The AGILE view on Galactic Gamma-Ray Sources

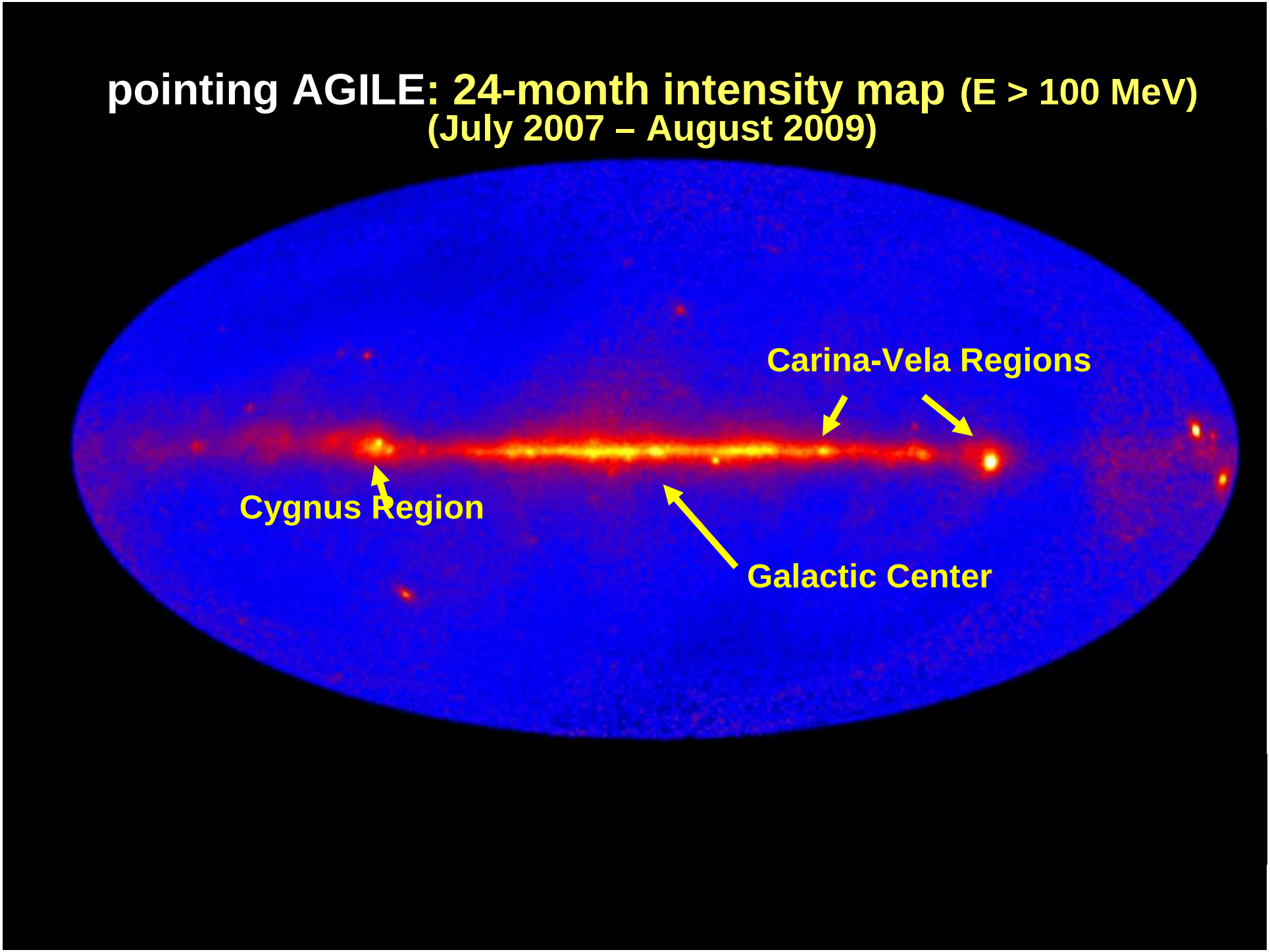
F.Verrecchia (ADC)

