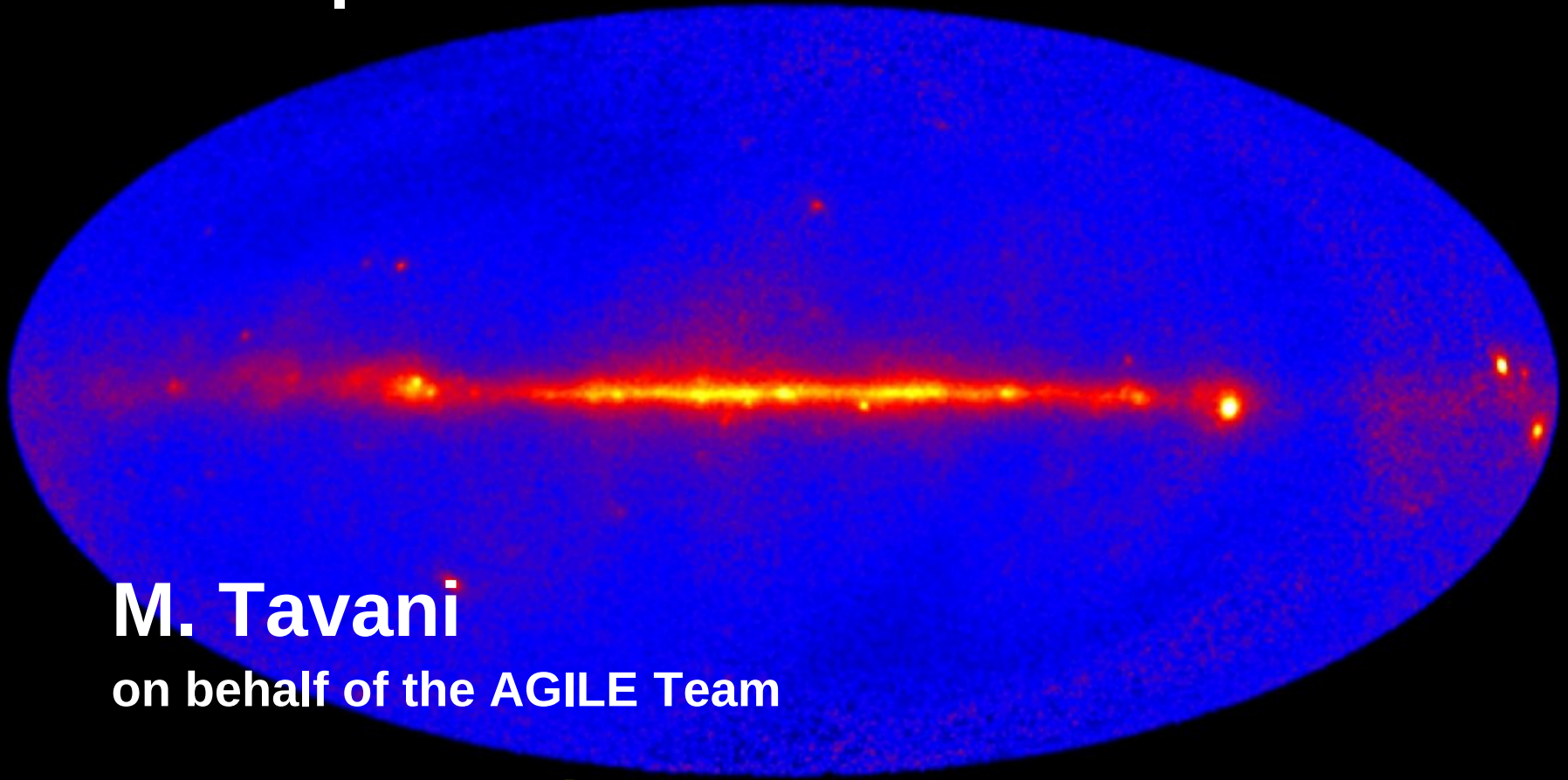
some results…

Galactic Gamma-Ray sources: Microquasars and new transients

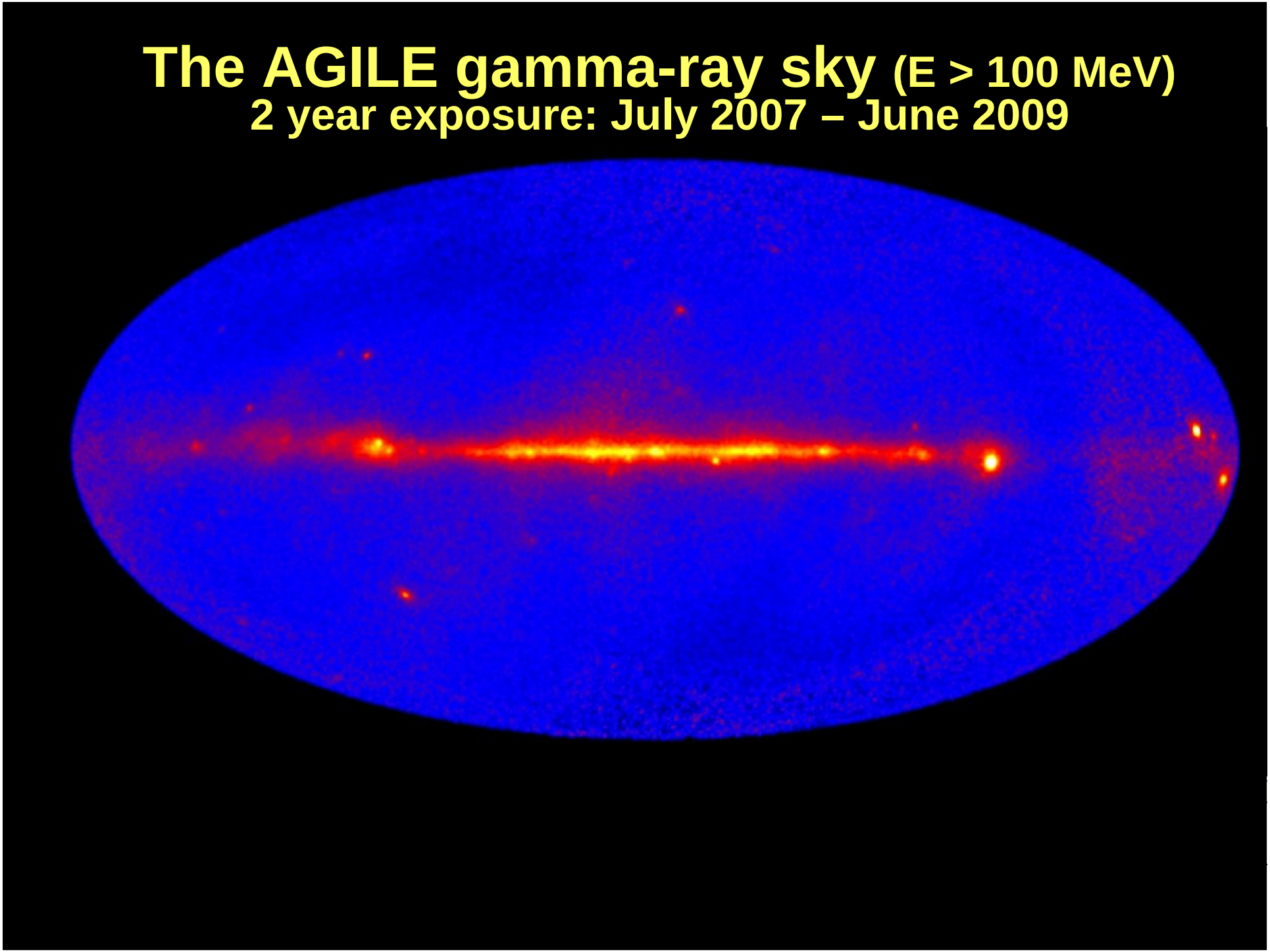


M. Tavani

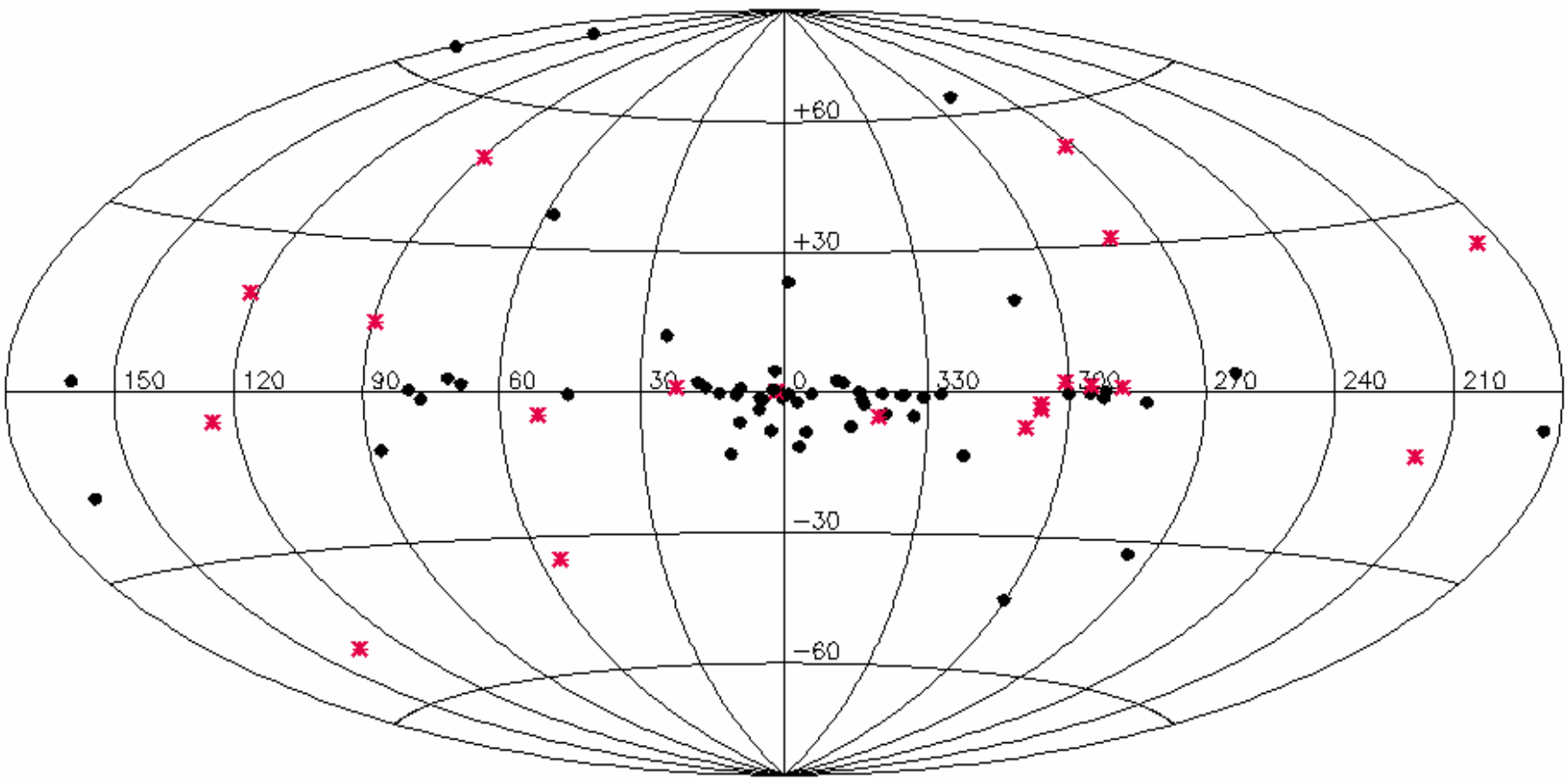
on behalf of the AGILE Team

***Fermi* Symposium, Nov. 5, 2009**

The AGILE gamma-ray sky (E > 100 MeV)
2 year exposure: July 2007 – June 2009



hard X ray sources (18 60 keV), 2 years

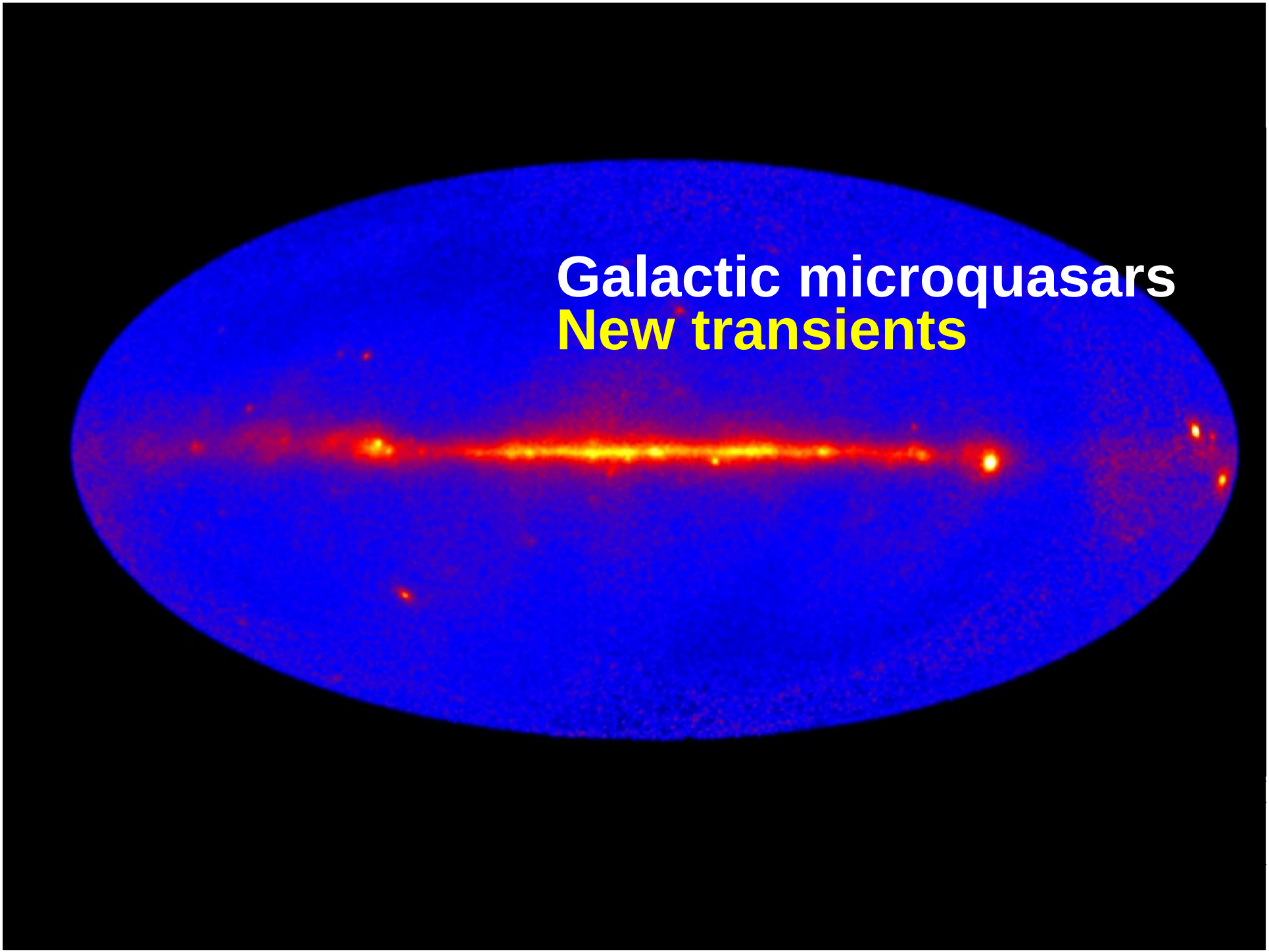


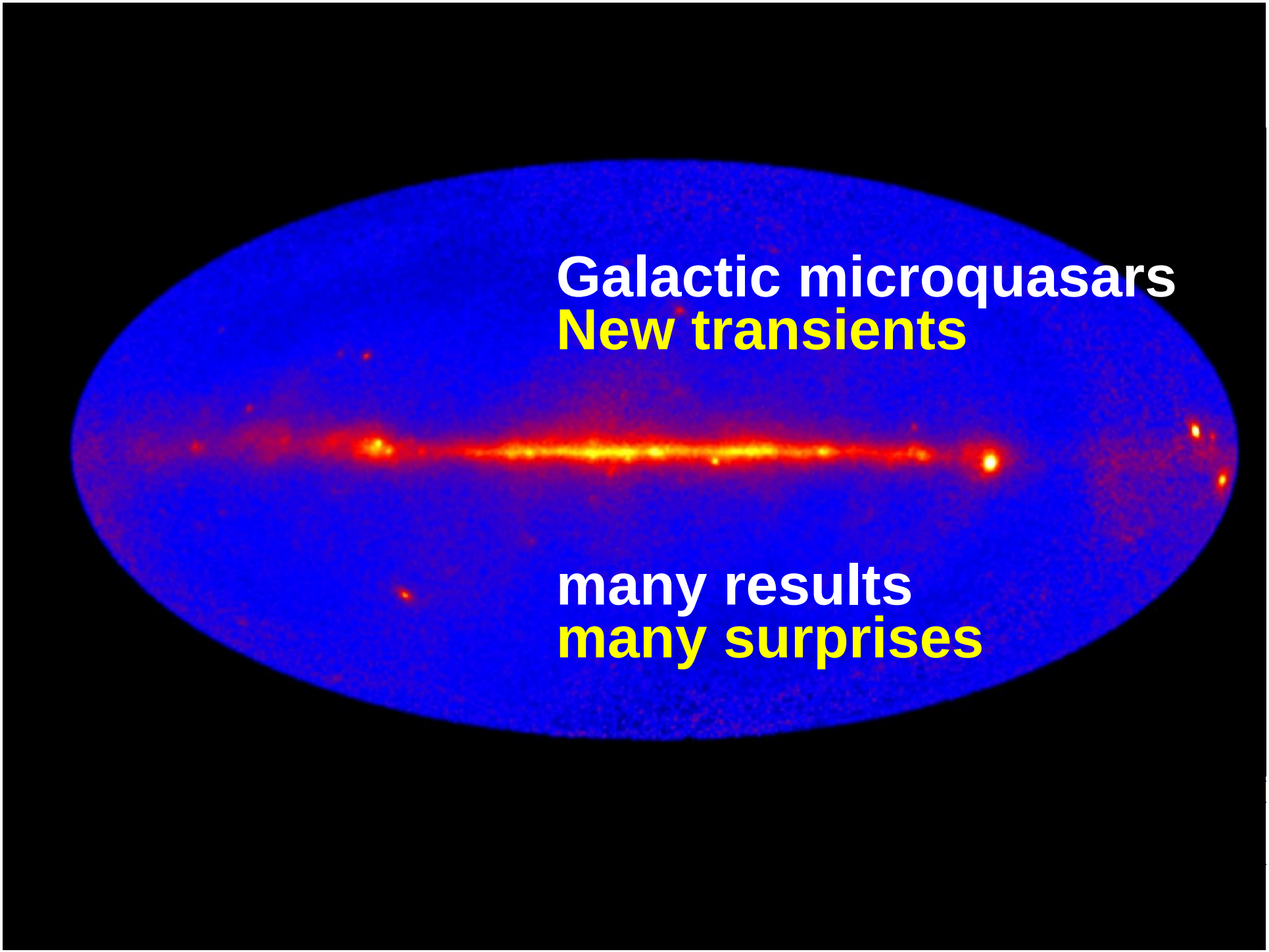
- **AGILE combination of co-aligned gamma-ray (50 MeV – 5 GeV) and hard X-ray (20-60 keV) imagers is optimal for Galactic source studies**

- **AGILE-GRID is optimized near 100 MeV**
  - **good PSF (~3º at 100 MeV)**
  - **typical daily exposure of ~ 10^7 cm^2 sec (at 100 MeV)**

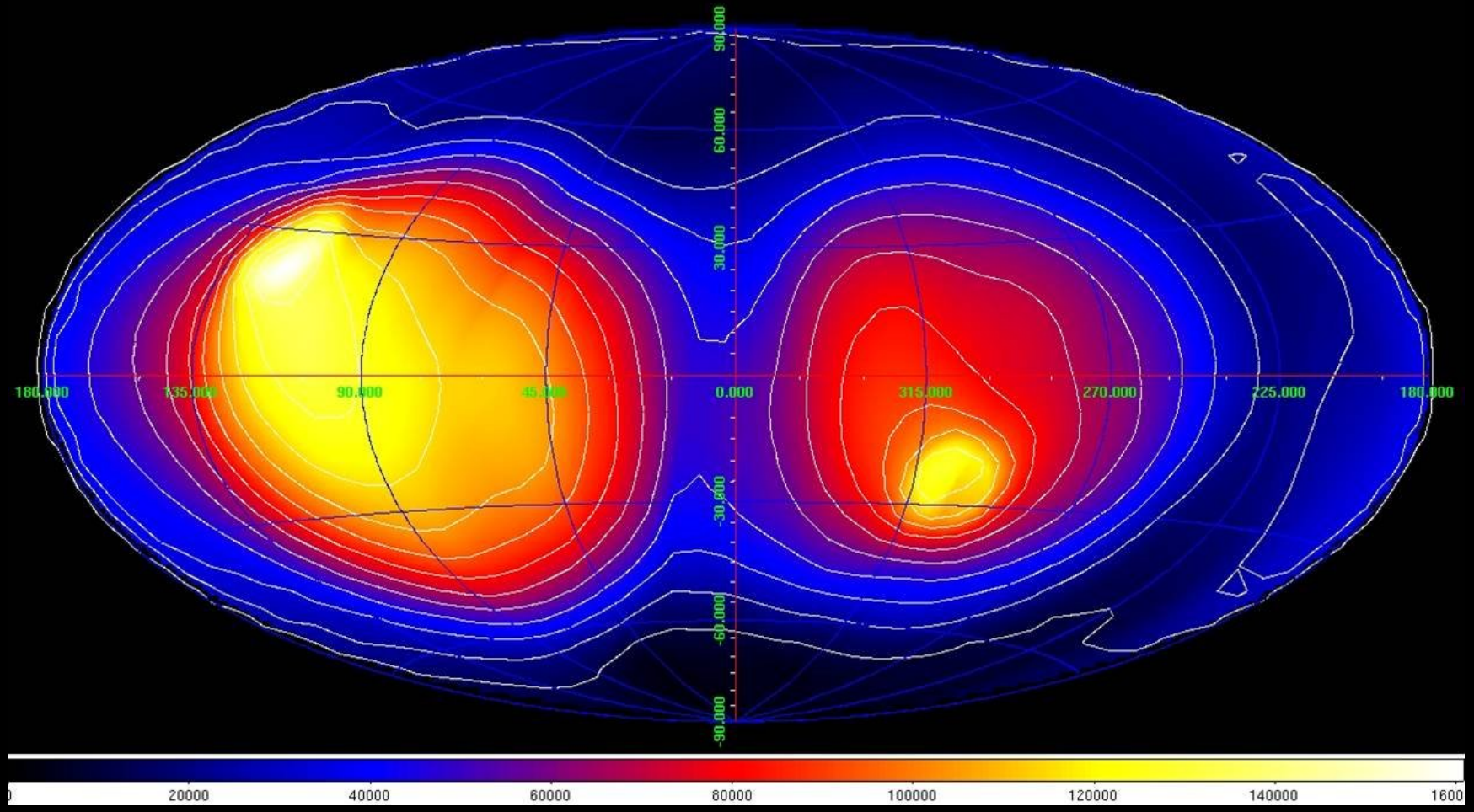
AGILE “Galactic” science topics

- new (soft) gamma-ray Pulsars
- PWNe
- microquasar studies, Gamma-ray emission from Gal. compact objects
- “new” gamma-ray transient candidates
- SNRs and origin of cosmic rays
- Molecular clouds, CR propagation

