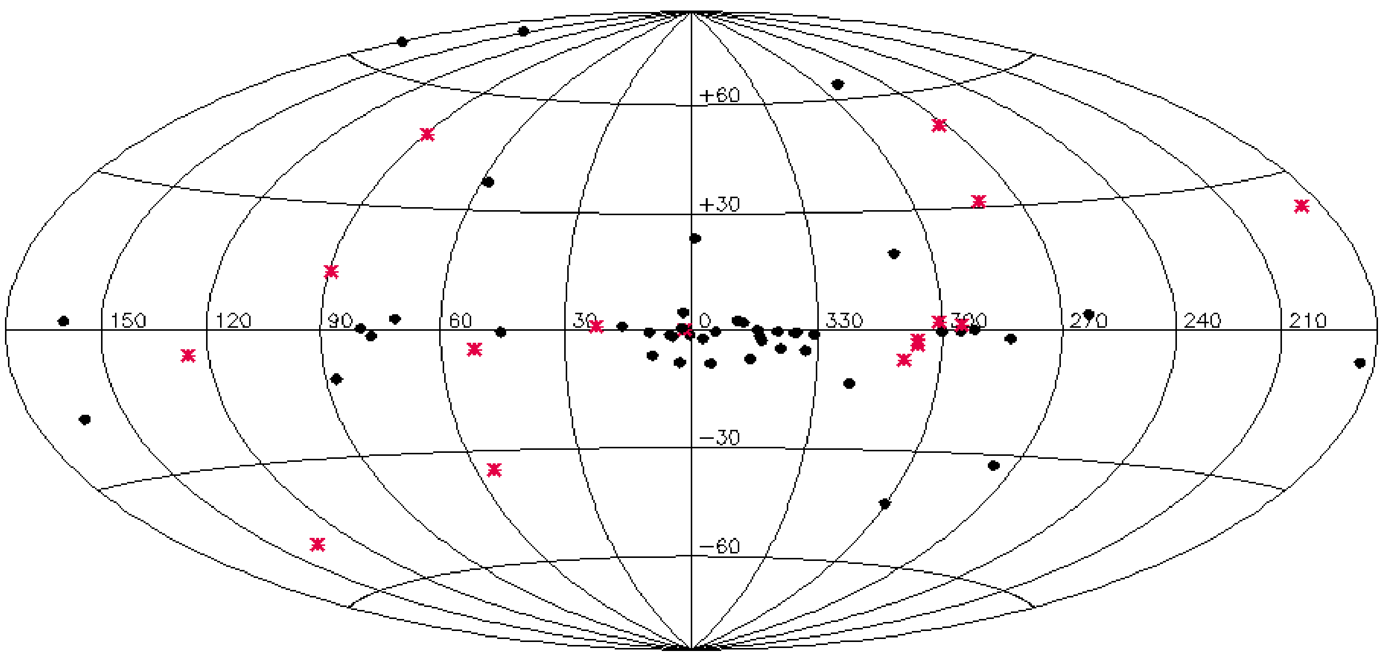
AGILE First Catalog of high-significance gamma-ray sources



Pittori et al., 2009

X-ray sources by SA

Map of X-ray Sources detected and localized by SuperAGILE
July 2007 – December 2008



Main Galactic science topics

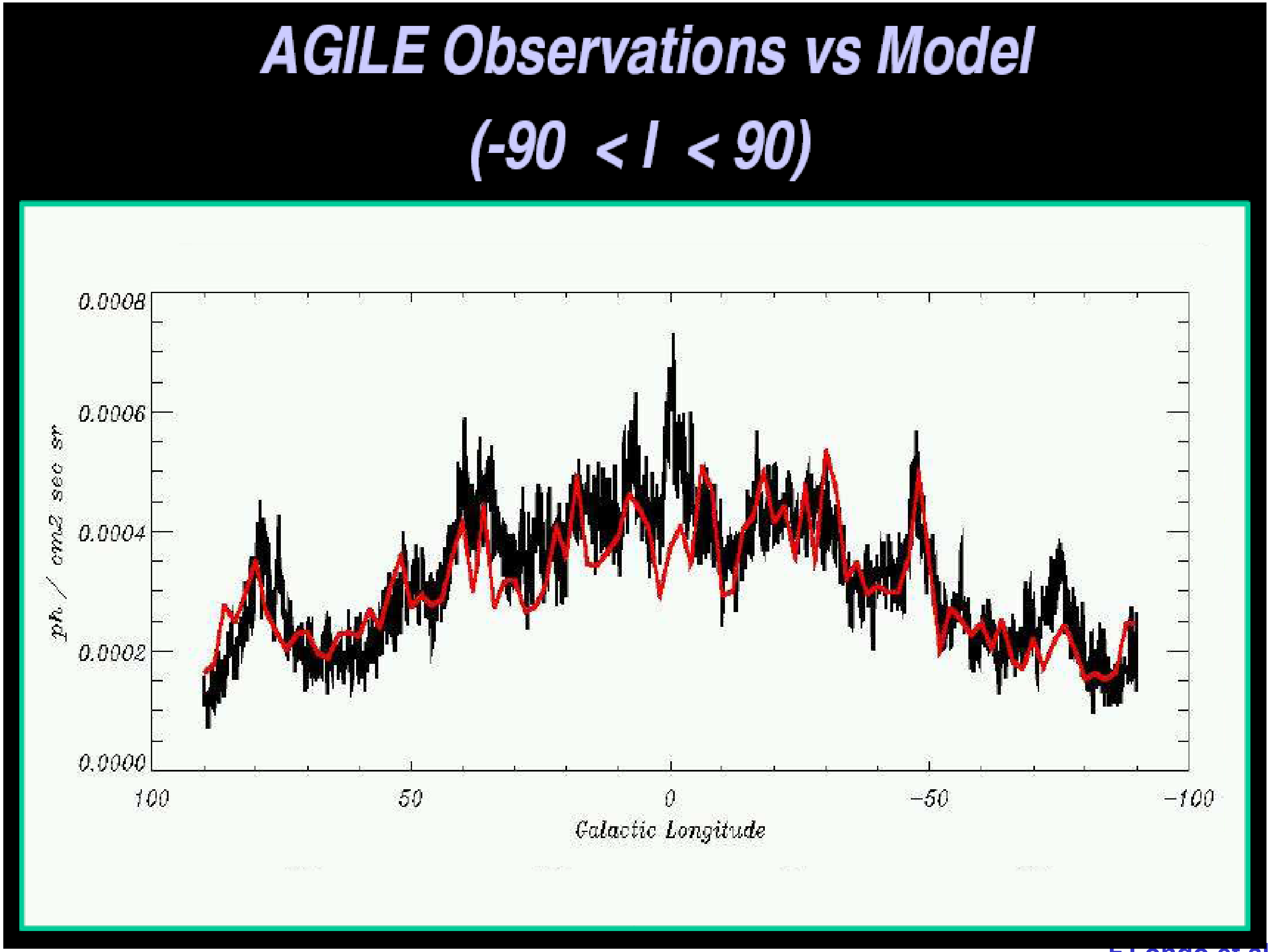
- Diffuse gamma-ray emission
- Pulsars (see M.Pilia's talk)
- SNRs and origin of cosmic rays
- Massive sources
- VARIABLE Galactic sources
- Microquasars, Gal. compact objects
- The Galactic center

AGILE Source List -- Partial

Fluxes in units of 10^{-8} ph/cm^2/s, E > 100 MeV

AGL J	L (deg)	B (deg)	Flux	Counts	sqrt(TS)	Δθ (deg)	Counterpart(s)
1805-2301	7.39	-0.93	104 ± 13	342 ± 44	8.81	0.62	3EG J1800-2338, W28
GUEST OBSERVER: T. MINEO							3EG J1856+0114, W44, PSR J1856+0113
GUEST OBSERVER: D. TORRES							GeV J1907+0557
GUEST OBSERVER: J. HALPERN							3EG J2021+3716?, PSR J2021+3651
2021+4032	78.35	2.08	119 ± 6	1778 ± 84	25.87	0.11	3EG J2020+4017, γ Cygni
2032+4106	80.03	0.71	34 ± 5	507 ± 77	7.03	0.41	3EG J2033+4118, TeV J2032+4130, Cyg OB2 #8a
2230+6120	106.86	2.94	26 ± 4	301 ± 45	7.50	0.41	3EG J2227+6122, PSR J2229+6114, SAX J2239.3+6116
GUEST OBSERVER: D. TORRES							3EG J0010+7309, CTA1
0240+6141	135.43	1.49	51 ± 7	225 ± 31	8.69	0.38	3EG J0241+6103, LSI +61° 303
0534+2207	184.50	-5.66	279 ± 10	1646 ± 58	42.85	0.08	Crab
0617+2235	189.05	3.06	47 ± 5	283 ± 33	10.61	0.22	3EG J0617+2238, IC443
0634+1748	195.13	4.33	315 ± 9	1896 ± 54	60.64	0.05	Geminga
0835-4511	263.57	-2.79	708 ± 24	1364 ± 47	48.55	0.08	Vela
1021-5817	284.32	-0.93	69 ± 6	725 ± 61	13.54	0.23	3EG J1027-5817, WR21a
GUEST OBSERVER: P. WELTEVREDE							3EG J1058-5234, PSR B1055-52
GUEST OBSERVER: T. MINEO							3EG J1048-5840, PSR B1046-58
1110-6115	291.15	-0.70	31 ± 5	334 ± 51	7.15	0.47	3EG J1102-6103?, PSR J1105-6107
GUEST OBSERVER: M. ROBERTS							3EG J1420-6038?, Kookaburra, Rabbit
GUEST OBSERVER: A. POSSENTI							3EG J1509-5850
GUEST OBSERVER: A. POSSENTI							3EG J1637-4642
1709-4429	343.06	-2.63	107 ± 7	870 ± 56	19.04	0.14	3EG J1710-4439, PSR B1706-44

The Galactic Diffuse Emission



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.