on behalf of the AGILE Galactic WG & the AGILE Collaboration

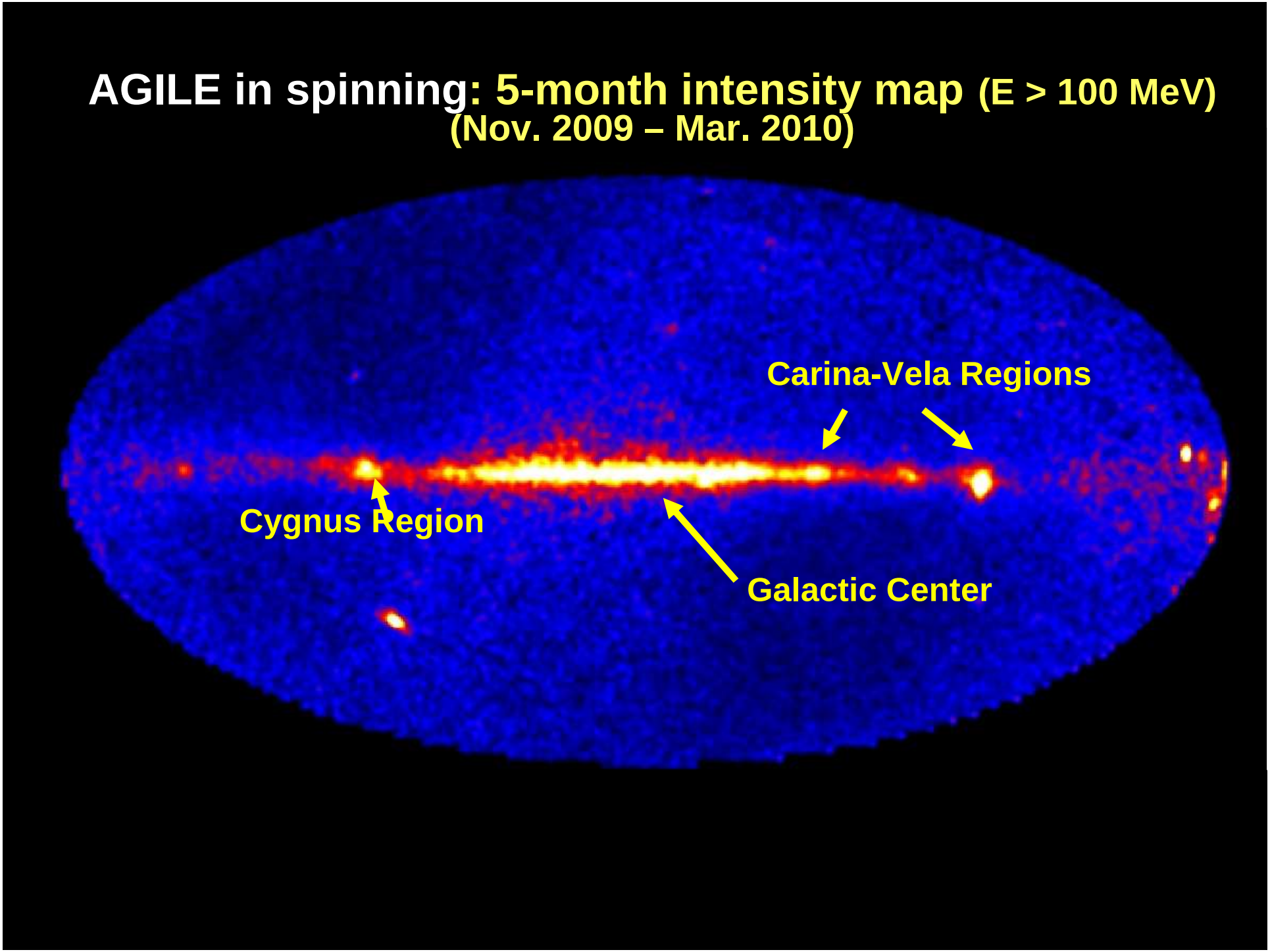
The Galactic WG

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

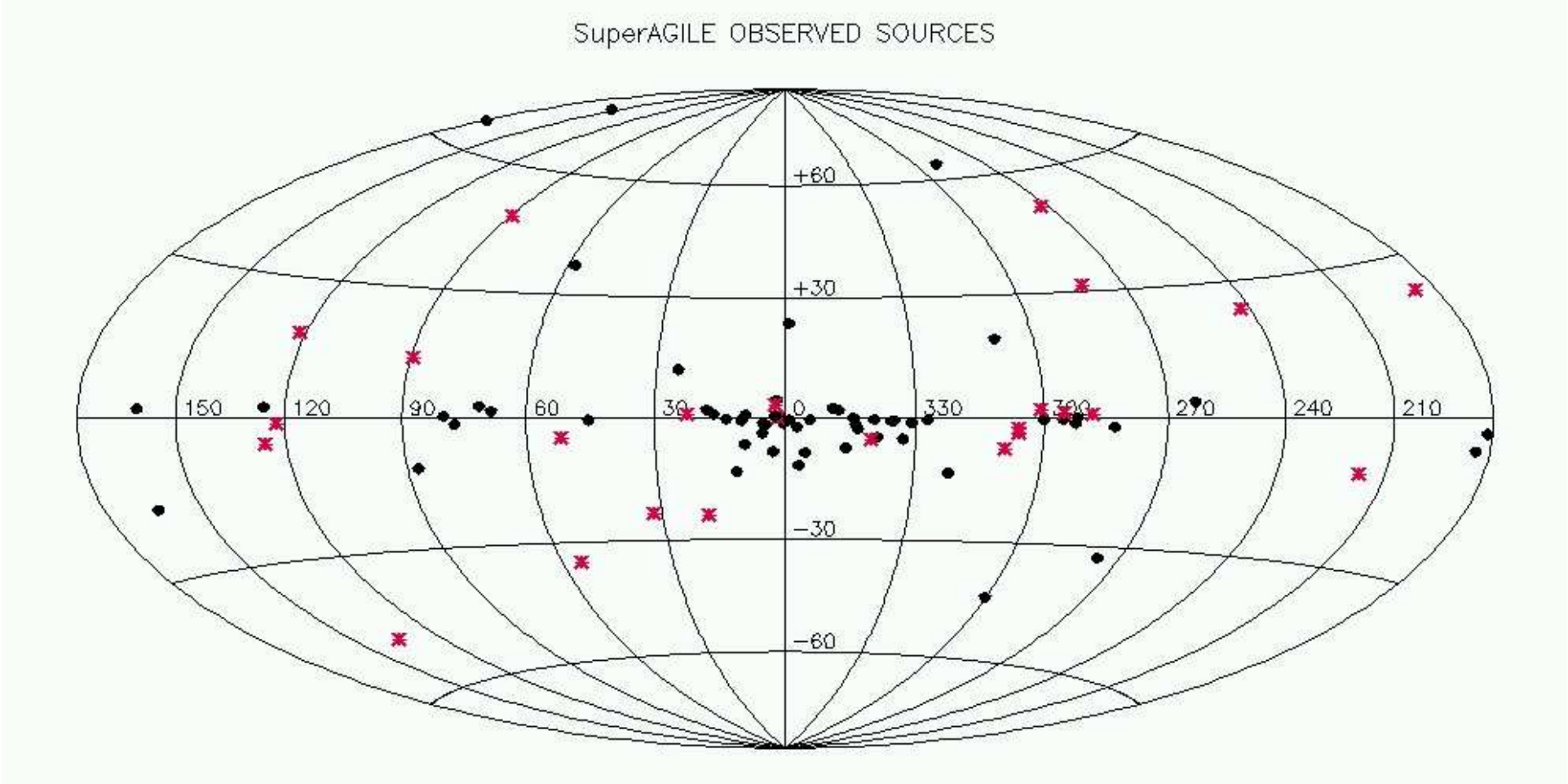
pointing AGILE: 24-month intensity map (E > 100 MeV)
(July 2007 – August 2009)