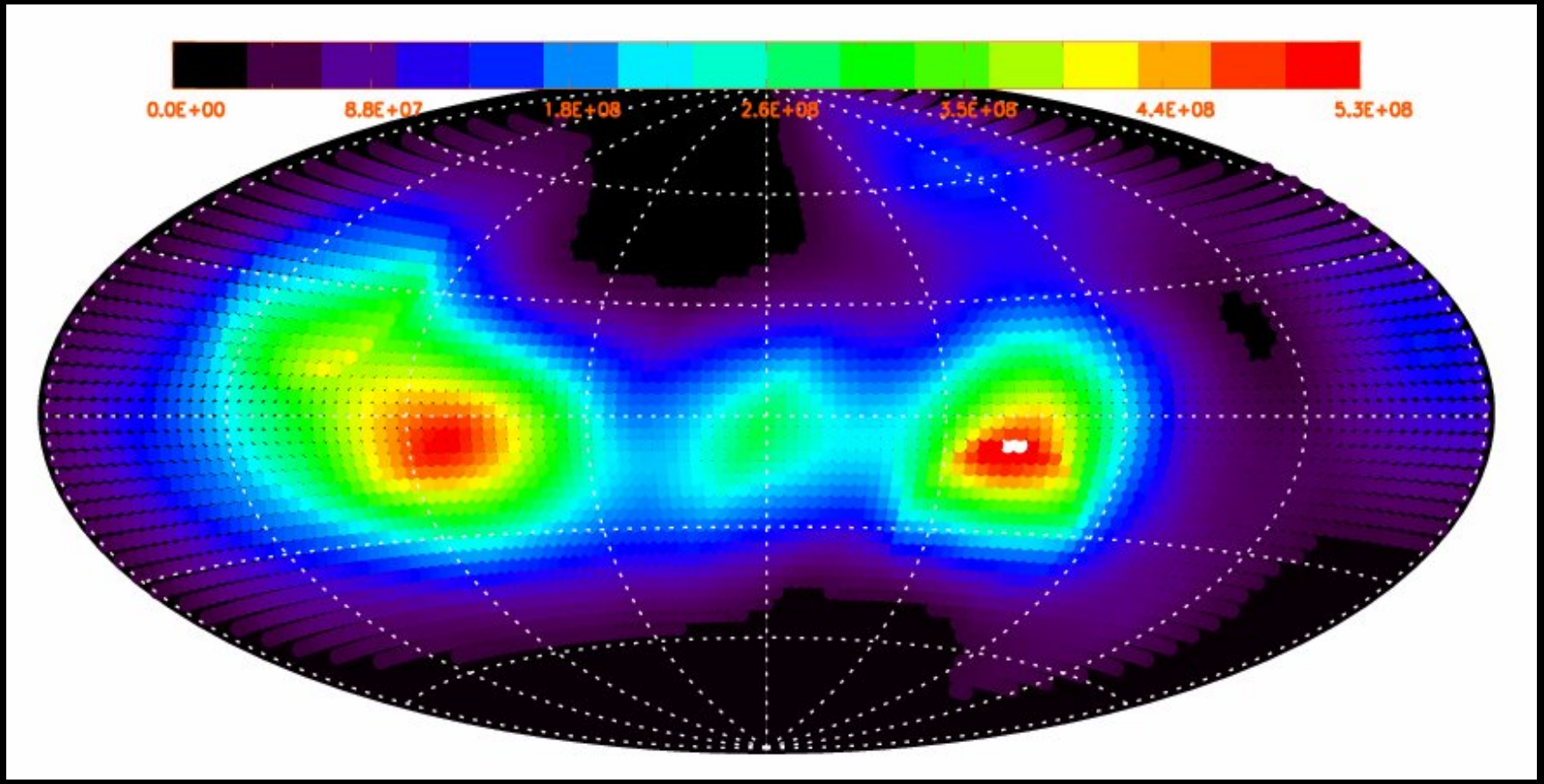

Galactic microquasars
New transients


Galactic microquasars
New transients
many results
many surprises

AGILE 2-year GRID exposure (100 MeV – 10 GeV)



AGILE 2-year Super-A exposure (20-60 keV)



Galactic “Micro-QSOs” (radio “jet” sources)

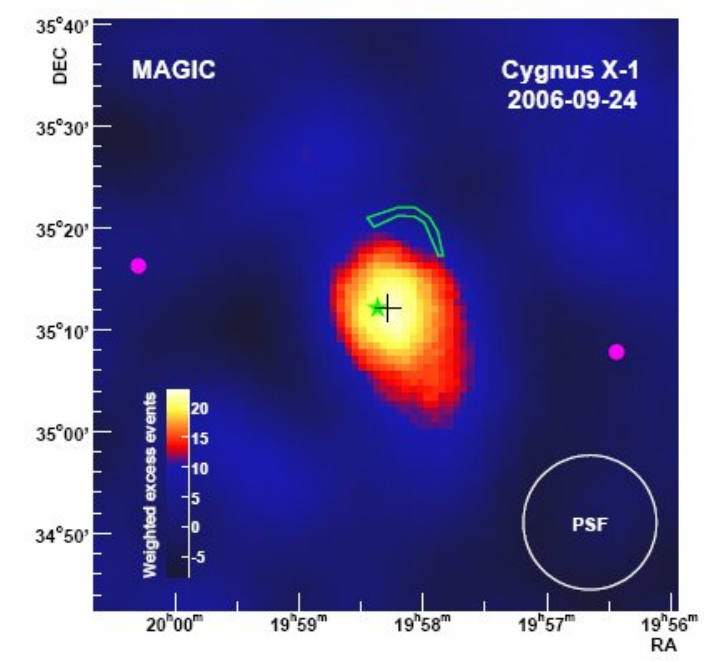
	Exposure
Cyg X-1	~ 1 year
Cyg X-3	~ 1 year
SS 433	~ 6-8 months
GRS 1915+104	~ 6-8 months
GRO J1655-40	~ 4-5 months
GRS 1758-258	~ 4-5 months
XTE J1550-564	~ 6-8 months
Sco X-1	~ 4-5 months
LS I 61 303	~ 4-5 months
LS 5039	~ 4-5 months

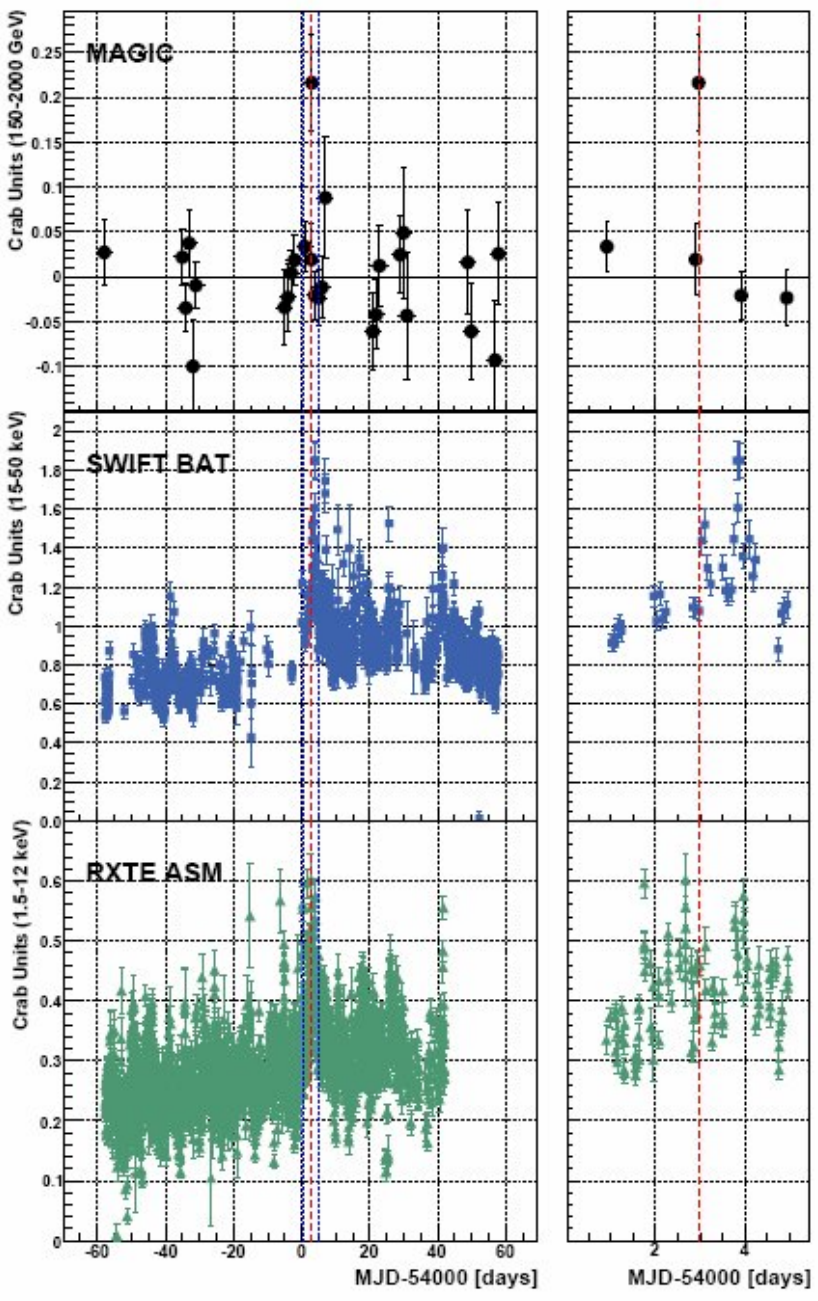
Galactic "Micro-QSOs" (radio "jet" sources)

	Θ (degrees)	β	Γ	L_X/L_E	γ/TeV
Cyg X-1	?	?	?	0.1-1	~5 MeV yes
Cyg X-3	< 14	> 0.8	> 1.6	0.1-1	?
SS 433	< 70	0.26	1.03	0.01	no
GRS 1915+104	70	0.92	2.5	0.1-1	no
GRO J1655-40	> 70	0.9	2.5	1	no
GRS 1758-258	?			0.1-1	no
XTE J1550-564	60-70	> 0.8	1.5	0.1-1	no
Sco X-1	> 70	> 0.8	> 1.6	0.1-1	no
LS I 61 303	?	?	?	10^{-4}	yes
LS 5039	< 80	> 0.2	?	10^{-4}	yes

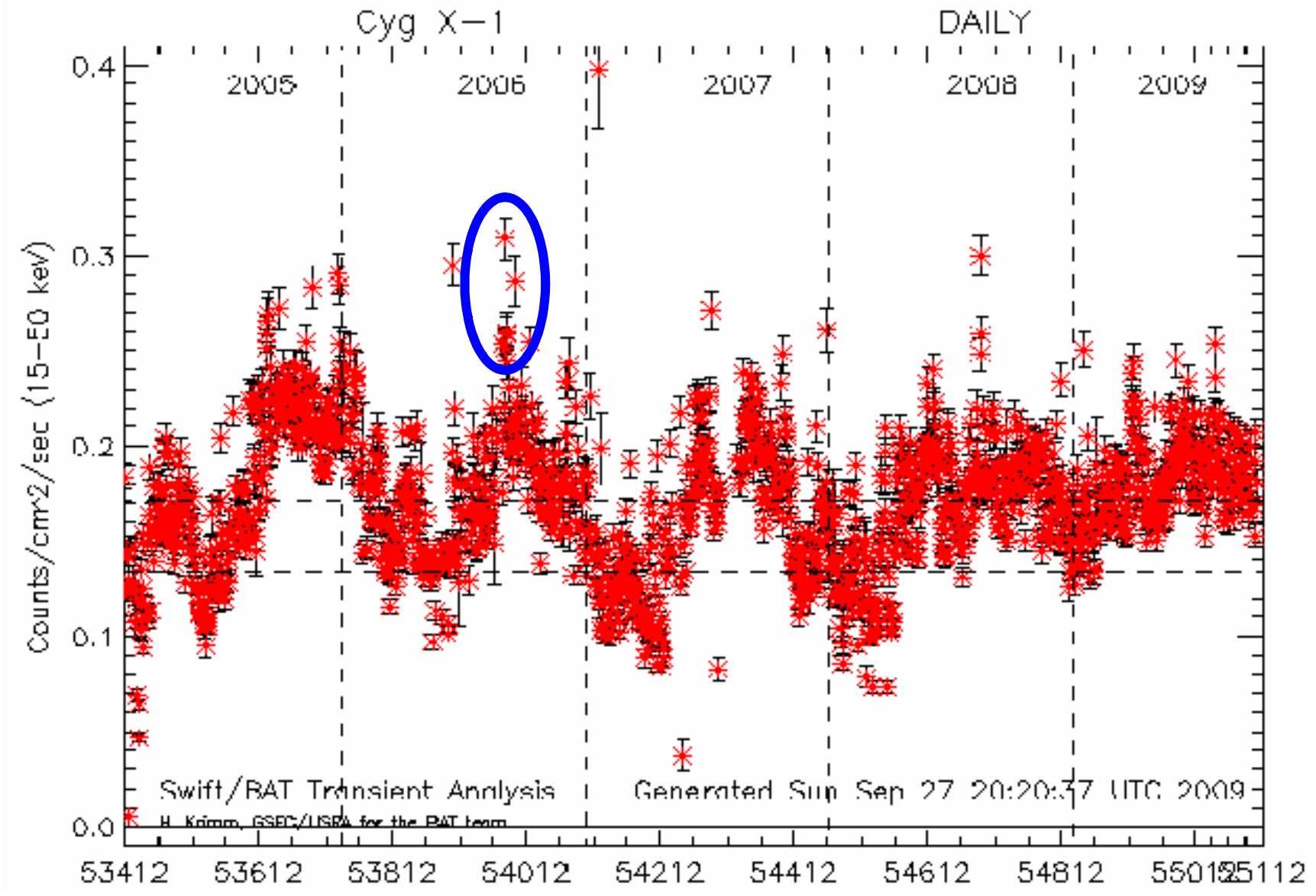
MAGIC single isolated detection of Cyg X-1, 24 Sept. 2006,

~ 79 min. TeV flare



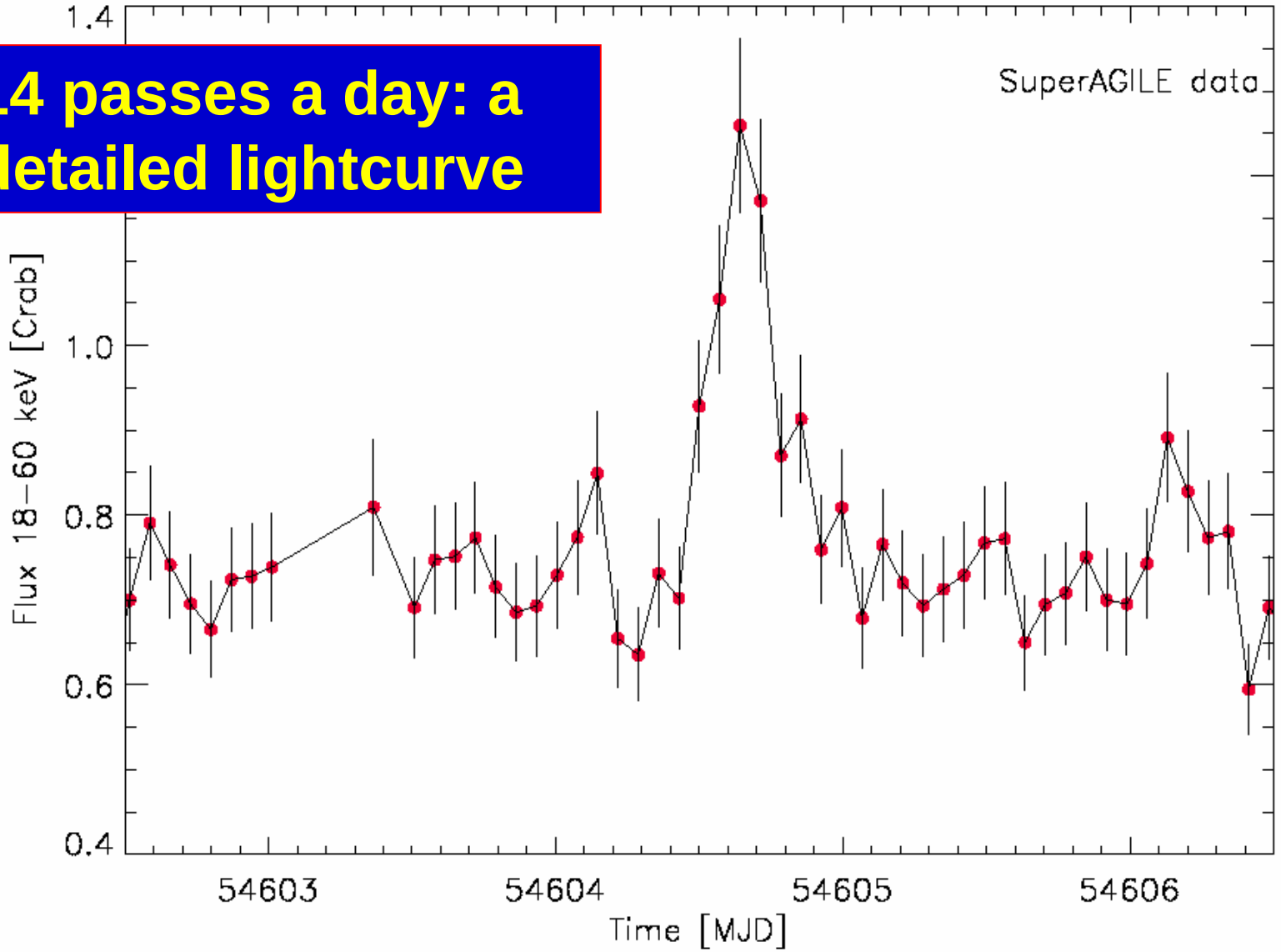


Cyg X-1 hard X-ray flux, Swift/BAT (15-50 keV)