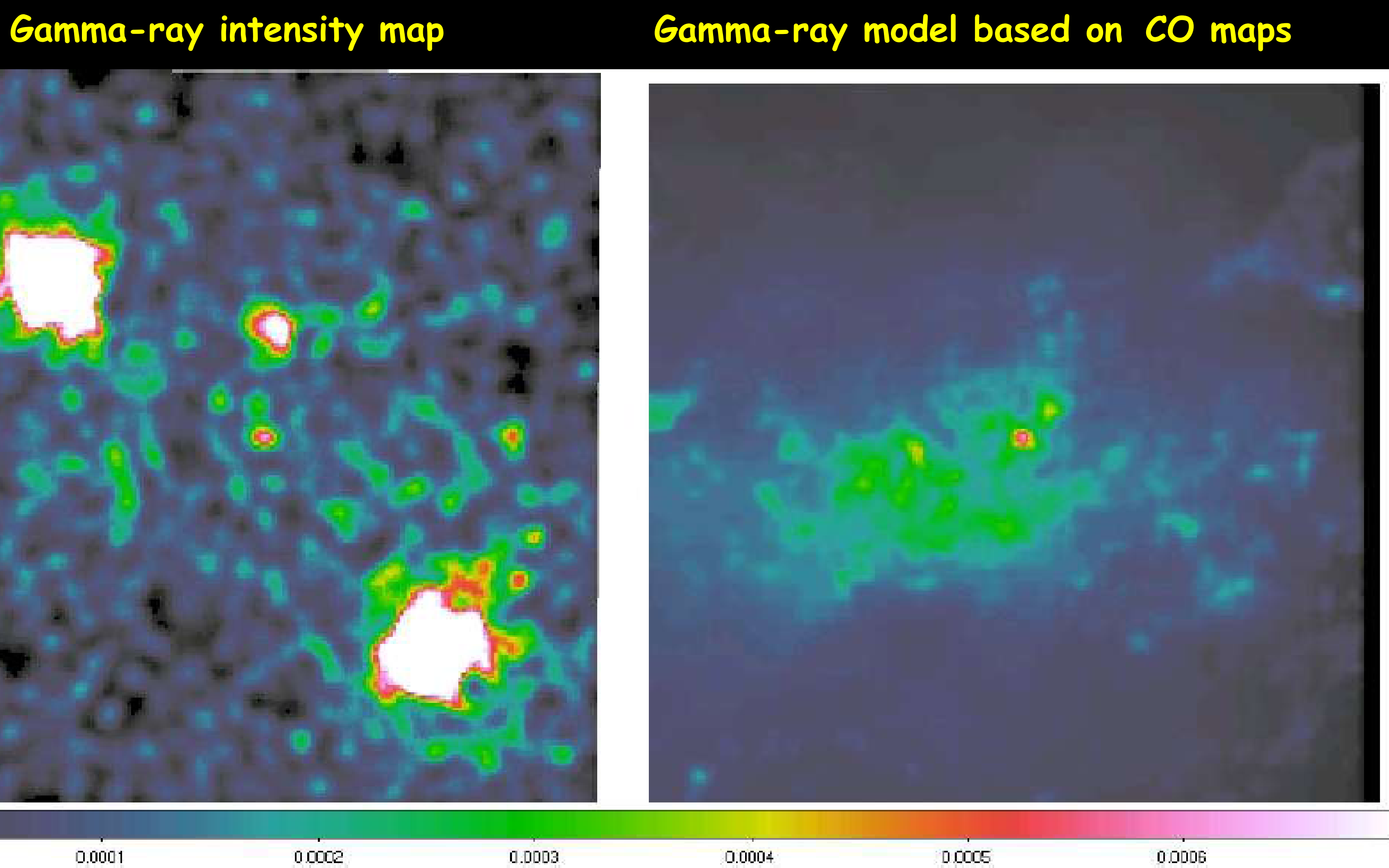
[c]Calculated with the expression $C_P f/E$, where C_p=pulsed counts, E=exposure, f=factor accounting for source counts at angular distance > 5 deg from source position according to the point spread function (f~1.3).

AGILE's new gamma-ray pulsars

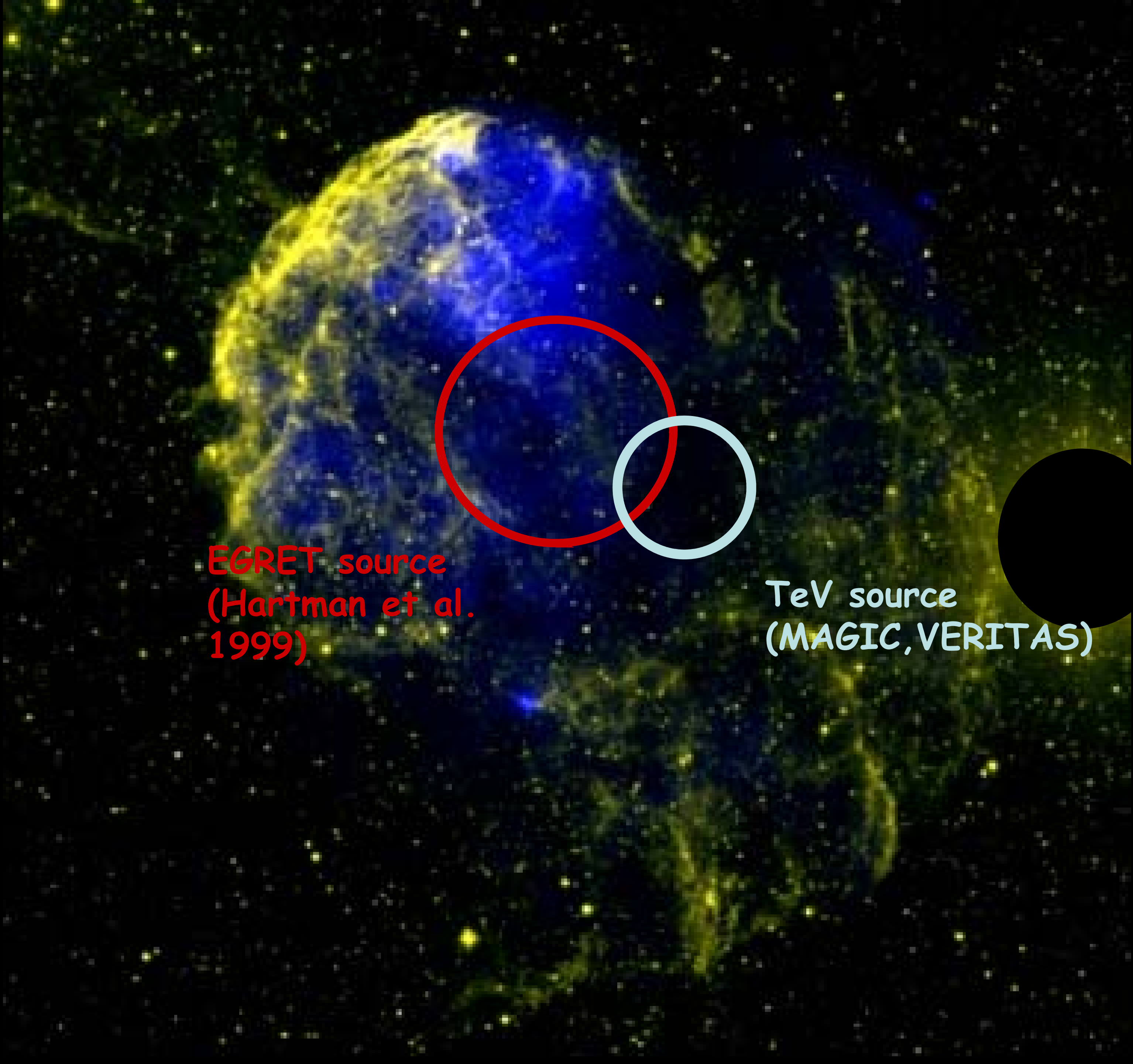
Pellizzoni et al. ApJ 695, L115 (2009)

PSR Name	G.Lon.	G.Lat.	P	τ^{a}	D^{a}	$\log \dot{E}$	$\chi^2_{red}(N_{st})^{b}$	$\sigma_{time}{}^{c}$	$\sigma_{space}{}^{d}$	$F_\gamma{}^{d}$	$\log L_\gamma{}^{e}$	$L_\gamma/\dot{E}$
	deg	deg	ms	yr	kpc	erg s^{-1}					erg s^{-1}	
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