AGILE in spinning: 5-month intensity map (E > 100 MeV)
(Nov. 2009 – Mar. 2010)



SuperAGILE detected sources in 3 years



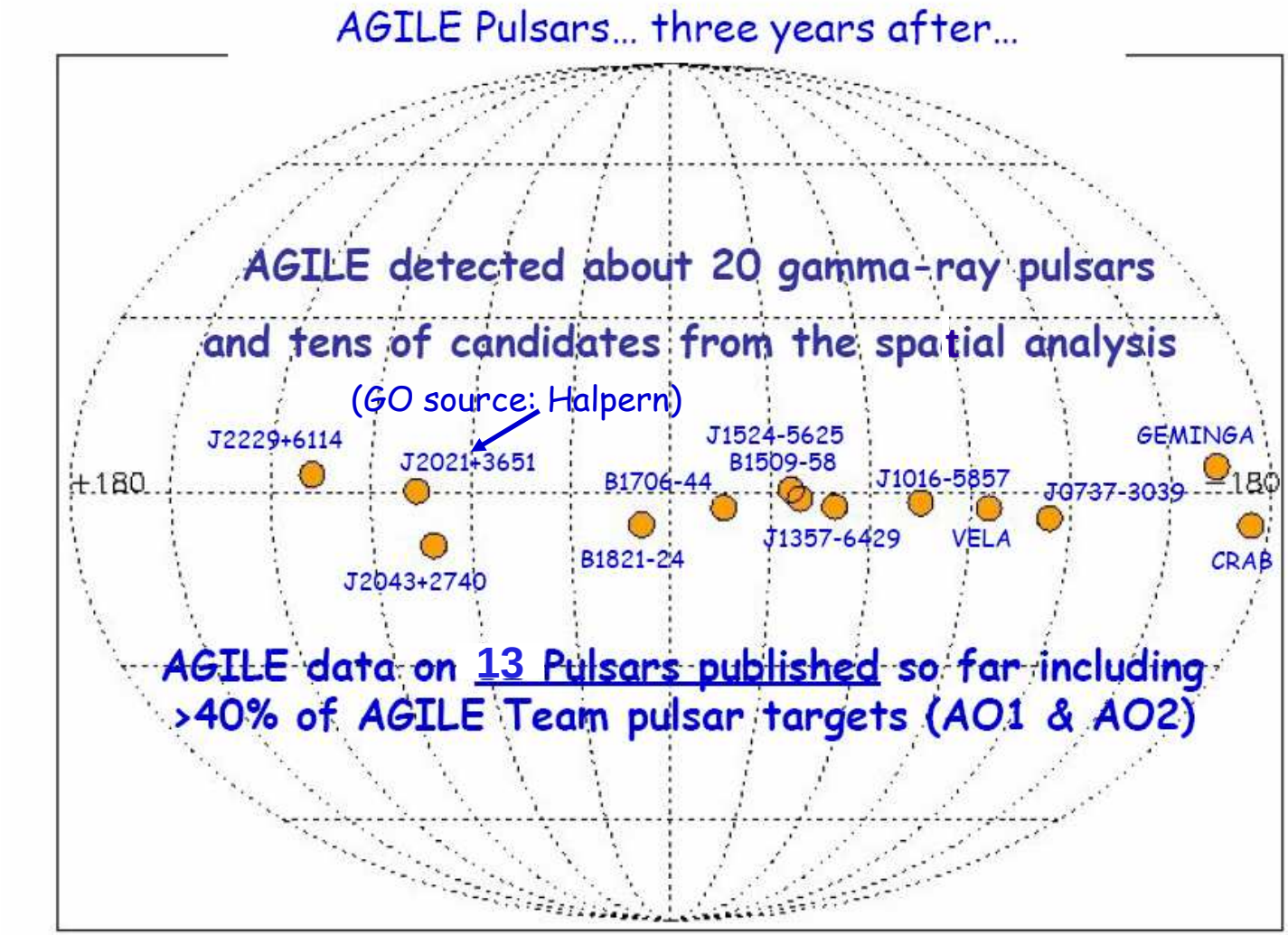
AGILE "Galactic" Science Topics

- 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
- Hard X-ray monitoring with Superagile
- Galactic Center (in progress)

