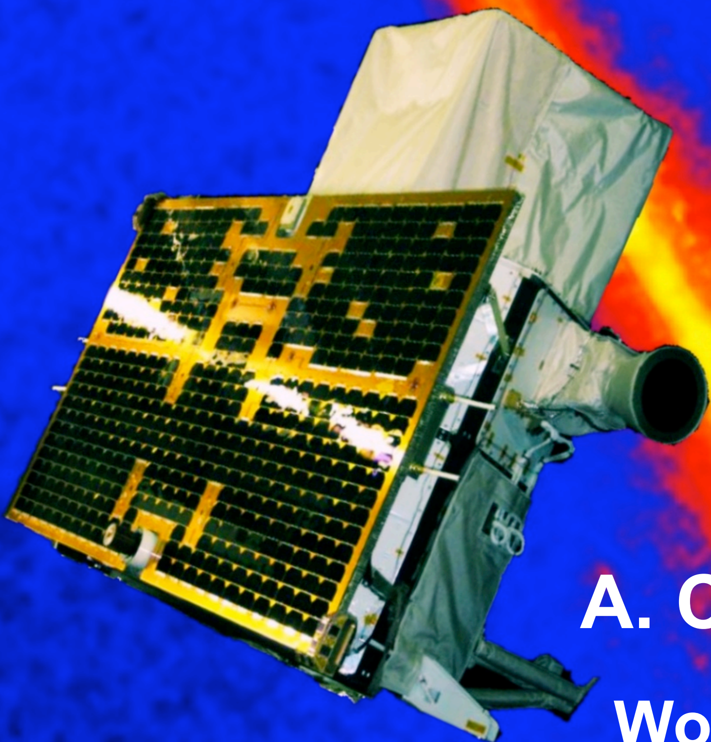
AGILE Observations of Variable and Transient Gamma-Ray Sources in the Galactic Plane



A. Chen (INAF – IASF Milano)

Workshop on "Variable Galactic Gamma-Ray Sources"

Heidelberg, 2 December, 2010

Variable Galactic Sources seen by AGILE

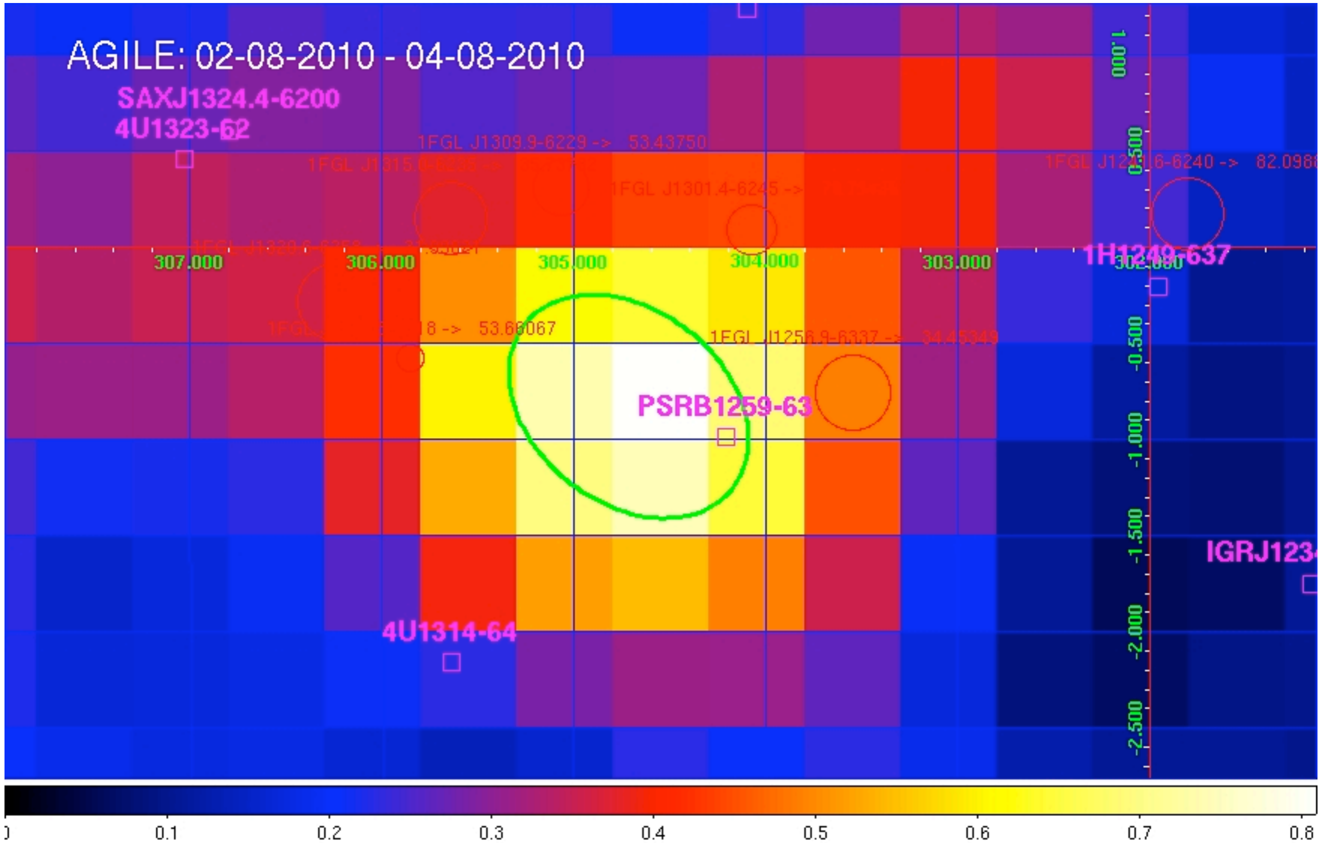
- Pulsars and PWNe – Crab, PSR B1259-63, γ-Cygni(?)
- X-ray binaries – Cyg X-3, Cyg X-1, LSI+61 303, IGR J17354-3255
- Colliding Wind Binaries – Eta Carinae
- "New" gamma-ray transient candidates

Pulsars and PWNe

Crab Flare – September 19-21, 2010

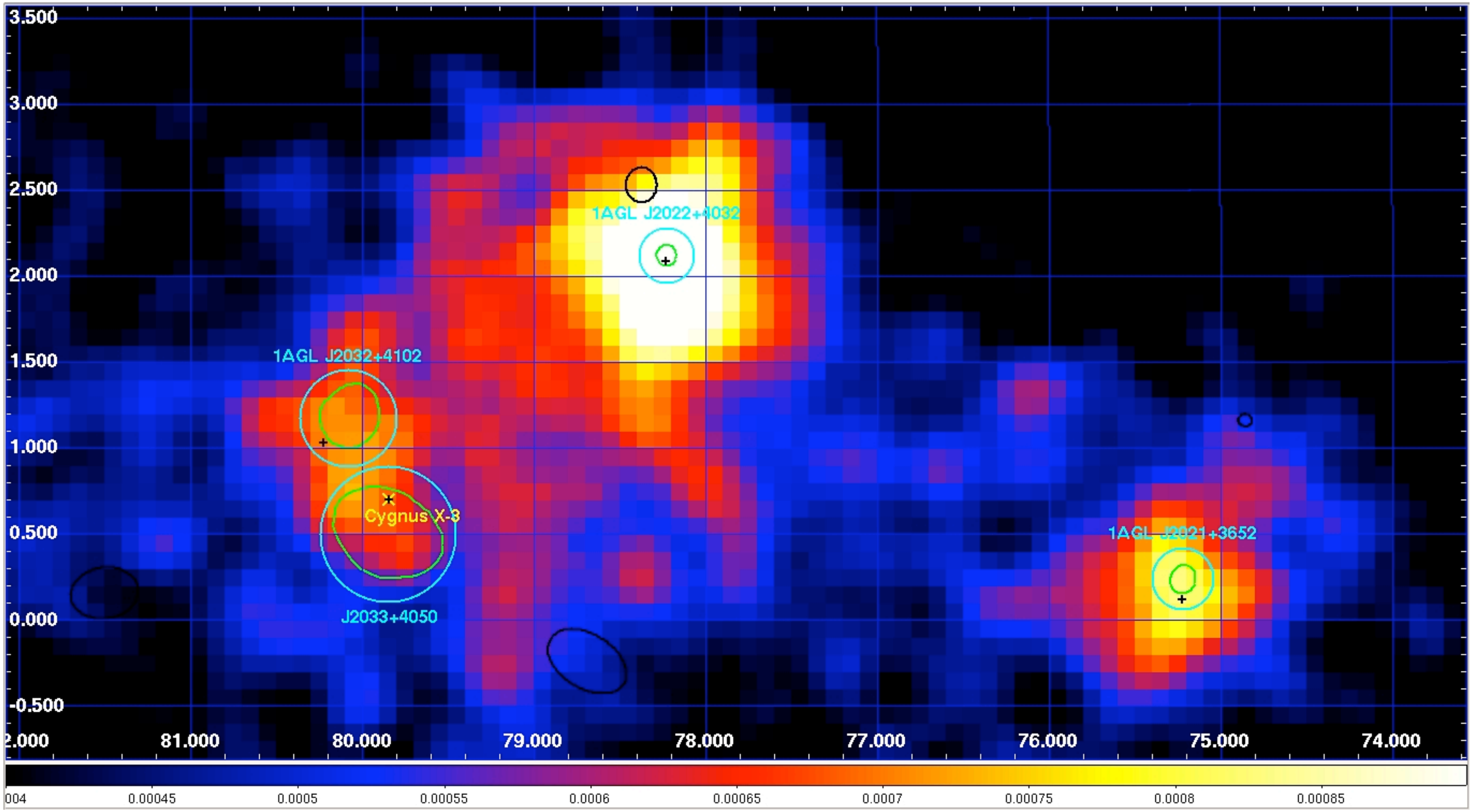
- **Tavani et al., ATel # 2855**
- AGILE is detecting an increased gamma-ray flux from a source positionally consistent with the Crab Nebula. Integrating during the period 2010-09-19 00:10 UT to 2010-09-21 00:10 UT the AGILE-GRID detected enhanced gamma-ray emission above 100 MeV from a source at Galactic coordinates (l,b) = (184.6, -6.0) +/- 0.4 (stat.) +/- 0.1 (syst.) deg, and flux F > 500 e-8 ph/cm2/sec above 100 MeV, corresponding to an excess with significance above 4.4 sigma with respect to the average flux from the Crab nebula (F = (220 +/- 15)e-8 ph/cm^2/sec, Pittori et al., 2009, A&A, 506, 1563).We strongly encourage multifrequency observations of the Crab Nebula region.

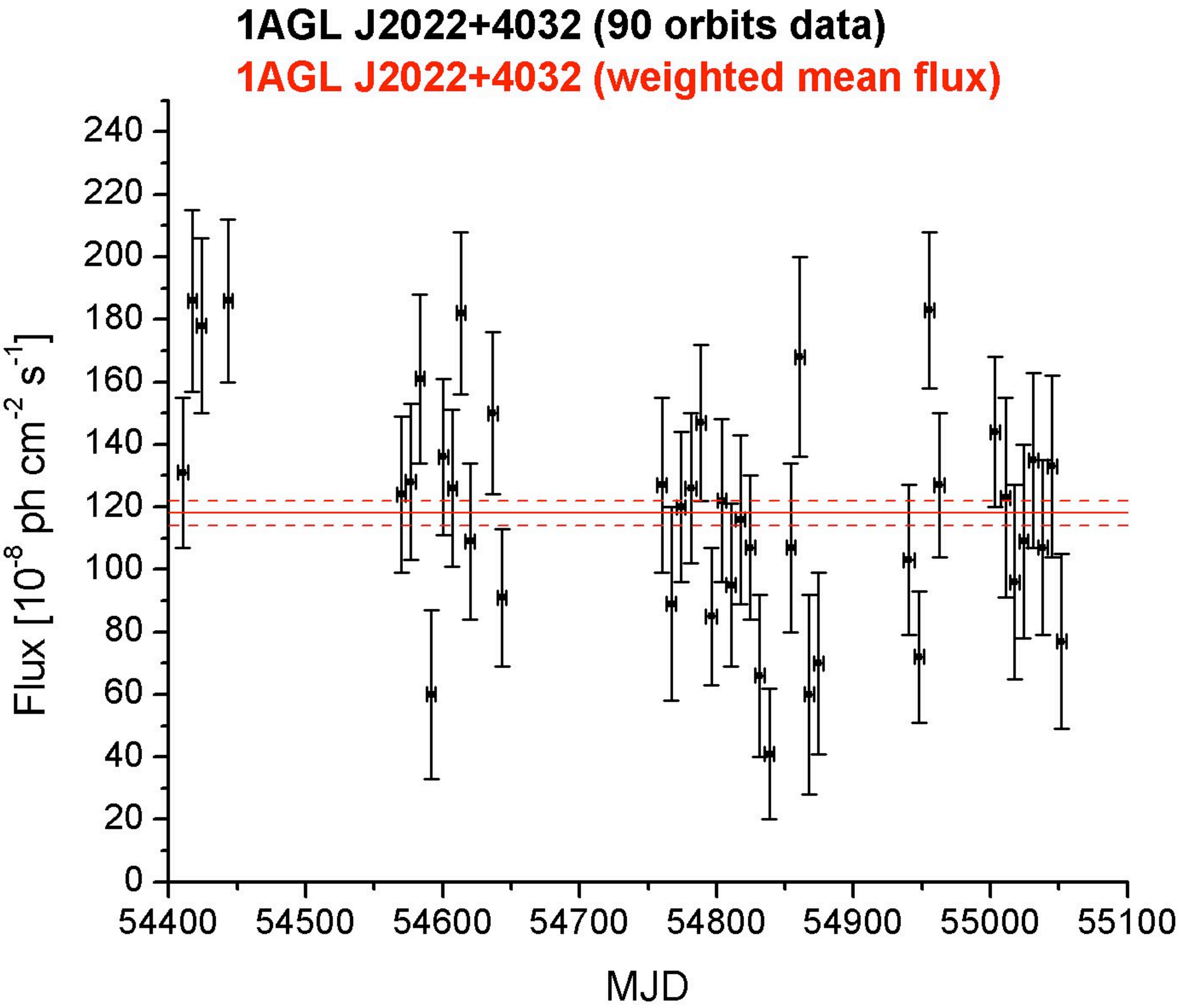
PSR B1259-63



- Tavani et al., Atel #2772
- 2-4 August 2010
- F ~ 4e-6 $cm^{-2}s^{-1}$ for E > 100 MeV
- Periastron in two weeks!

Could γ-Cygni be another variable PWN?




1AGL J2022+4032 (90 orbits data)
1AGL J2022+4032 (weighted mean flux)
Flux [10^{-8} ph cm^{-2} s^{-1}]
MJD
0
20
40
60
80
100
120
140
160
180
200
220
240
54400
54500
54600
54700
54800
54900
55000
55100

1AGL 2022+4032

- V = 2.18 (P = 0.0066)
- Could also be due to transient source superposition
  - Corresponding error circle has radius ~1°
  - Variable component of flux may be due to unidentified, steep spectrum source within 6 day error circle
  - – Nearby source 1FGL J2020.0+4049, associated with VER J2019+407
  - Variable X-ray source in FOV, from Chandra data
  - Chen et al. 2011 A&A, 525, A33

Micro-QSOs

AGILE and Cygnus X-3

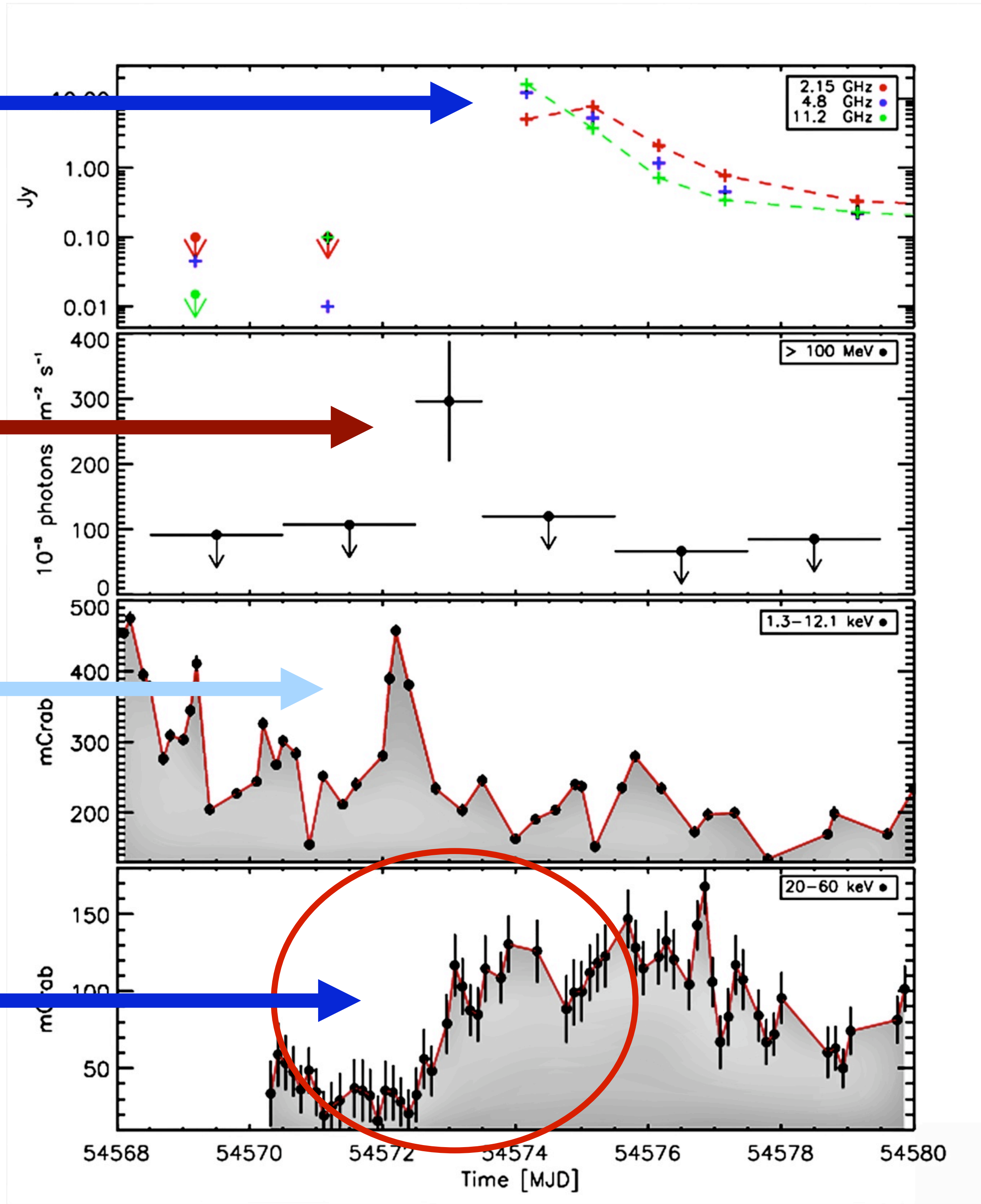
- *Nature*, Nov. 22, 2009
  - see also Fermi detection of Cyg X-3, Abdo et al. *Science* Nov. 26, 2009
  - Bulgarelli et al., submitted to A&A
- AGILE detects several gamma-ray flares from Cygnus X-3, and also weak persistent emission above 100 MeV
- very interesting correlations with radio and X-ray spectral state changes