Anticenter – Molecular Clouds Complex



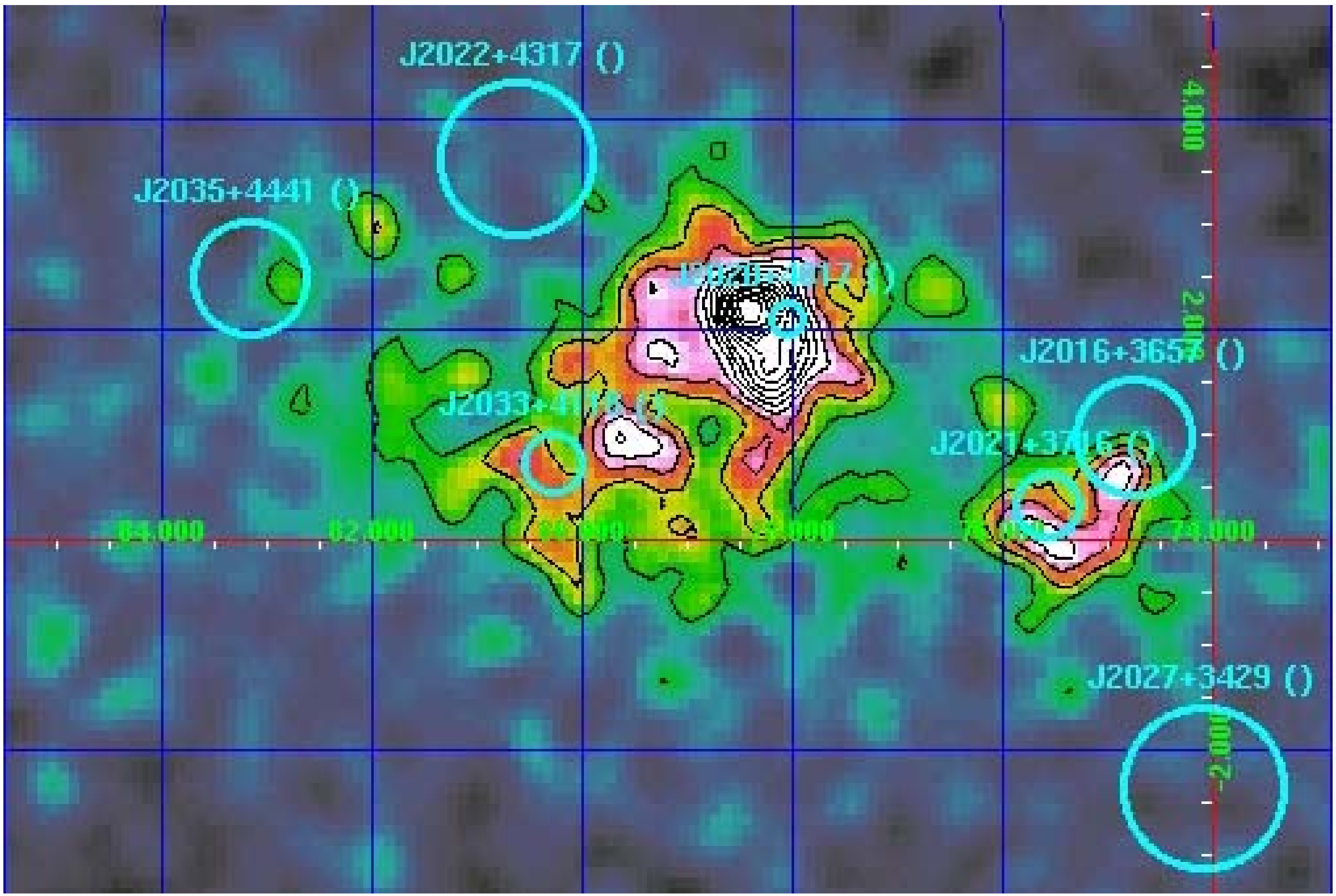
Intensity map – ph/cm^2 sec sr


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

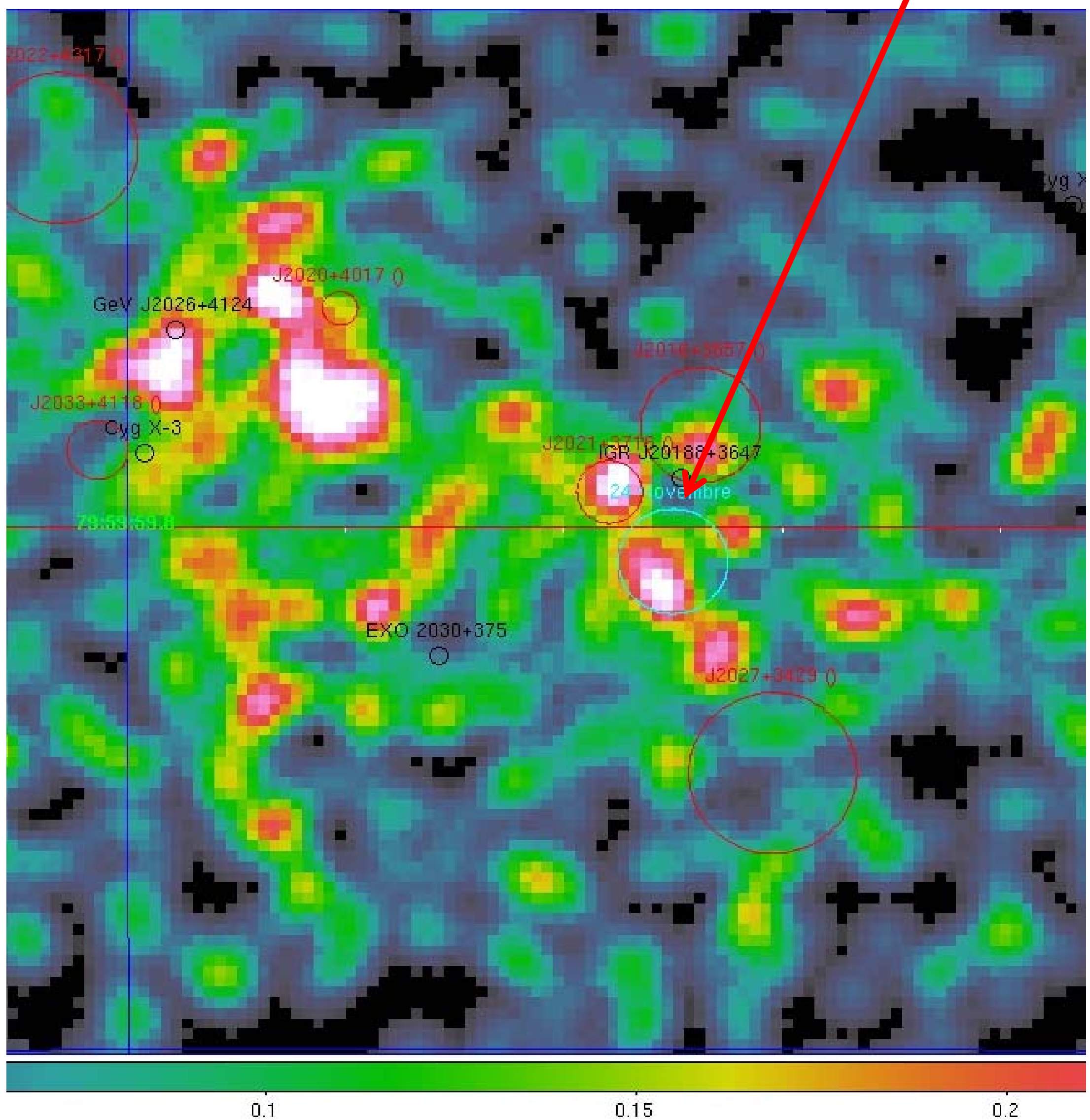
Proton acceleration in IC 443?

- 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

Cygnus Region   2007 -2008



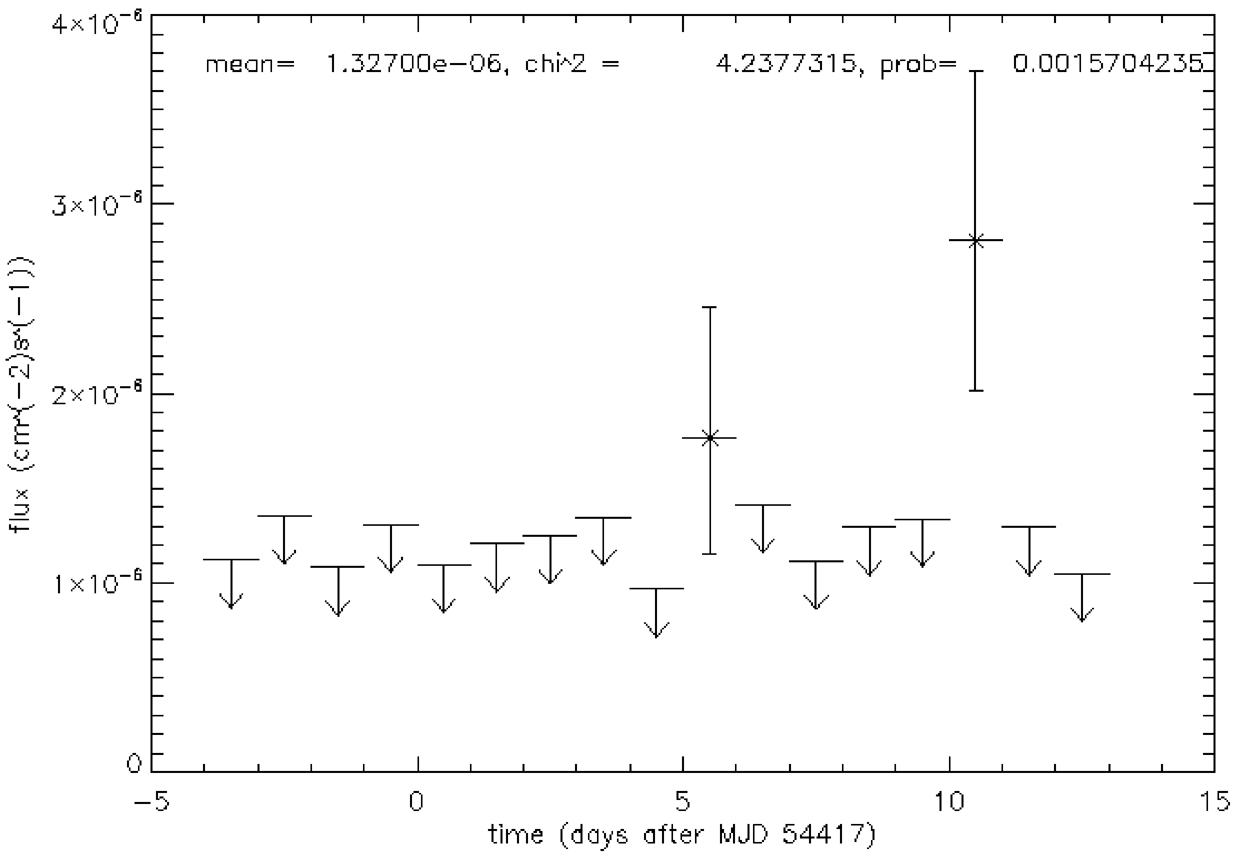
Cygnus Region Nov 18-28, 2007



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 σ
- Position (l,b)=(74.4,-0.5)°, error ~ 0.8°