AGILE Gamma-Ray Pulsars and PWNe

A.Pellizzoni, M.Pilia, A.Trois and the AGILE Pulsar WG

Gamma-ray Pulsars by AGILE



AGILE new Pulsars

New Gamma-Ray Pulsars

J2229+6114, J2021+3651, …: Vela-like

J1513-5908: High B pulsar

J1824-2452: ms PSR in Globular Cluster

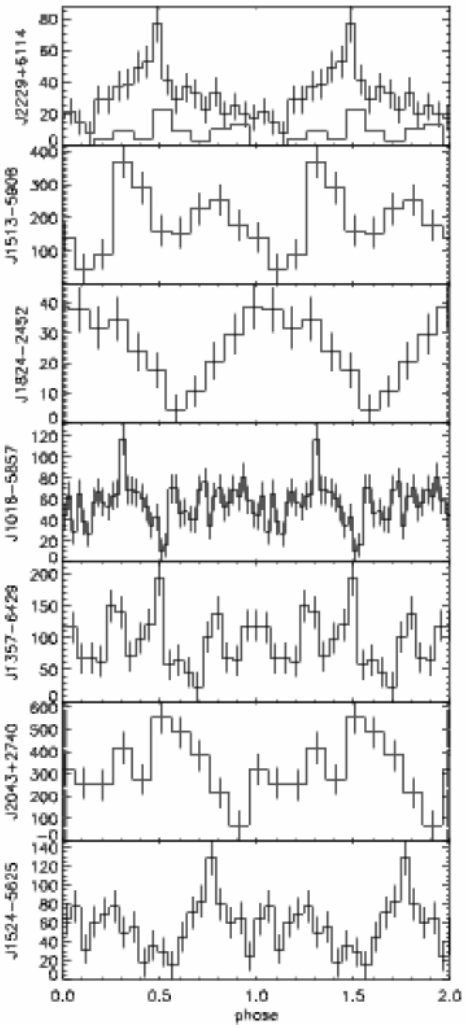
J1016-5857: possibly 3EG source

J1357-6429

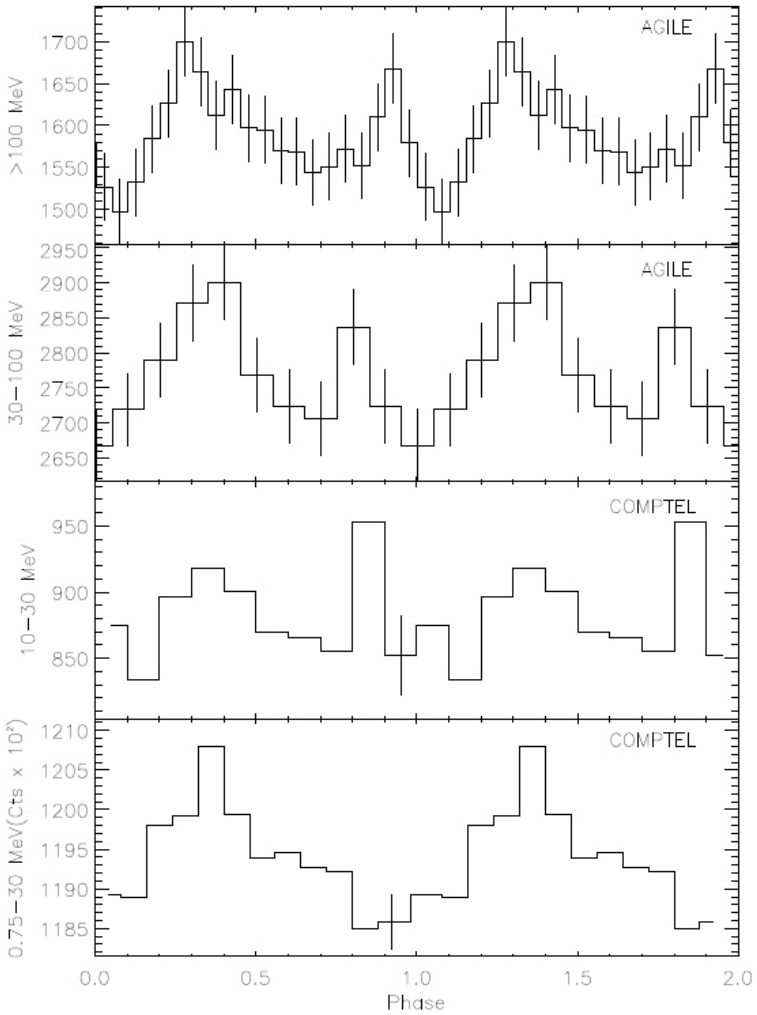
J2043+2740: oldest gamma-ray pulsar

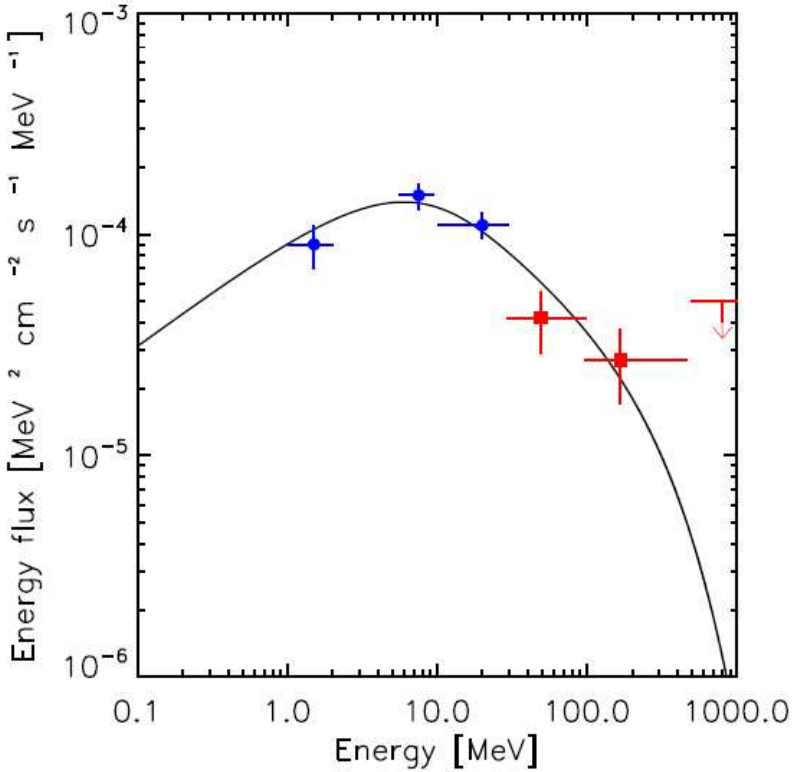
J1524-5625

Pellizzoni et al., 2009



PSR B1509-59