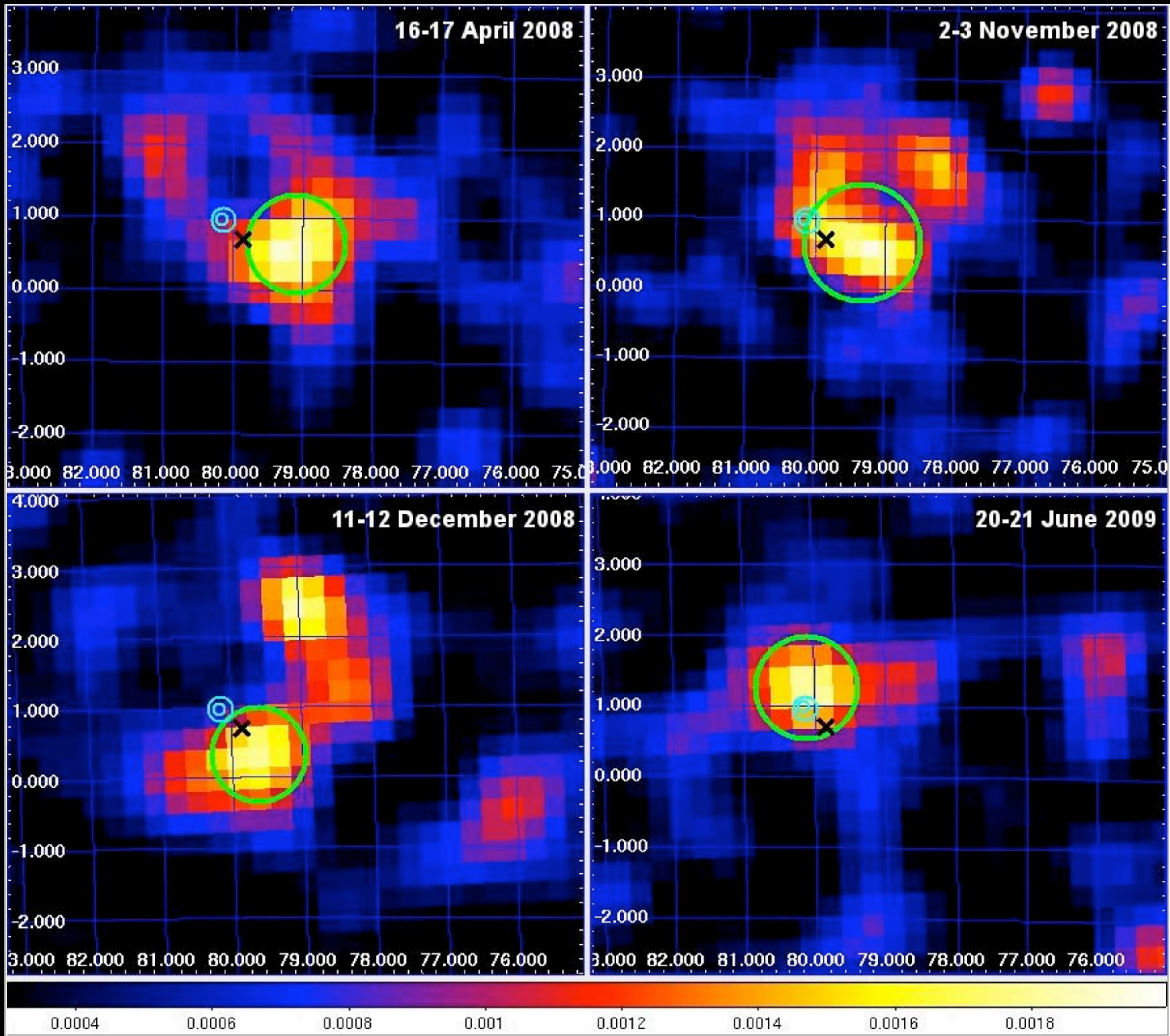
very strong radio flare, presumably with jet ejection

strong gamma-ray flare

X-ray (1-10 keV) flare

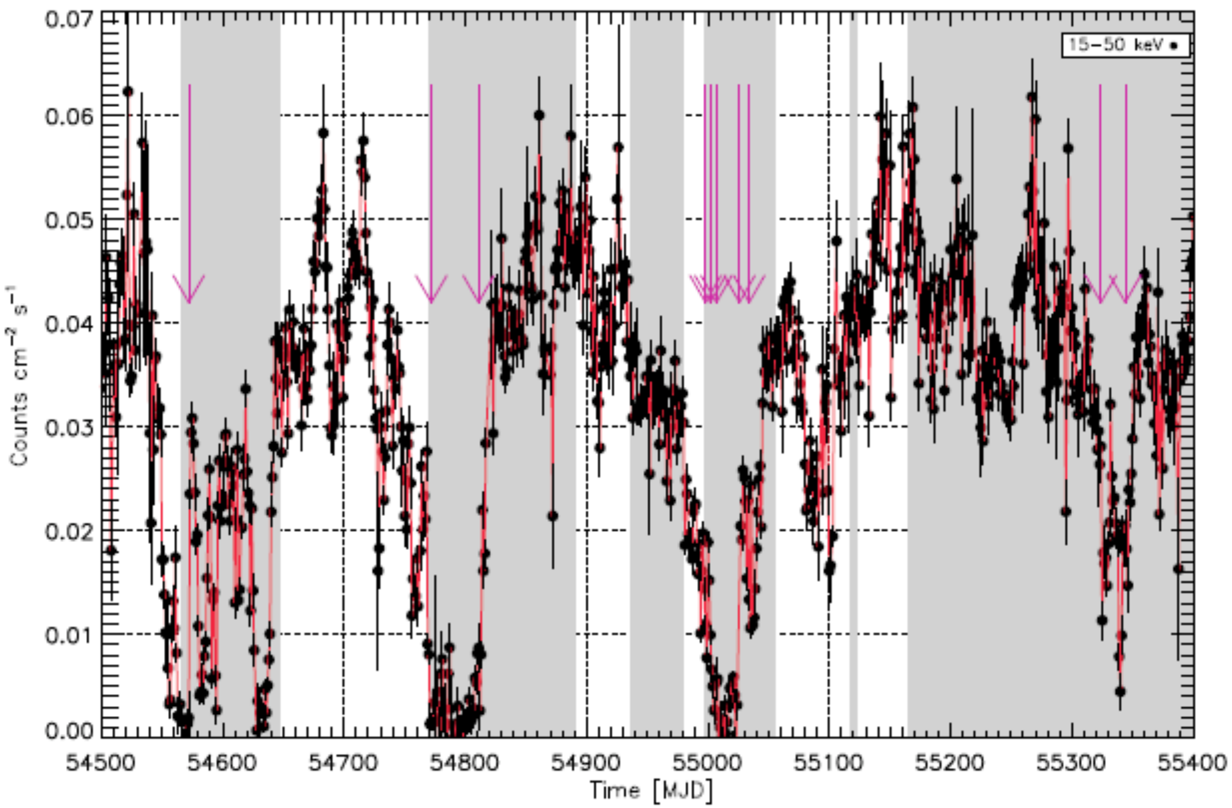
Hard X-ray flux state change (Super-A monitoring)





16-17 April 2008
2-3 November 2008
11-12 December 2008
20-21 June 2009
0.0004
0.0006
0.0008
0.001
0.0012
0.0014
0.0016
0.0018

AGILE/GRID and Swift/BAT data of Cygnus X-3
Jan 2008 - Jun 2010



Variety of distinct X-ray states

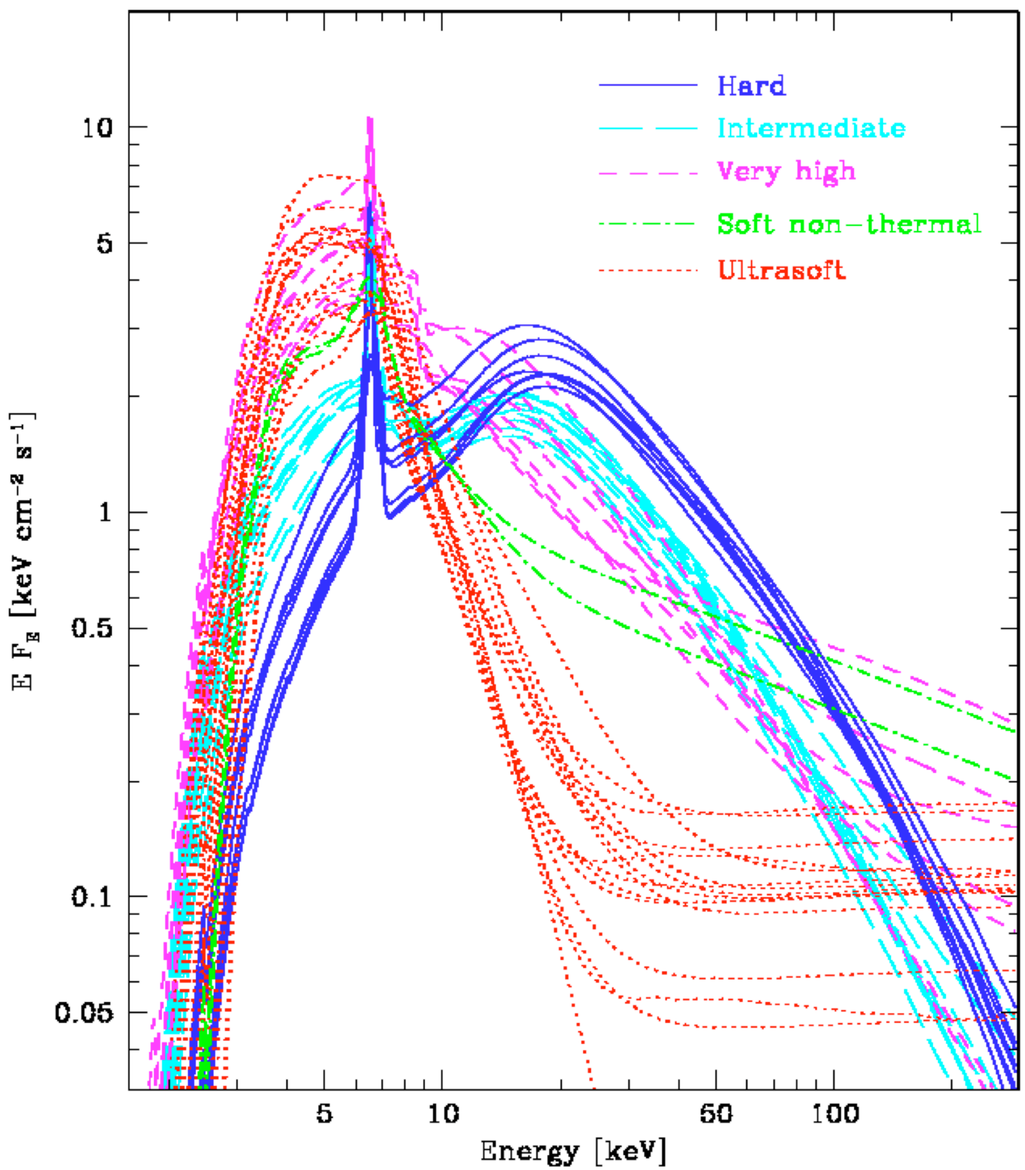


figure adapted from Hjalmarsdotter et al. (2008)

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

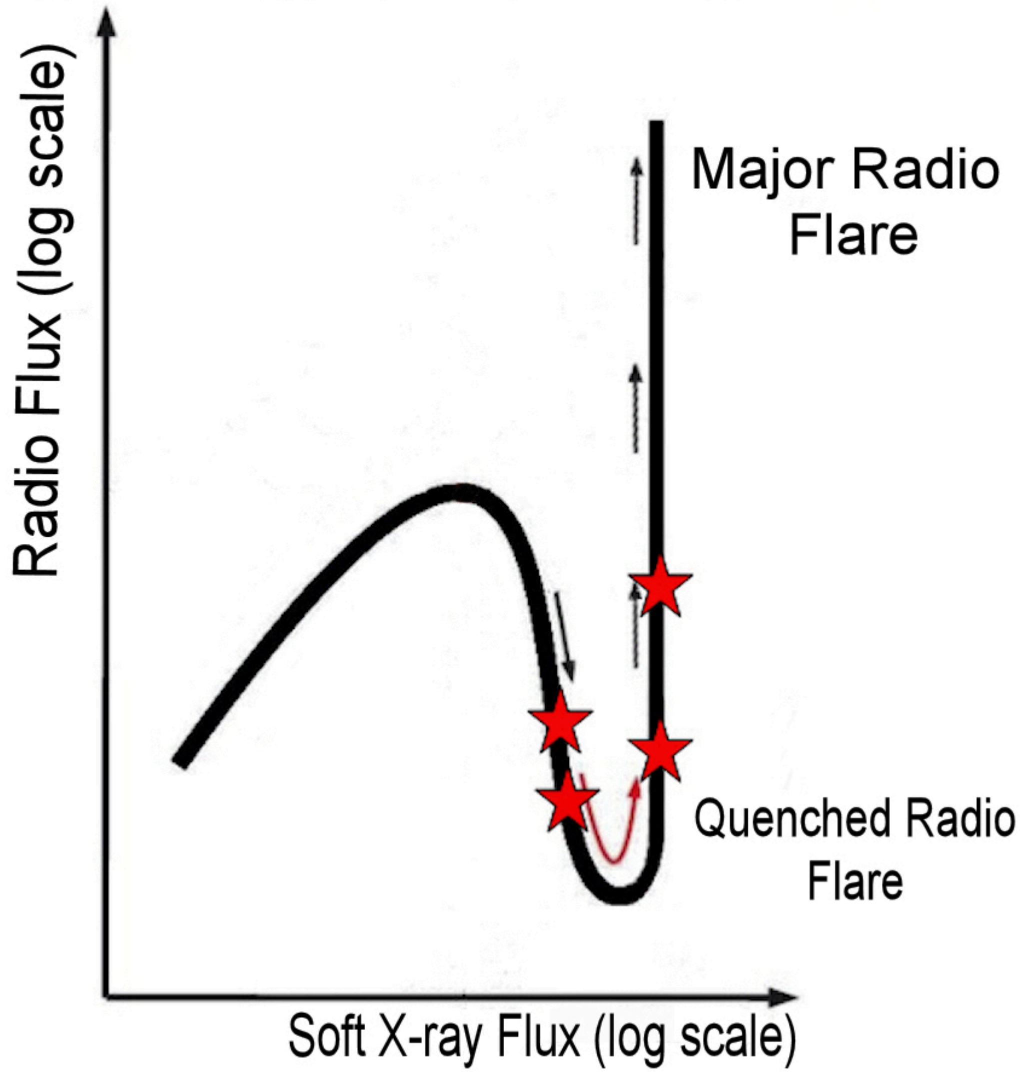
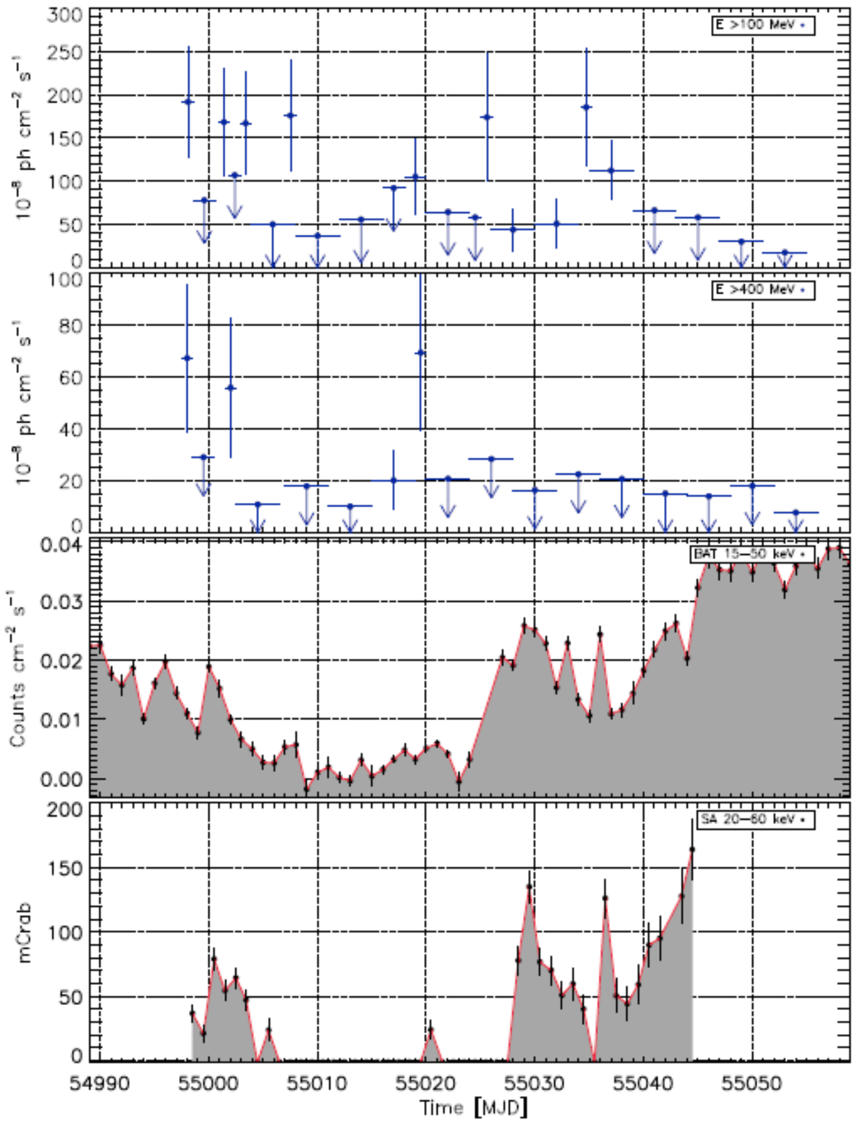
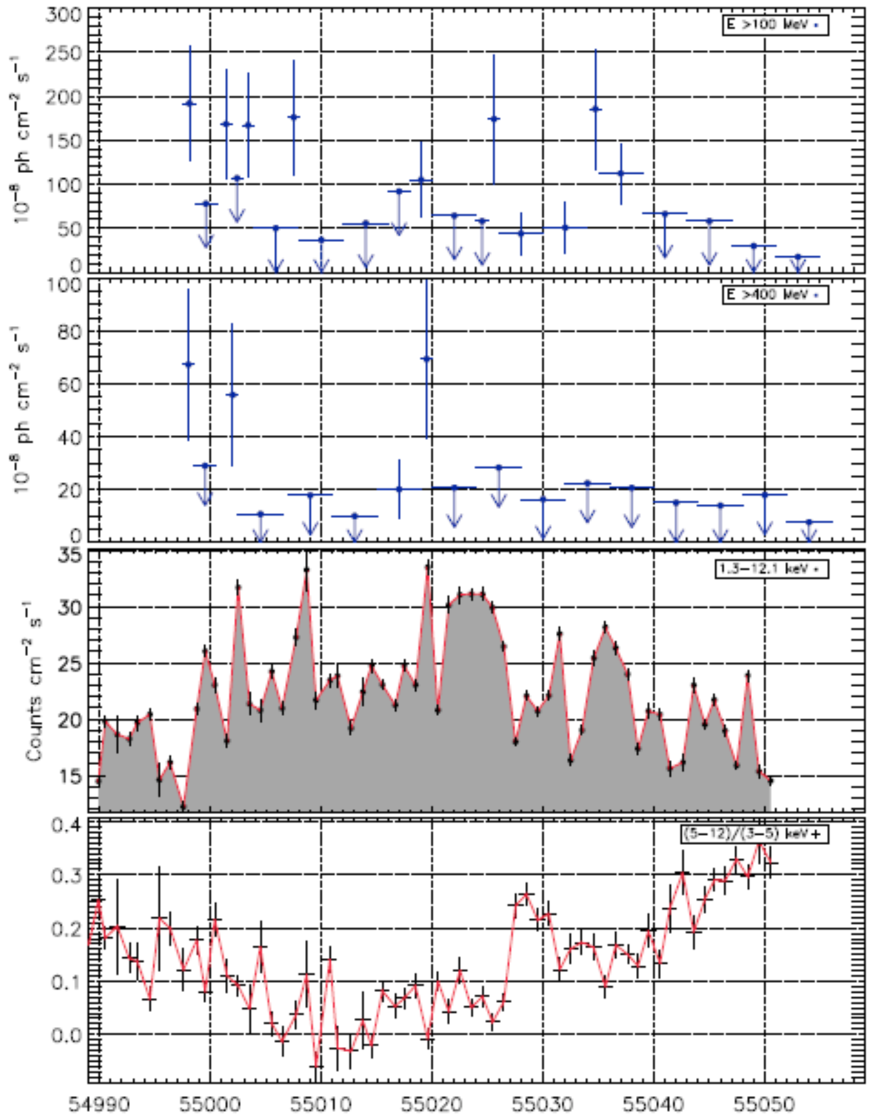