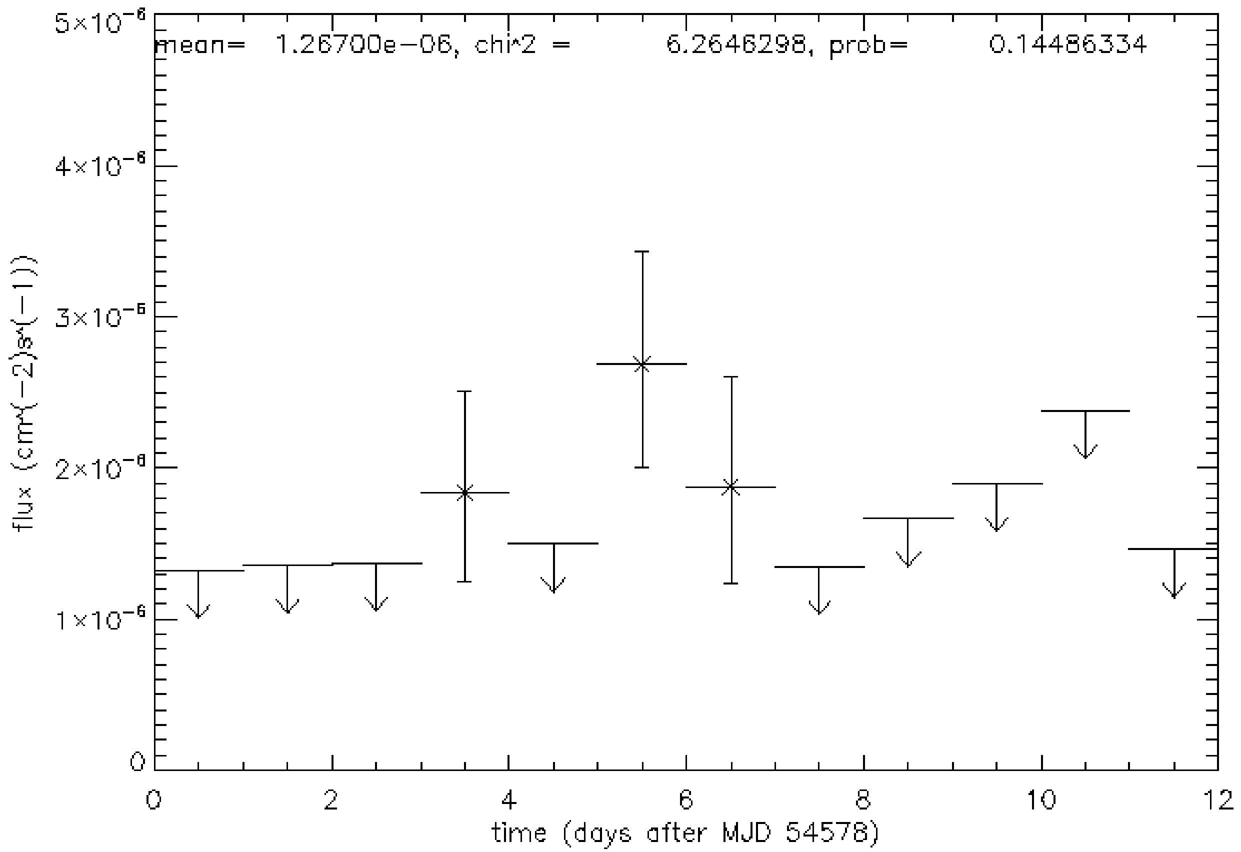
AGLJ2022+3622 -- Light Curve



1AGL J2022+4032

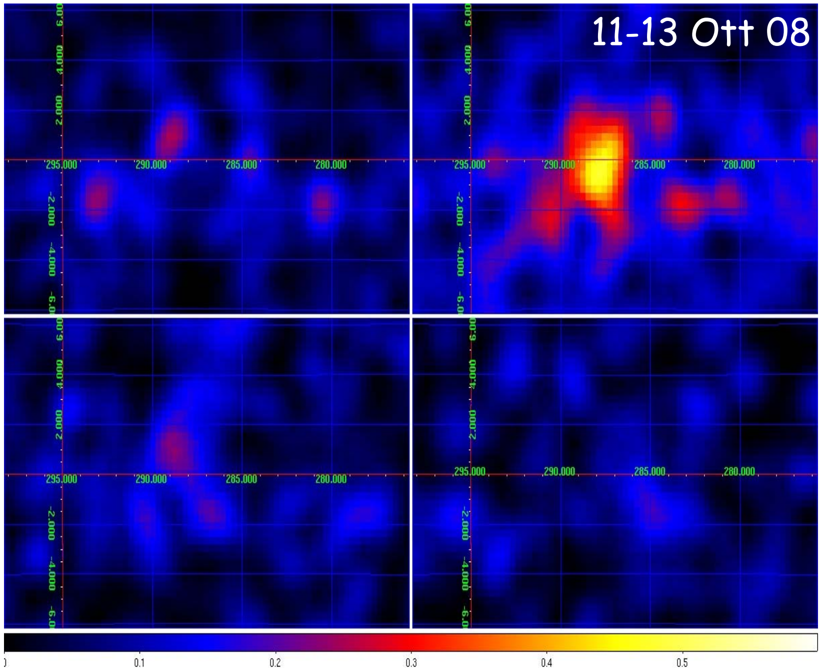
- **Cygnus Region**
  - **Persistent Emission**
  - **$(1.20 \pm 0.07) \times 10^{-6}$ cm^{-2} s^{-1} at 23,4 σσ**
- **Position: (l,b) = (78.37, 2.04)°, error ~ 0.12°**
  - 1-day flare on April 27-28, 2008 [ATel #1492]
    - »(2.9 ± 0.8) × 10-6 cm-2 s-1 at 3.7 σ
    - »Position: (l,b) = (78.1, 2.0)°, error ~ 0.8°
  - 1-day flare on June 20-21, 2008 [ATel #1585]
    - »$(2.5 \pm 0.7) \times 10^{-6}$ cm^{-2} s^{-1} at 4.9 σ
    - »Position (l,b) = (78.6, 1.6)°, error ~ 0.7°
  - 1-day flare on November 16-17, 2008 [ATel #1848]
    - »$(2.5 \pm 0.7) \times 10^{-6}$ cm^{-2} s^{-1} at 4.8 σ
    - »Position (l,b) = (78.6, 2.1)°, error ~ 0.7°
- **Gamma association:** ***3EG J2020+4017 - 0FGL J2021.5+4026***

1AGL J2022+4032 -- April 27-28, 2008

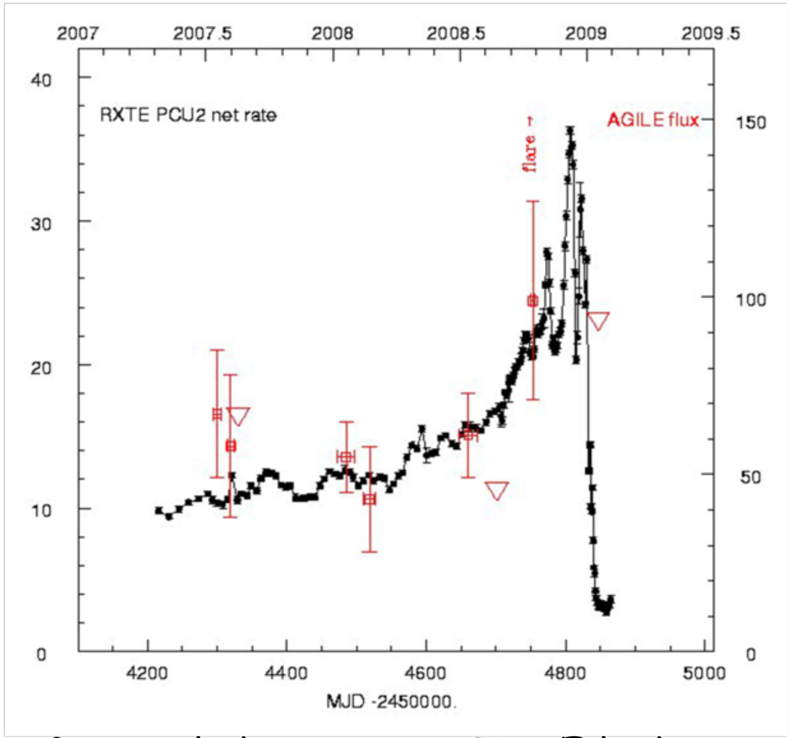


Very difficult to react in such a short time

Transient in the Carina Region



2 days integration maps - counterclockwise



Gamma light curve vs RXTE lught curve

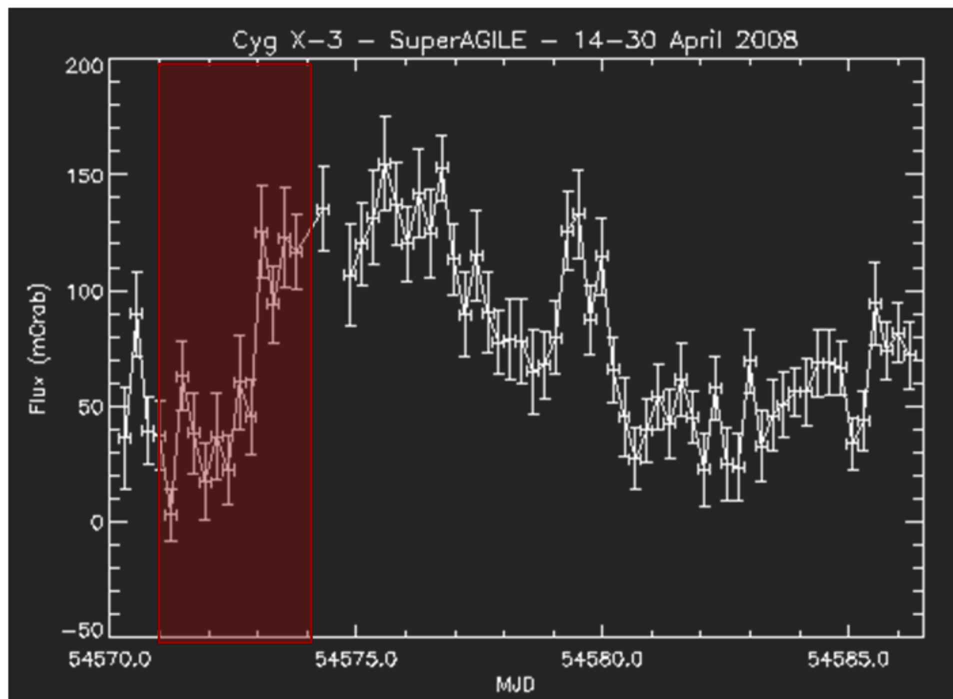
Tavani et al., 2009

Cygnus X-3

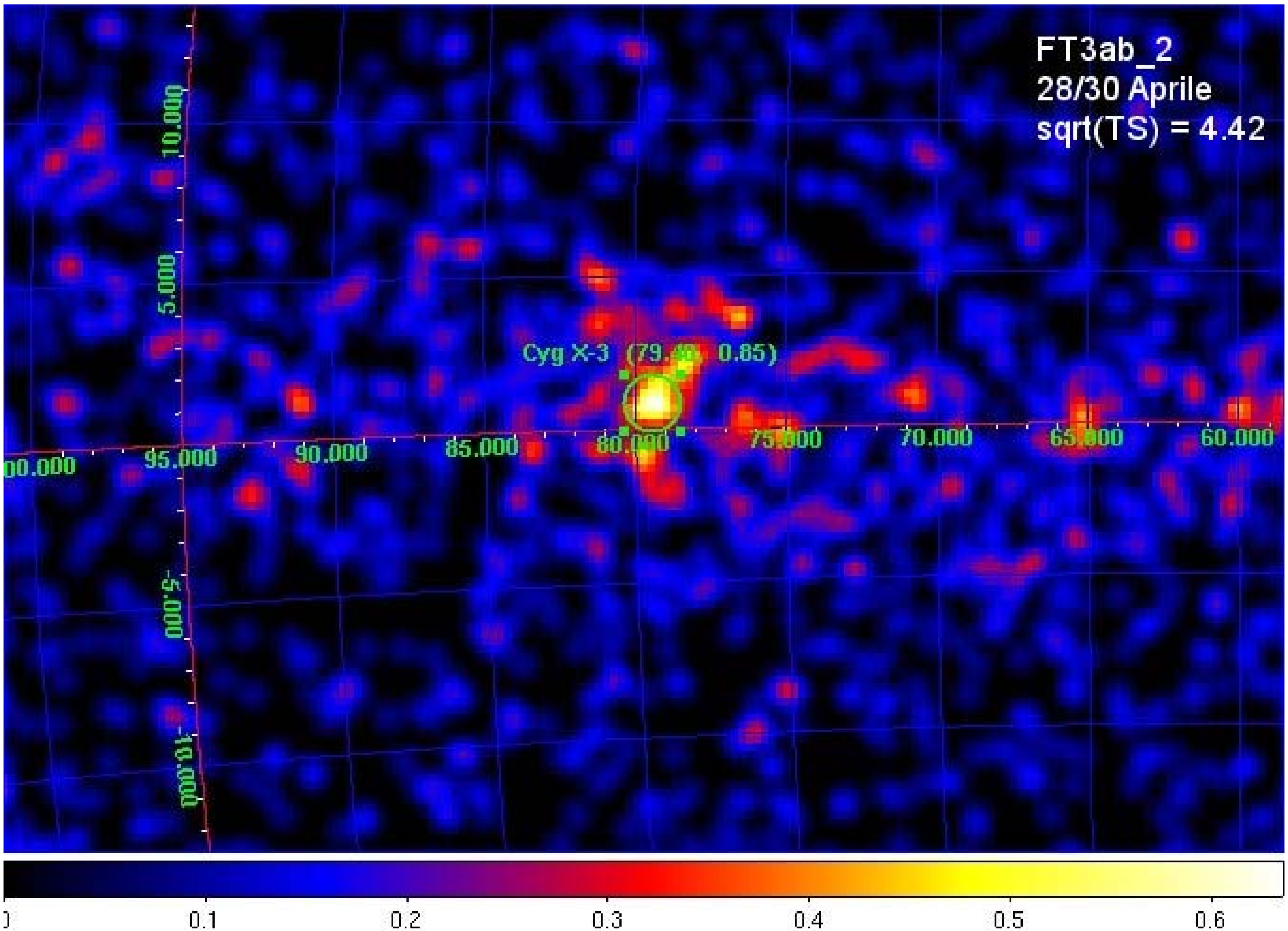
15 - 18 April 2008

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 !