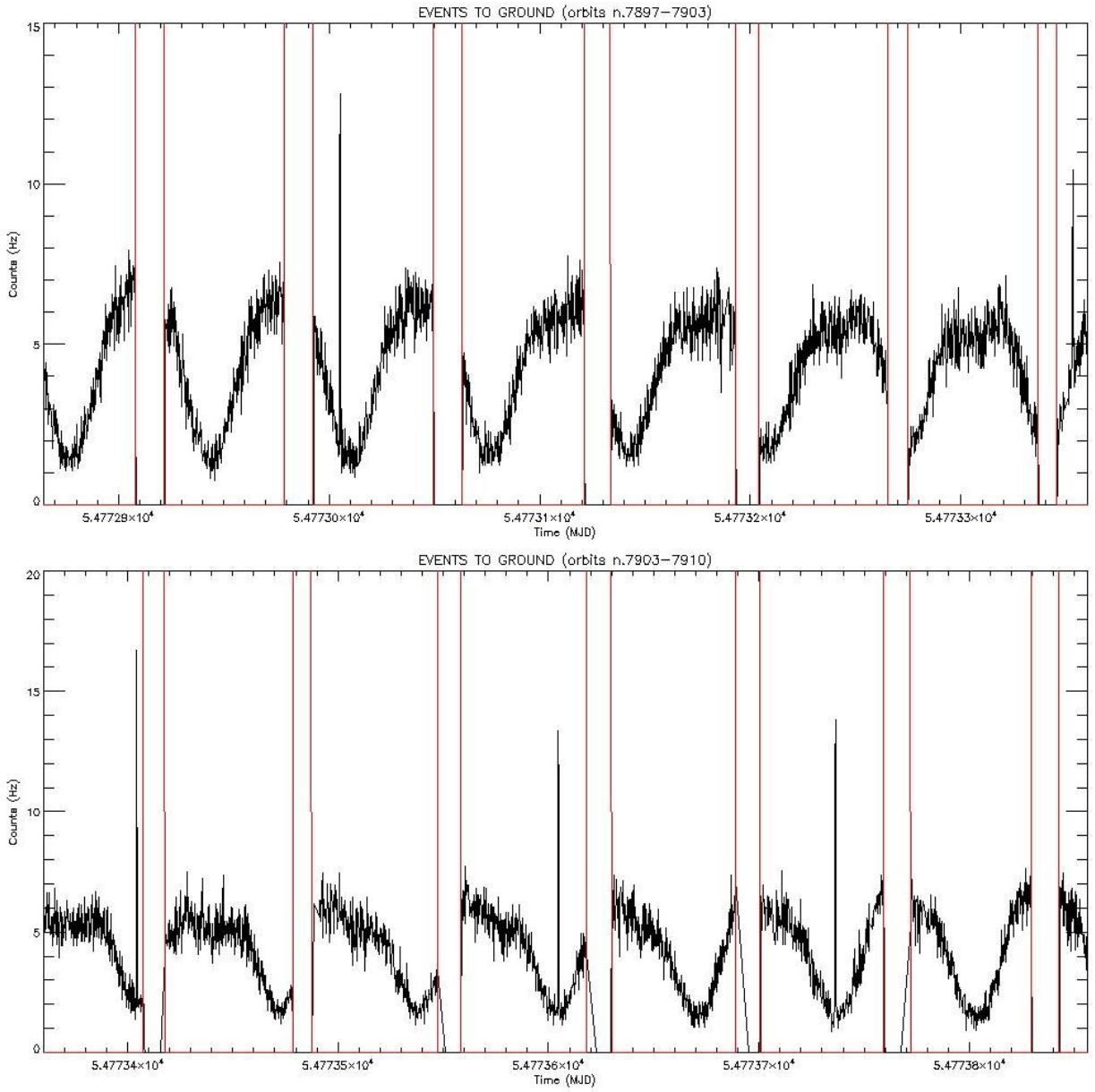


Cygnus X 1 monitoring

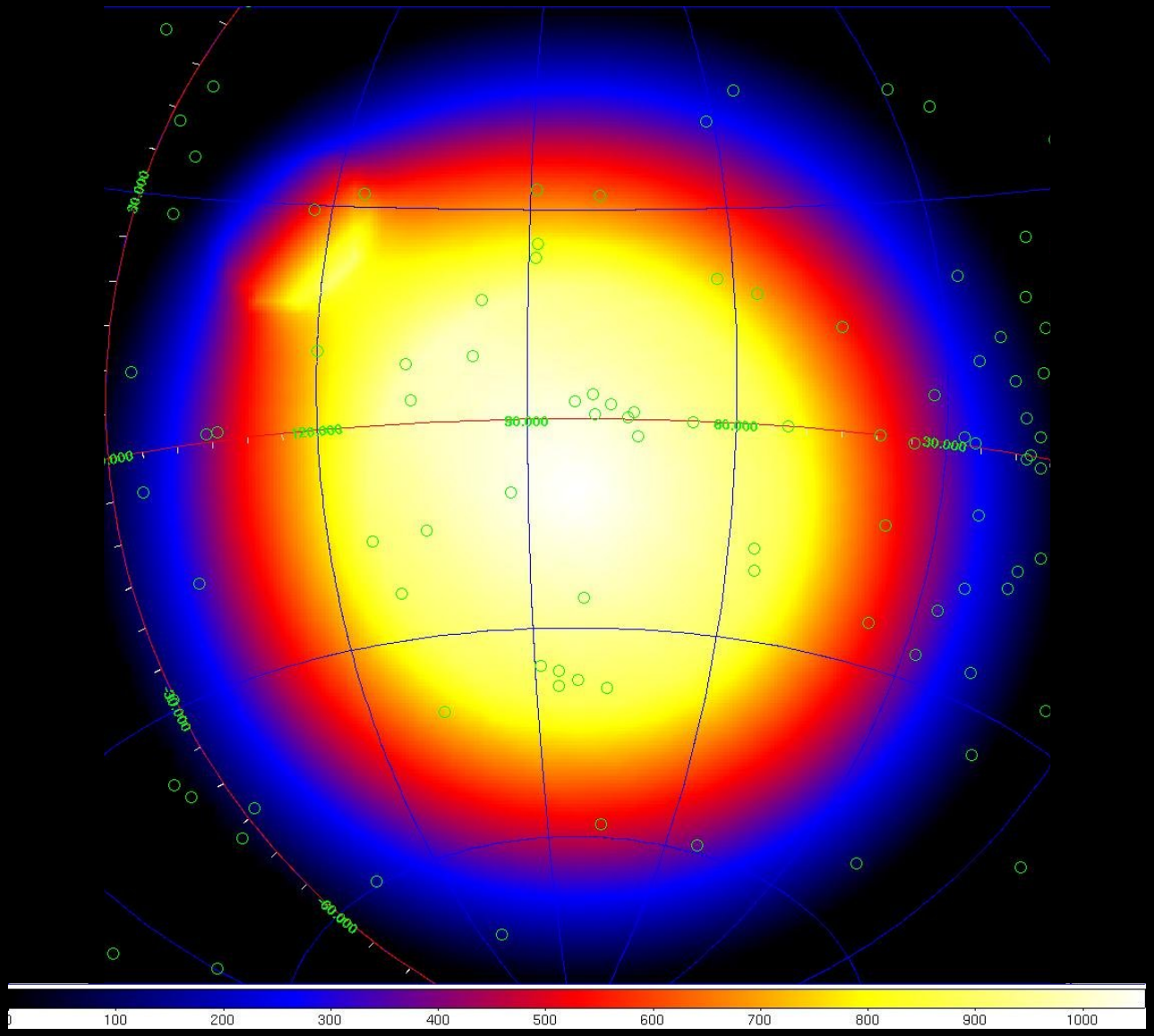
14 passes a day: a detailed lightcurve



AGILE-GRID telemetry on Nov. 3, 2008

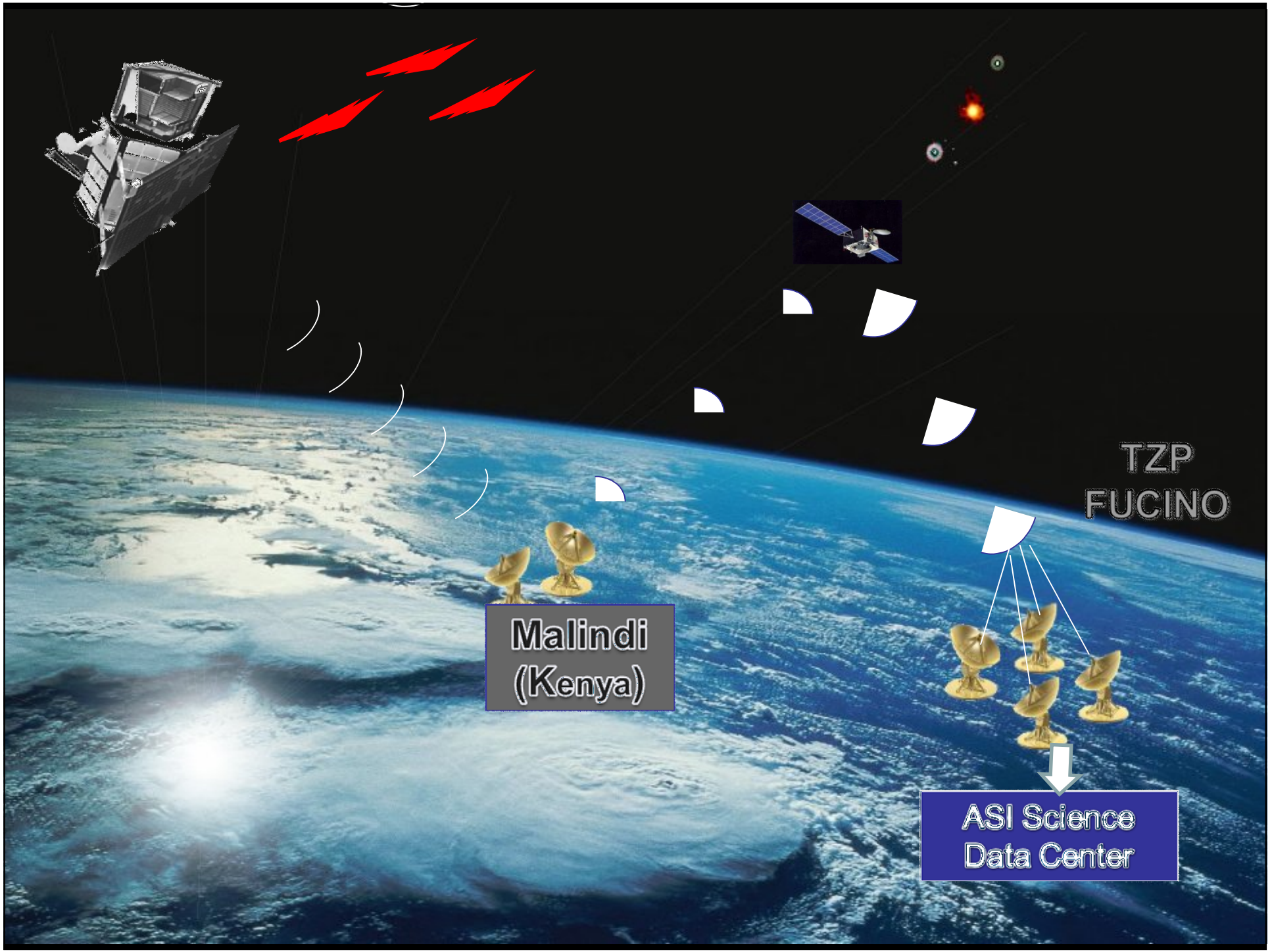


The AGILE 1-day exposure (E > 100 MeV) (30 Nov. 2008)

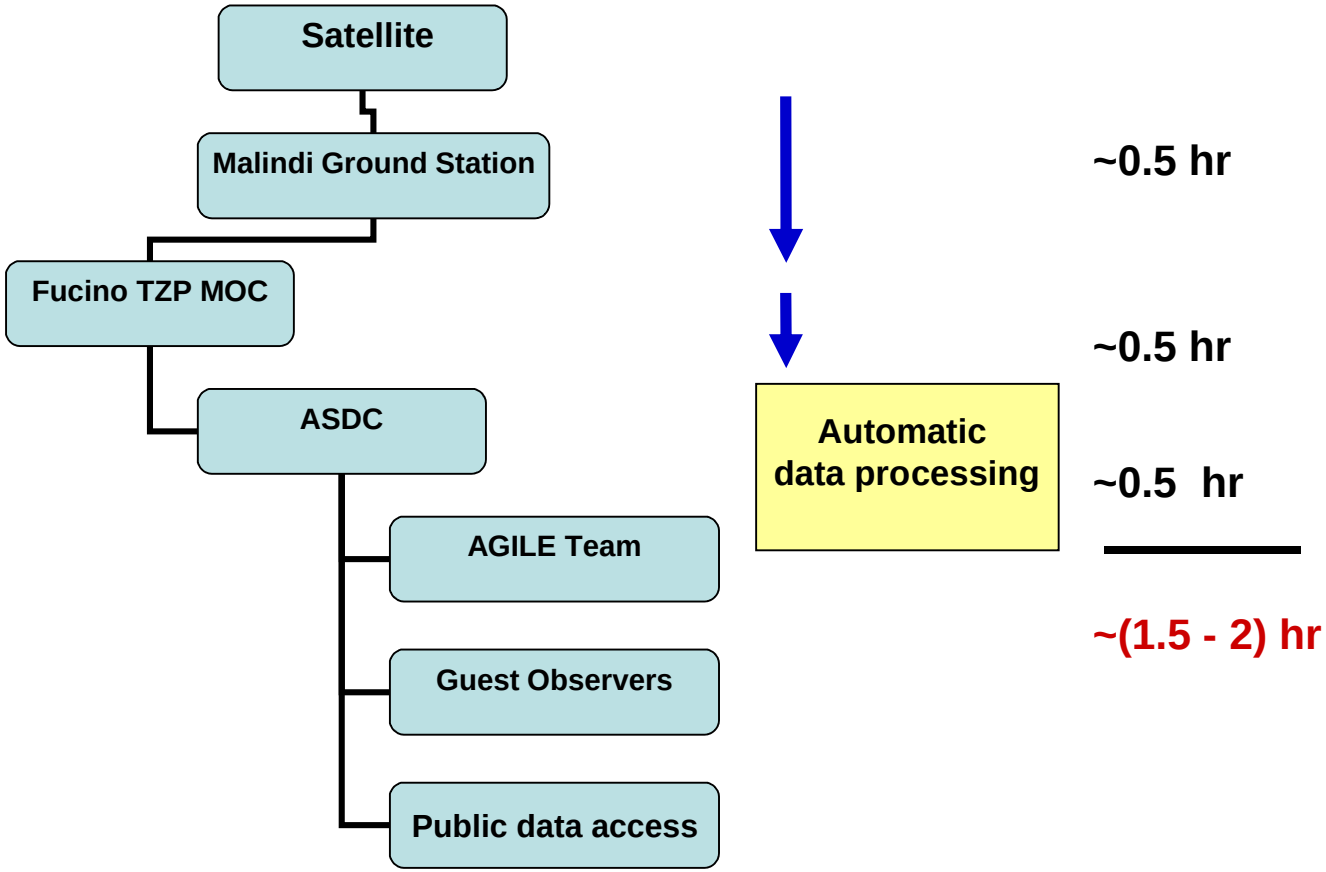


a comparison: 1-day exposure

	AGILE (GRID)	FERMI (LAT)
FOV (sr)	2.5	2.5
sky coverage	1/5	whole sky
Source livetime fraction	~ 0.5	~ 0.16
1 day exposure (30 degree off axis, 100 MeV)	~ $2\ 10^7$ cm^2 sec	~ $(1\text{-}2)\ 10^7$ cm^2 sec
Attitude	fixed	variable

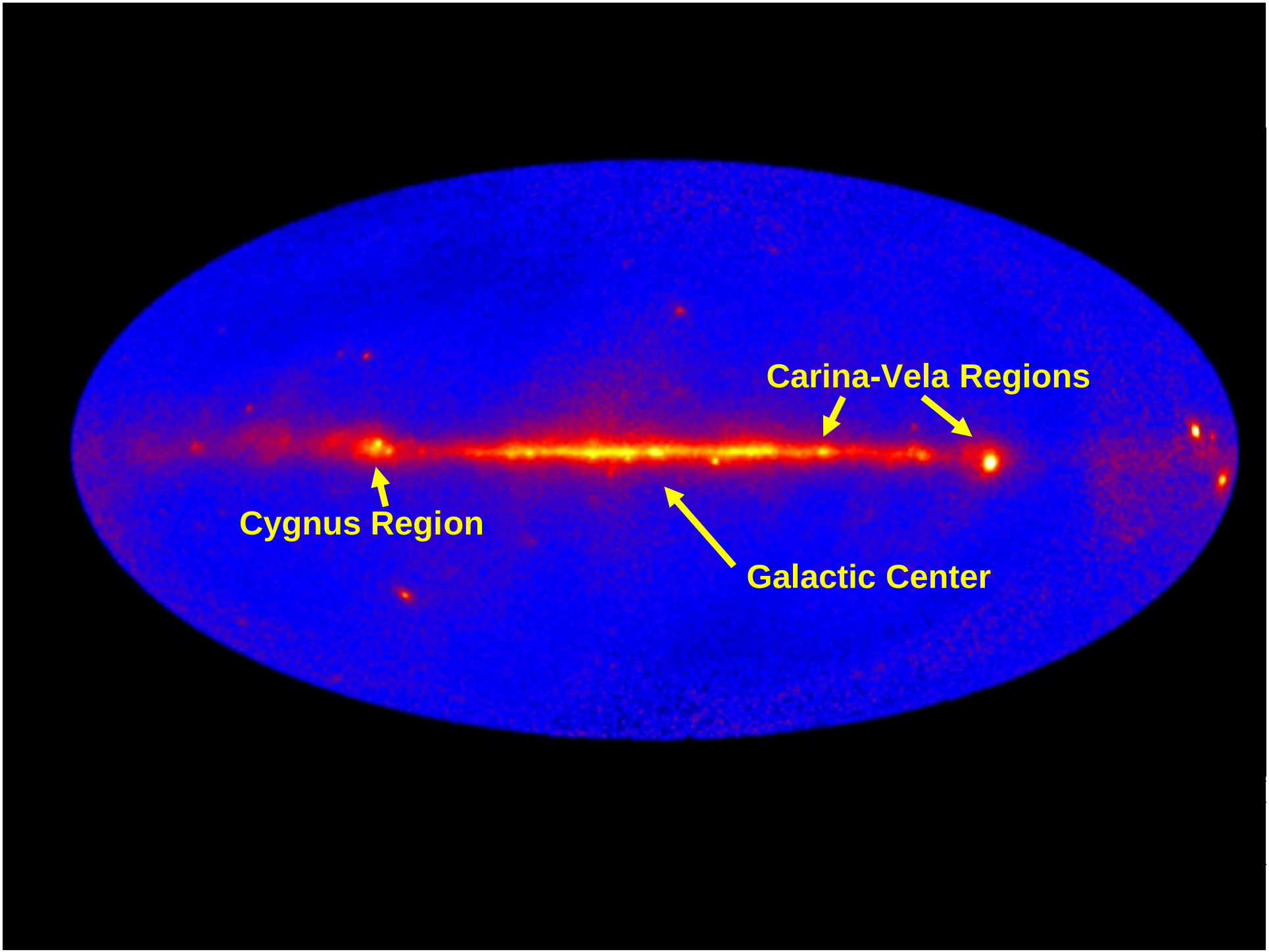

TZP
FUCINO
Malindi
(Kenya)
ASI Science
Data Center

AGILE Ground Segment



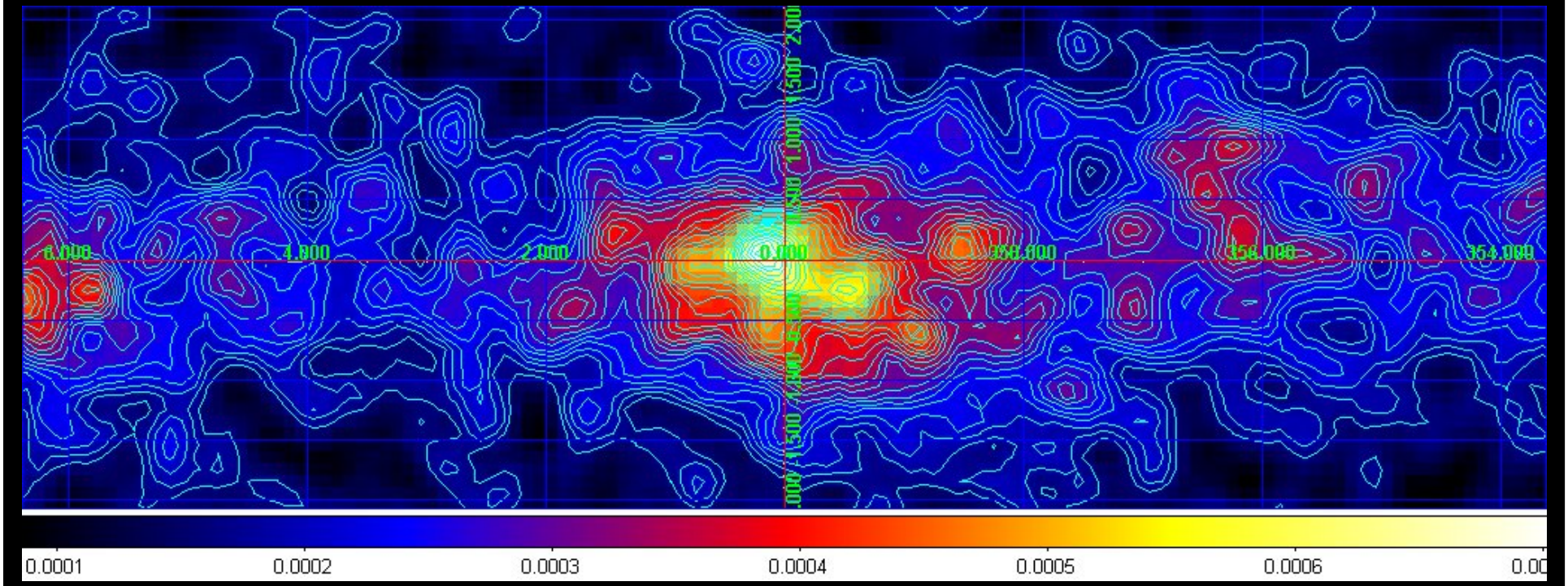
Multifrequency science

- AGILE, FERMI
- Radio Telescopes (VLA, Mojave, Michigan, AMI-LA, RATAN)
- Optical Obs. Networks (GASP, REM, …)
- SWIFT, Suzaku, XMM
- INTEGRAL
- TeV (MAGIC, HESS, VERITAS)

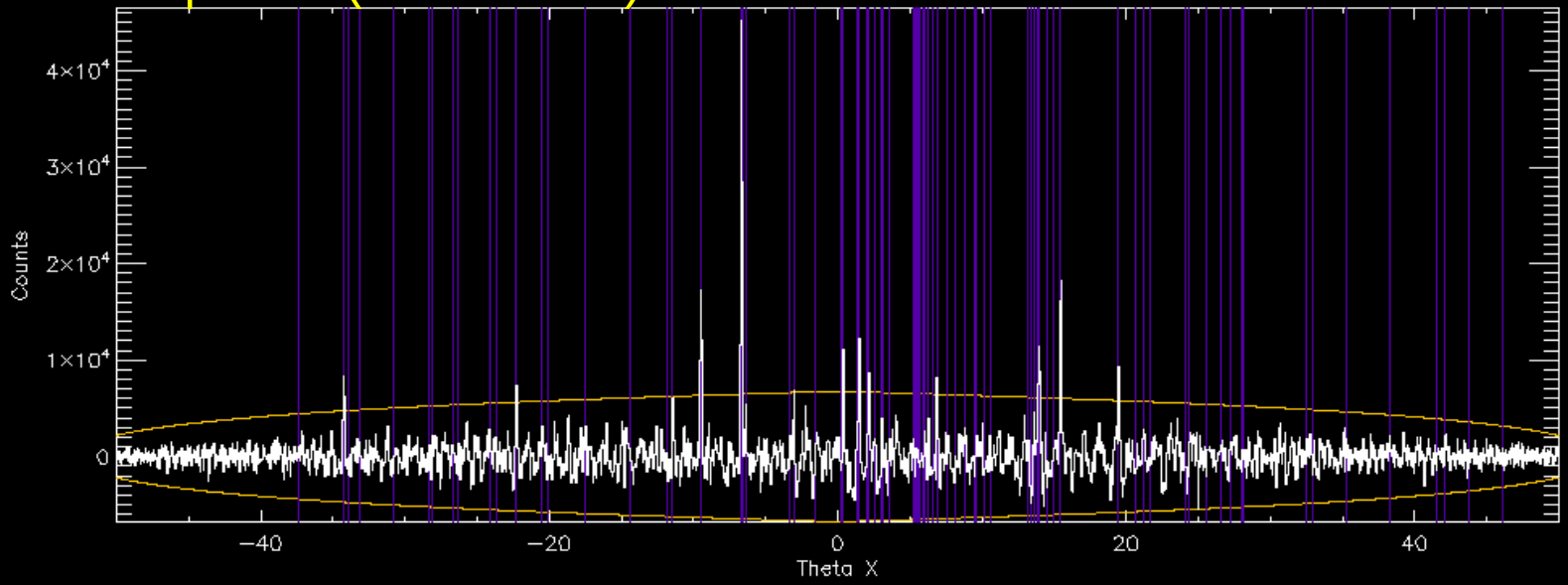

Carina-Vela Regions
Cygnus Region
Galactic Center

The Galactic Center

GC region, AGILE B19b,FM (E > 400 MeV)



Example: October 1, 2009 view of the Galactic Center region with Super-A (20-60 keV)