figure adapted from Szostek Zdziarski & McCollough (2008)

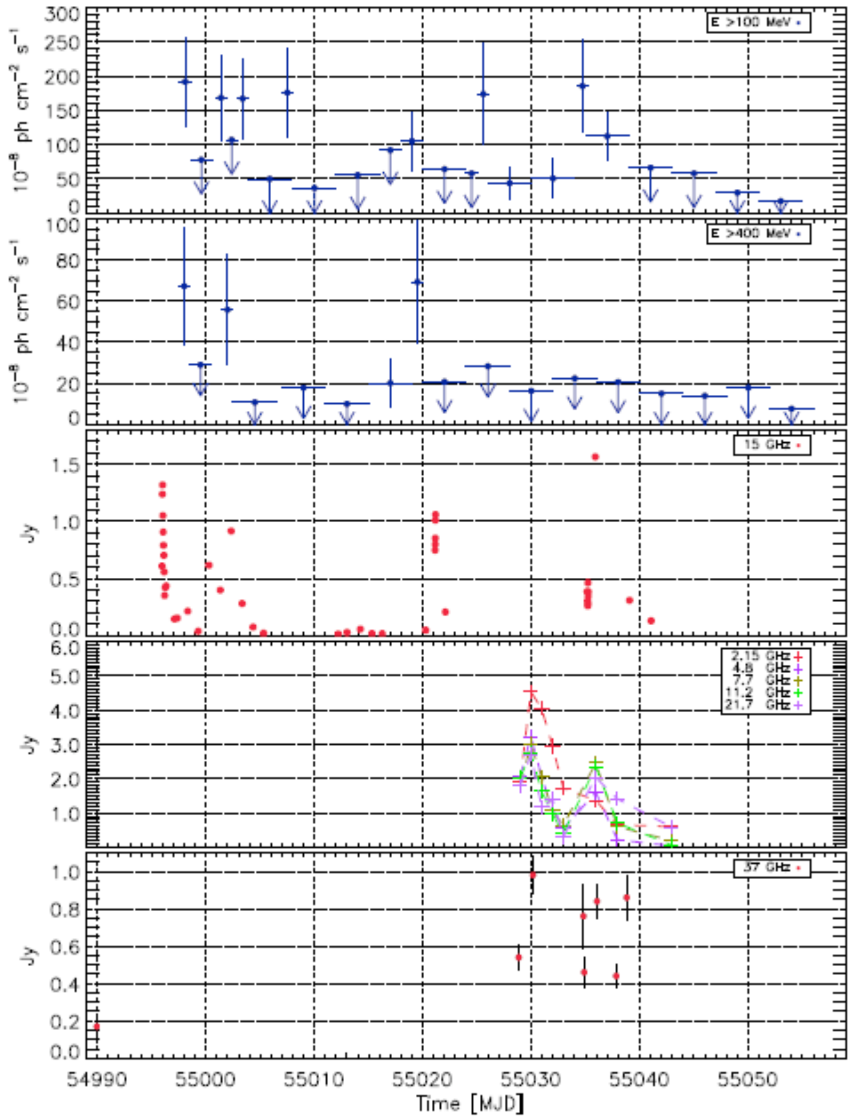
Multiwavelength monitoring of Cygnus X-3, Jun-Jul 2009



Multiwavelength monitoring of Cygnus X-3, Jun-Jul 2009



Multiwavelength monitoring of Cygnus X-3, Jun-Jul 2009

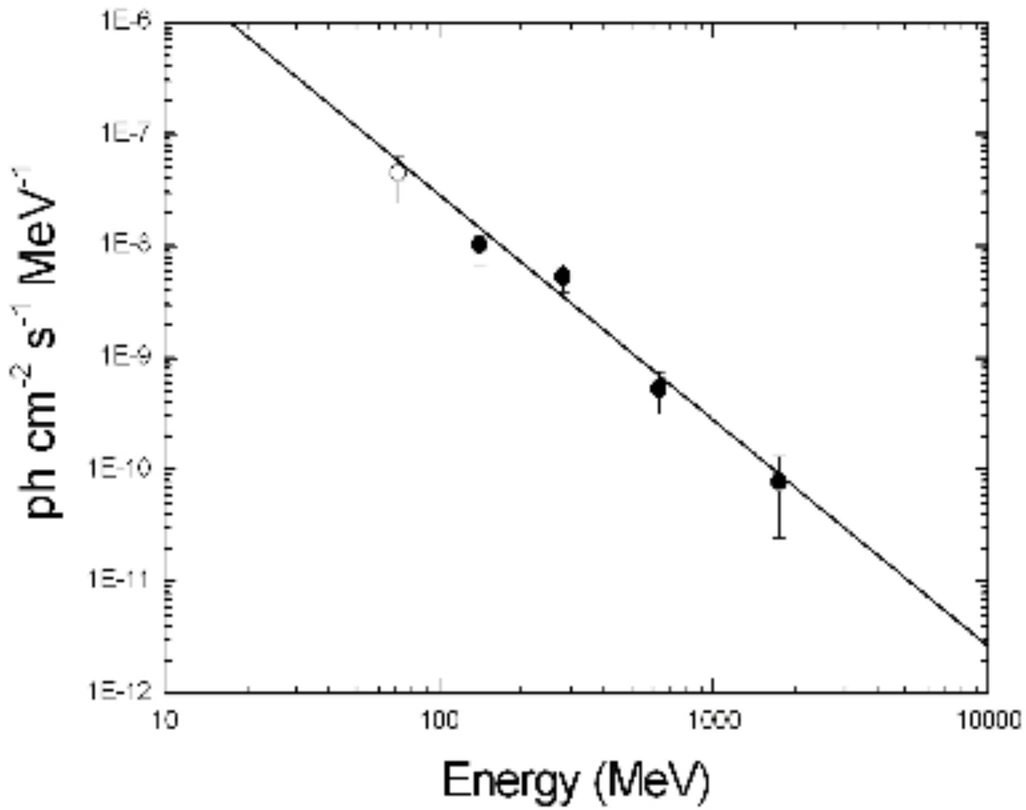


Spectrum of Cygnus X-3, Jun-Jul 2009

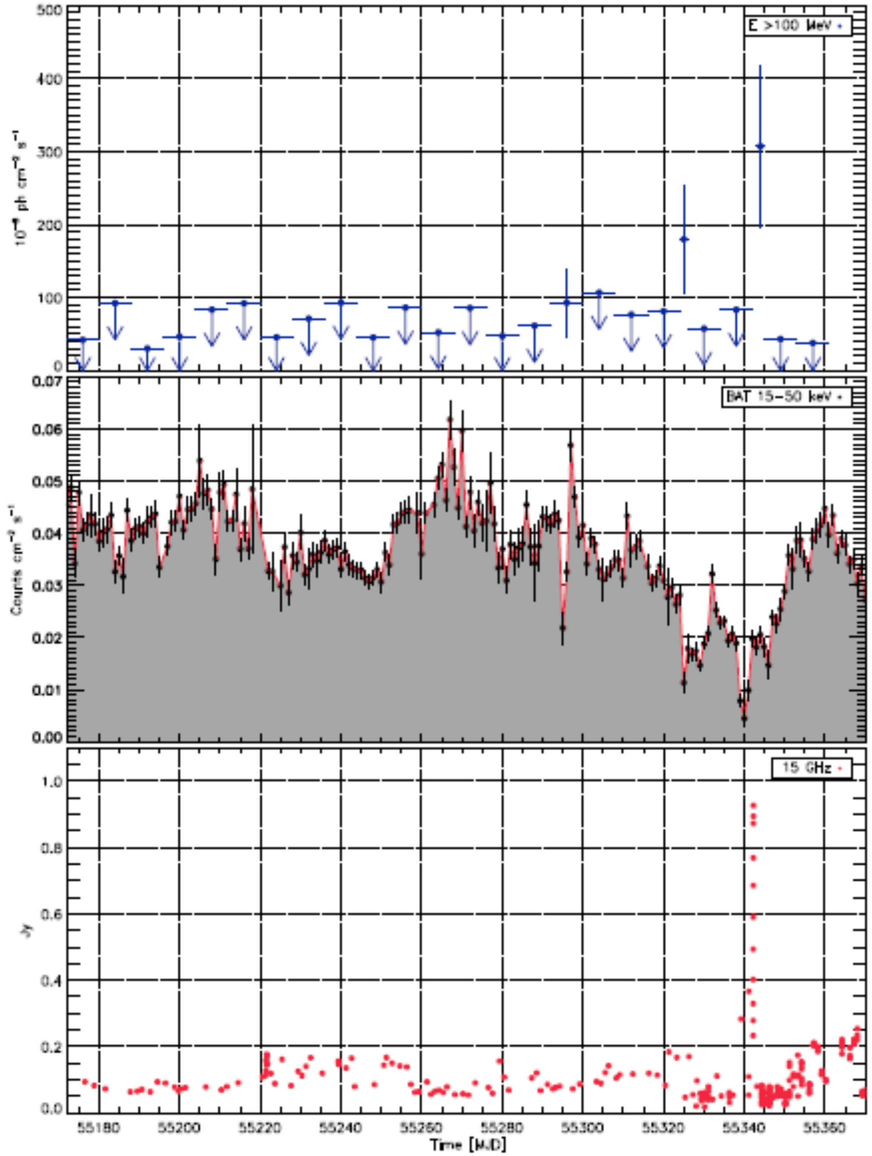
Obtained by integrating flaring episodes

Single power law

$\alpha = 2.02 \pm 0.28$



Multiwavelength monitoring of Cygnus X-3
Dec 2009 - Jun 2010



Implications…

- Cygnus X-3 can teach about BH systems and possibly also about blazars

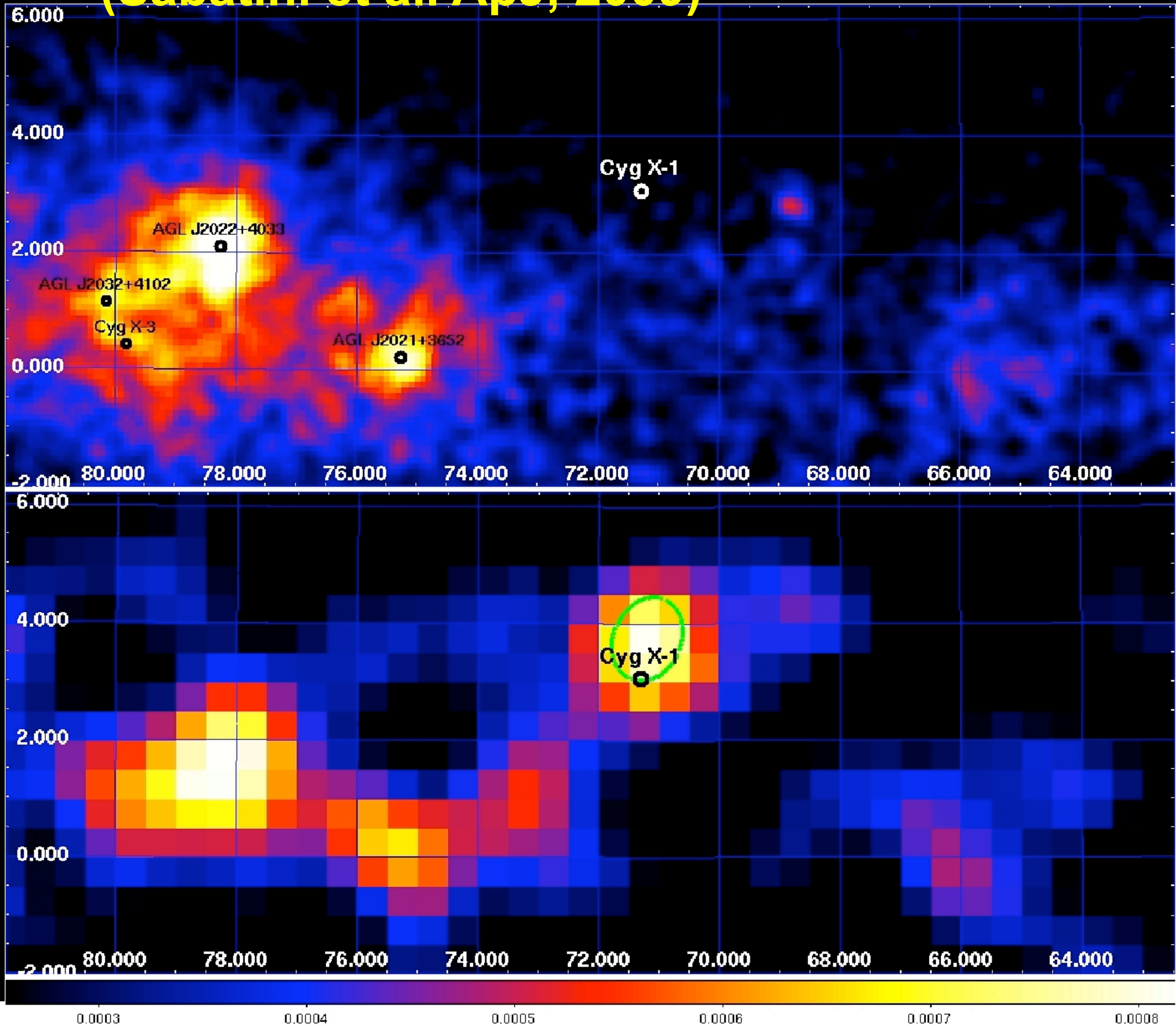
- Its jet is pointing at us, it is a "micro-blazar"