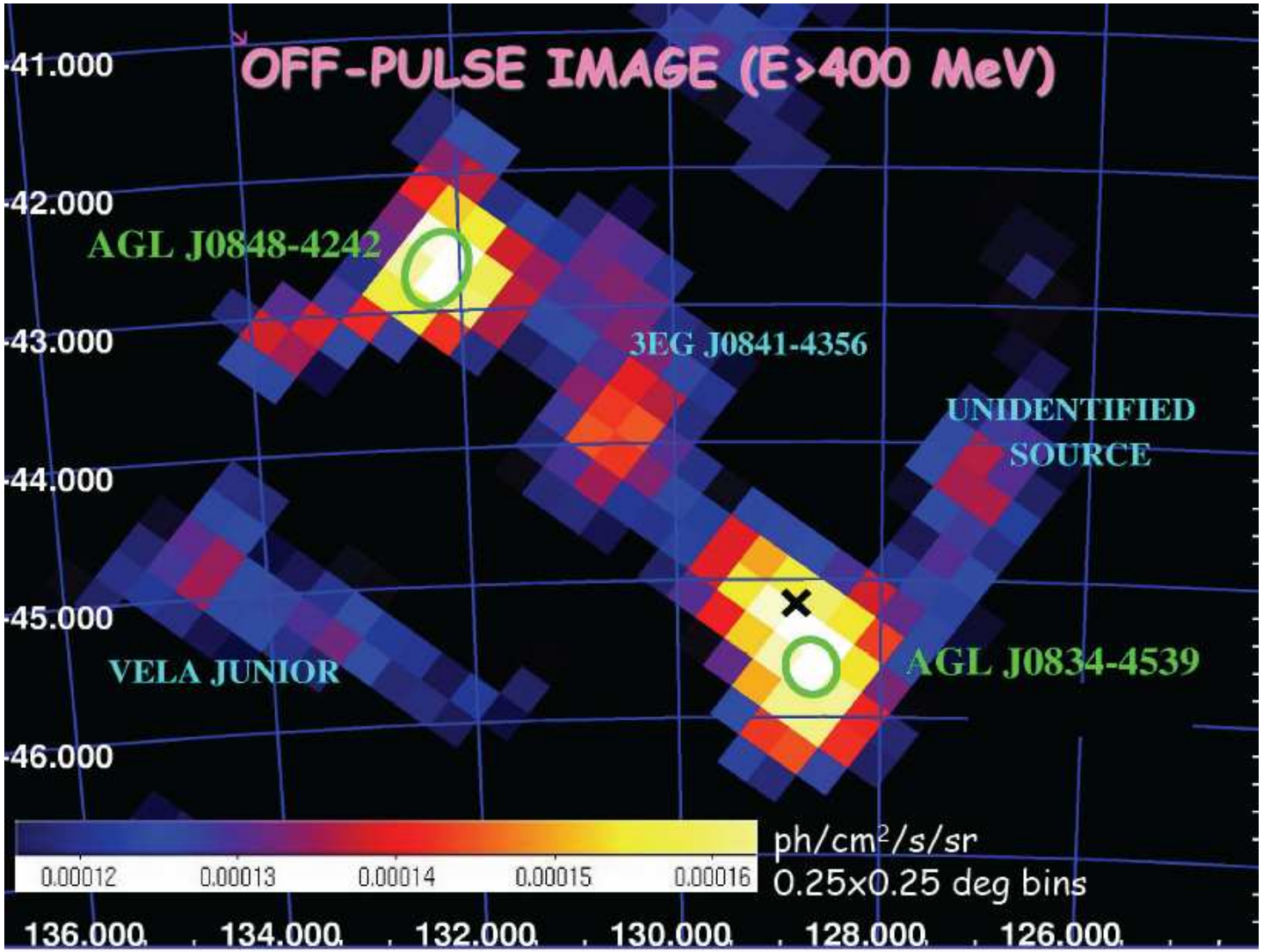


COMPTEL

AGILE

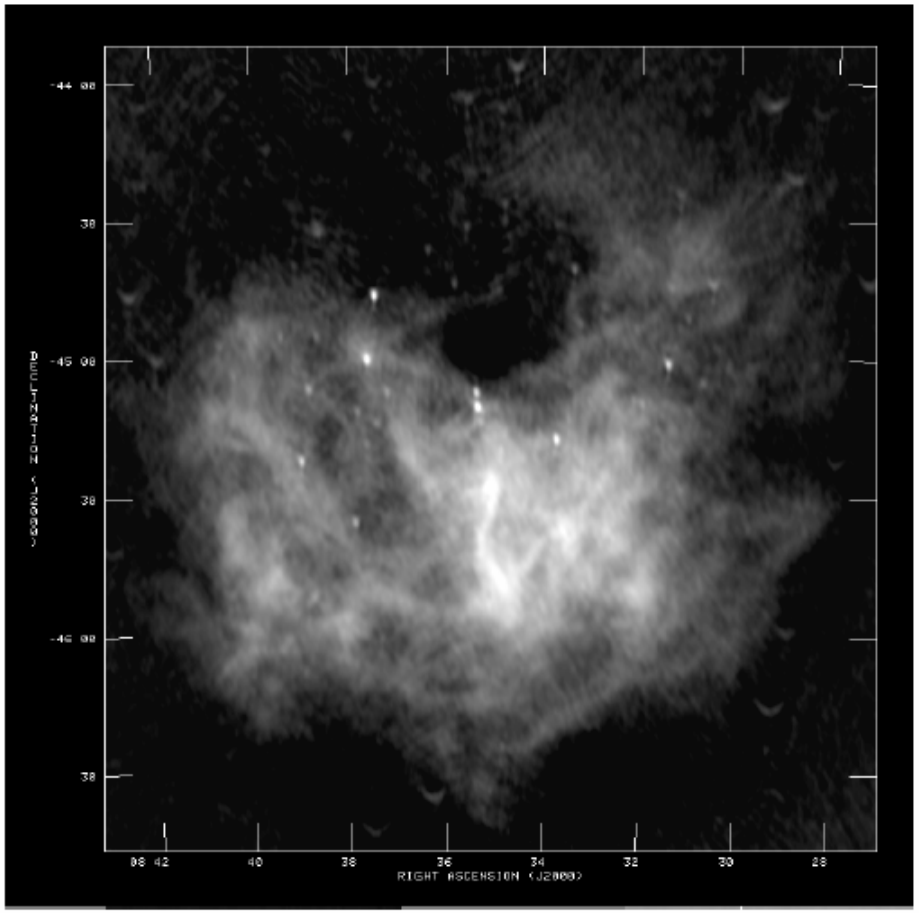
(Pilia et al., 2010, submitted to ApJ)

The Vela X region
(Pellizzoni et al., 2010, Science)



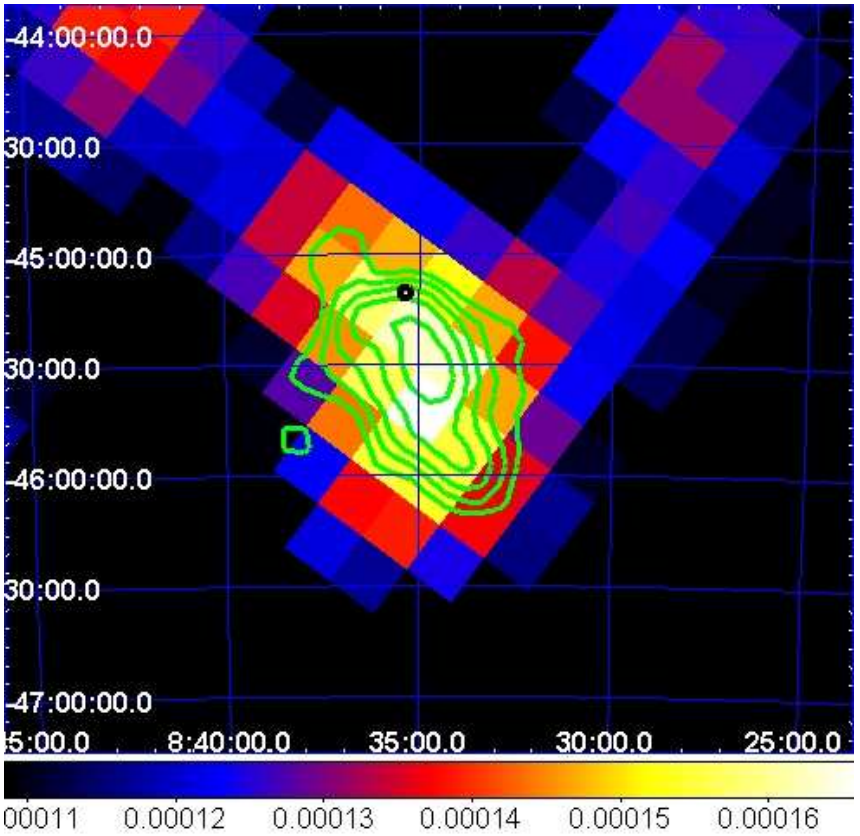
Vela X pulsar wind nebula

Radio map (90 cm)