SKYBIN	SKYCOORD	DIRECTION	ZONE	RATE	ERR_RATE	CTS cm-2 s-1	EXPOSURE	NAME	SIGN
1428.88	-6.68057	X	15	1.39655	0.279310	0.457440	45017.2	Sco X-1	34.9787
1891.71	15.4799	X	12	0.586521	0.117304	0.0465814	46703.6	4U 1700-377	15.1582
1370.05	-9.49395	X	8	0.495455	0.0990910	0.0171424	43871.6	GX 17+2	13.5986
1857.82	13.9335	X	12	0.360108	0.0720216	0.0270270	46456.0	GX 349+2	9.33134
1597.11	1.49684	X	9	0.429247	0.0858494	0.0139616	44629.1	GX 5-1	9.15980
766.920	-34.2576	X	3	0.312803	0.0625605	0.0589205	43524.2	GRS 1915+105	8.73901
1574.64	0.400699	X	7	0.331132	0.0662264	0.00958806	44375.7	Ginga 1826-24	8.26159
1982.02	19.4848	X	12	0.248696	0.0497392	0.0222842	47381.2	OAO 1657-415	7.98617
1610.88	2.16789	X	9	0.253957	0.0507915	0.00847812	44675.7	GRS 1758-258	6.53055
1085.47	-22.2762	X	10	0.271741	0.0543482	0.0174138	43800.0	SWIFT J1753.5-0127	6.49230
1708.84	6.91432	X	8	0.202768	0.0405536	0.00648387	44998.6	4U 1820-303	6.39260
1503.75	-3.05522	X	9	0.170617	0.0341235	0.00582340	44294.8	GX 9+1	5.16577
1329.26	-11.4187	X	7	0.181133	0.0362266	0.00669337	43824.1	1M 1812-121	4.80630

One-day automatic integration on the GC: 13 sources from 38 mCrab to 3 Crab

AGILE capabilities

- **Semi-continuous monitoring of sources in the FOV (14 passes/day)**
  - **SAA and Earth occultation**
- **Good sensitivity near 100 MeV**
- **Simultaneous hard X-ray and gamma-ray monitoring**
- **Careful statistical analysis: likelihood and FDR methods, post-trial significance**

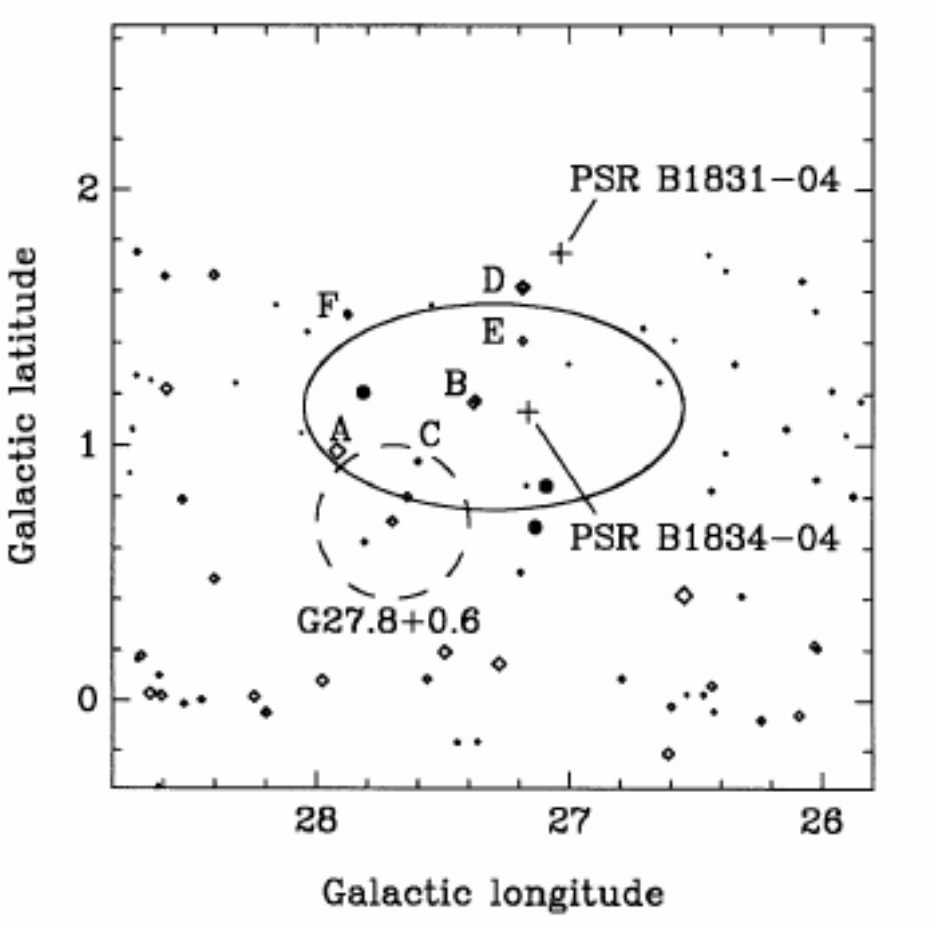
Gamma-Ray Galactic Transients

- **Big issue since EGRET, some detection/hints**
  - **example: GRO J1838 04**

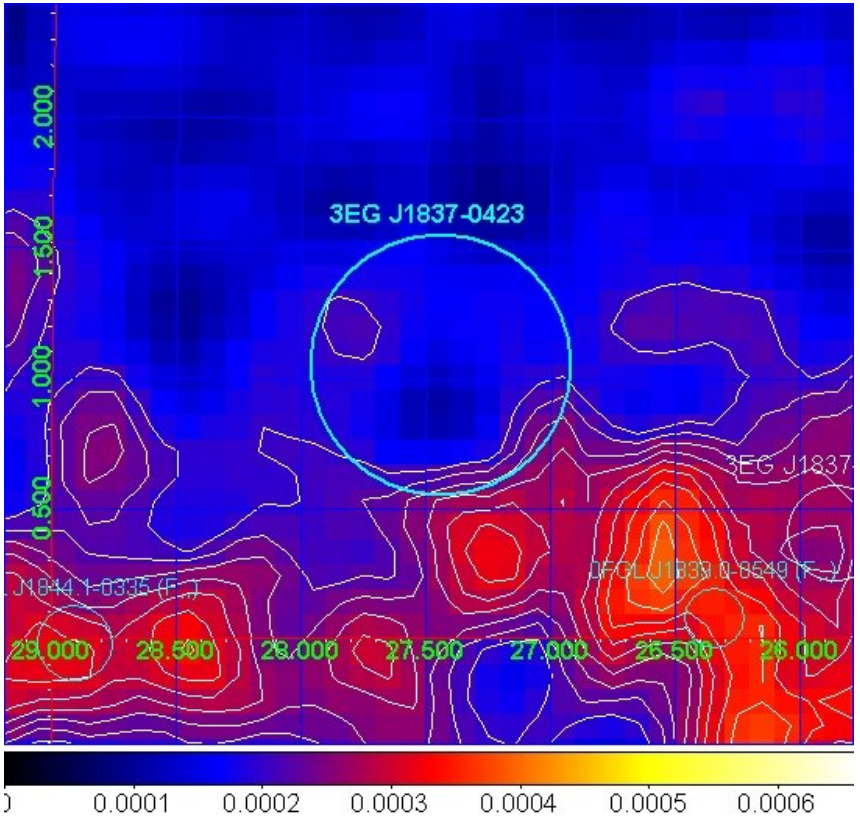
- **AGILE discovery of several gamma-ray transients in the plane (usually low-energy)**
  - **Examples:**
    - **24 Nov. 2007**
    - **Crux Region transients**
    - **Carina Region transients**
    - **Eta-Car**
    - **Galactic Center transients (March 09)**
    - **L= 17**
    - **L = 8 (Easter-09 transient)**
    - **Cygnus transients**

GRO J1838-04 (blazar-less EGRET transient)

EGRET



AGILE (all data)



Galactic gamma-ray transients:

- **GC region**
- **Cygnus region**
- **Carina region**
- **Crux region**

- **AGILE observes variability and detects new transients on time scales of 1-2 days at flux levels of 10^{-6} $cm^{-2}s^{-1}$, even in crowded, high diffuse emission Galactic plane regions.**
- **NO detectable simultaneous hard X-ray emission (F < 20-30 mCrab, 18-60 keV, 1-day integration)**

AGILE facts and surprises

- in general, no obvious X-ray or hard X-ray strong source (above 10 mCrab)
- some SWIFT follow-ups: no obvious detections, (except one…)
- but…Eta-Car and Cygnus X-3 examples

Energetics…

- **Gamma-ray luminosity above 100 MeV**

$$L = 7 \times 10^{34}\, d^2_{kpc}\ \mathrm{erg/s}$$

Energetics…

- **Gamma-ray luminosity above 100 MeV**

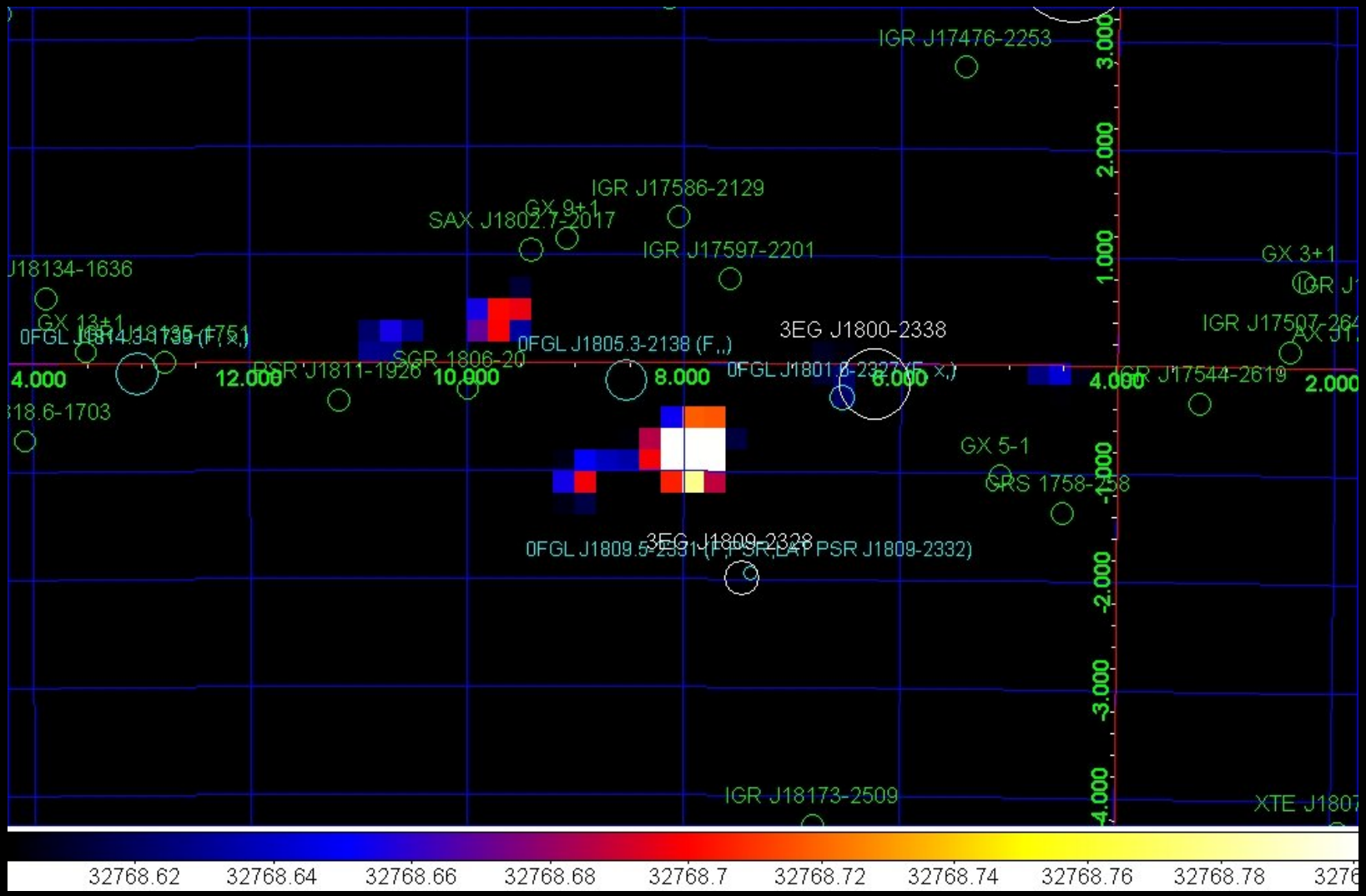
  $$L = (\text{a few}) \times 10^{34}\ d^2_{kpc}\ \text{erg/s}$$

- **Compatible with WR/CWB expectations**
  - **It could be a class of WR/CWB or flaring stars**

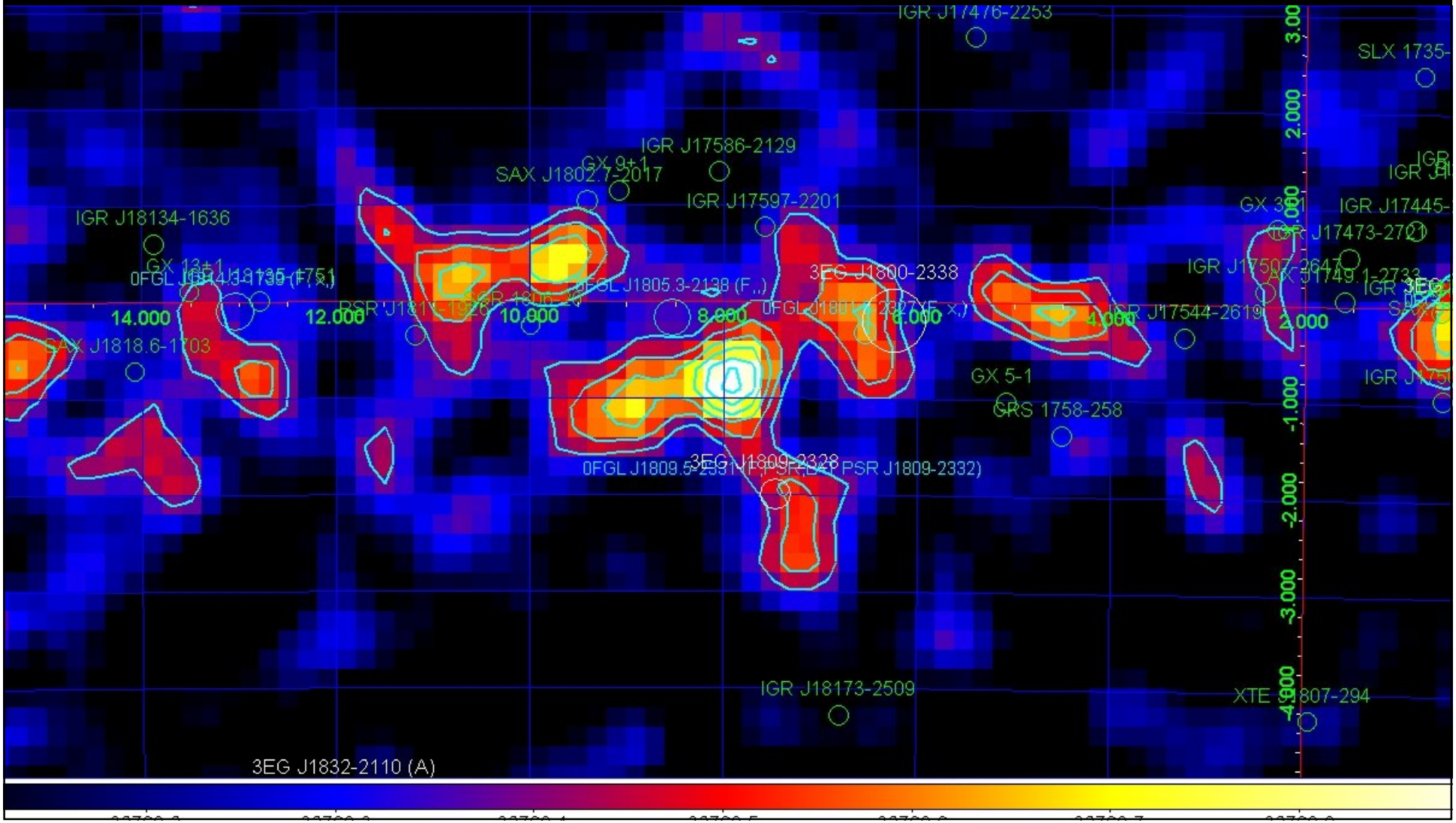
- **But also it could be a NEW CLASS of (non-accreting or low X-ray) sources**

Easter 2009 transient

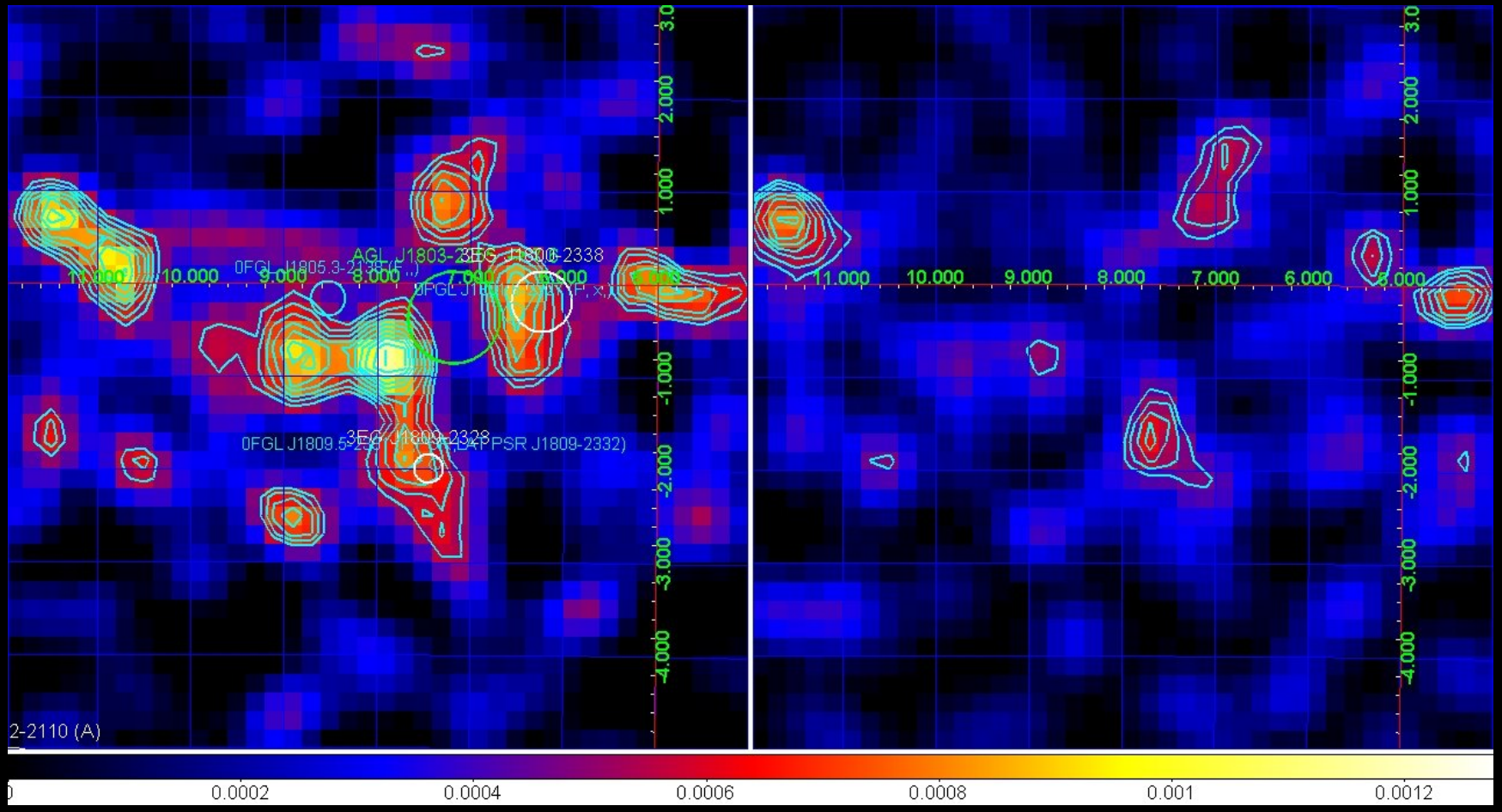
Easter transient: 10-13 April 2009, 10143-10180, bin =0.2, B16, FM, E>100 MeV



Easter transient: 10-13 April 2009, 10143-10180, bin =0.2, B16, FM, E>100 MeV



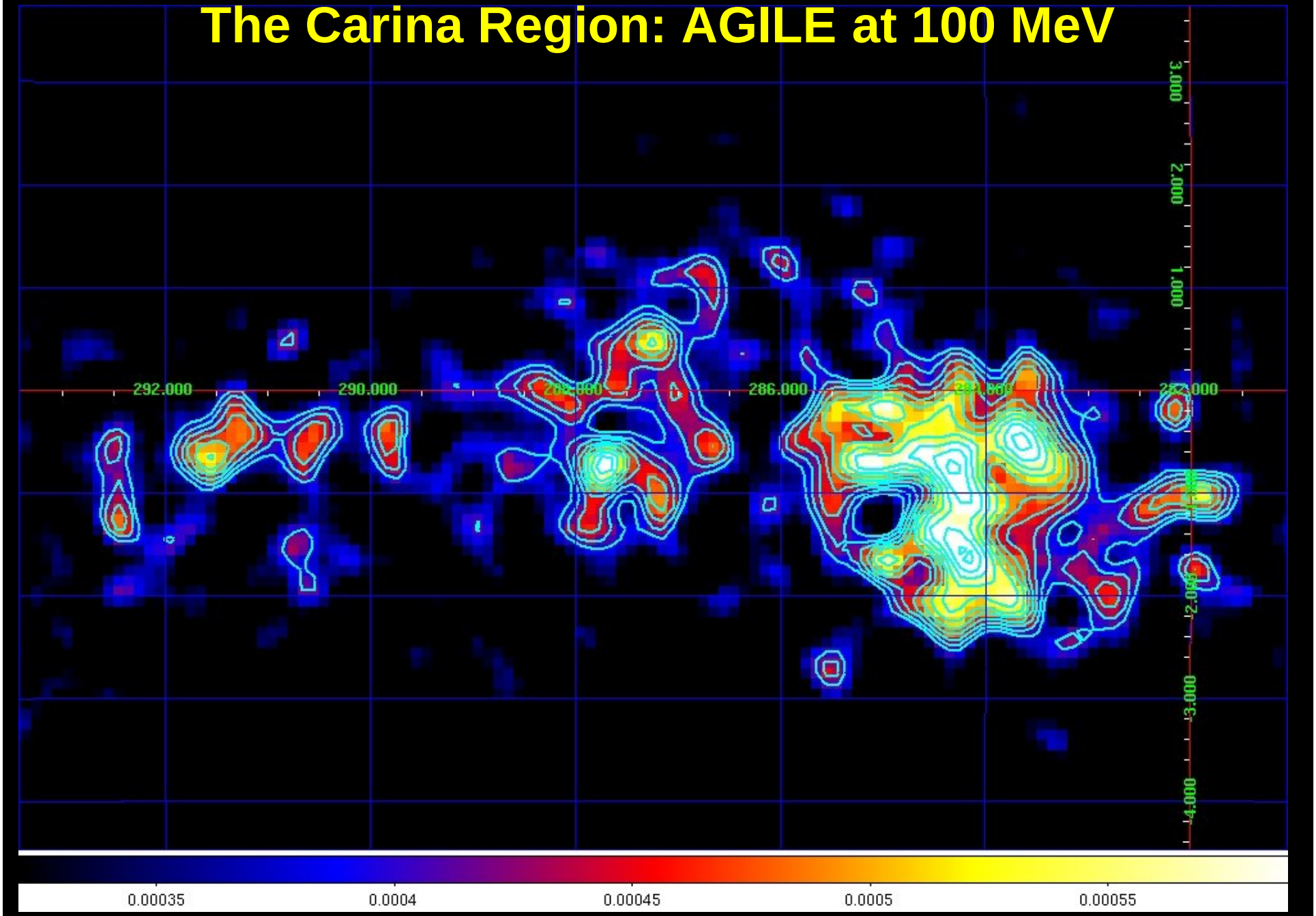
Easter transient: 10-13 April 2009, 10143-10180, bin =0.2, B17b, FT