- "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

EPISODIC TRANSIENT GAMMA-RAY EMISSION FROM CYG X-1

AGILE gamma-ray detection of Cygnus X-1 (Sabatini et al. ApJ, 2009)

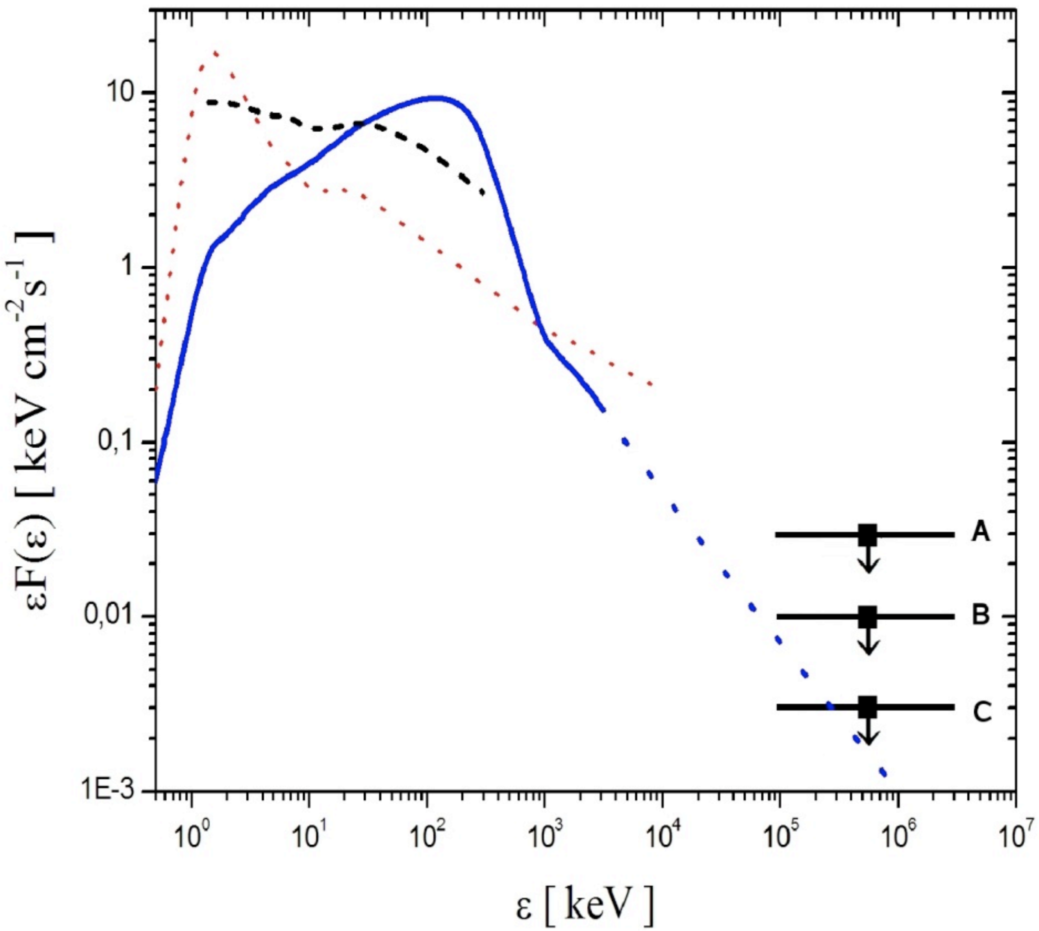


CygX-1 Spectral Energy Distribution - persistent
(Sabatini et al., 2010, ApJL)

Spectral energy distribution in typical states for Cyg X-1

Agile 2-sigma upper limits above 100 MeV for
A)2 weeks
B)4 weeks
C)315 days **(first slide "deep integration")**

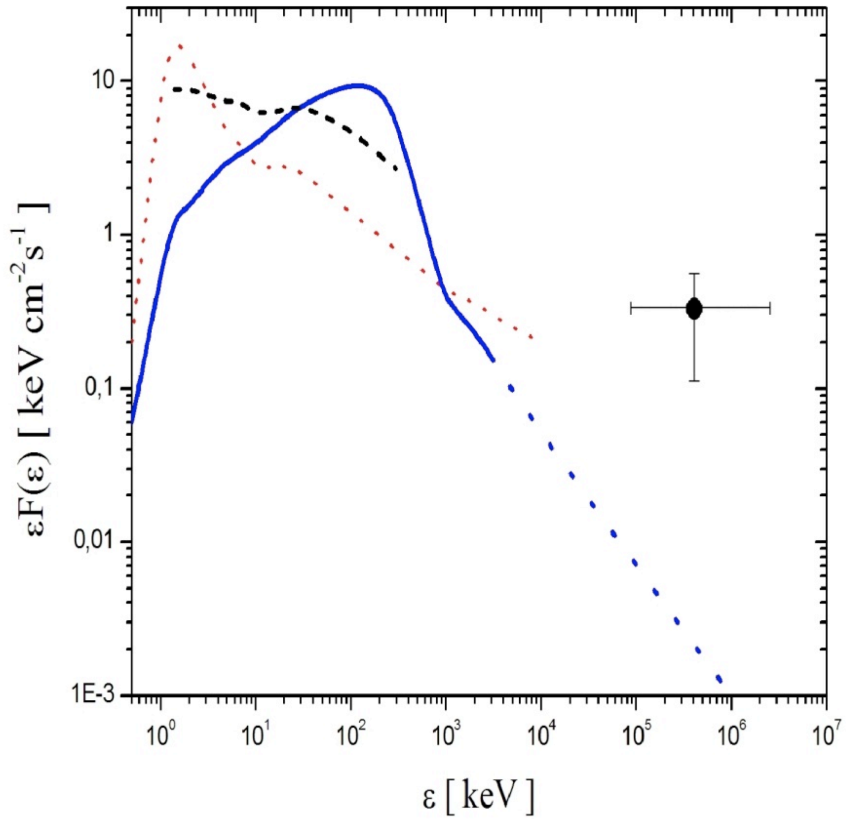
->average gamma-ray spectra in hard-state: a spectral cut-off



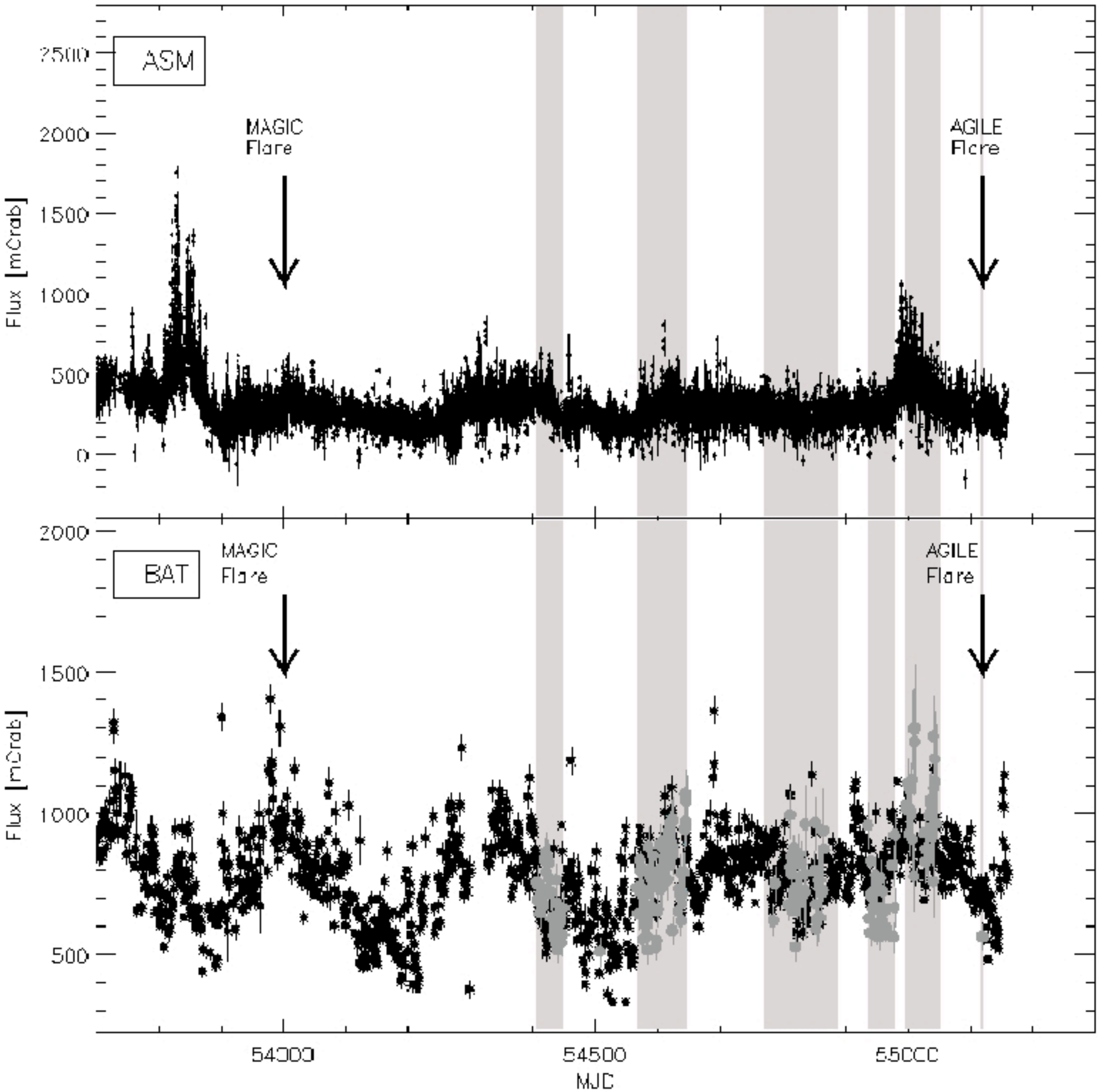
CygX-1 Spectral Energy Distribution - Flare

Spectral energy distribution for Cyg X-1 and AGILE data above 100 MeV for the flaring episode (15 October 09)

->First reported 1-day gamma-ray flare (0.1-3 GeV) in hard state!

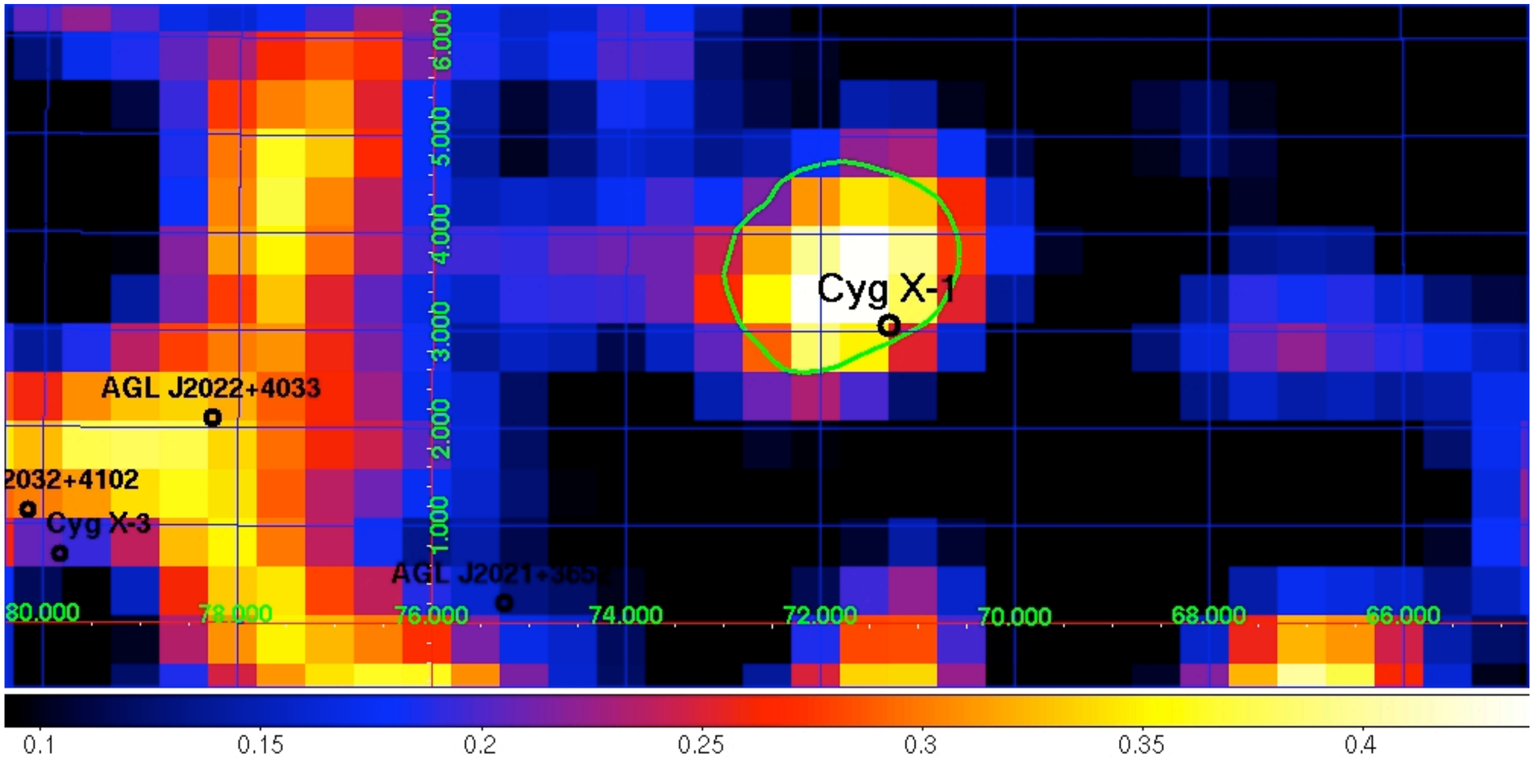


(for a 1 year monitoring with AGILE: Del Monte et al., 2010, accepted by *A&A*)