AGILE gamma-ray map

(E > 100 MeV) + HESS contours

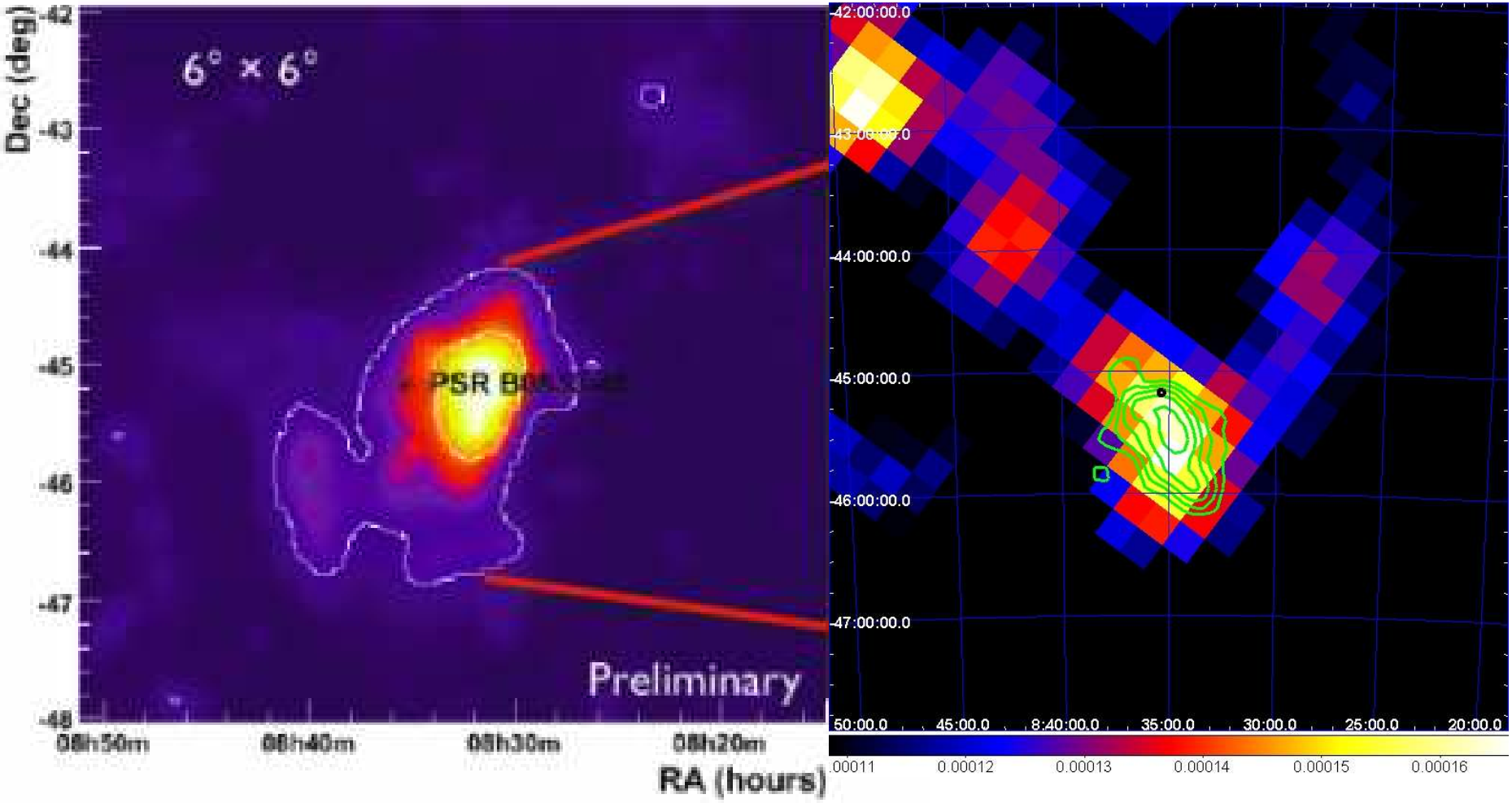


Vela-X, Fermi-AGILE difference

TS map

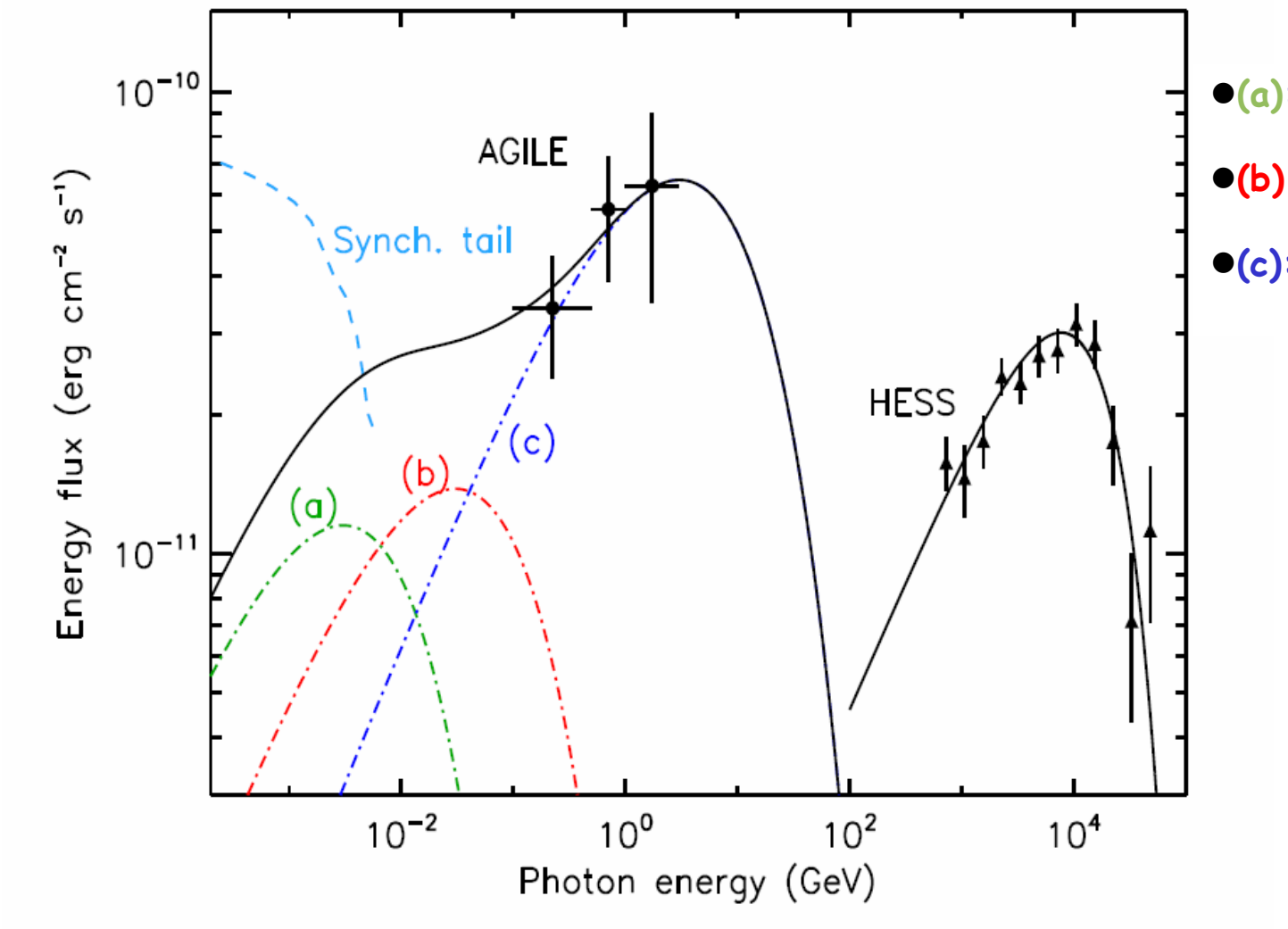
FERMI (E > 800 MeV)