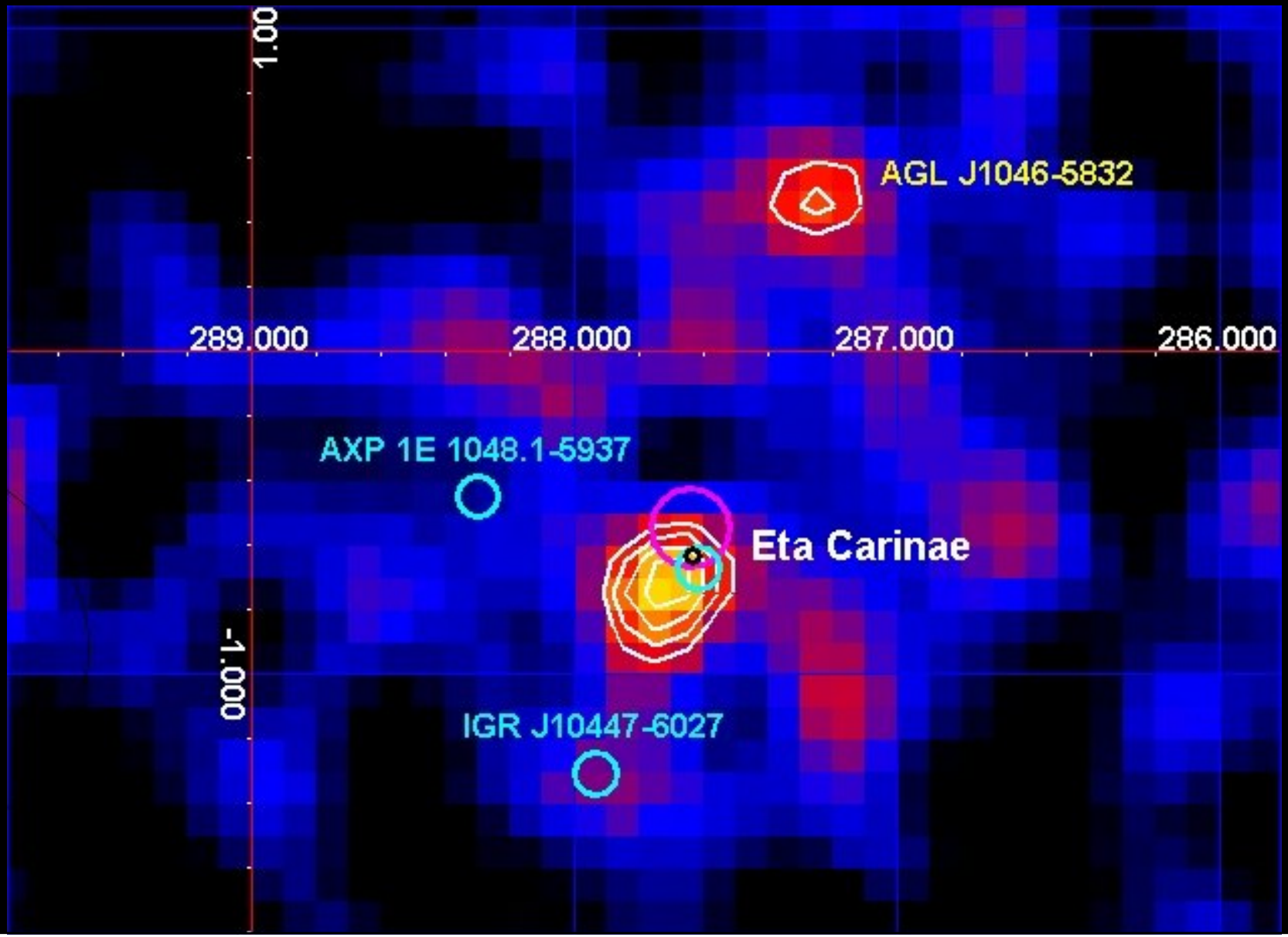
E > 100 MeV

E > 400 MeV

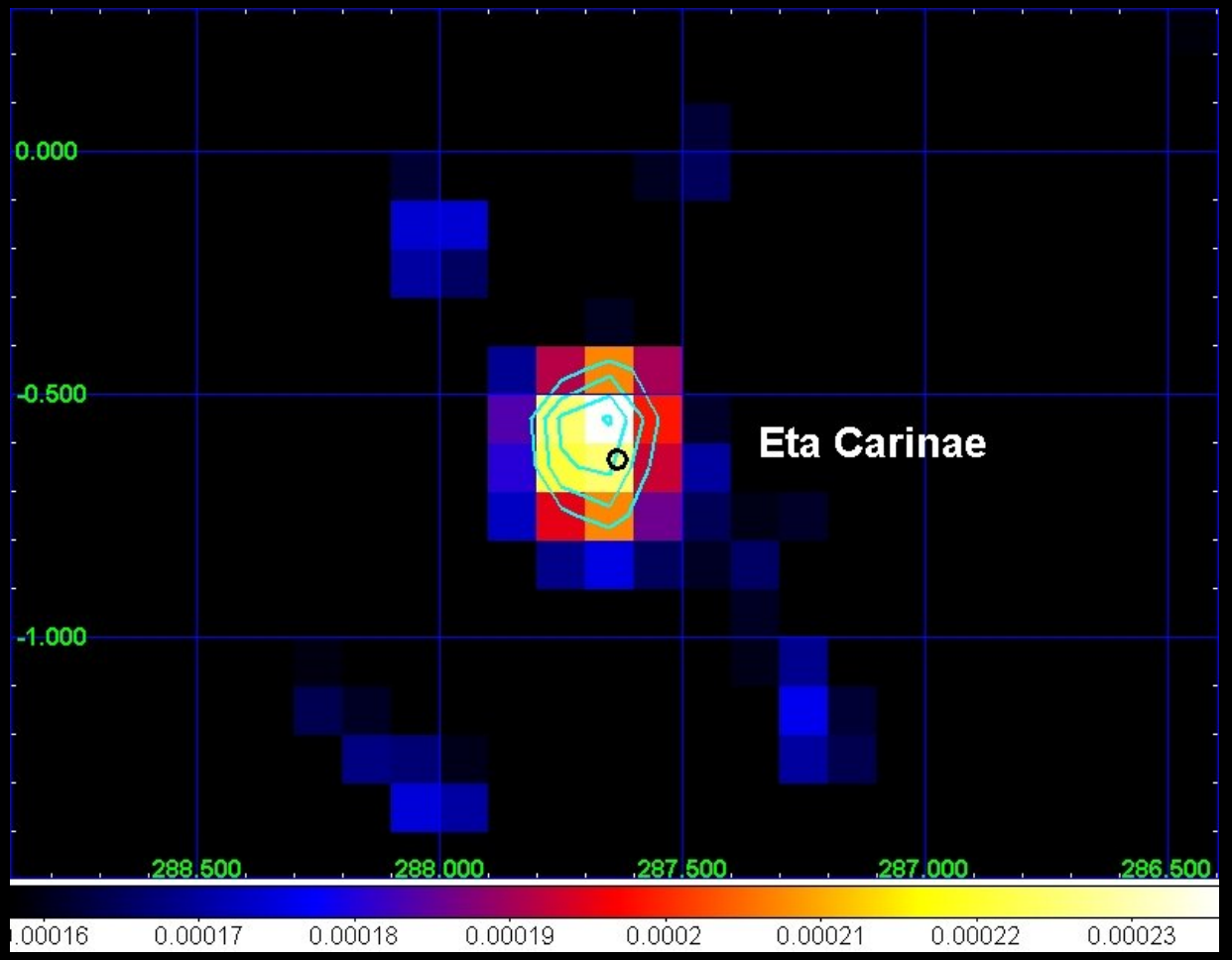
The Carina Region: AGILE at 100 MeV



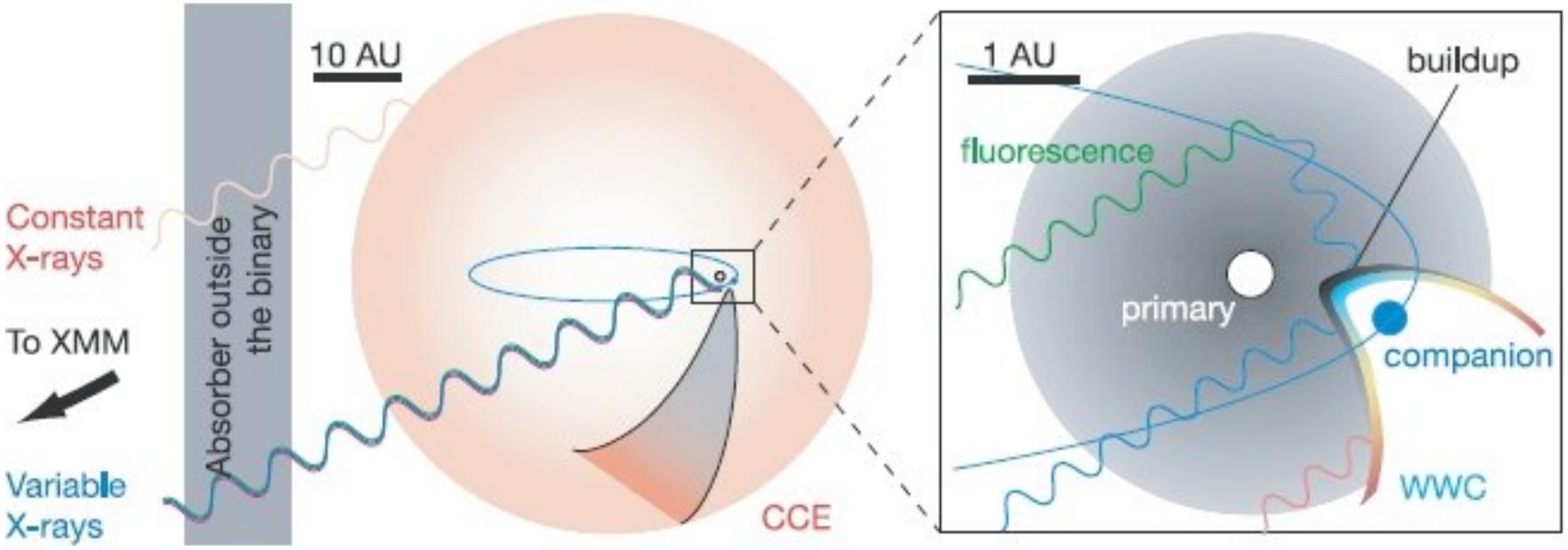
AGILE discovery of gamma ray emission from the Eta Carinae region



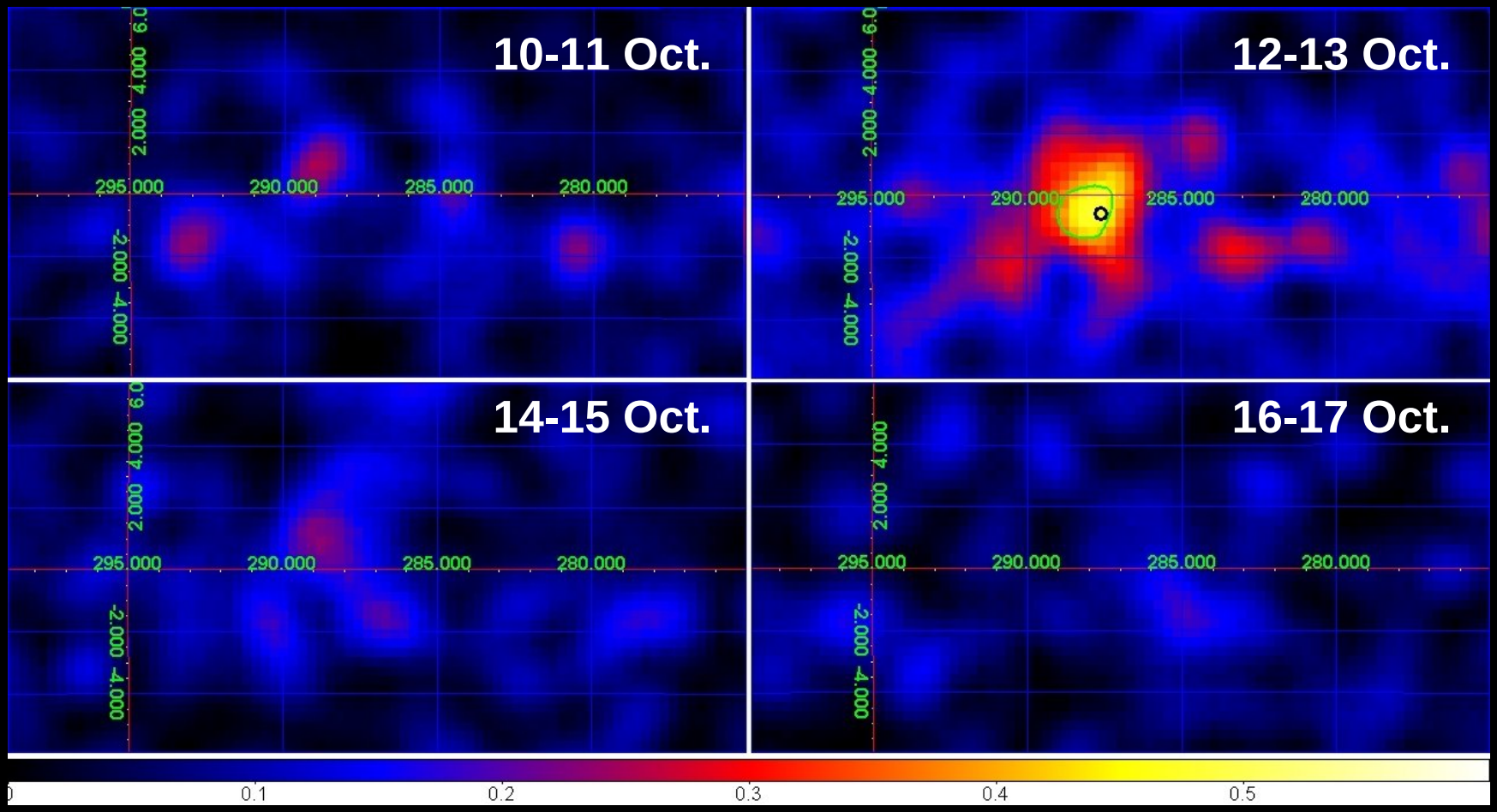
AGILE-GRID, Eta Carinae at 400 MeV



The Eta Carinae system: a colliding wind binary



Transient gamma-ray emission from Eta Carinae (12-13 Oct., 2008)



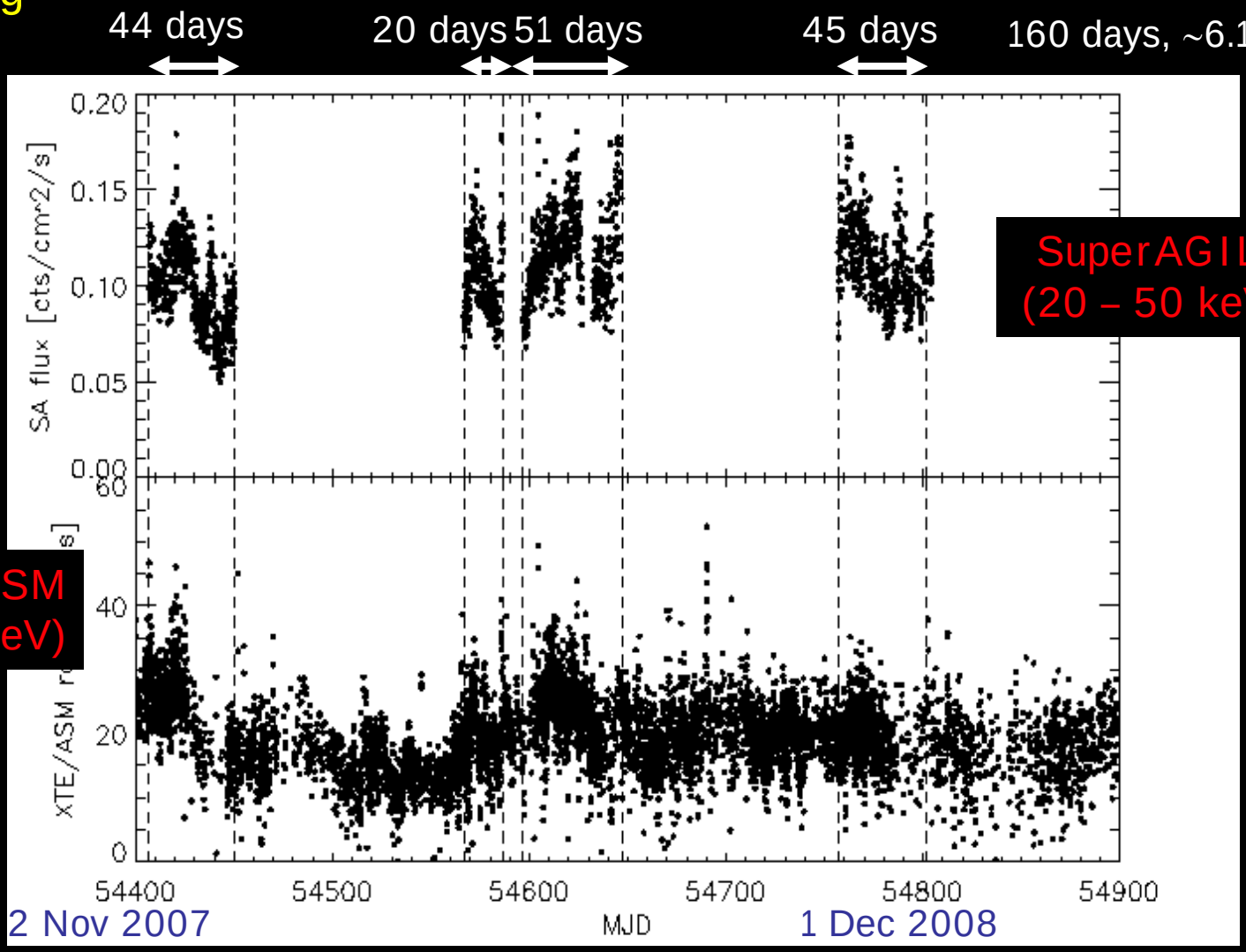
monitored Micro-QSOs

- Cyg X-1
- Cyg X-3
- GRS 1915+105
- SS 433
- ….