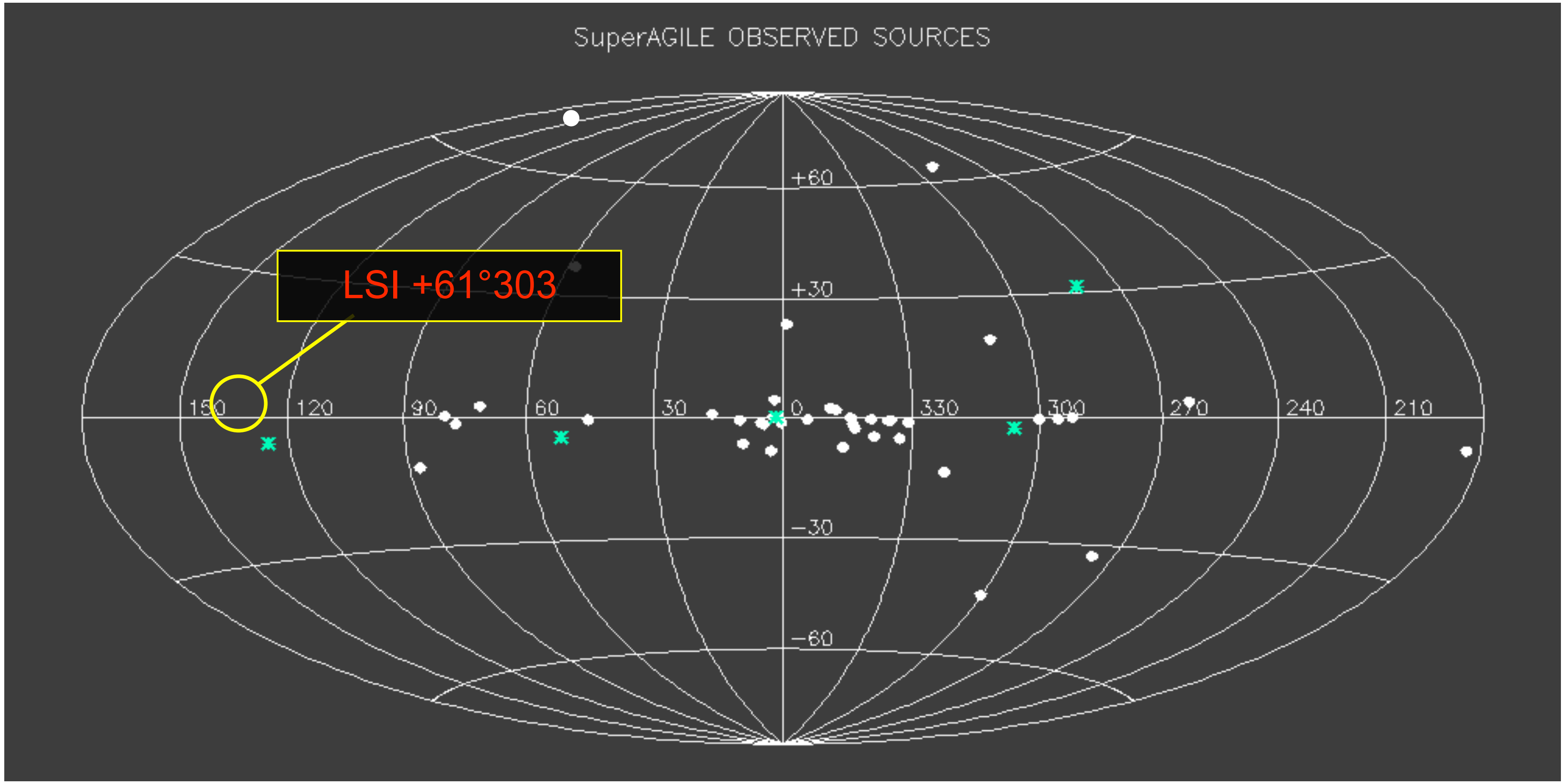


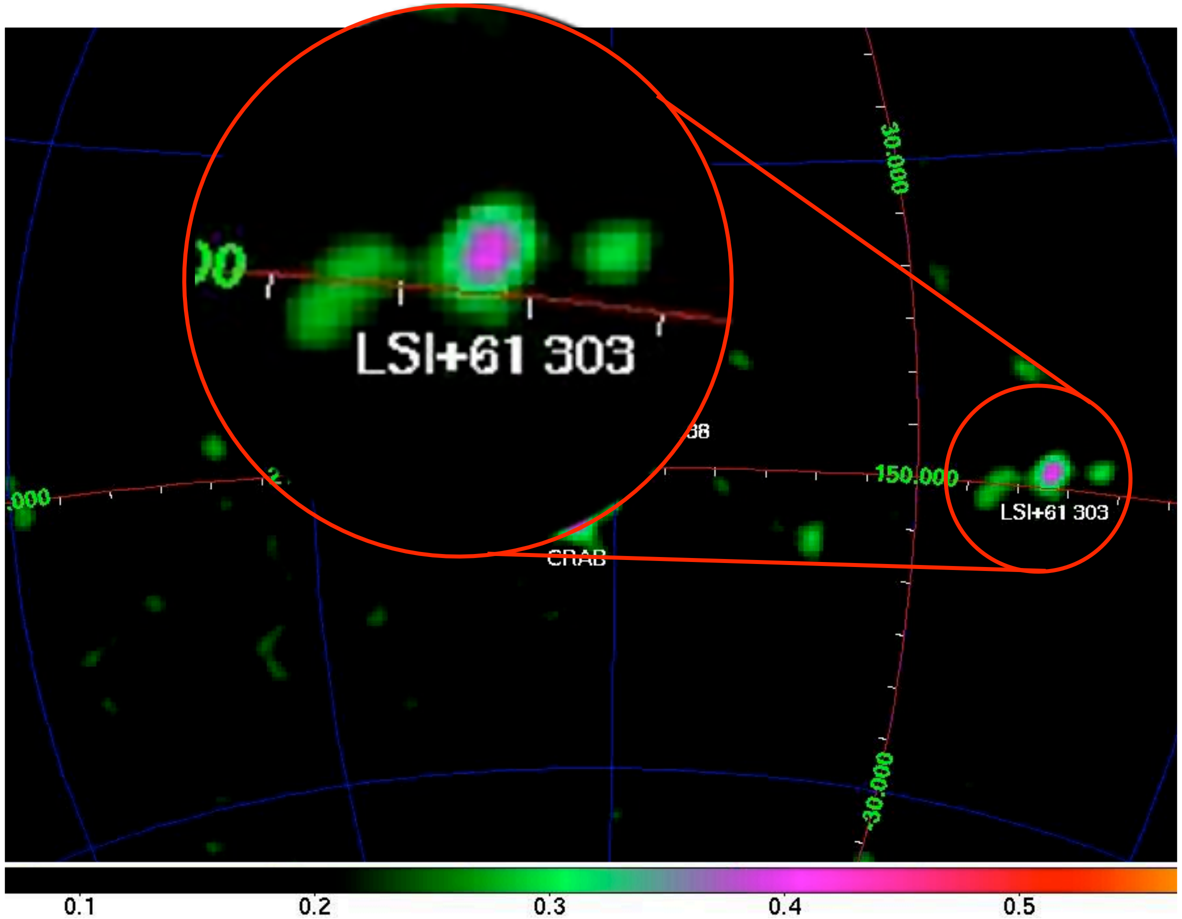
ASM
MAGIC
Flare
AGILE
Flare
Flux [mCrab]
2500
2000
1500
1000
500
0
BAT
MAGIC
Flare
AGILE
Flare
Flux [mCrab]
2000
1500
1000
500
54000
54500
55000
MJD

CygX-1 Flare – 30/6 – 2/7/2010

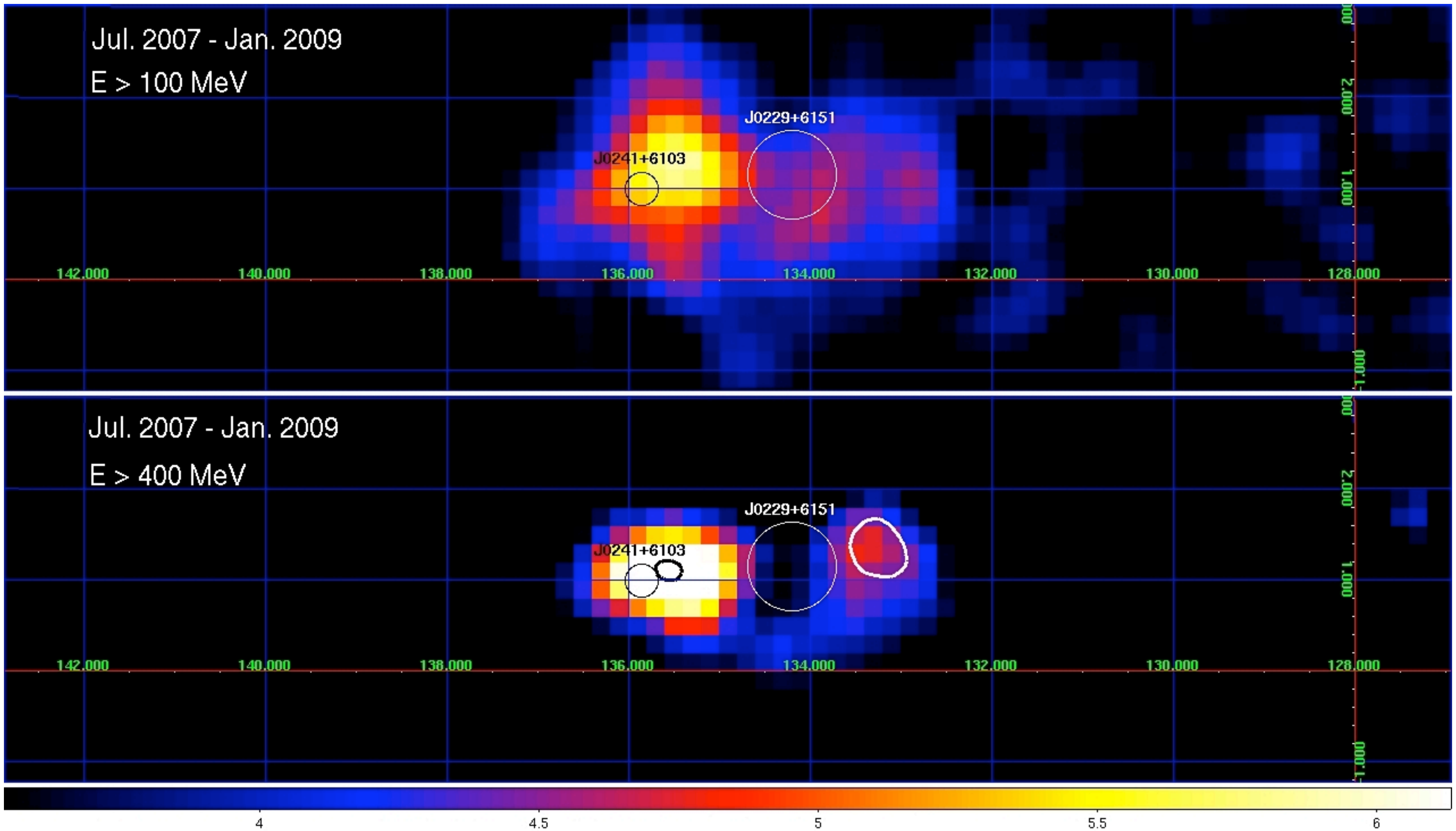


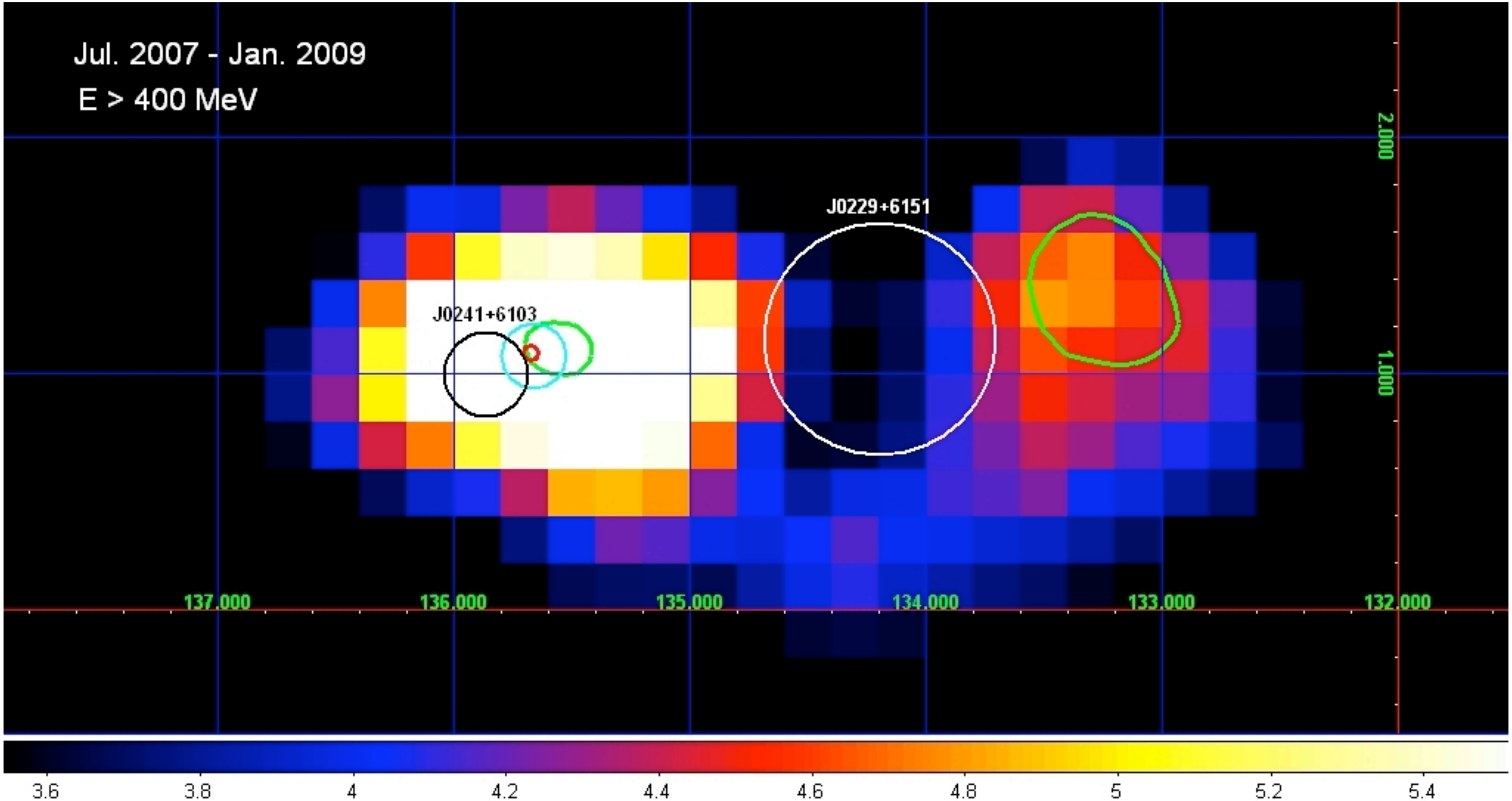
- **Transition to the soft spectral state**
  - **MAXI/GSC (ATel #2711)**
  - **RXTE-ASM (ATel #2714)**
- **F ~ 2 x 10^{-6} ph/cm^2/s (E > 100 MeV)**

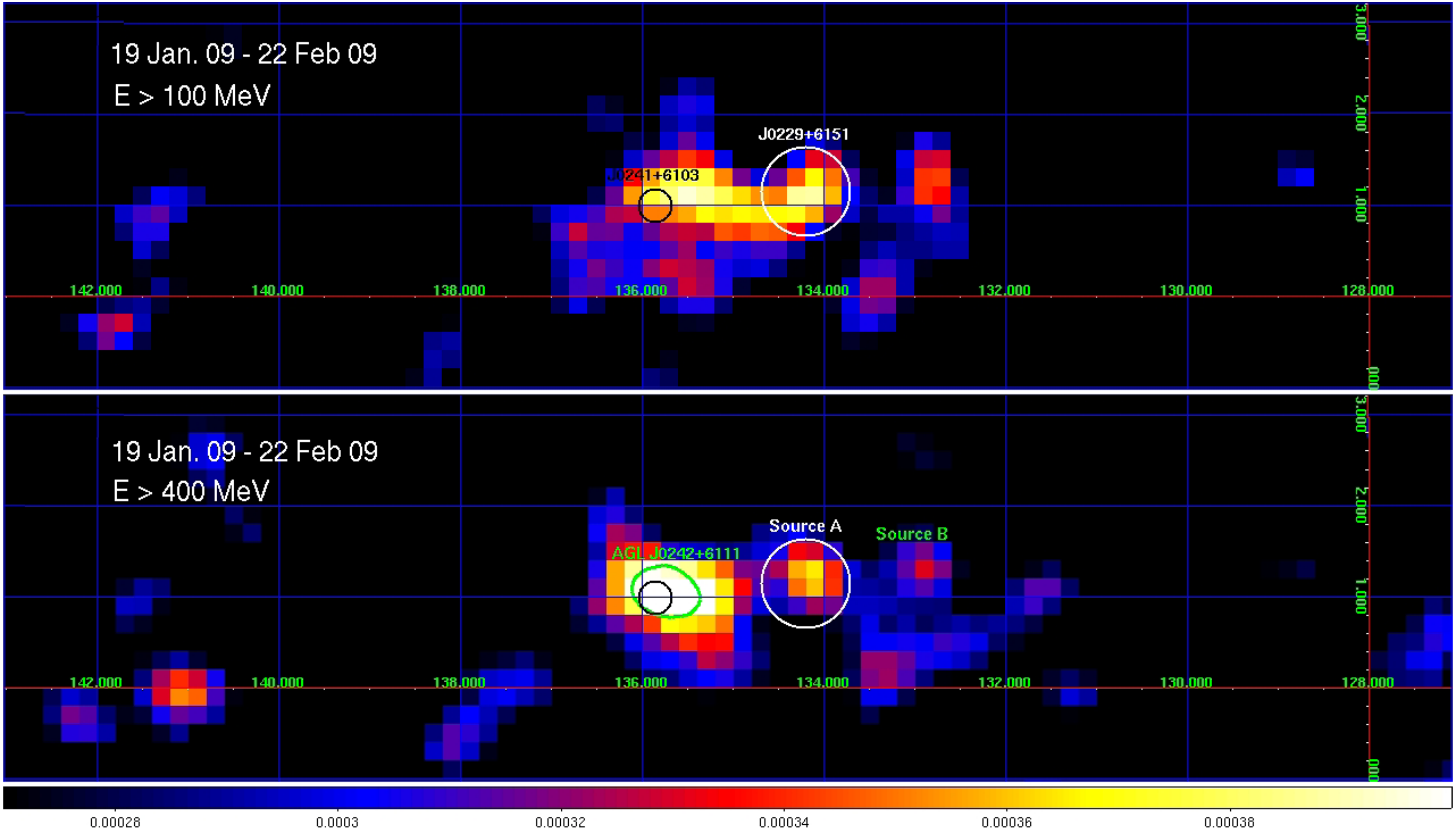

SuperAGILE OBSERVED SOURCES
LSI +61°303
+60
+30
-30
-60
150
120
90
60
30
0
330
300
270
240
210


LSI+61 303
30.000
150.000
-30.000
CRAB
0.1
0.2
0.3
0.4
0.5

LSI 61 303 field (all data)

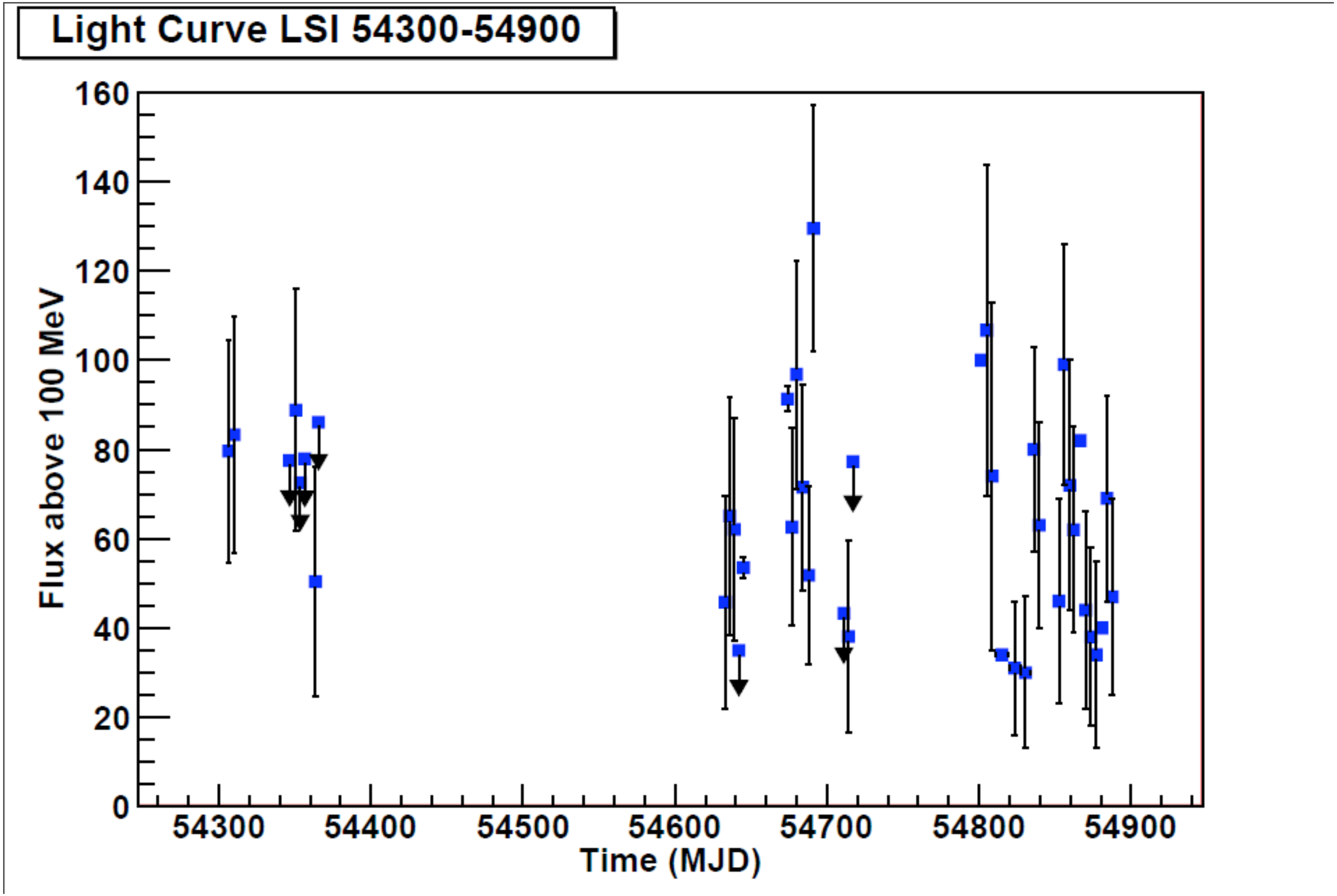



Jul. 2007 - Jan. 2009
E > 400 MeV
J0241+6103
J0229+6151
2.000
1.000
137.000
136.000
135.000
134.000
133.000
132.000
3.6
3.8
4
4.2
4.4
4.6
4.8
5
5.2
5.4