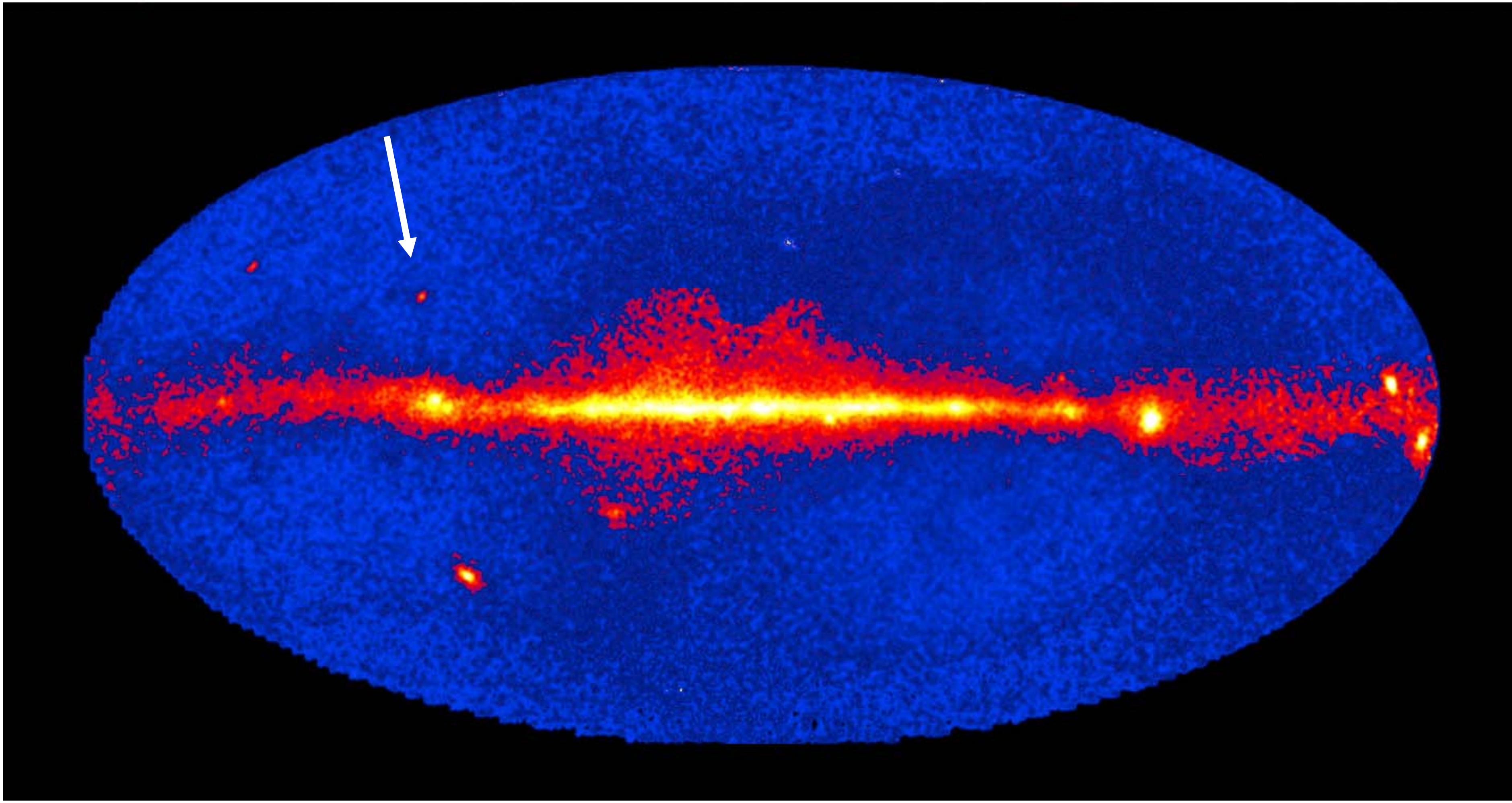
In the same period SuperAGILE revealed an X-ray flare



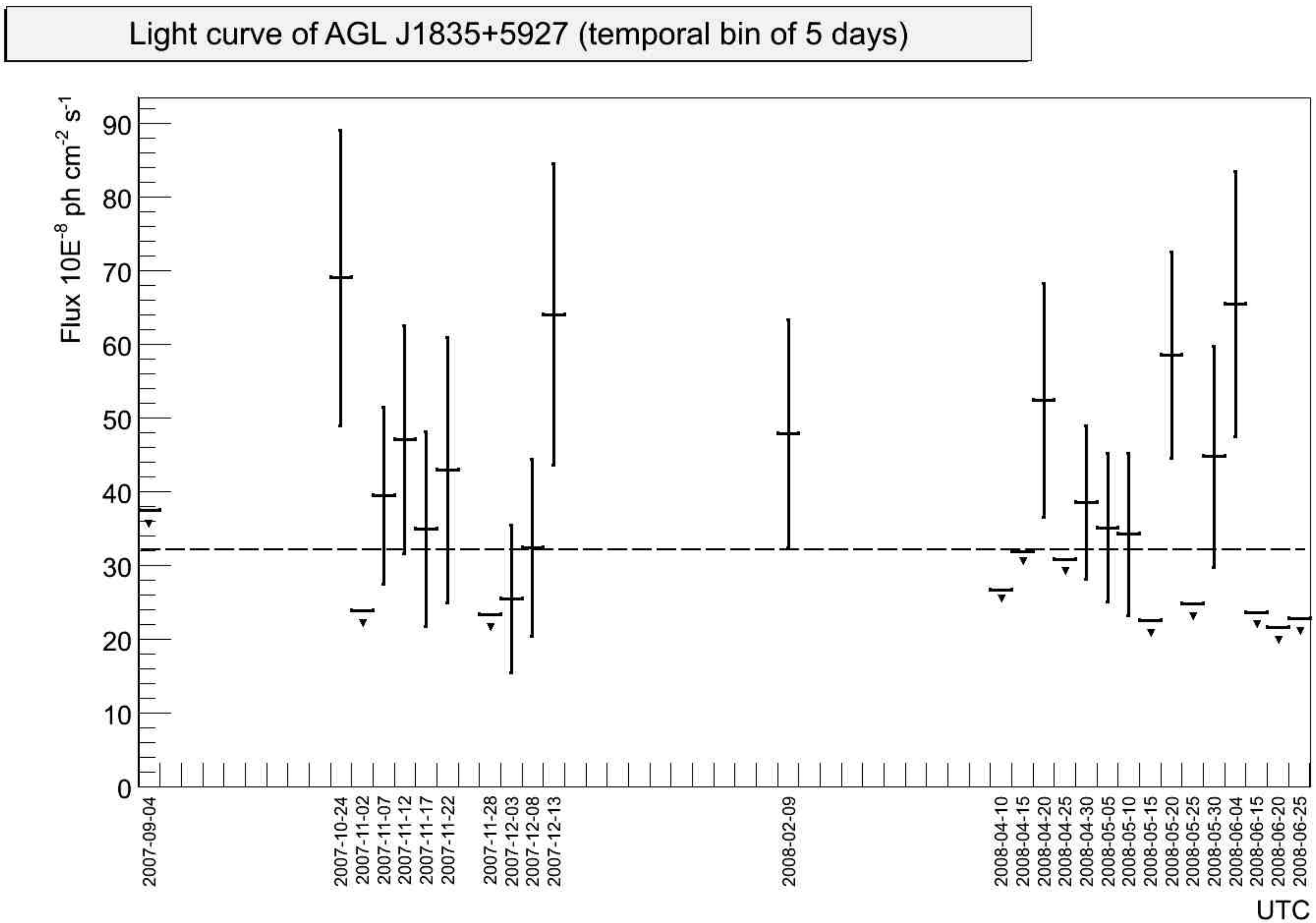
Cygnus X-3


FT3ab_2
28/30 Aprile
sqrt(TS) = 4.42
Cyg X-3
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