Challenges…

- **are Cyg X-1-like fast transients common ?**
- **AGILE did not detect (yet) Cyg X-1 above 100 MeV**
- **detect gamma-ray variability within 1 day…or even less**

Cyg X-1 monitoring (2007-mid 2009): in hard state, no gamma-ray flaring



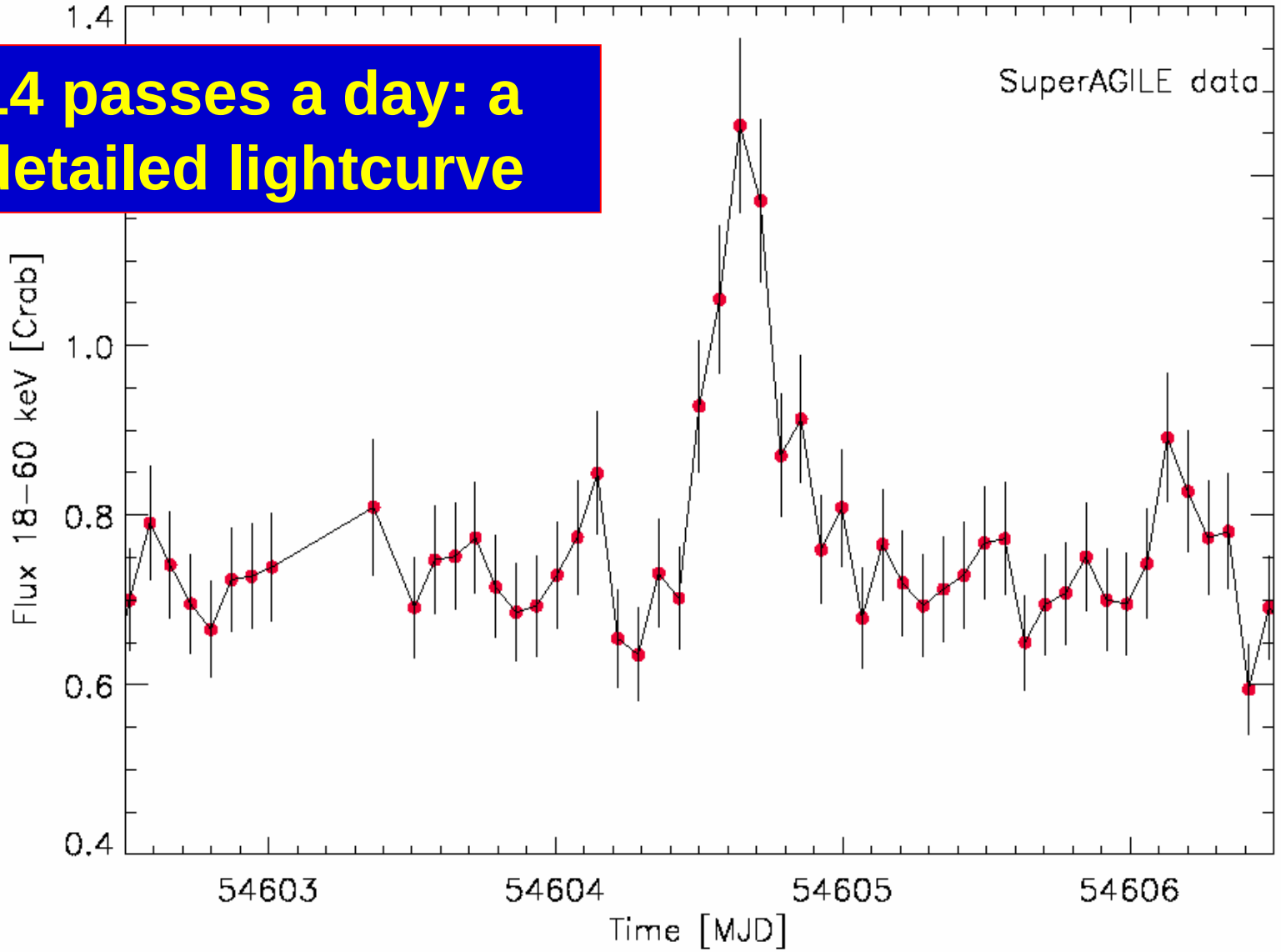
SuperAGILE (20 – 50 keV)

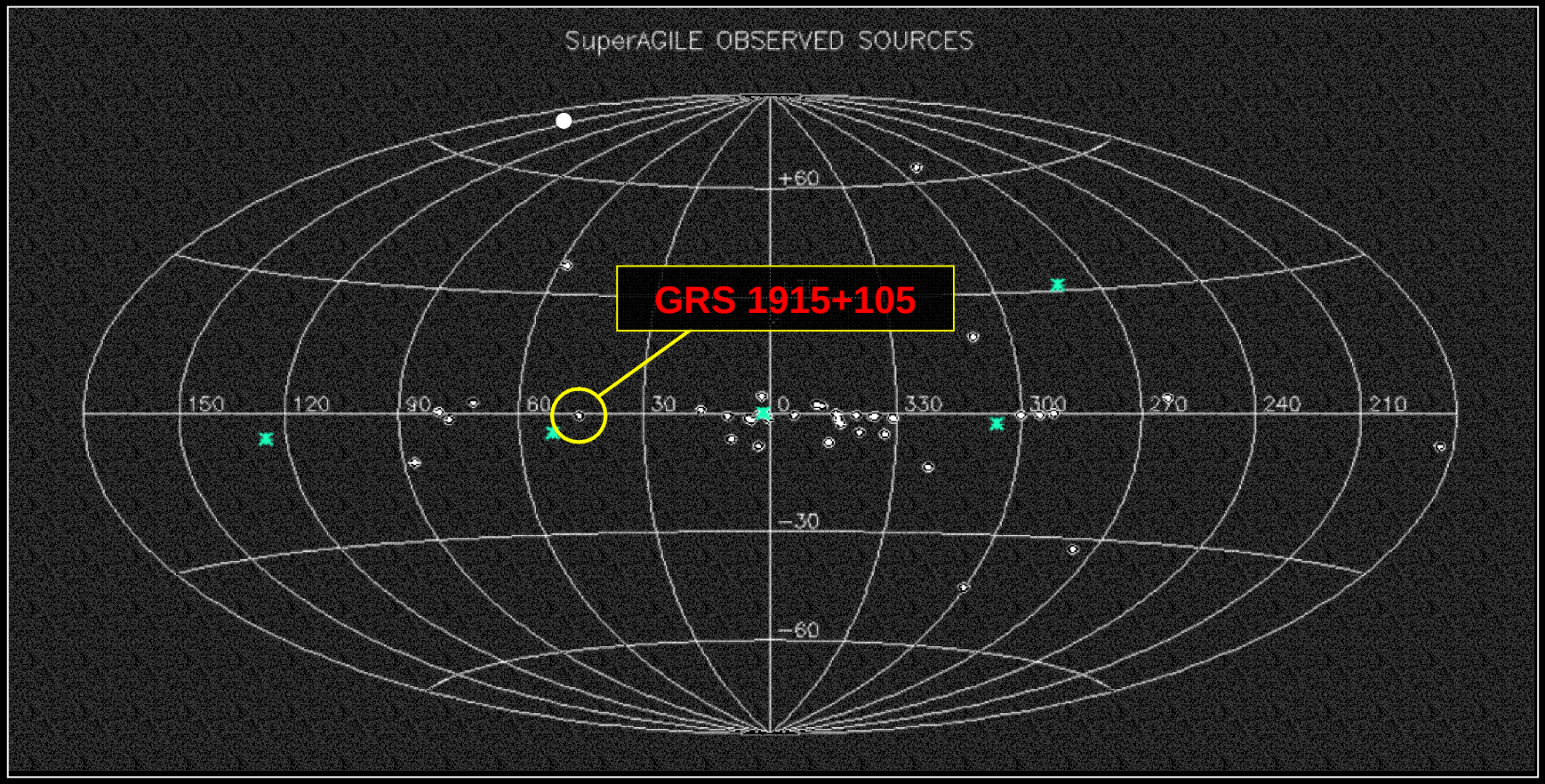
RXTE/ASM (2 – 12 keV)

Del Monte et al. Submitted to A&A

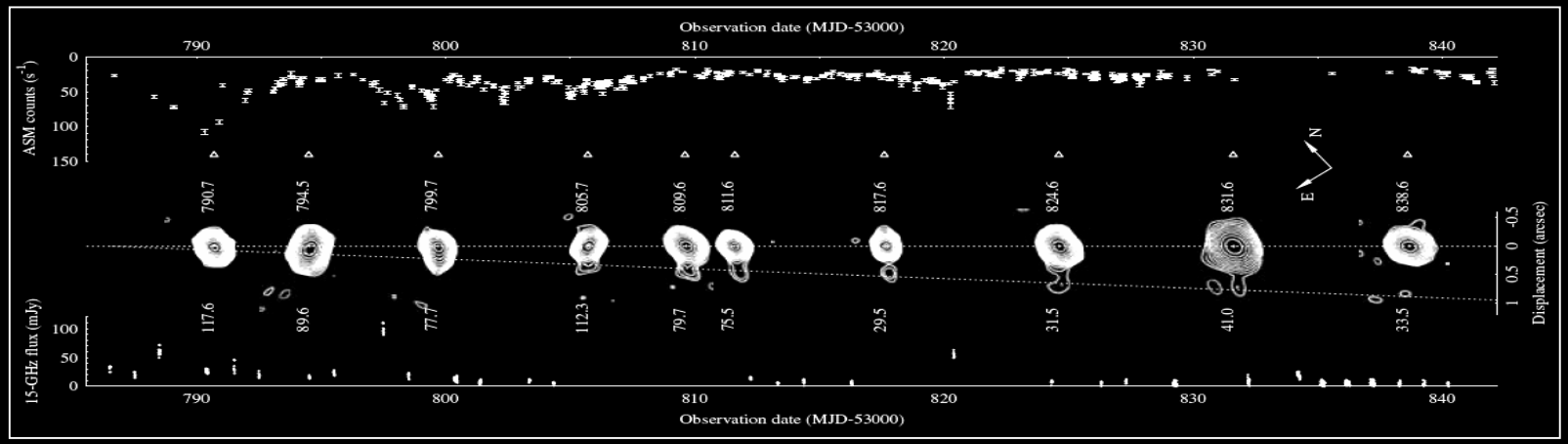
Cygnus X 1 monitoring

14 passes a day: a detailed lightcurve



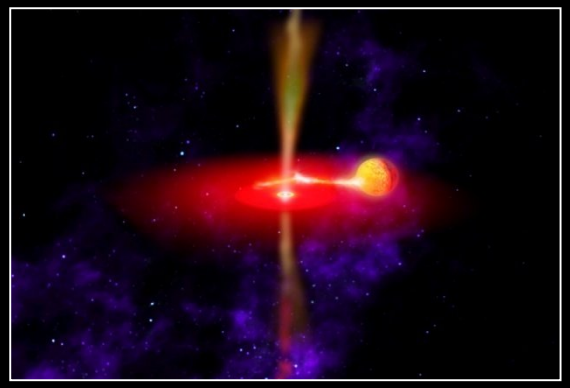

SuperAGILE OBSERVED SOURCES
GRS 1915+105
+60
−30
−60
150
120
90
60
30
0
330
300
270
240
210

GRS 1915+105: historical radio flaring



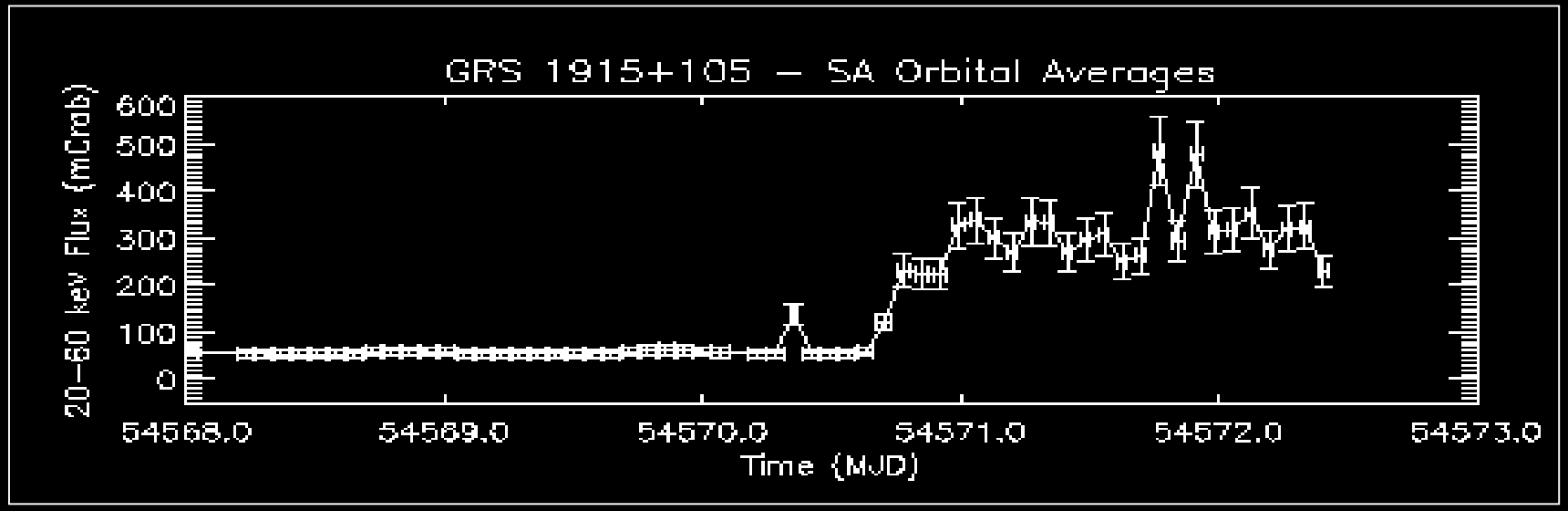
(J.C.A. Miller-Jones, 2007)

GRS 1915+105



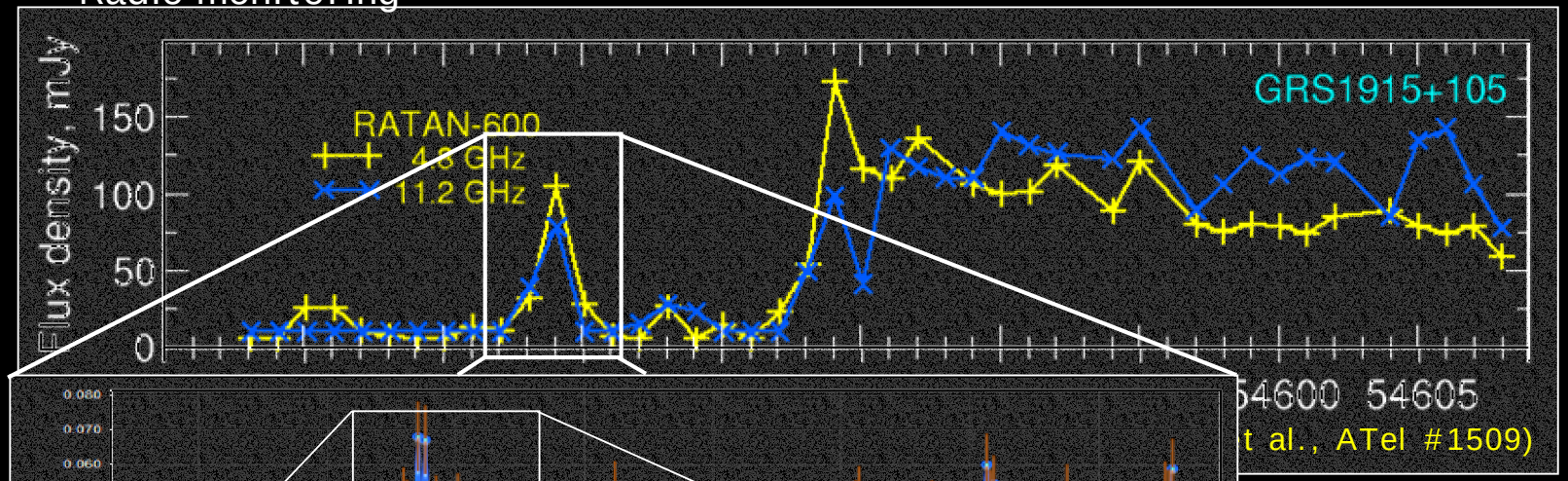
15 April, 2008

Hard X-ray re-activation of GRS 1915+105



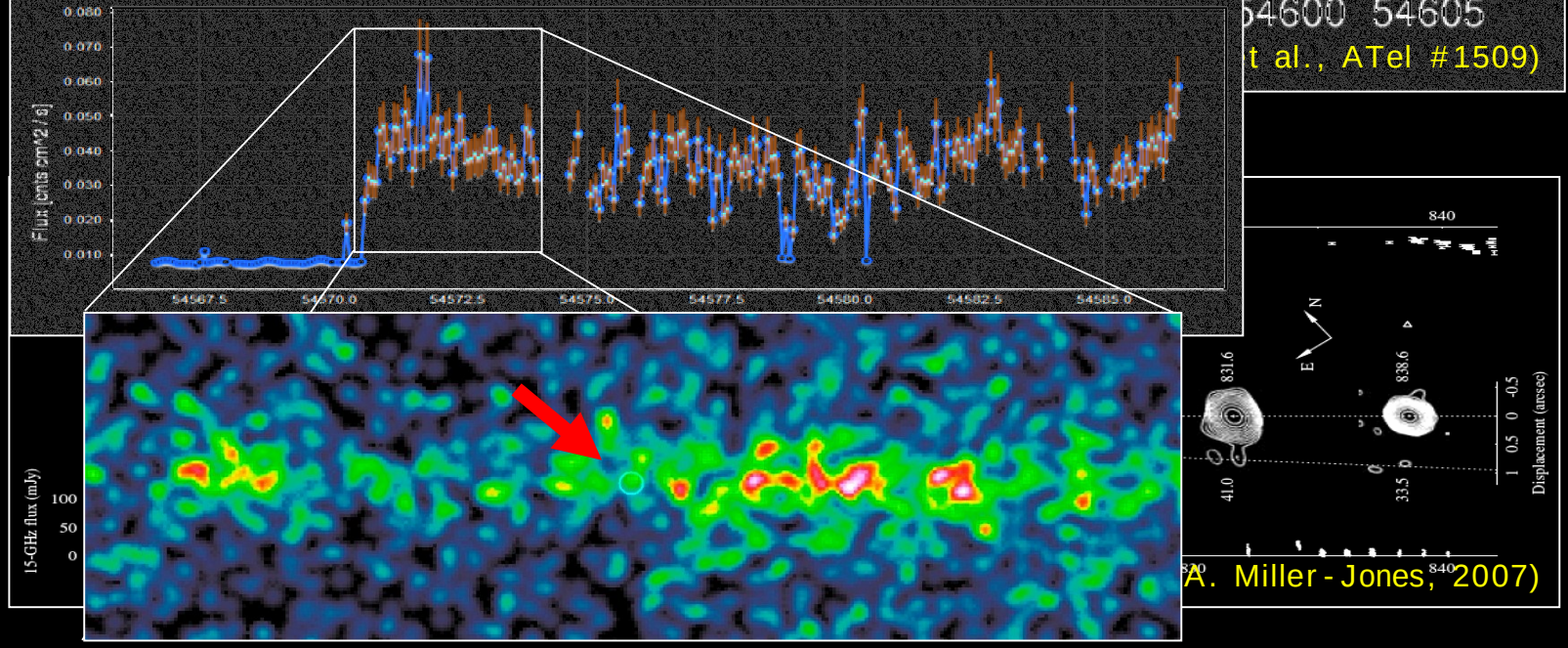
GRS 1915+105 during a radio flare

Radio monitoring



t al., ATel #1509)