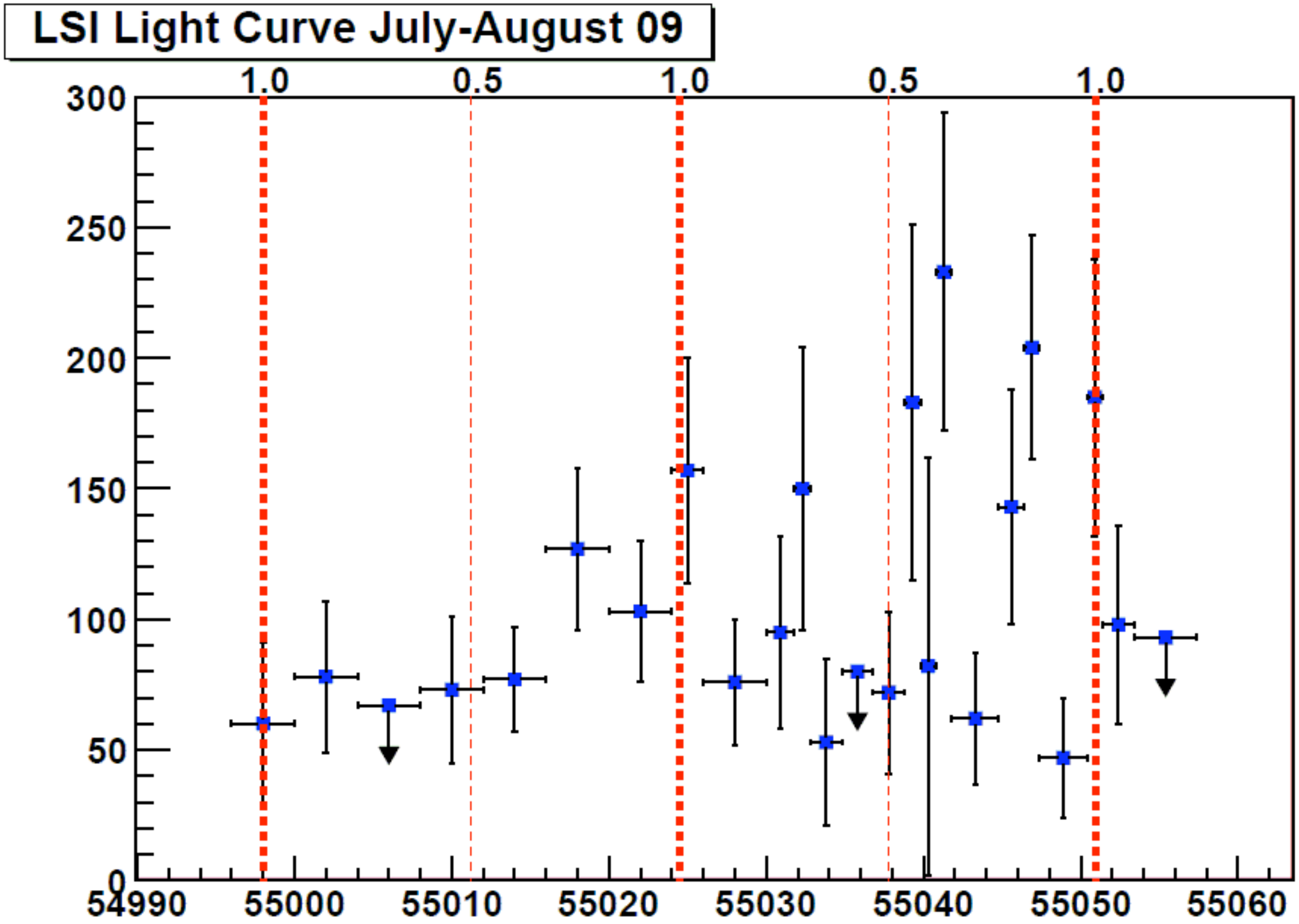


GAMMA-RAY SOURCES NEAR LS I +61 303

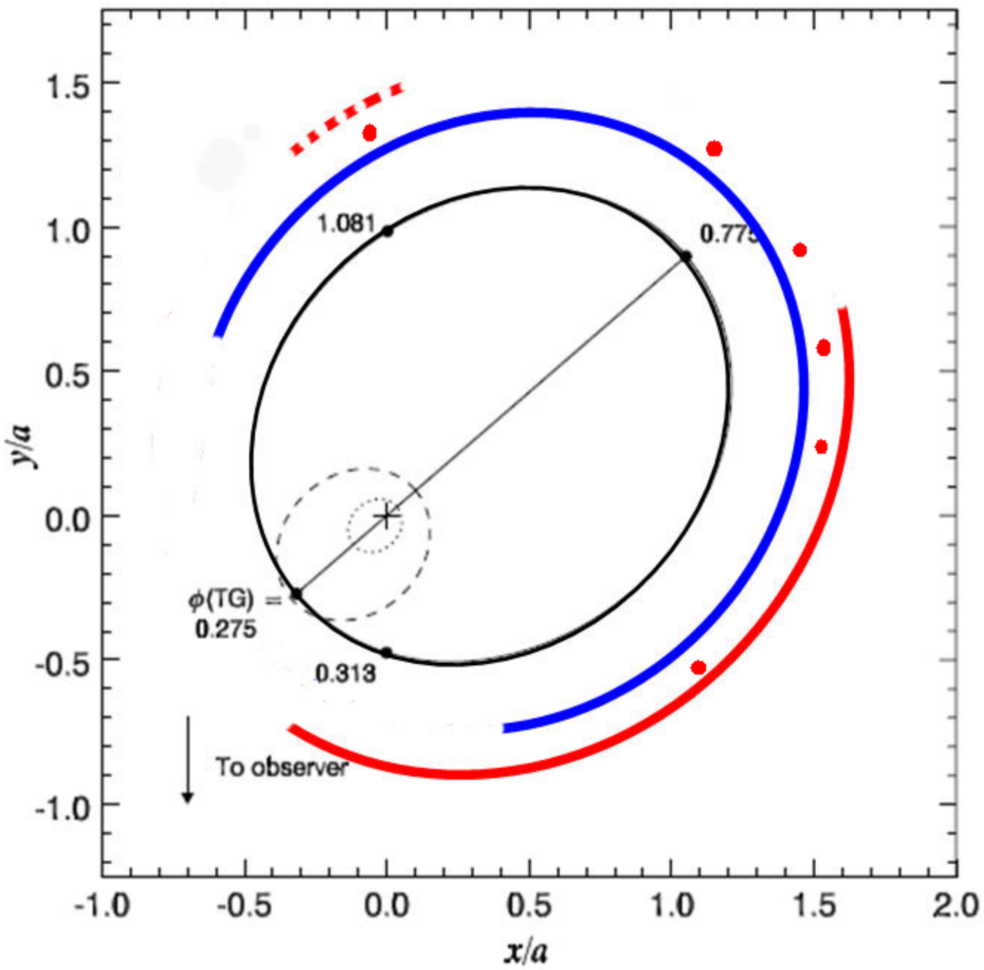
Source	AGILE contacts	l	b	error box radius	Average flux above 100 MeV (10^{-8} phcm^{-2}s^{-1})
LS I +61 303 (AGL J0242+6111)	1200-9994	135.54	1.1	0.1	41.7 ± 2.8
Source B (3EG J0229+6151)	1200-9994	133.3	1.4	0.3	14.6 ± 2.5
Source A	8996-9472	134.2	1.2	0.3	13.8 ± 3.5

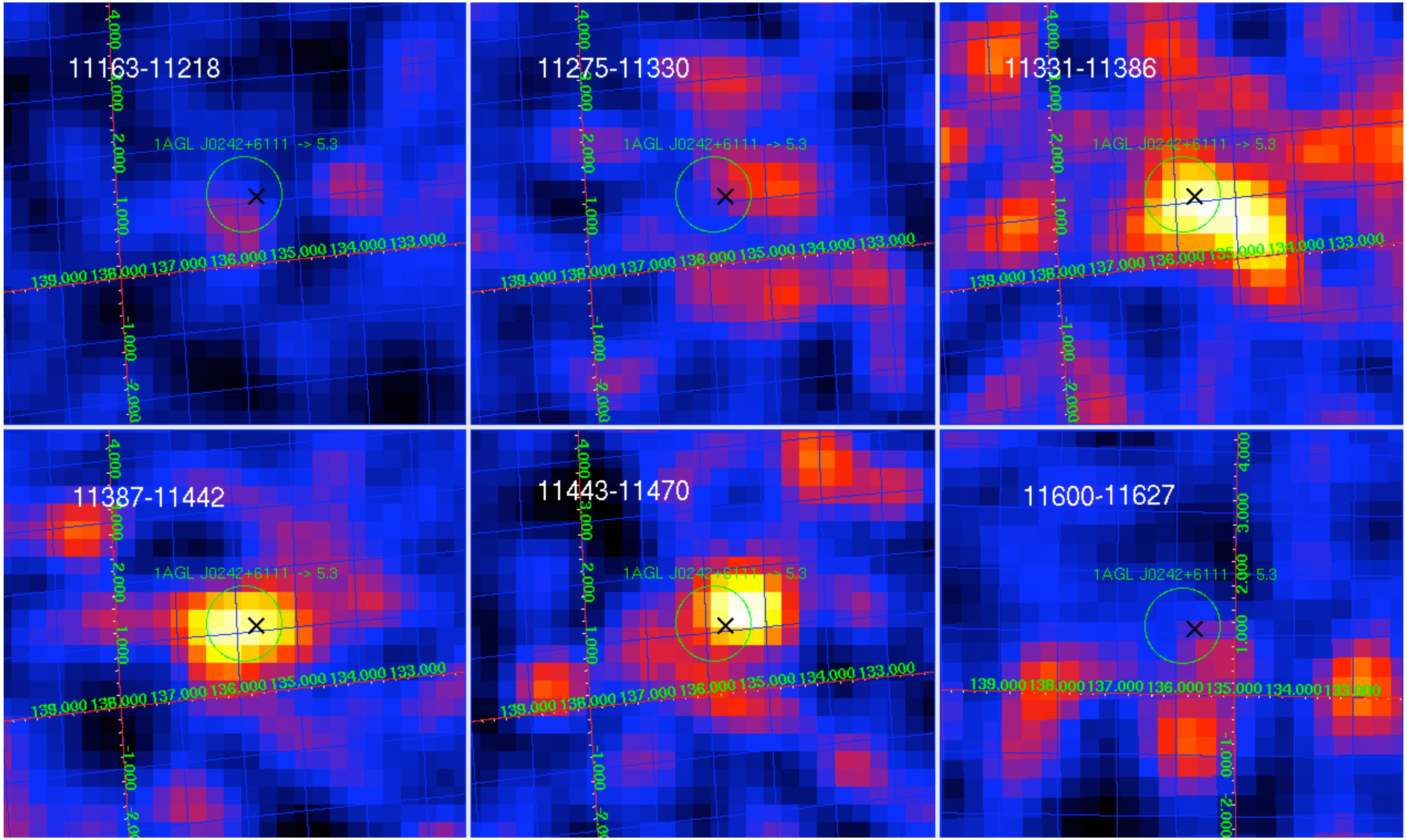


Light Curve LSI 54300-54900
Flux above 100 MeV
Time (MJD)
0
20
40
60
80
100
120
140
160
54300
54400
54500
54600
54700
54800
54900


LSI Light Curve July-August 09
1.0
0.5
1.0
0.5
1.0
300
250
200
150
100
50
0
54990
55000
55010
55020
55030
55040
55050
55060

peak phase	MJD
0.7	54885
0.6	54855
0.8	54835
(0.65)	(54805)
0.4	54960
0.5	54350
(~1)	(54868)
~ 1	55026




11163-11218
11275-11330
11331-11386
11387-11442
11443-11470
11600-11627
1AGL J0242+6111 -> 5.3

Variability of LSI 61 303

E > 100 MeV with 10% systematic error on fluxes

$\chi 2$ = 33.7832 for 23 degrees of freedom

V = 1.1652

Pvar = 0.931641

NB:	V < 0.5	nonvariable source
	0.5 < V < 1	uncertain
	V > 1	variable source

(McLaughlin et al. 1996)

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

	Θ (degrees)	β	Γ	L_X/L_E	γ/TeV
Cyg X-1	?	?	?	0.1-1	YES
Cyg X-3	< 14	> 0.8	> 1.6	0.1-1	YES
SS 433	80	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

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

	Θ (degrees)	β	Γ	L_X/L_E	γ/TeV
Cyg X-1	?	?	?	0.1-1	YES
Cyg X-3	< 14	> 0.8	> 1.6	0.1-1	YES
S					no
G					o
G					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

also the jet geometry of Cyg X-3 and Cyg X-1 could explain the variability and the gamma-ray activity recently detected

HMXB IGR J17354-3255

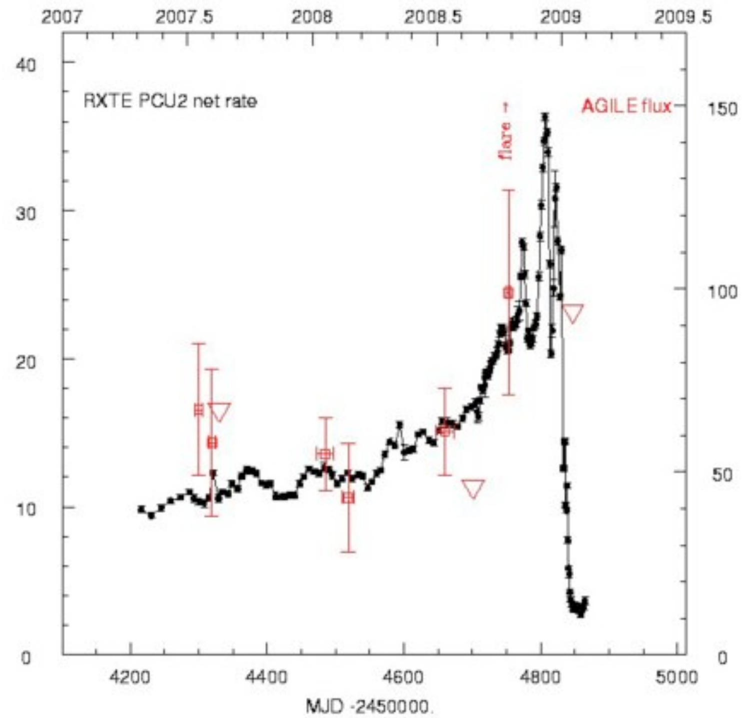
- AGILE Detection - 14 April 2009
  - Bulgarelli et al. 2009 - ATel # 2017
  - F = 3.5e-6 $cm^{-2}s^{-1}$
- Localized by Swift & Chandra
  - Vercellone et al. 2009 – ATel # 2019
  - Tomsick et al. 2009 - ATel # 2022
  - Highly absorbed power law
    - N_H = 7.5e22 cm^2, Γ=0.54, f=1.3e-11 $erg/cm^2/s$
- Orbital period found by Swift/BAT
  - D'Ai' et al. 4 May 2010 – ATel # 2596
  - P = 8.452 days, inferred eclipse at MJD 52726.25 ± nP_{orb}
  - Power law with exponential cutoff (15-150 keV)
    - Γ=1.4, E_{cut}=27 keV, f = 2e-11 $erg/cm^2/s$