A different kind of variability



AGL J1835+5927

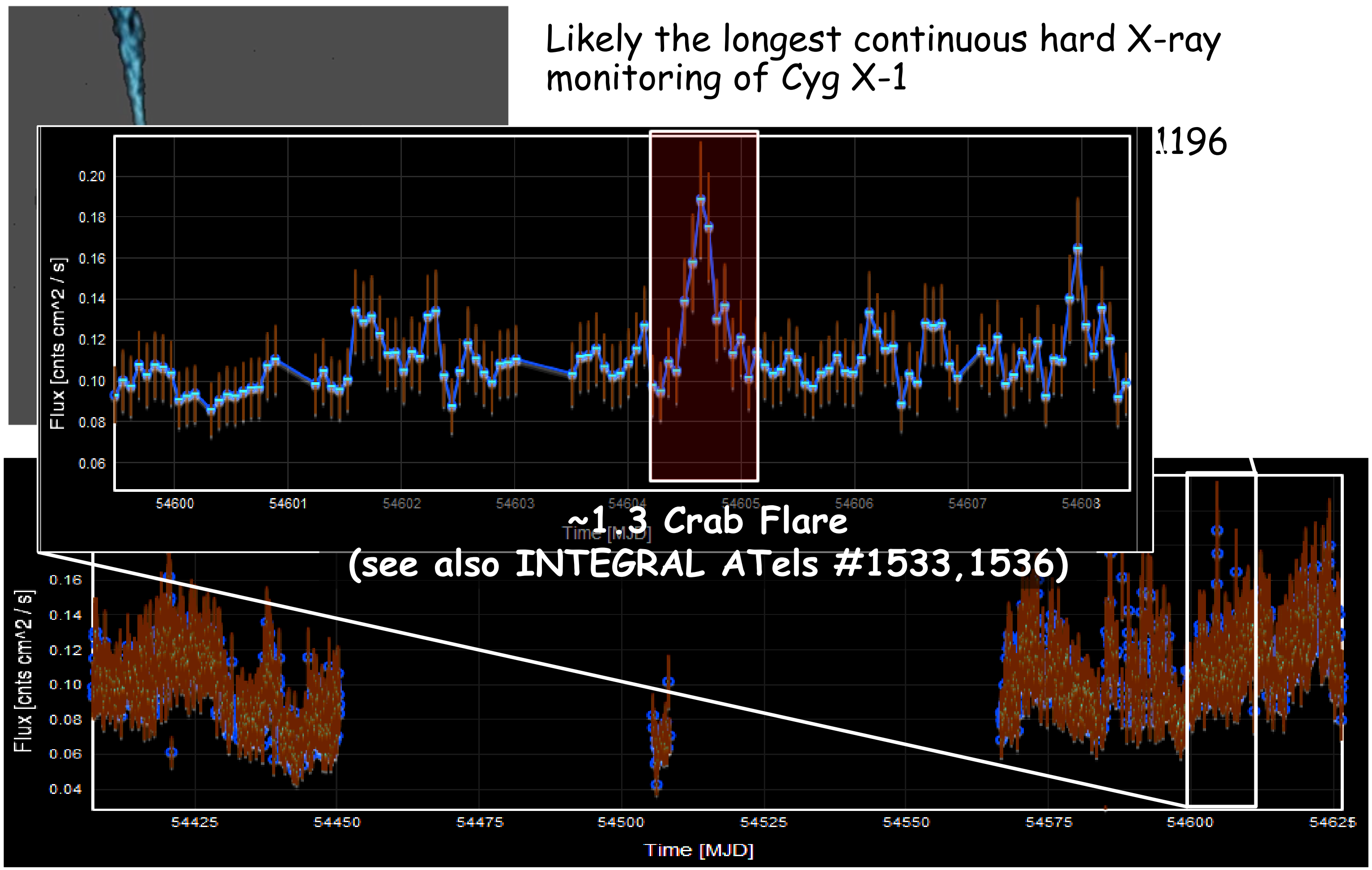


Bulgarelli et al., 2009 2008A&A...489L..17B

Cyg X-1

Likely the longest continuous hard X-ray monitoring of Cyg X-1

!1196



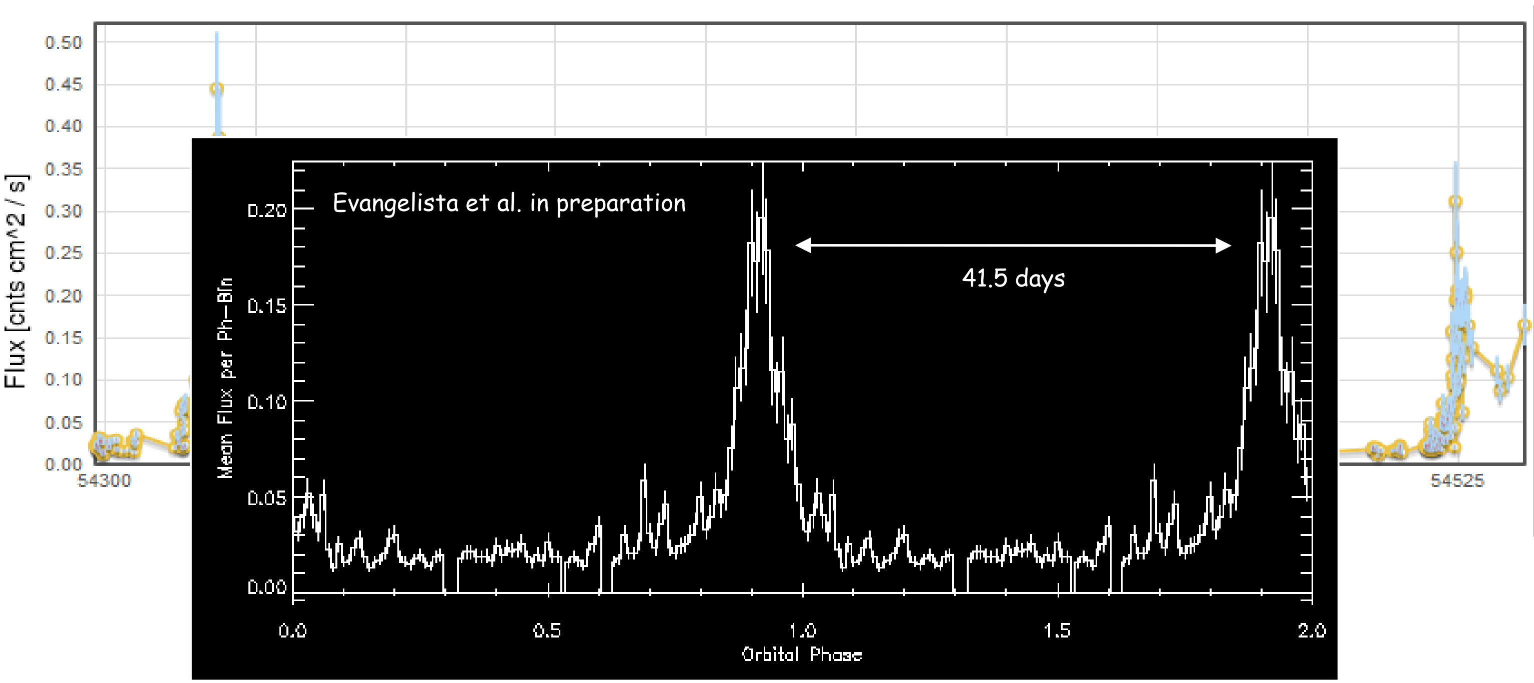
~1.3 Crab Flare

(see also INTEGRAL ATels #1533,1536)