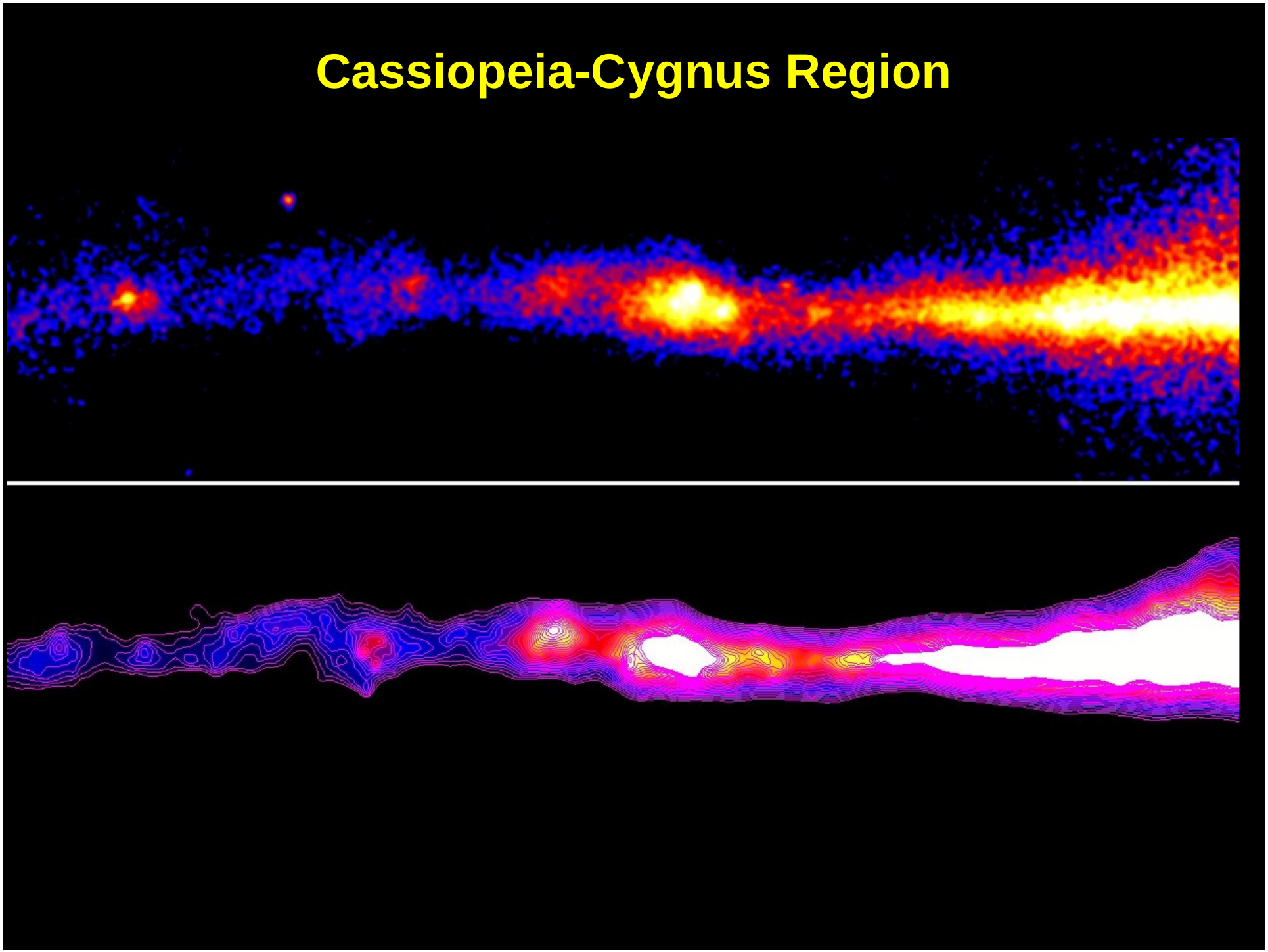
Historical radio mapping



A. Miller-Jones, 2007)

Cygnus region

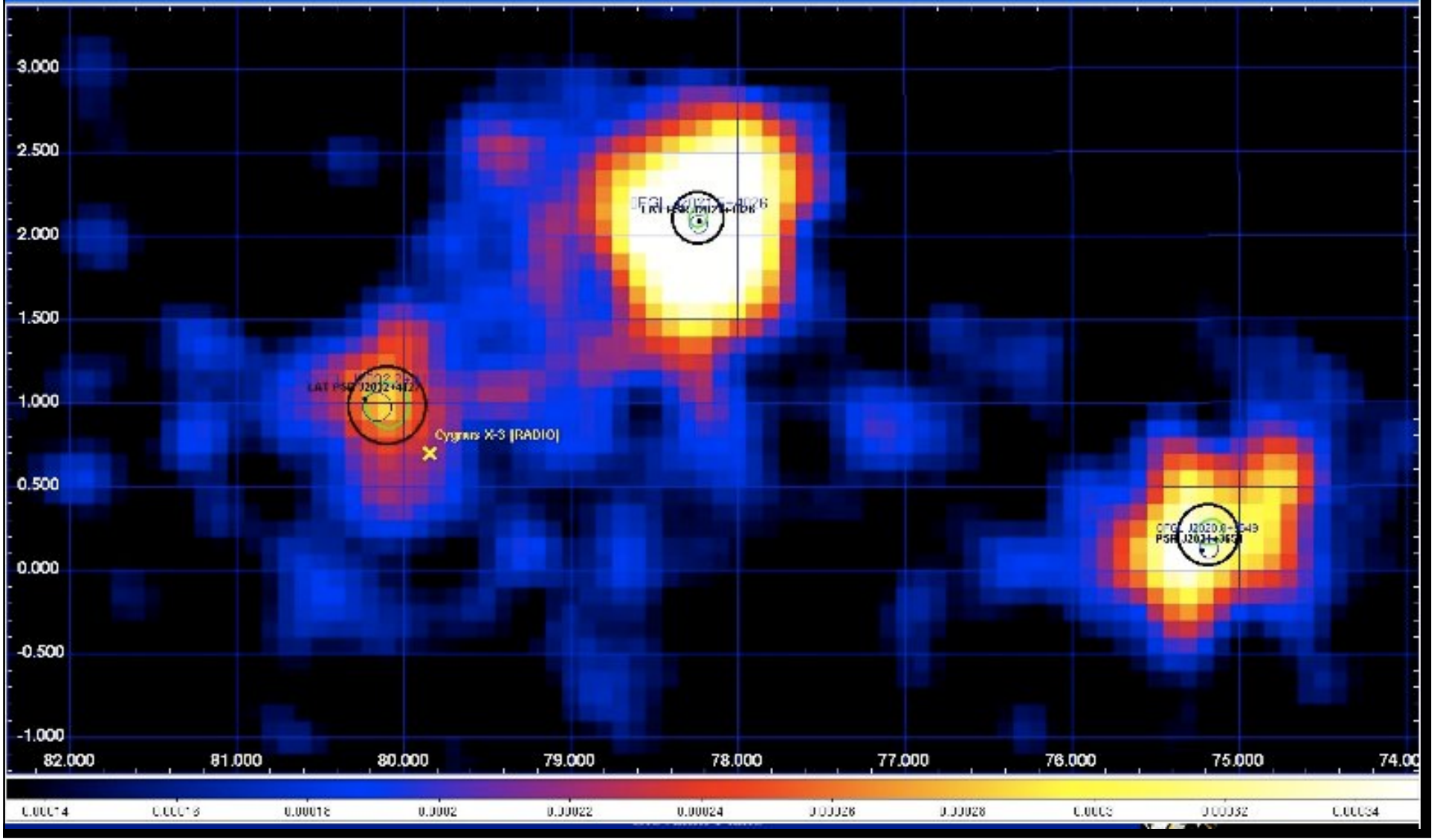
Cassiopeia-Cygnus Region

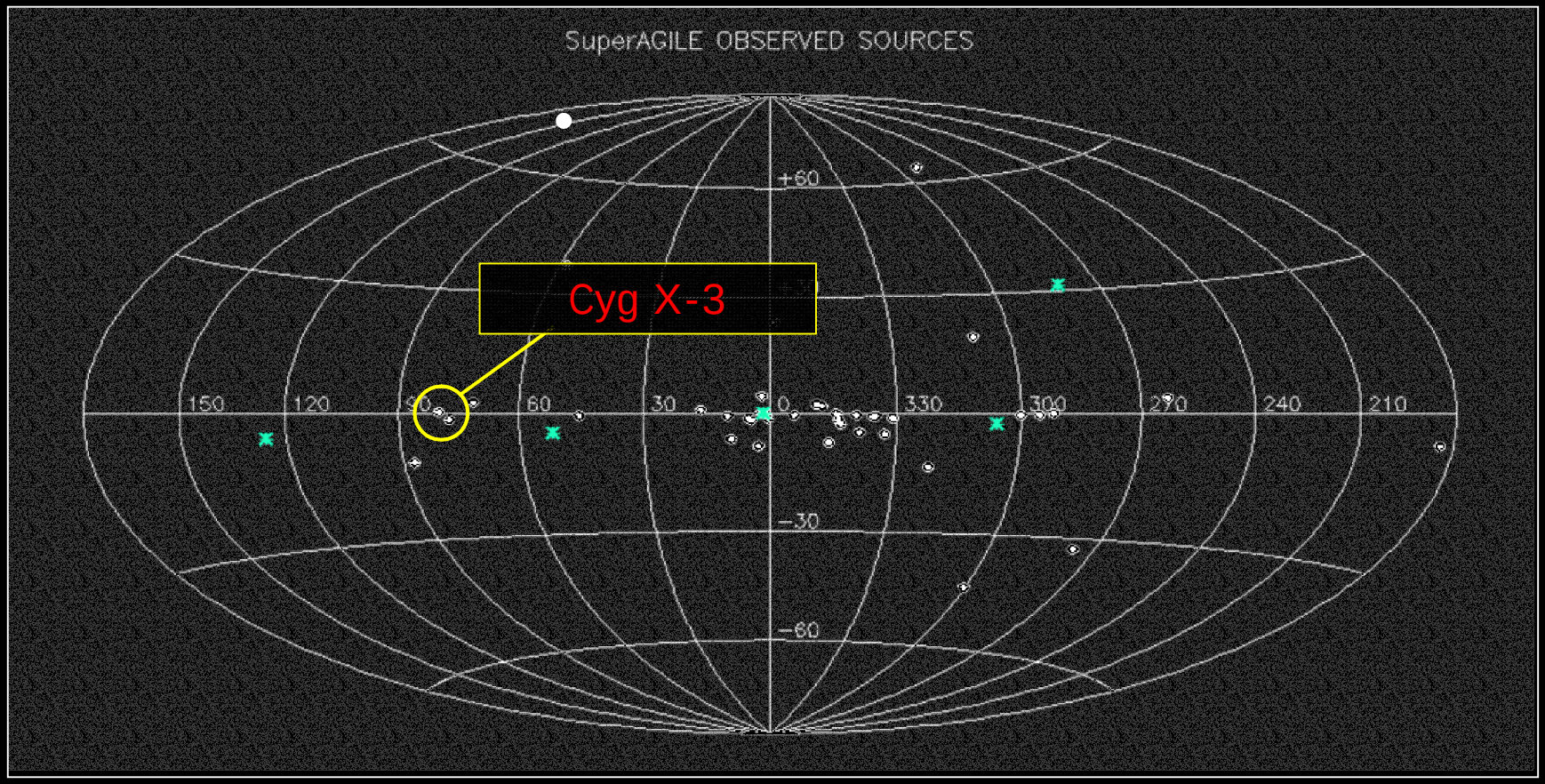


Cygnus Region

2007 – November → 2009 - August

above 400 MeV

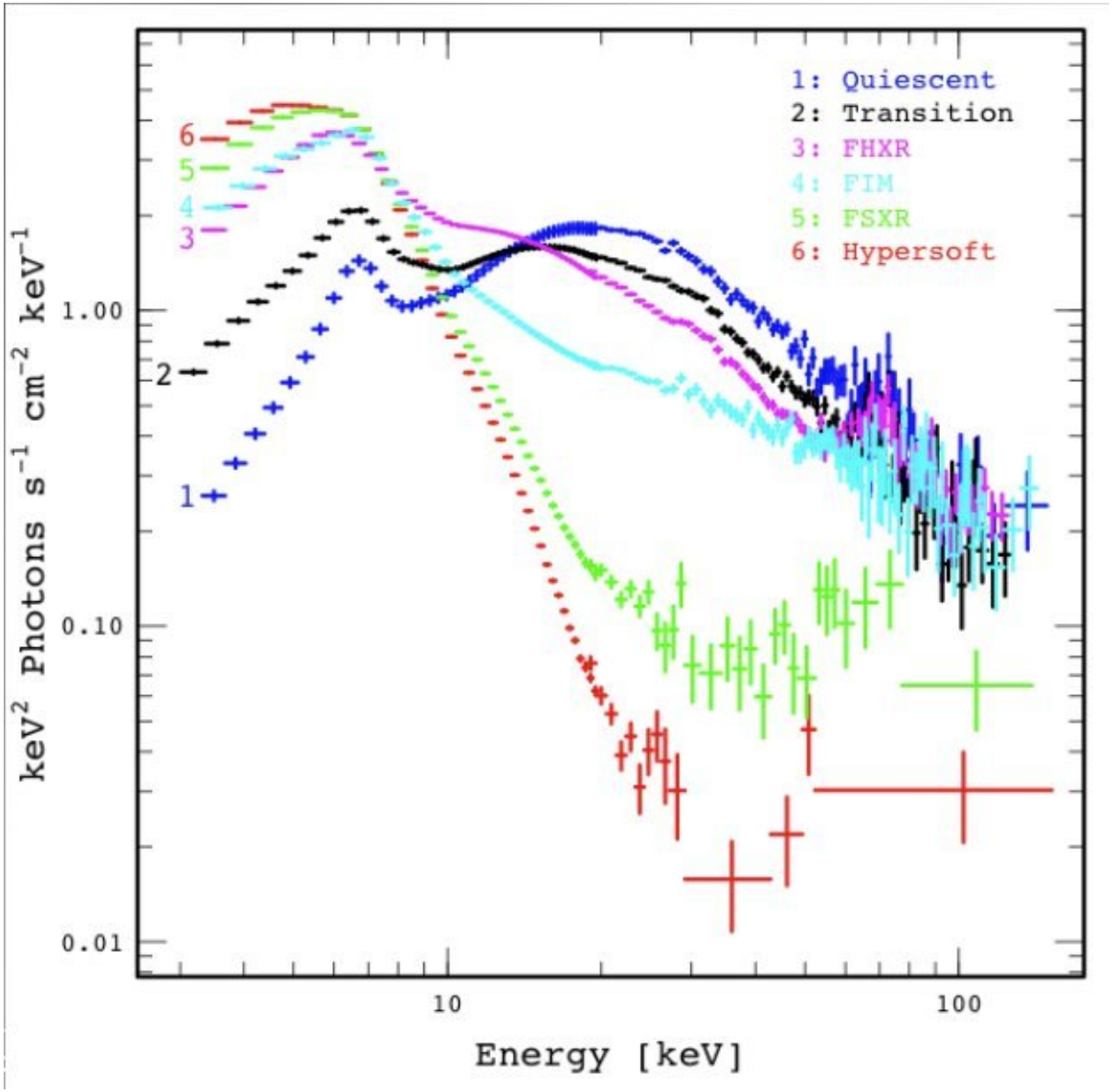



SuperAGILE OBSERVED SOURCES
Cyg X-3
+60
-30
-60
150
120
90
60
30
0
330
300
270
240
210

Cygnus X-3

- erratic and powerful microquasar (not clear yet whether BH or unusual NS)
- radio and X-ray spectral state studies (G.Pooley, R.Hjellming's group, S. Trushkin, M. McCollough, D. Hannikainen et al.)
- difficult to find a pattern, soft and hard X-ray emission is anticorrelated

Koljonen et al., in prep. (see also Szostek, Zdziarski, Mc Collough et al., 2008)



AGILE and Cygnus X-3

(recent paper accepted by *Nature*)

- **AGILE detects several gamma-ray flares from Cygnus X-3, and also weak persistent emission above 100 MeV**
- **very interesting correlations with radio and X-ray spectral state changes**
- **gamma-ray flares usually *before* radio flares**

- **a pattern emerges !**

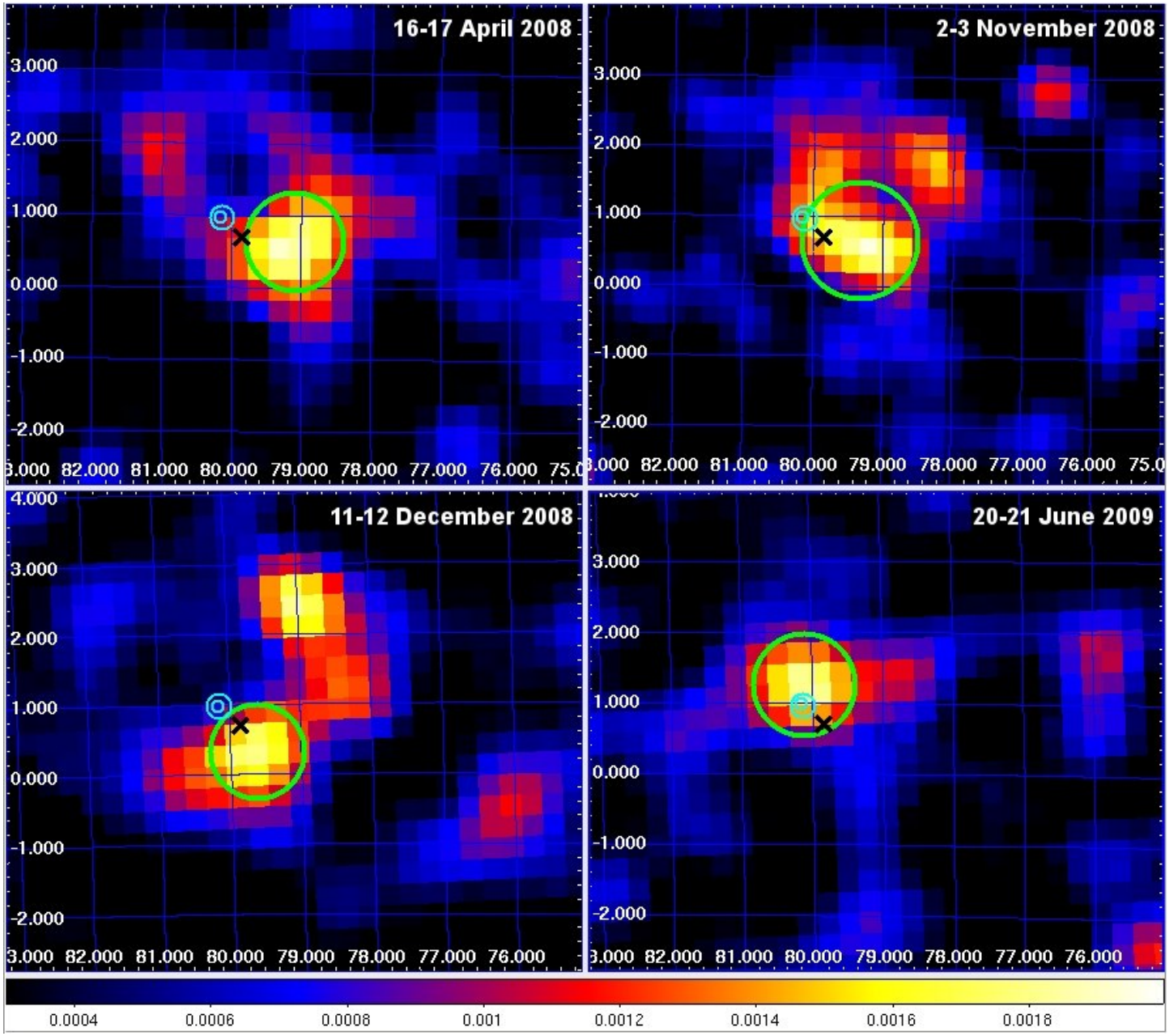
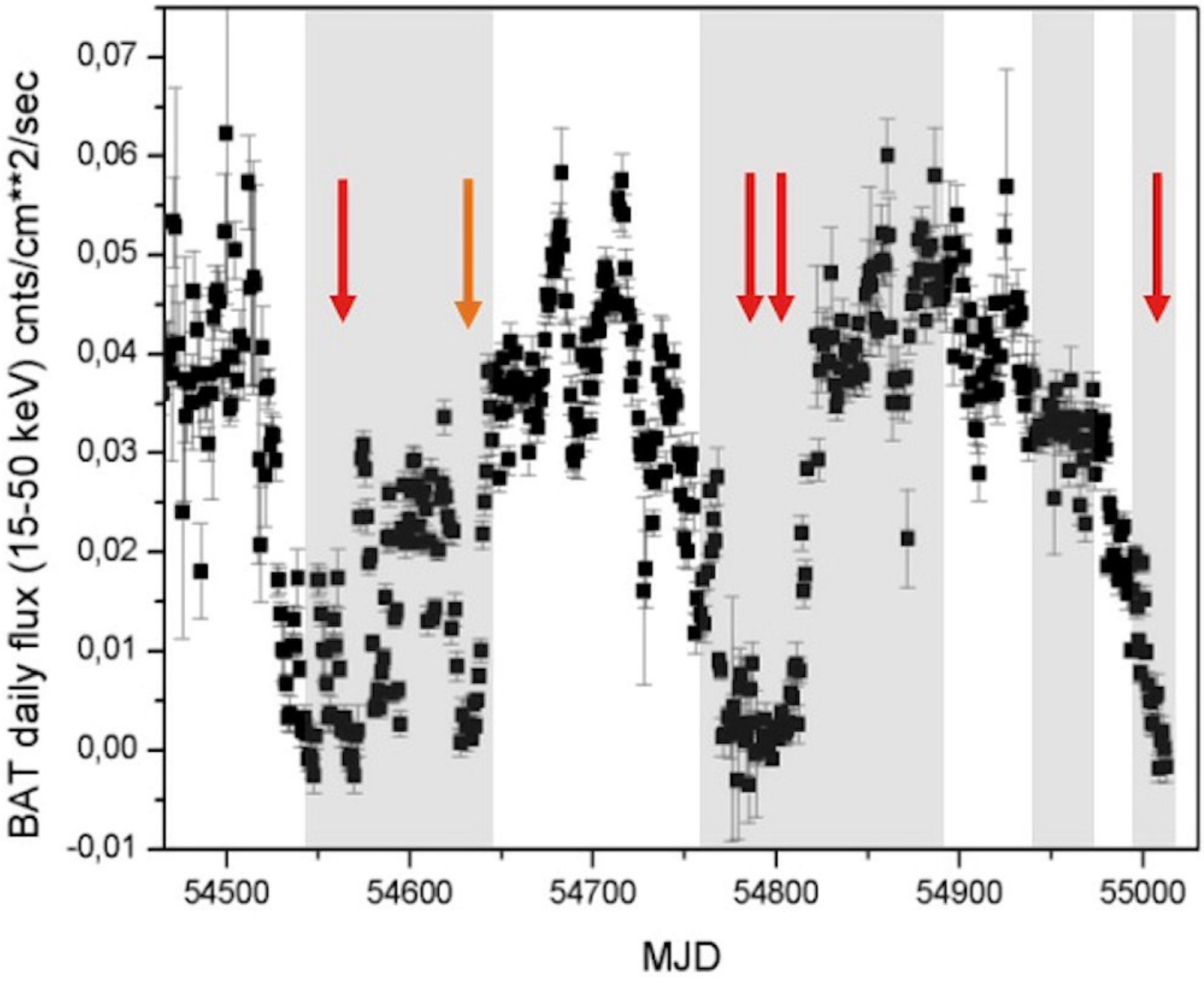

16-17 April 2008
2-3 November 2008
11-12 December 2008
20-21 June 2009
3.000
2.000
1.000
0.000
-1.000
-2.000
82.000 81.000 80.000 79.000 78.000 77.000 76.000
0.0004 0.0006 0.0008 0.001 0.0012 0.0014 0.0016 0.0018

Table 1 – Major gamma-ray flares of Cygnus X-3

Gamma-ray flaring date	X-ray state	radio state	δT_1 (days)	following radio flare	δT_2 (days) γ-ray/radio	γ-ray flux 10^{-8} ph. cm^{-2} s^{-1} (E > 100 MeV)
(1)	(2)	(3)	(4)	(5)	(6)	(7)
16-17 Apr. 2008 (MJD = 54572-54573)	soft	pre-flare		~ 16 Jy (11 GHz)	~ 0-1	260 +/- 80
2-3 Nov. 2008 (MJD = 54772-54773)	soft	pre-quenched	3-4	~ 1 Jy (15 GHz)	~ 8-9	258 +/- 83
11-12 Dec. 2008 (MJD = 54811-54812)	soft	opt. thick-thin change		~ 3 Jy (11 GHz)	~ 9-10	210 +/- 73
20-21 Jun. 2009 (MJD = 55002-55003)	soft	pre-quenched	~4-5			212 +/- 75

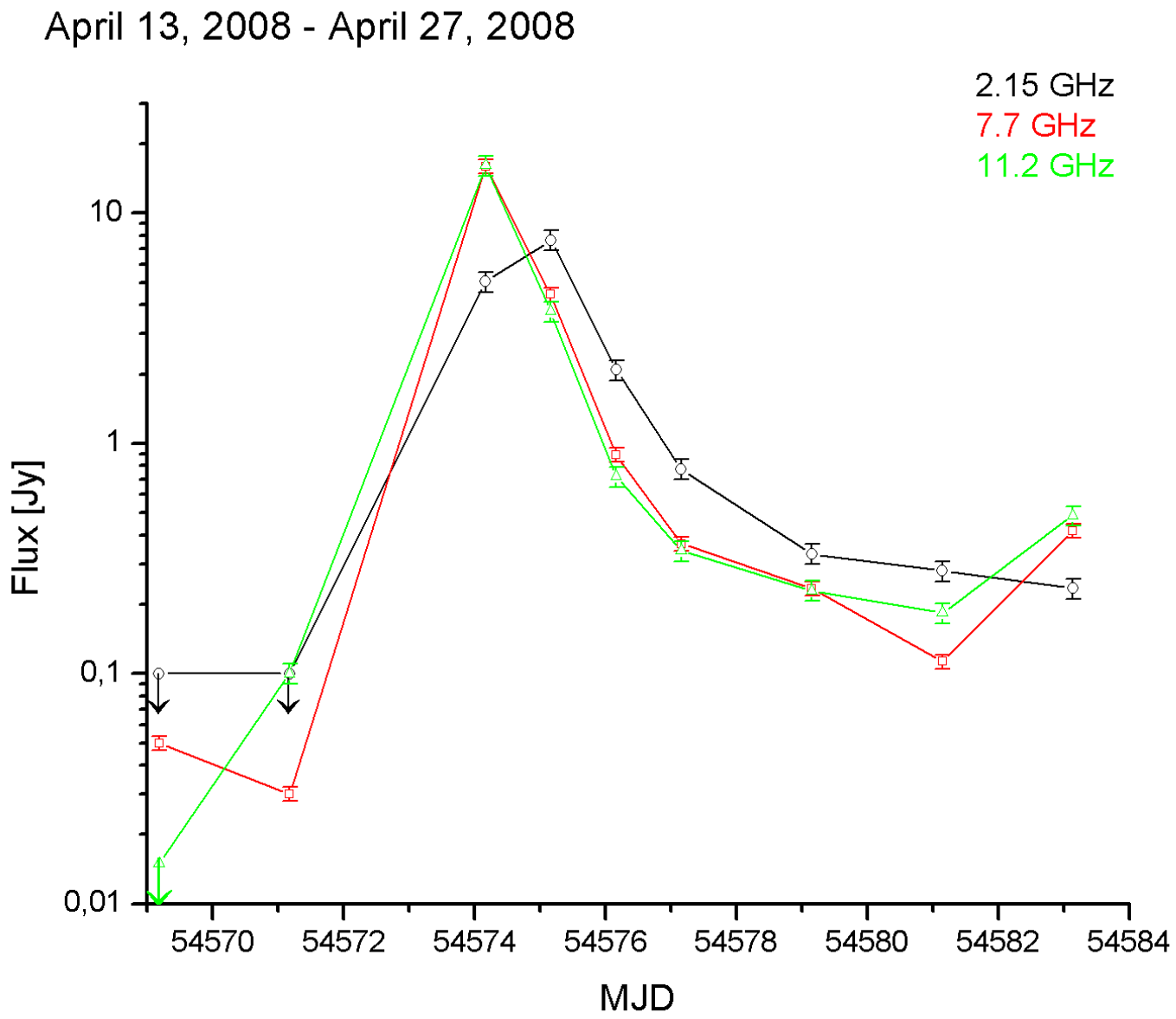
Cyg X-3 long timescale monitoring (Swift-BAT)



example: very strong radio flare of Cygnus X-3 in April 2008

- Strong radio-flare reaching ~20 Jy on Apr. 18, 2008 (RATAN)
- good exposure by AGILE before, during and after the radio flare, both in hard X-rays and gamma-rays
- gamma-ray flare detected at the onset of the radio flare