Eta Carinae

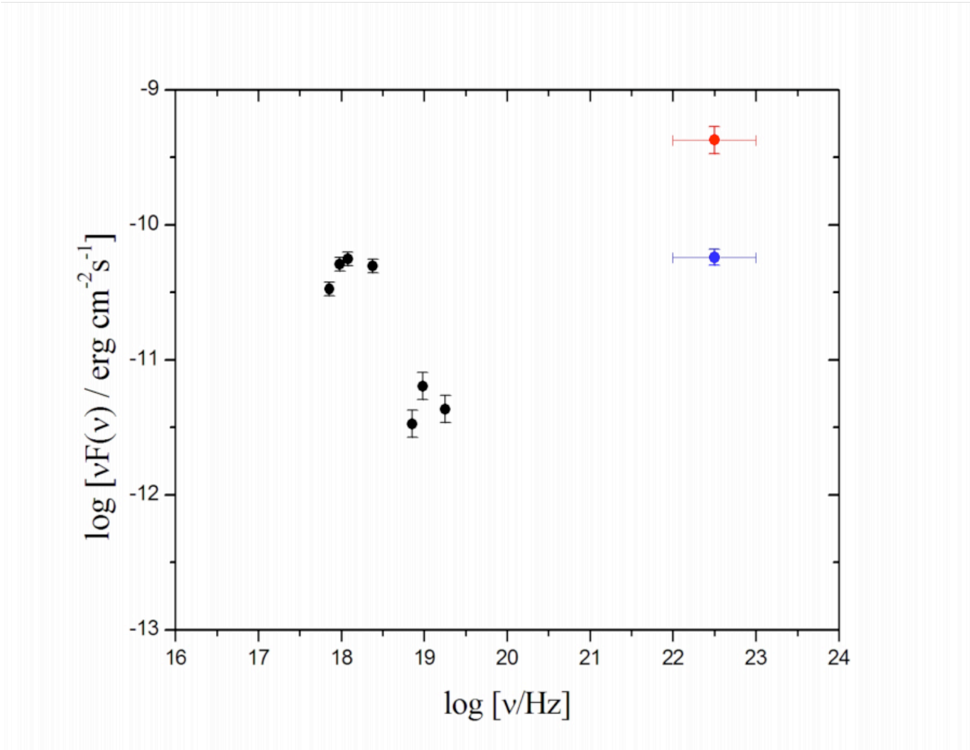
Tavani et al. 2009 ApJ, 698, L142

Eta Carinae - light curve

- 10-17 October 2008
- Peak flux = (270 ± 65) × 10^{-8} ph cm^{-2} s^{-1}
- RXTE PCU2 data shows typical abrupt decrease near periastron in X-rays



Eta Carinae - spectrum

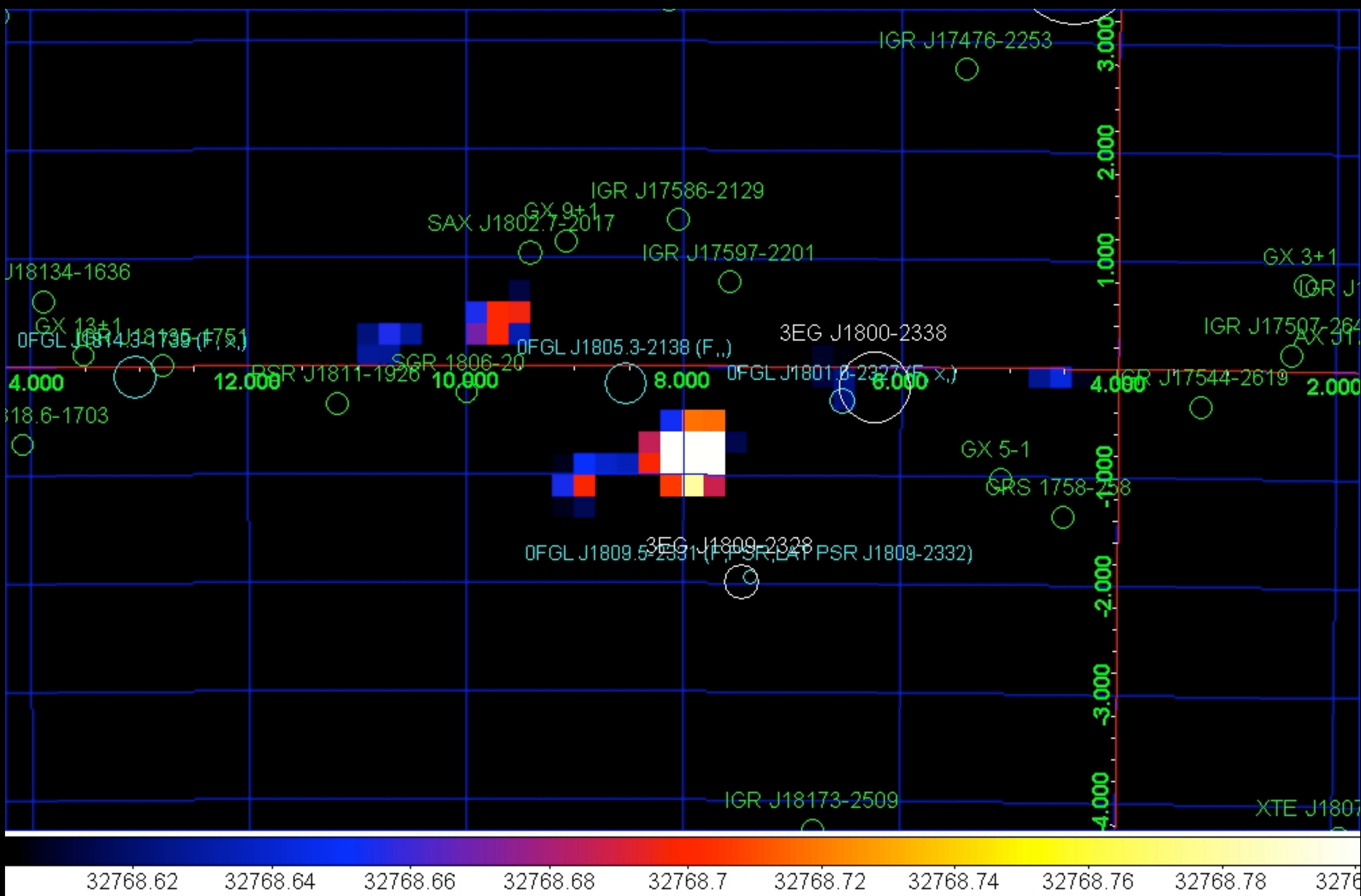


- Non-simultaneous data from INTEGRAL and SAX-MECS

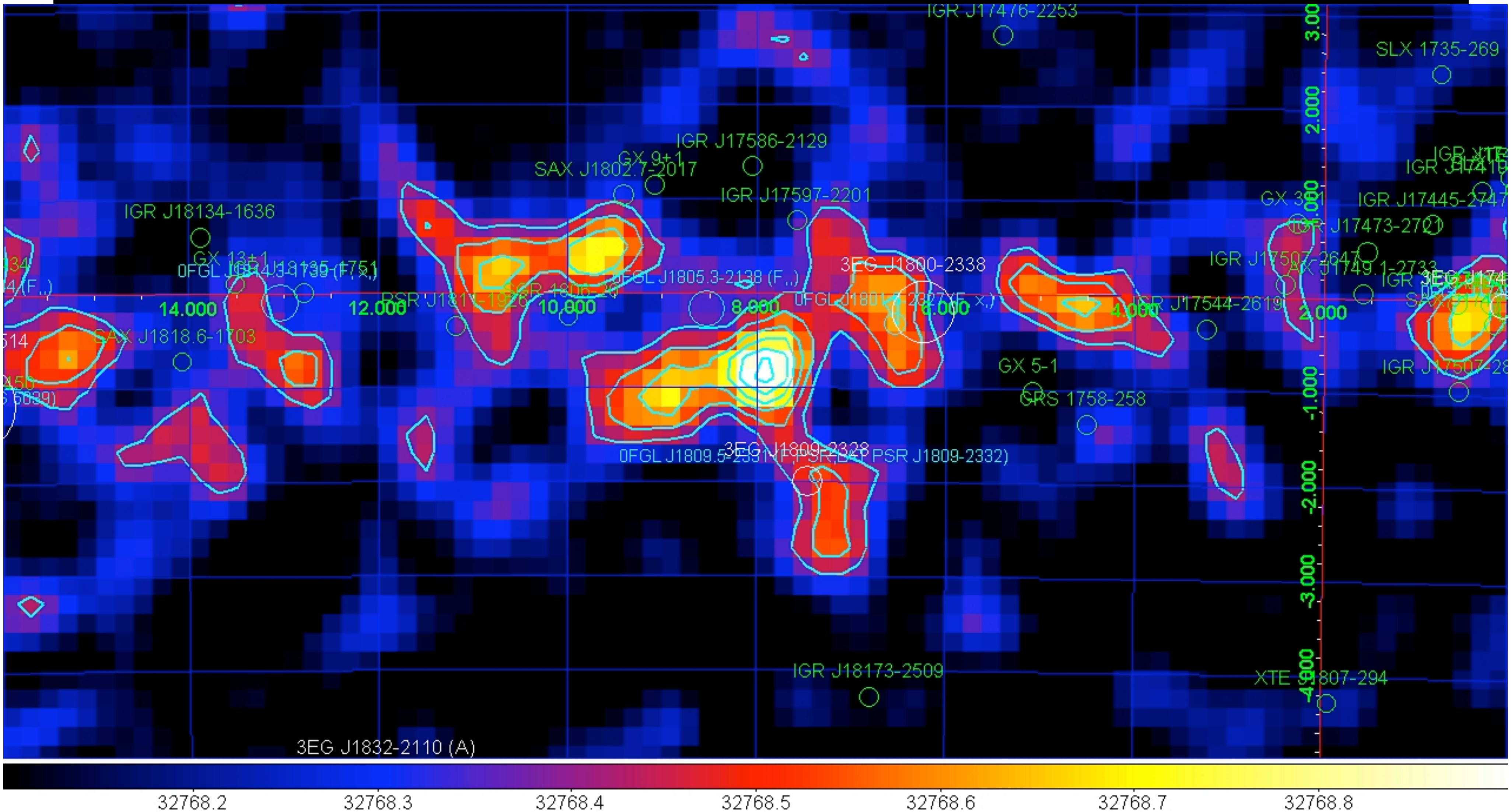
Gamma-Ray Galactic Transients

- Some detection/hints from EGRET
  - example: GRO J1838-04 (Tavani et al. 1997)
  - anti-example: IAU-Circulars on transients then retracted e.g., (Kanbach et al…)
- AGILE detection of many tens of candidates (usually low-energy)
  - Examples:
    - 24 Nov. 2007
    - Crux Region transients
    - Carina Region transients (e.g. 4U 1036-56, 30/11/2010)
    - Eta-Car
    - Galactic Center transients (March 09)
    - L= 17
    - L = 8 (Easter-09 transient)
    - Cygnus transients
    - AGL J2241+4454, AGL J2206+6203

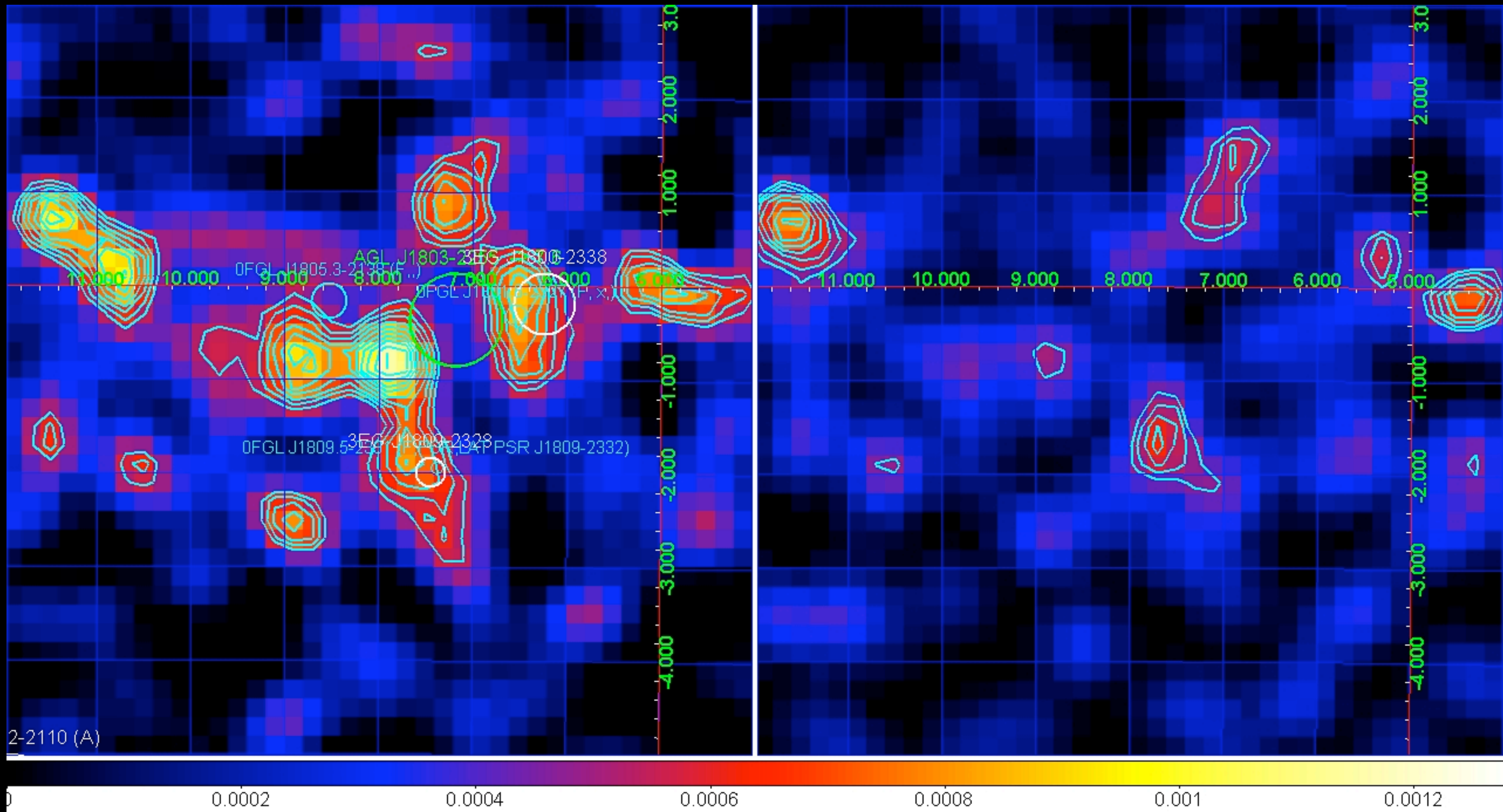
Easter transient: 10-13 April 2009, 10143-10180, bin =0.2, B16, FM, E>100 MeV



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

Galactic gamma-ray transient candidates:

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

- AGILE observes variability and detects new transients on time scales of 1 day 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)