GX 301-2

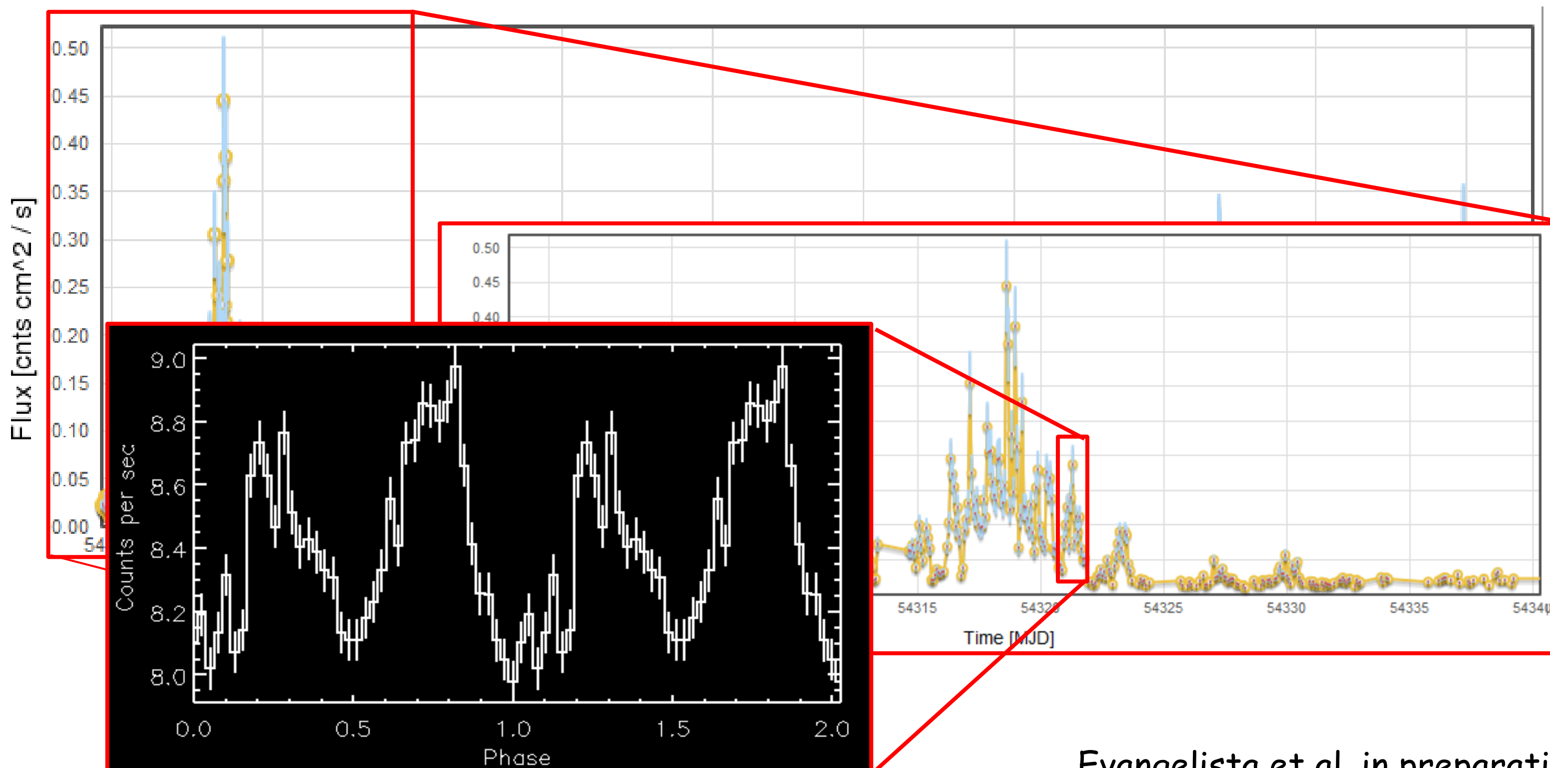
41.5 d orbital period

The regular flares 1-2 days before periastron…



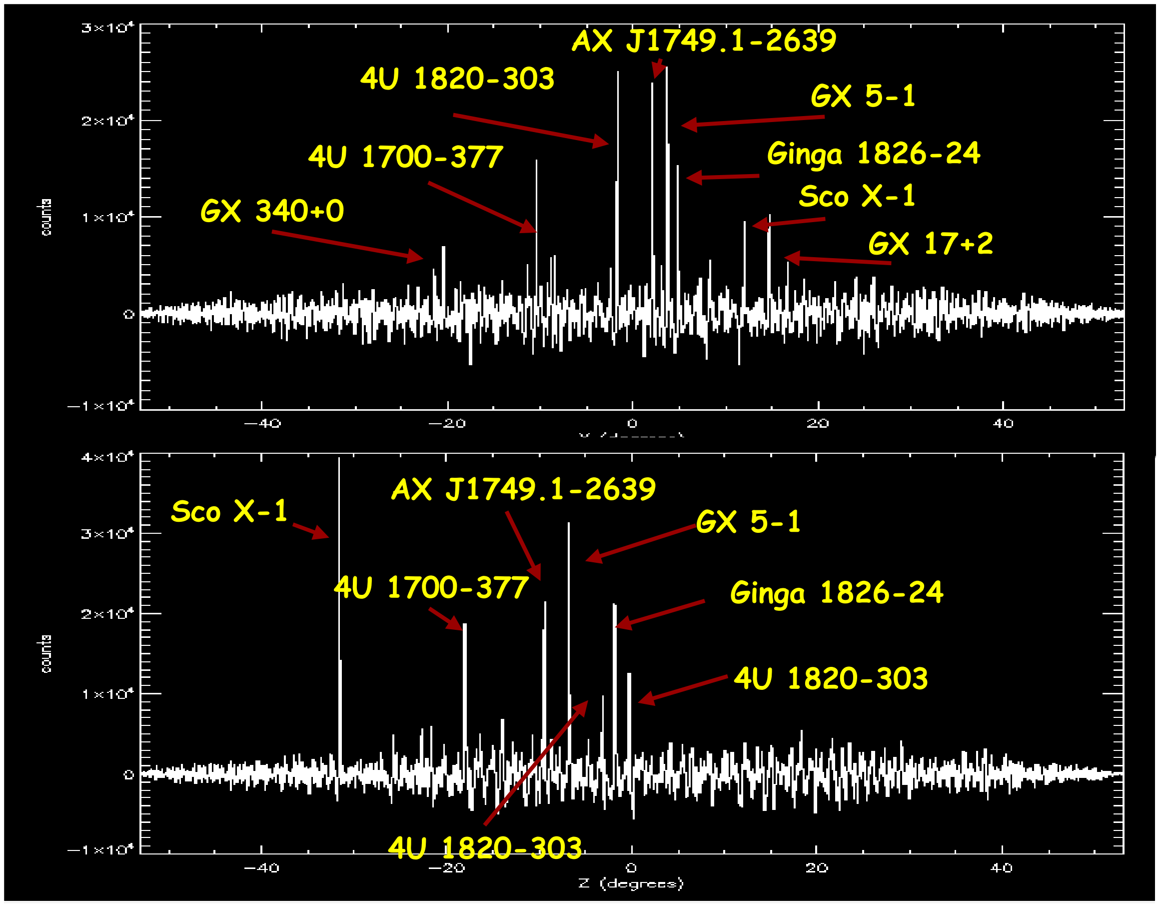
GX 301-2

And the 680s X-ray Pulsar

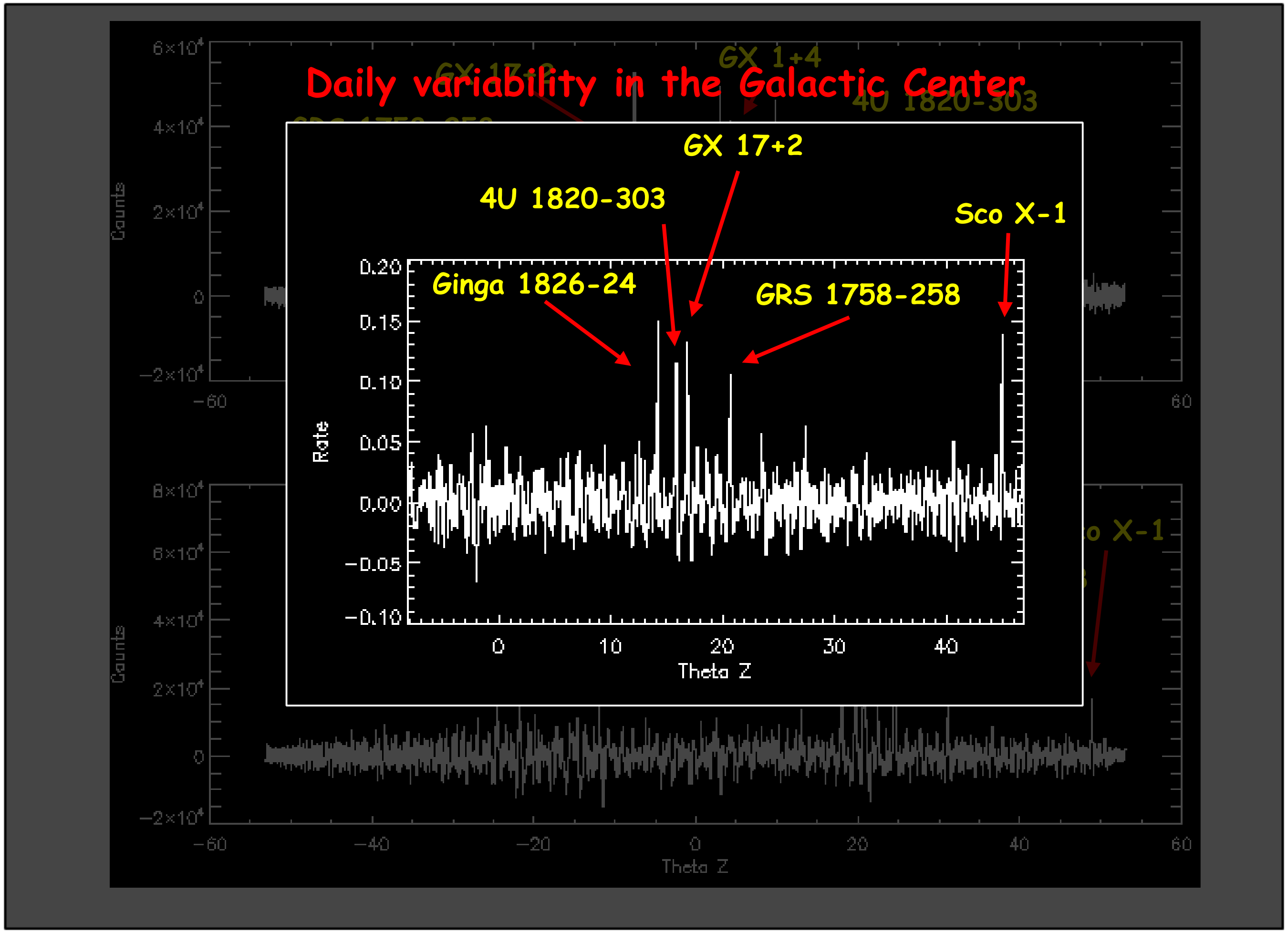


Evangelista et al. in preparation

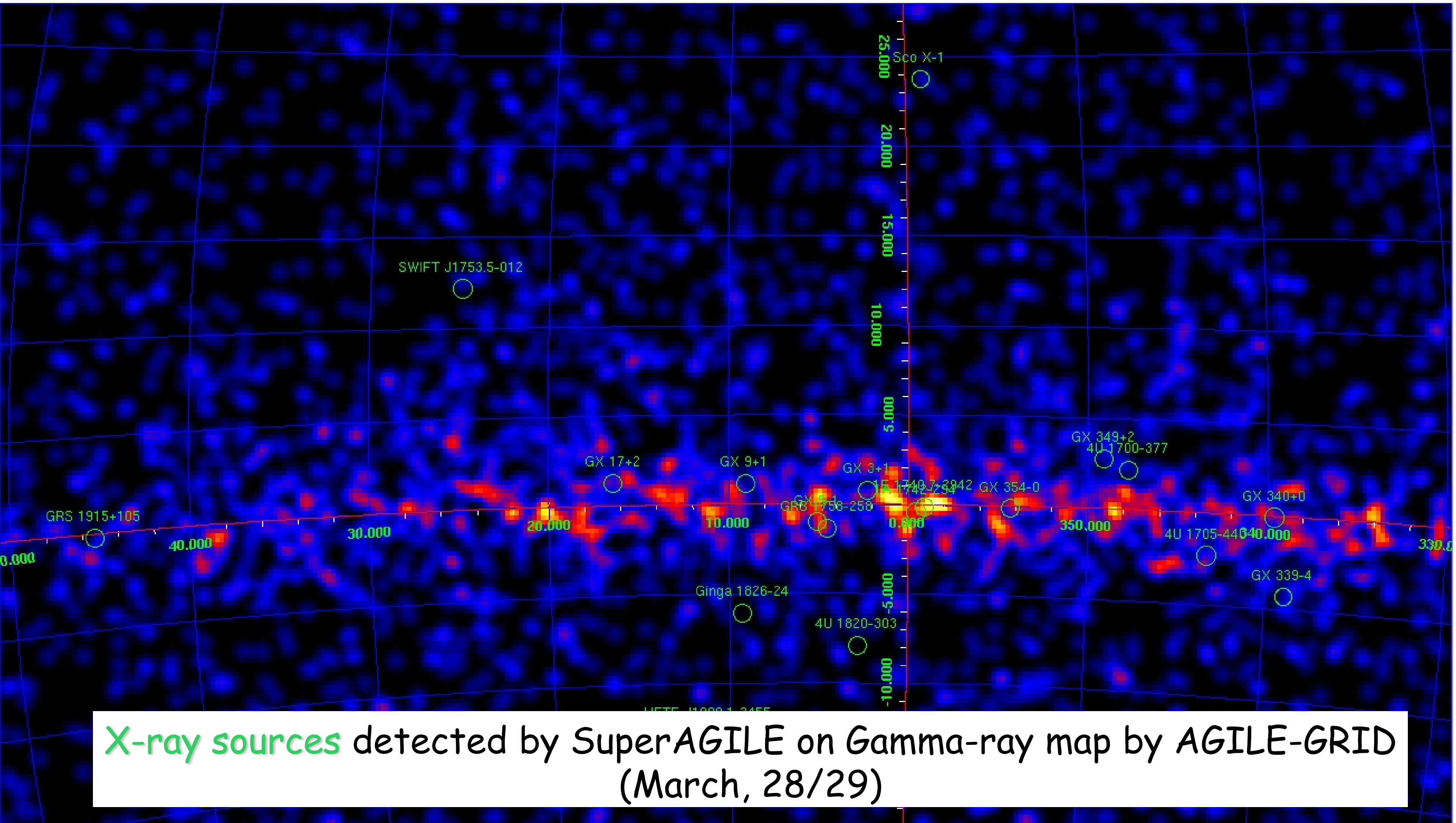
Galactic Center as seen by SuperAGILE



Galactic Center as seen by SuperAGILE

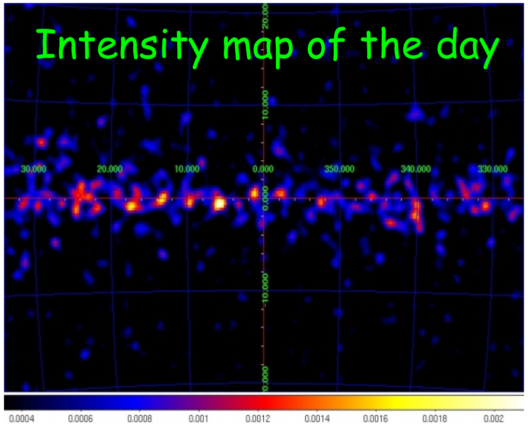


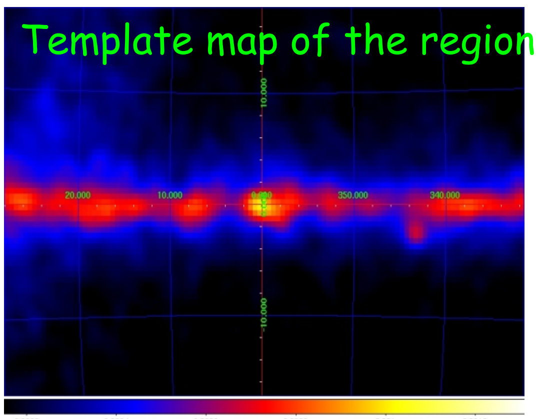
Galactic Center

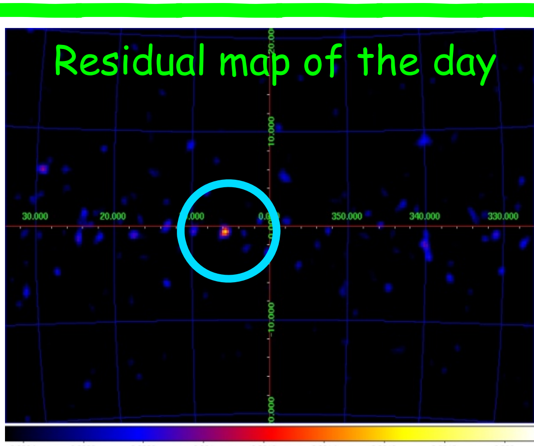


X-ray sources detected by SuperAGILE on Gamma-ray map by AGILE-GRID (March, 28/29)

Searching for transient sources: the maps subtraction method





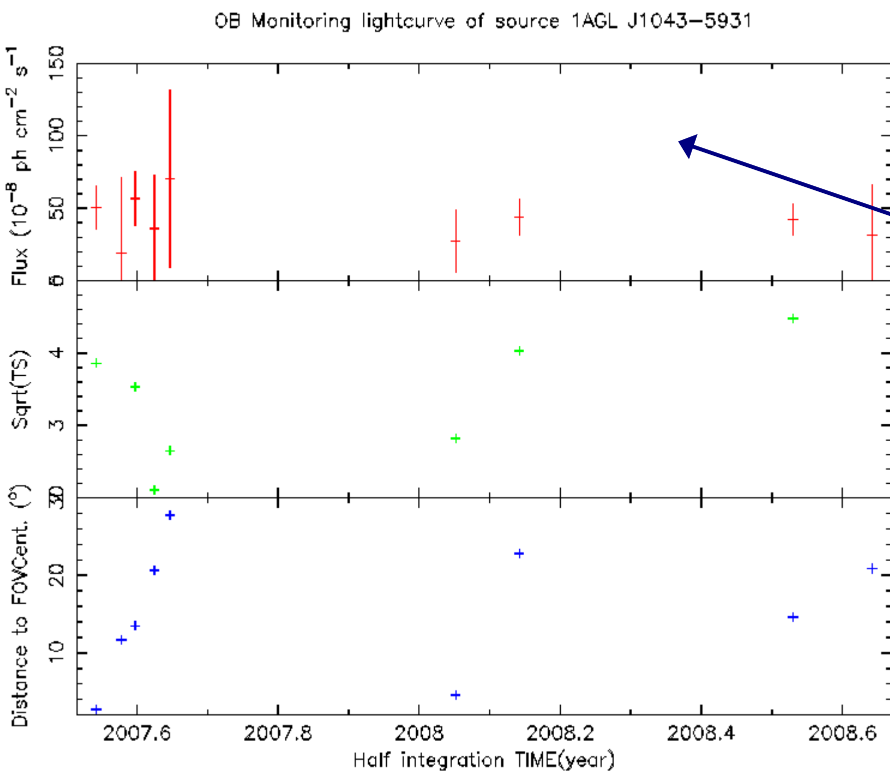


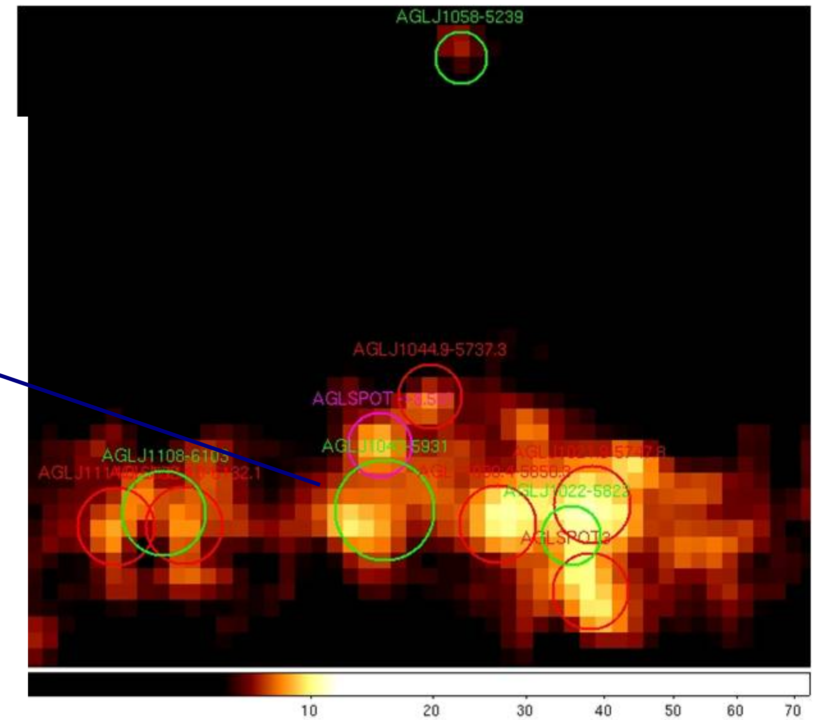