RATAN Obs. (S. Truskhin et al.) Apr. 13 – Apr. 27, 2008

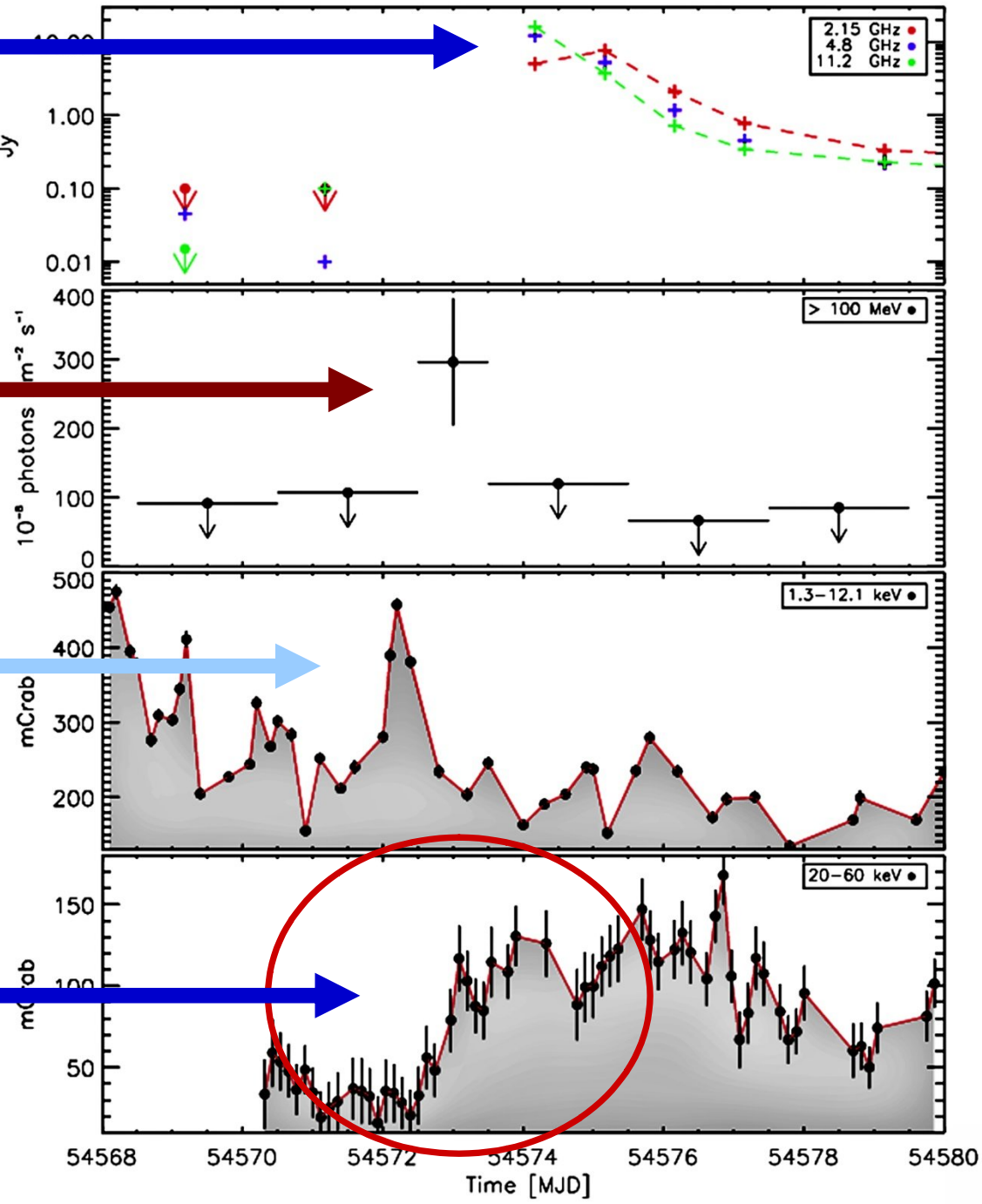


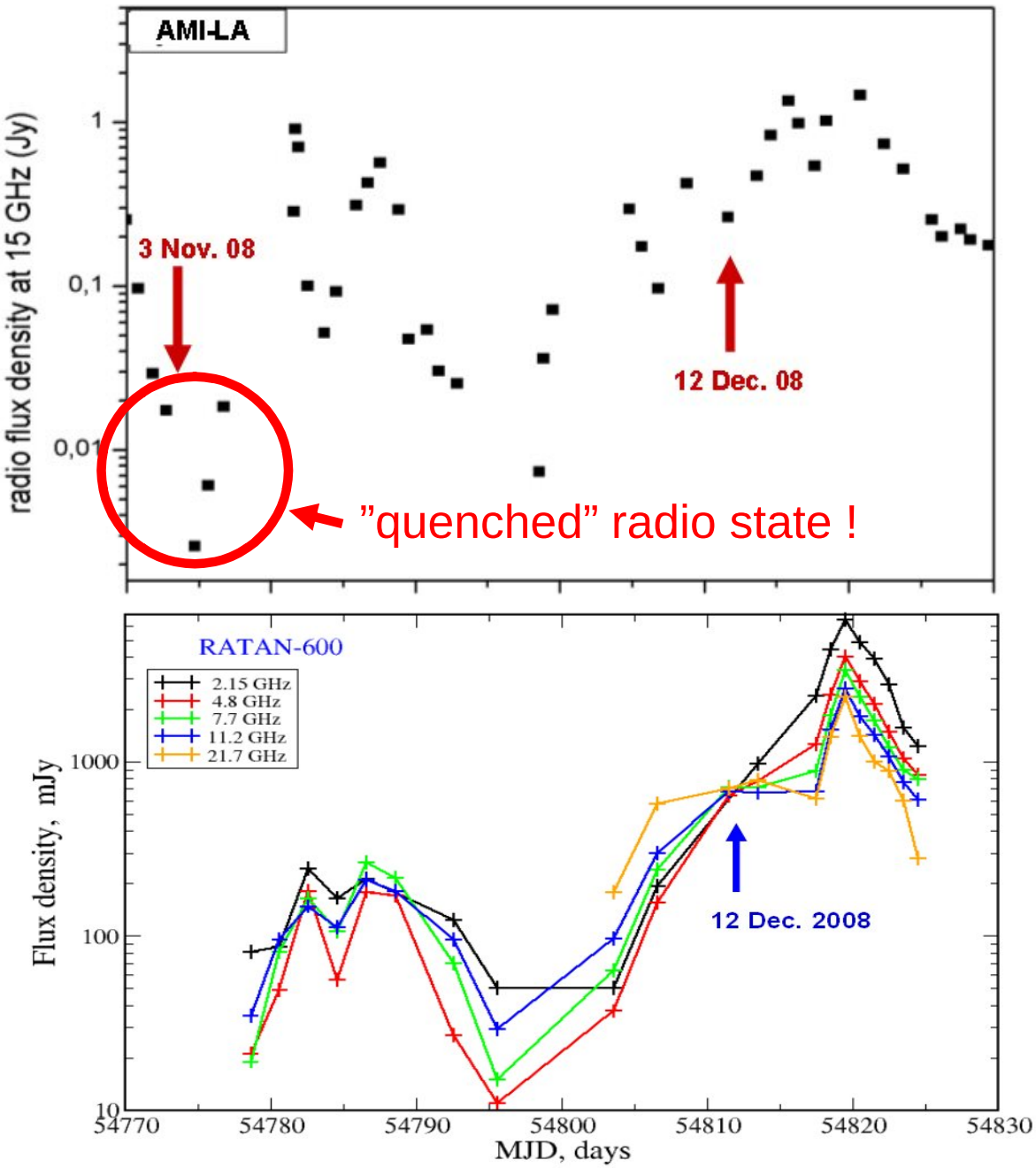
very strong radio flare, presumably with jet ejection

strong gamma-ray flare

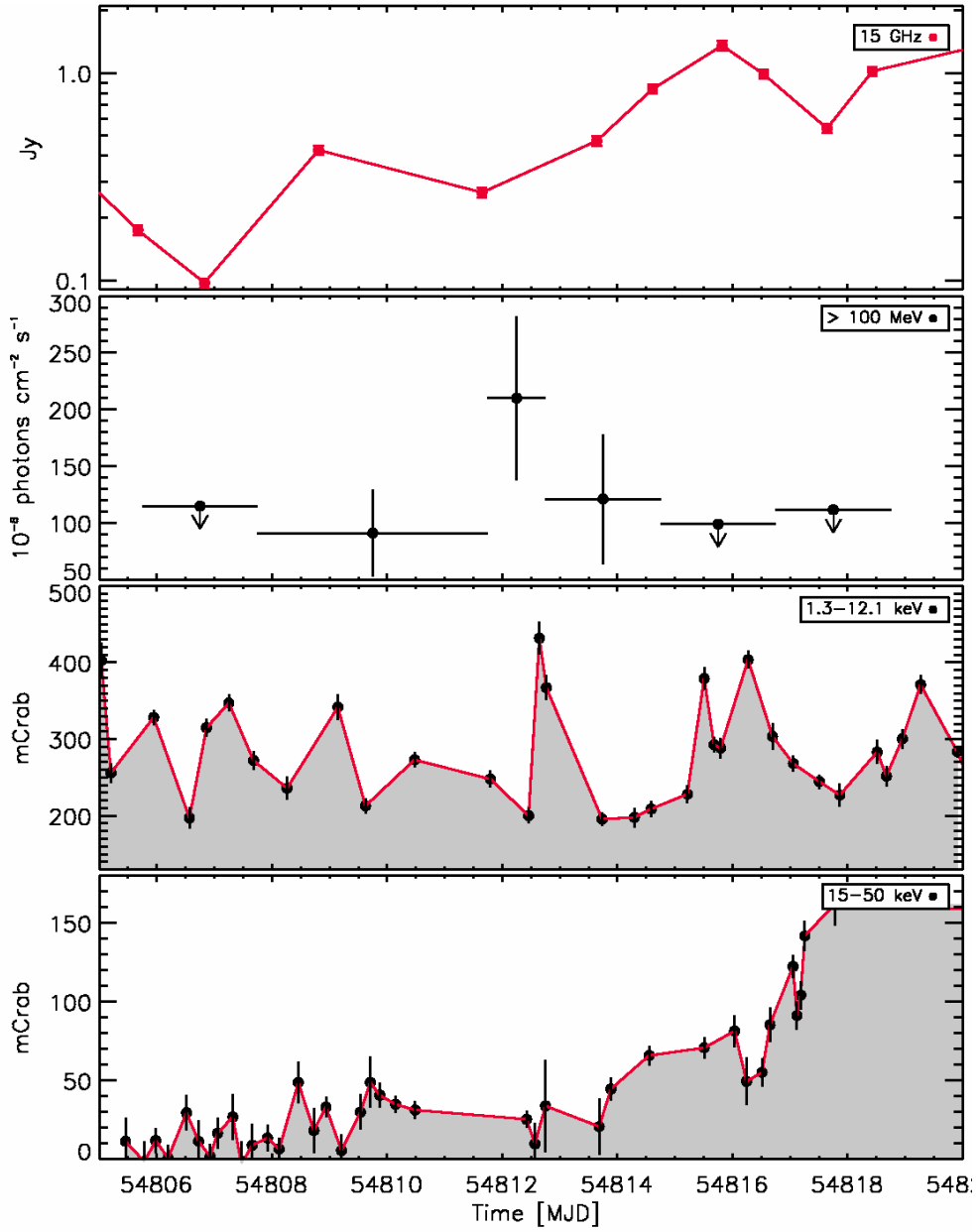
X-ray (1-10 keV) flare

Hard X-ray flux state change (Super-A




AMI-LA
radio flux density at 15 GHz (Jy)
1
0,1
0,01
3 Nov. 08
12 Dec. 08
"quenched" radio state !
RATAN-600
2.15 GHz
4.8 GHz
7.7 GHz
11.2 GHz
21.7 GHz
Flux density, mJy
1000
100
10
12 Dec. 2008
54770
54780
54790
54800
54810
54820
54830
MJD, days

Dec. 2008 gamma-ray flare



Major gamma-ray flares in special transitional states in preparation of radio flares !

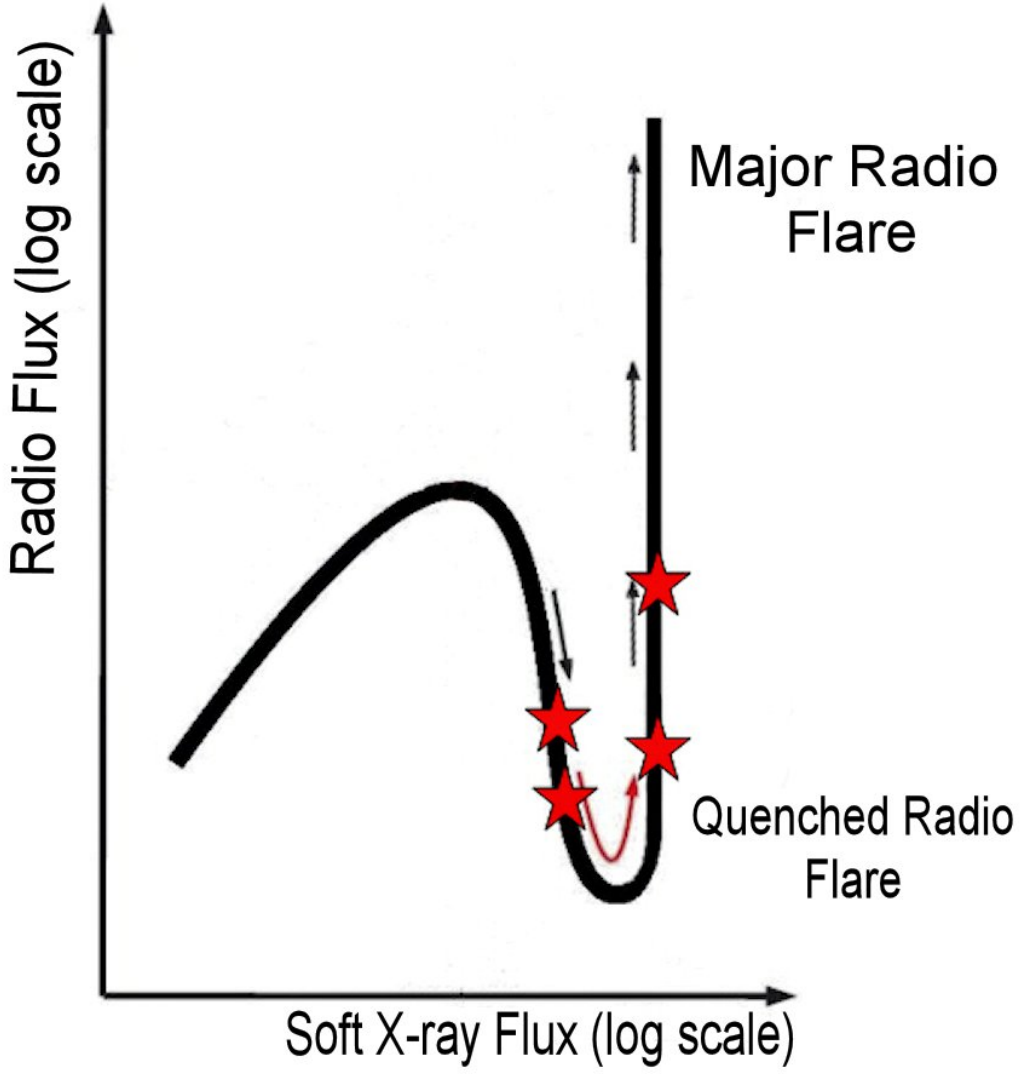
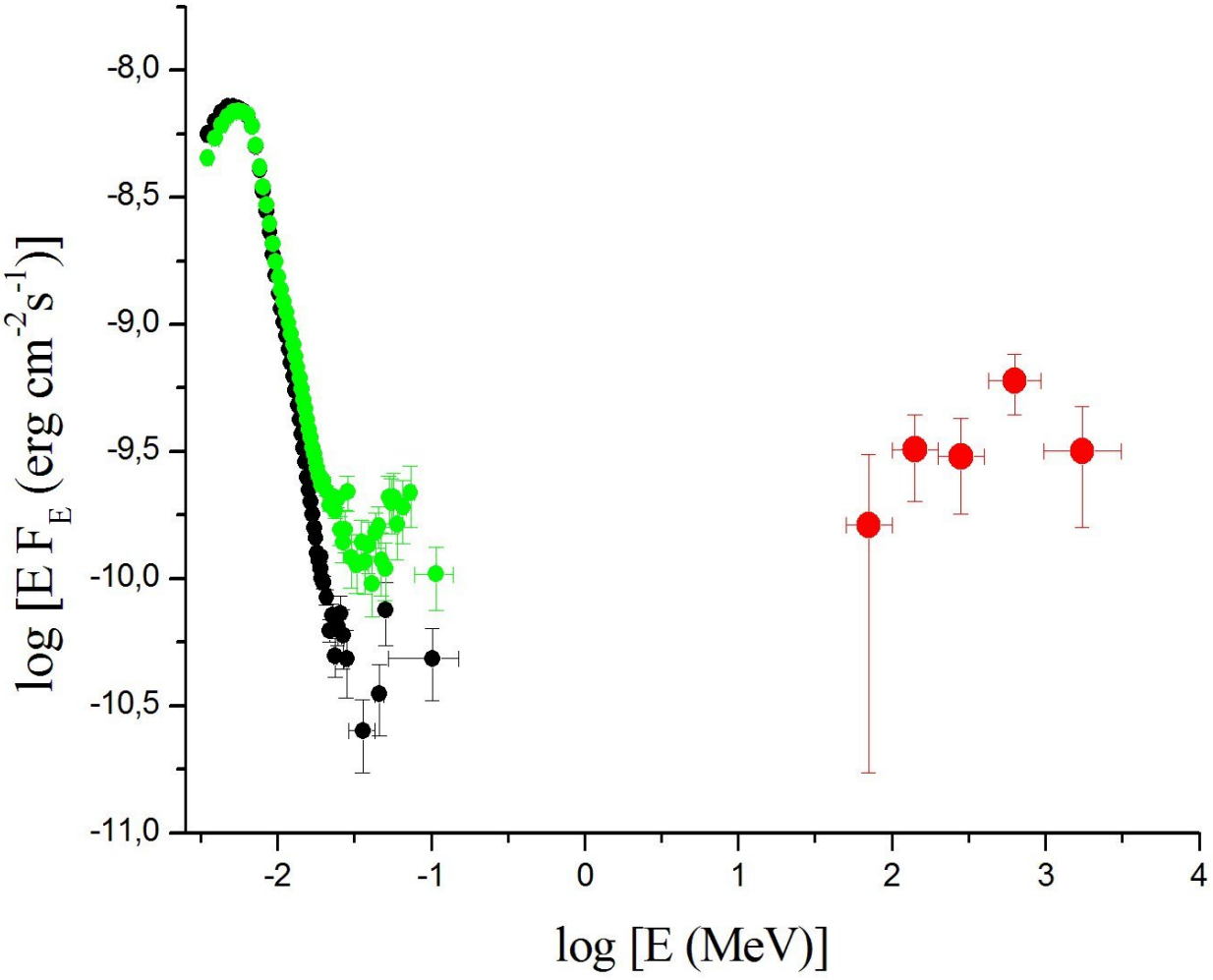


figure adapted from Szostek Zdziarski & McCollough (2008)

Gamma-ray flaring of Cyg X-3: average AGILE spectrum (preliminary)



Cygnus X-3 and other micro-qso's

- **deep theoretical implications: optically thick Comptonized models inadequate (hybrid models: quasi-thermal + PL)**

- **microquasar jet formation (and preparation) associated with extreme high-energy particle acceleration above GeV energies**

- **correlation with hard X-ray/soft X-ray/radio states,**
  - **in the inner accretion disk region**
  - **in outwardly propagating shocks**

Implications…

- **Cygnus X-3 can teach about BH systems and possibly also about blazars**
- **Its jet is pointing at us, it is a "micro-blazar"**
- **"preparation" for a major jet ejection and non-thermal extreme particle acceleration with GeV emission before plasmoid production is suggested also in some blazars**
- **Bright future for understanding BHs**

Galactic "Micro-QSOs" (radio "jet" sources)

	Θ (degrees)	β	Γ	L_X/L_E	γ/TeV
Cyg X-1	?	?	?	0.1-1	~5 MeV yes
Cyg X-3	< 14	> 0.8	> 1.6	0.1-1	?
SS 433	< 70	0.26	1.03	0.01	no
GRS 1915+104	70	0.92	2.5	0.1-1	no
GRO J1655-40	> 70	0.9	2.5	1	no
GRS 1758-258	?			0.1-1	no
XTE J1550-564	60-70	> 0.8	1.5	0.1-1	no
Sco X-1	> 70	> 0.8	> 1.6	0.1-1	no
LS I 61 303	?	?	?	10^{-4}	yes
LS 5039	< 80	> 0.2	?	10^{-4}	yes

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Conclusions

- very exciting time for Galactic gamma-ray source studies, AGILE and FERMI
- detections by AGILE of Galactic transients
  - no hard X-ray outbursts
  - low flux X-ray sources
- the Cyg X-3 “clock”, a clear pattern of gamma-ray emission
- FAST alerts and follow-up multi-freq. observations !
- Archival long-baseline studies and cross-correlation