Energetics…

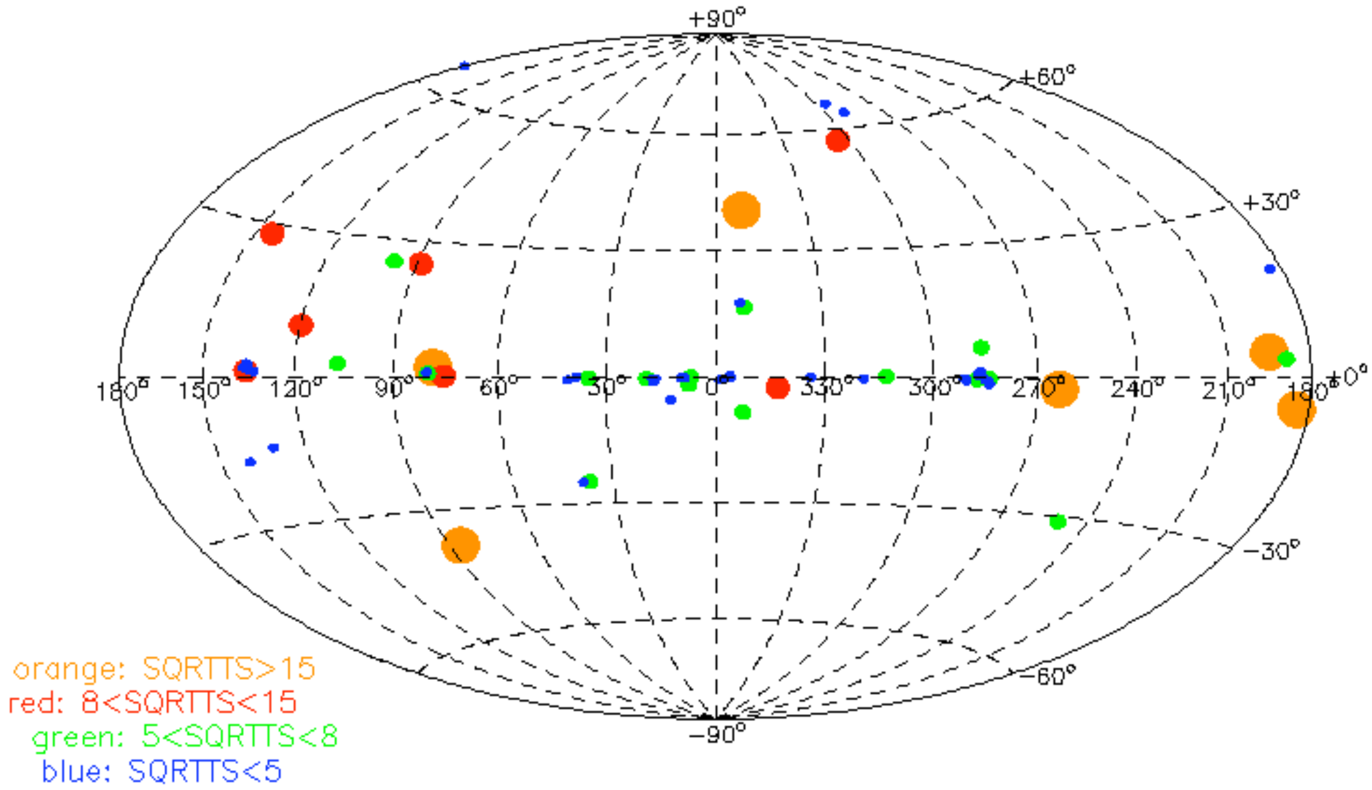
- Gamma-ray luminosity above 100 MeV

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

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

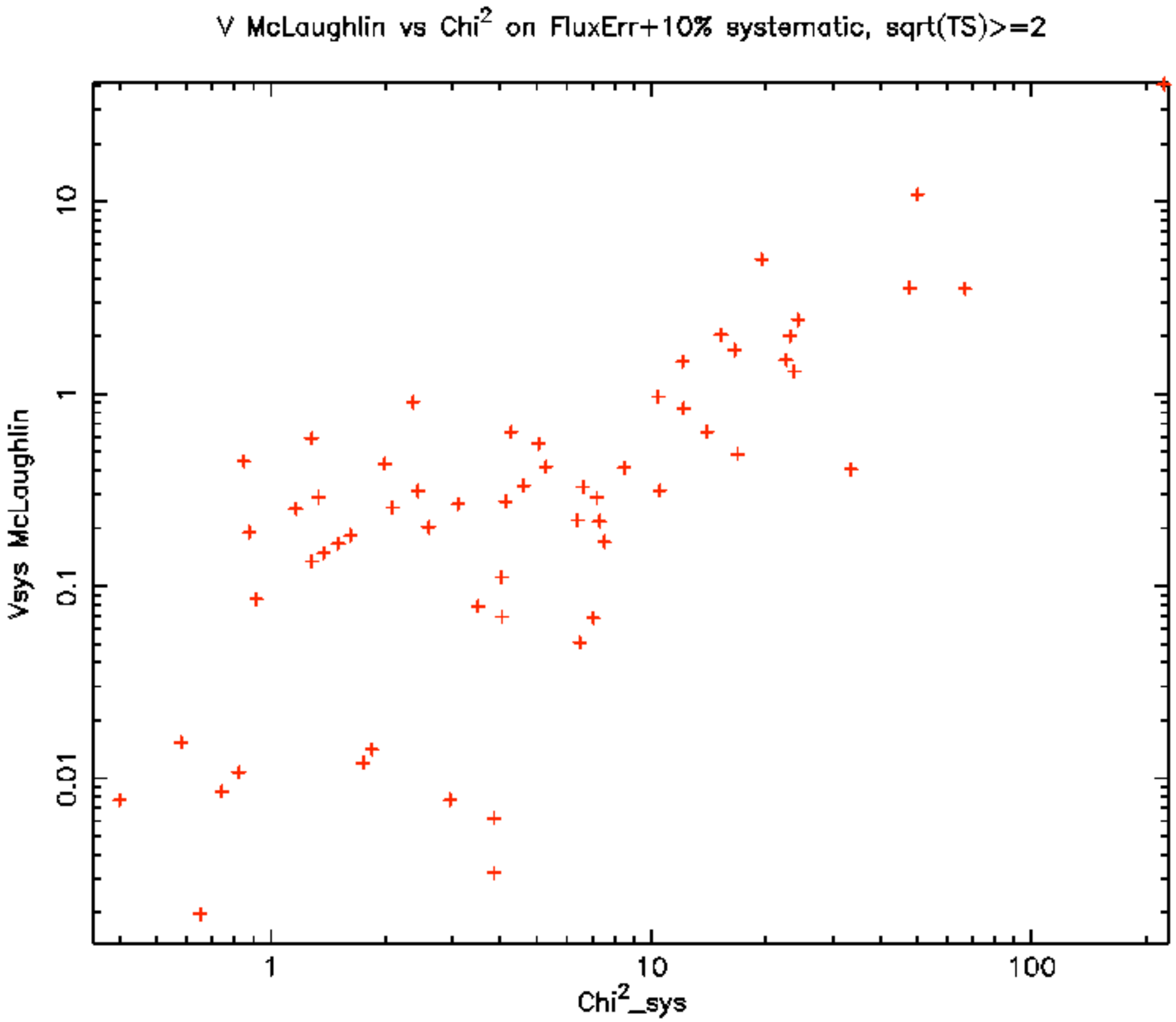
- But also it could be a NEW CLASS of (non-accreting or low X-ray) sources

AGILE Catalog of Variable and Transient Sources in preparation



- **F. Verrecchia et al 2011, in preparation**

AGILE Catalog of Variable and Transient Sources in preparation



Conclusions

- Wide variety of variable gamma γ-ray sources
- Discovery of PWN variability
- Microquasar γ-ray flares coincide with radio/X state transitions
- Many Galactic transients observed
  - Some source variability may be due to hidden transients
  - Catalog in preparation

Backup Slides

AGILE vs. Fermi: different results

- AGILE-GRID is optimized near 100 MeV, Fermi-LAT at E > 1 GeV
  - Fermi extrapolates from E > 200 MeV to determine flux E > 100 MeV
  - Due to AGILE energy resolution, E > 100 MeV flux contains large contribution from sub-100 MeV photons

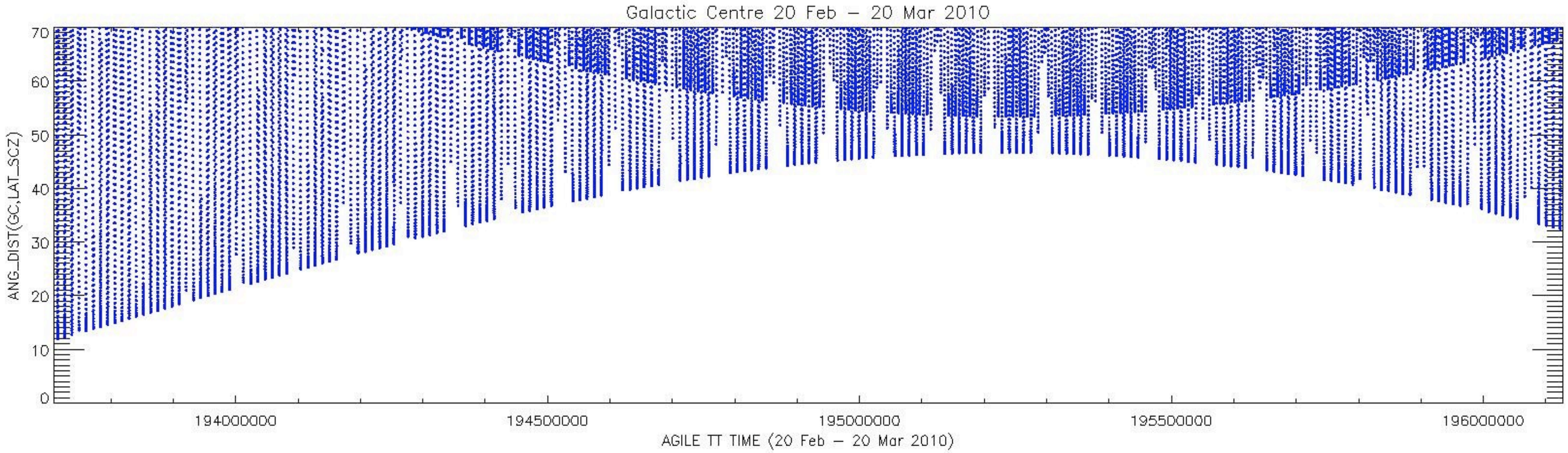
AGILE vs. Fermi: different results

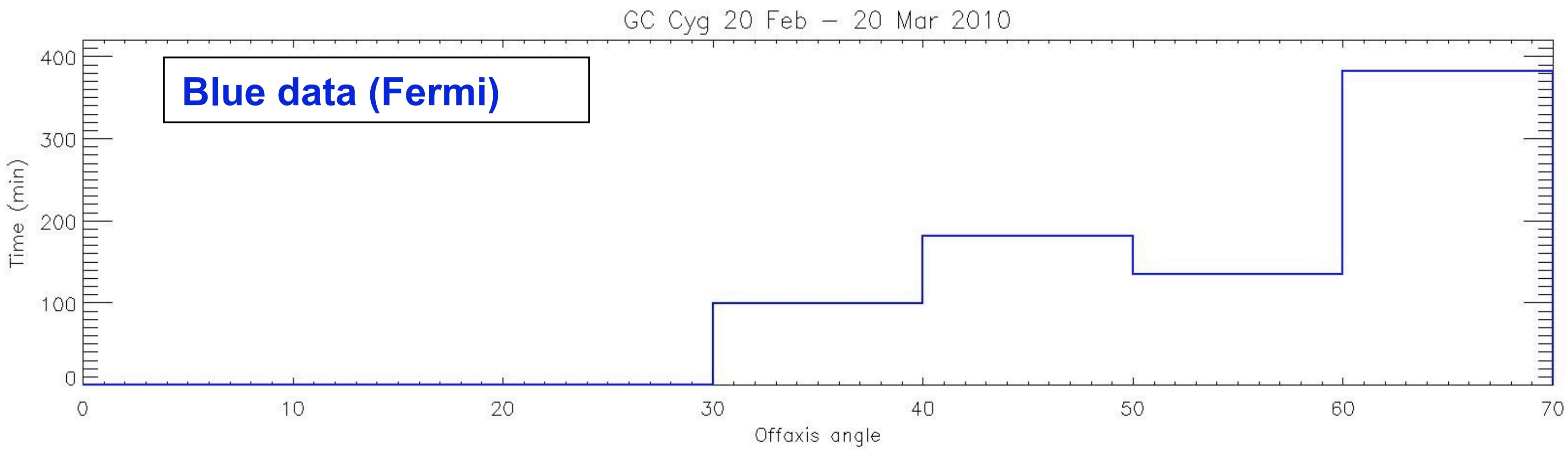
- depending on the season and source position, AGILE and Fermi can have quite different exposure below 1 GeV
  - exposure and off-axis distribution
  - different livetime sequence, different time windows

a comparison: 1-day exposure

	p-AGILE (GRID)	sp-AGILE (GRID)	FERMI (LAT front)
FOV (sr)	2.5	2.5	2.5
Attitude	fixed	variable (spinning)	variable
sky coverage	1/5	~ 70%	whole sky
Source livetime fraction	~ 0.5	~ 0.2	~ 0.16
1-day exposure (30 degree off-axis, 100 MeV)	~ 2 10^7 (cm^2 sec)	(0.5-1) 10^7 (cm^2 sec)	~(1-2) 10^7 (cm^2 sec)

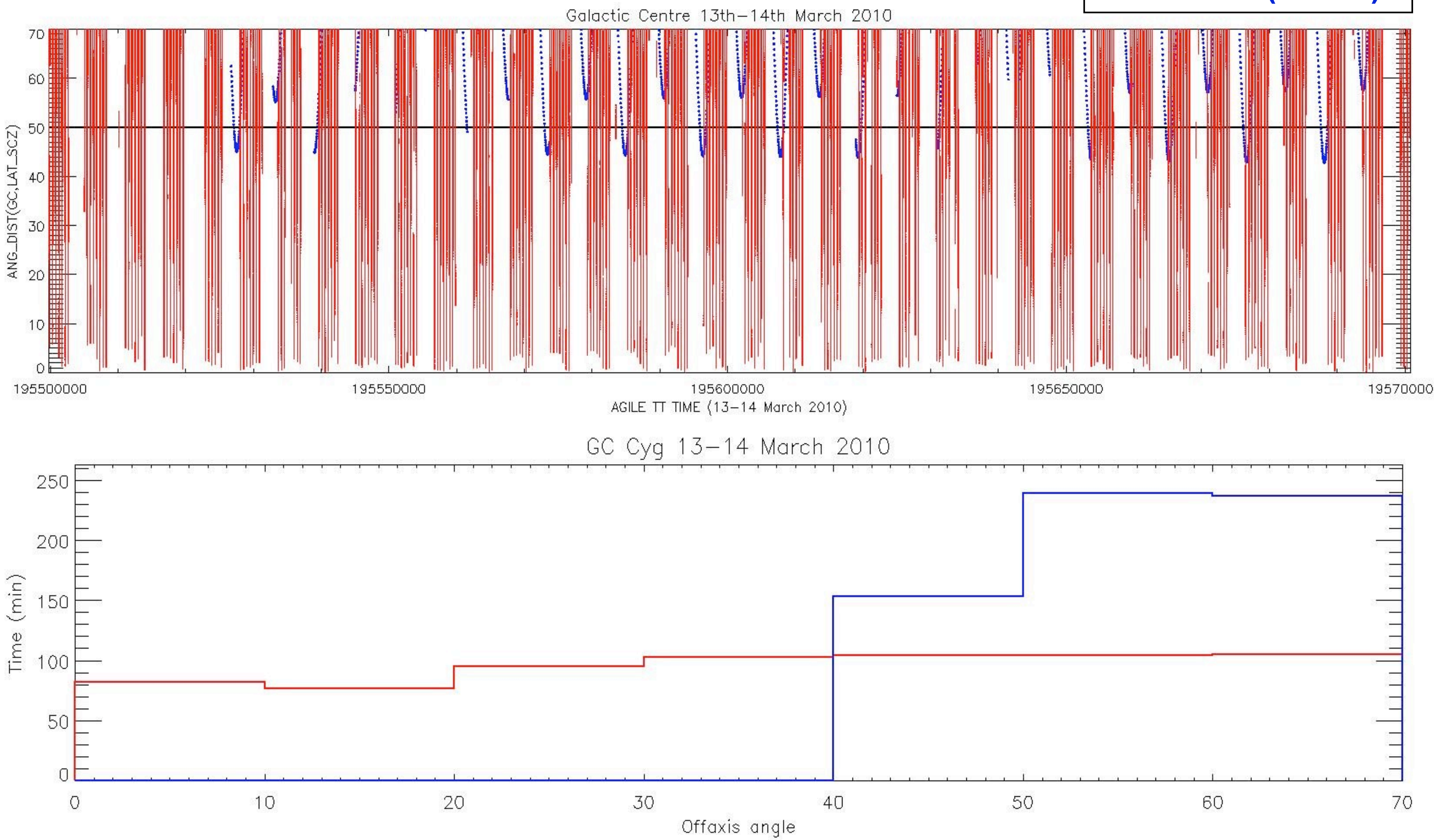
Example: Fermi Galactic Centre 1-month integration (20 Feb-20 Mar 2010)
off-axis angle vs. time and cumulative histogram (Sabatini etal. 2010)



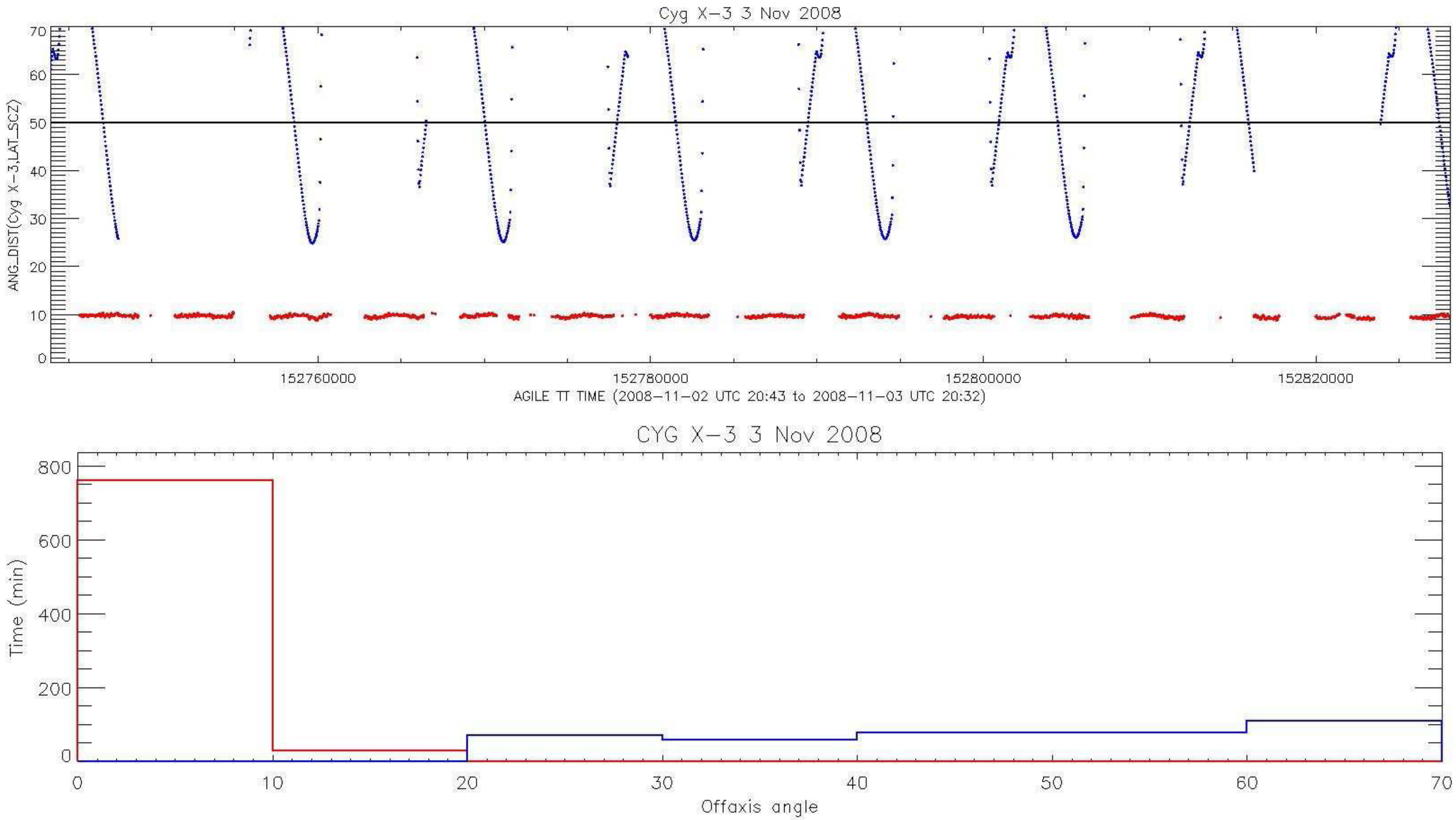


Example: Galactic Centre 2-days integration (13-14 Mar 2010)
AGILE spinning mode vs. Fermi (Sabatini et al. 2010)

Red data (AGILE)
Blue data (Fermi)



Cyg X-3: AGILE and Fermi time coverage and off-axis angle



AGILE and Fermi off-axis angle
(18-28 July 2009)