Residual maps contain:

1) fluctuations due to statistical noise
2) fluctuations due to possible transient sources appearing in the map of the day

Statistical significance of fluctuations can be assigned and tested towards a null hypothesis

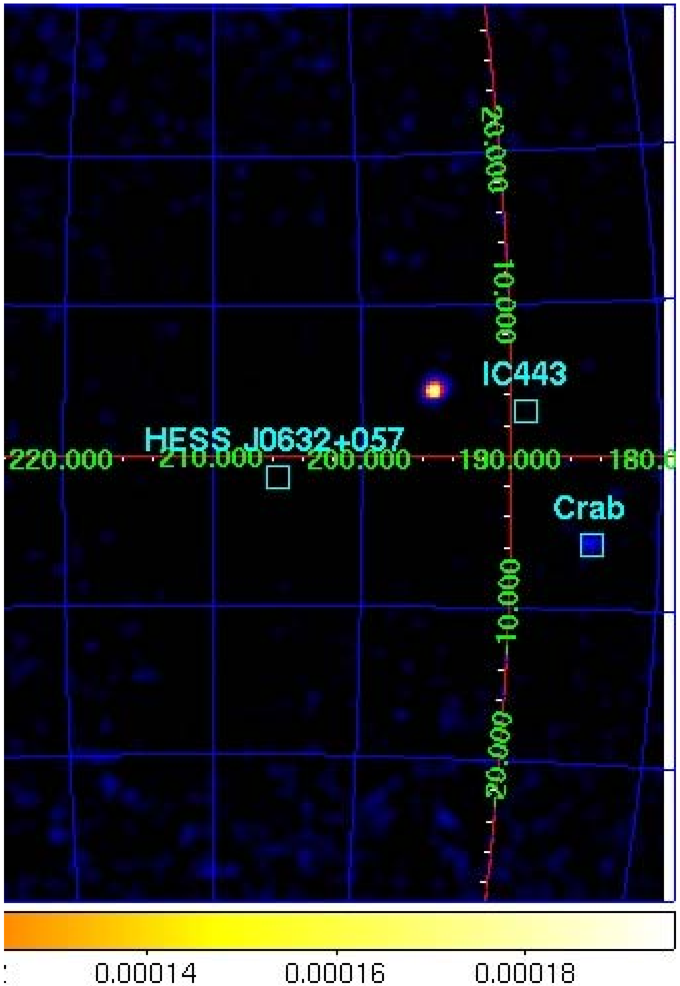
Variability of 1AGL sources

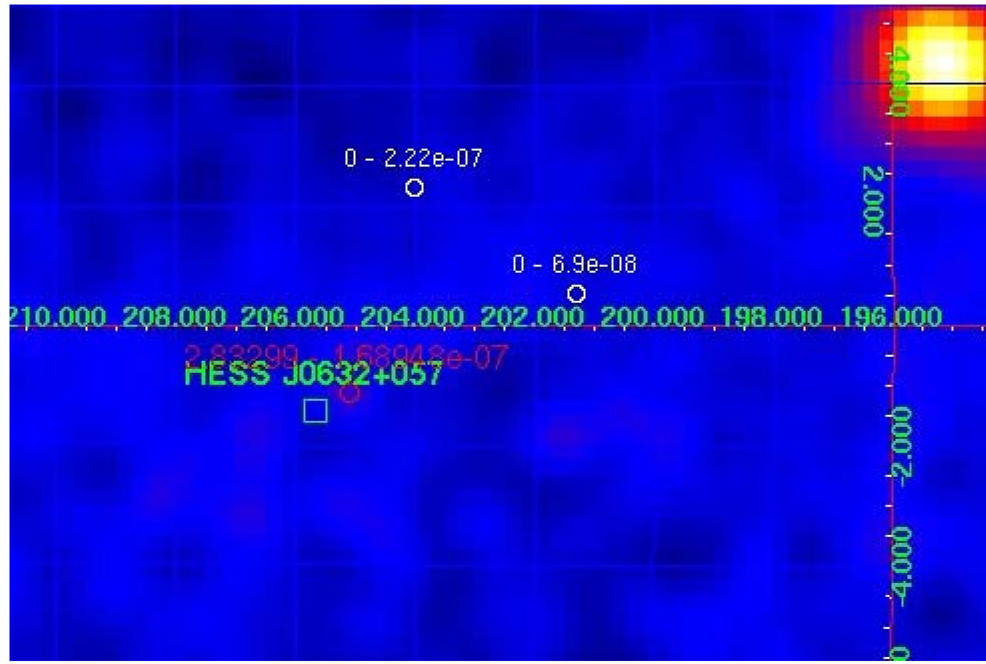




Observation Block (OB) timescale (tipically 1 month)
and intra-OB weekly timescale.
⇒Monitoring (flux history) of 1AGL sources on shorter timescales over a period of almost 2 years (from July 2007 to January 2009)

TeV sources search





Search for AGILE counterparts of TeV Catalog sources

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.

- Analysis of SNR & PSR/PWN
- Study of diffuse emission