AGILE (E > 100 MeV)



Vela X PWN spectrum

(Pellizzoni et al., 2010, Science)



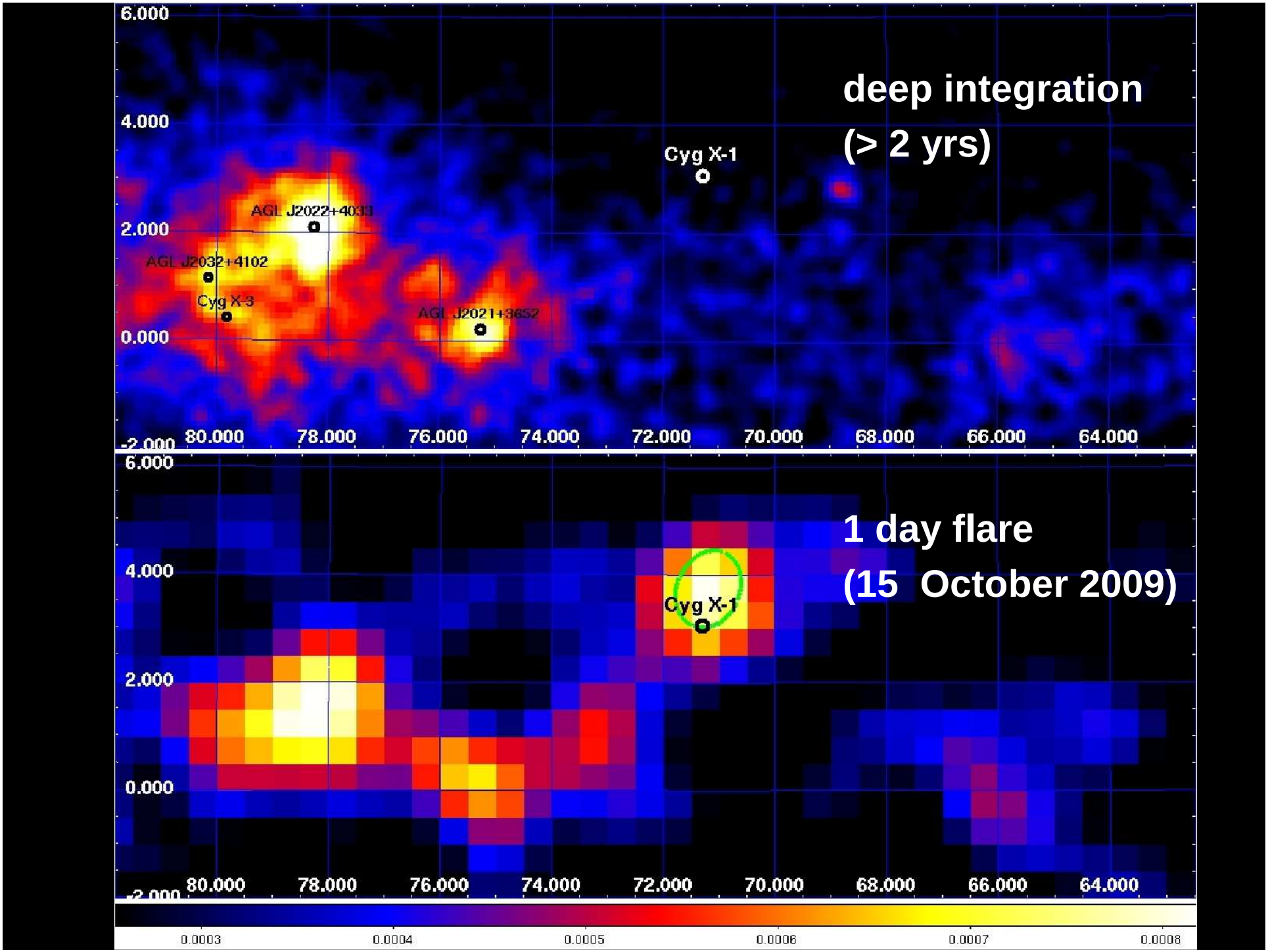
- (a): IC on CMBR
- (b): IC on FIR
- (c): IC on starlight

AGILE observations of microquasars

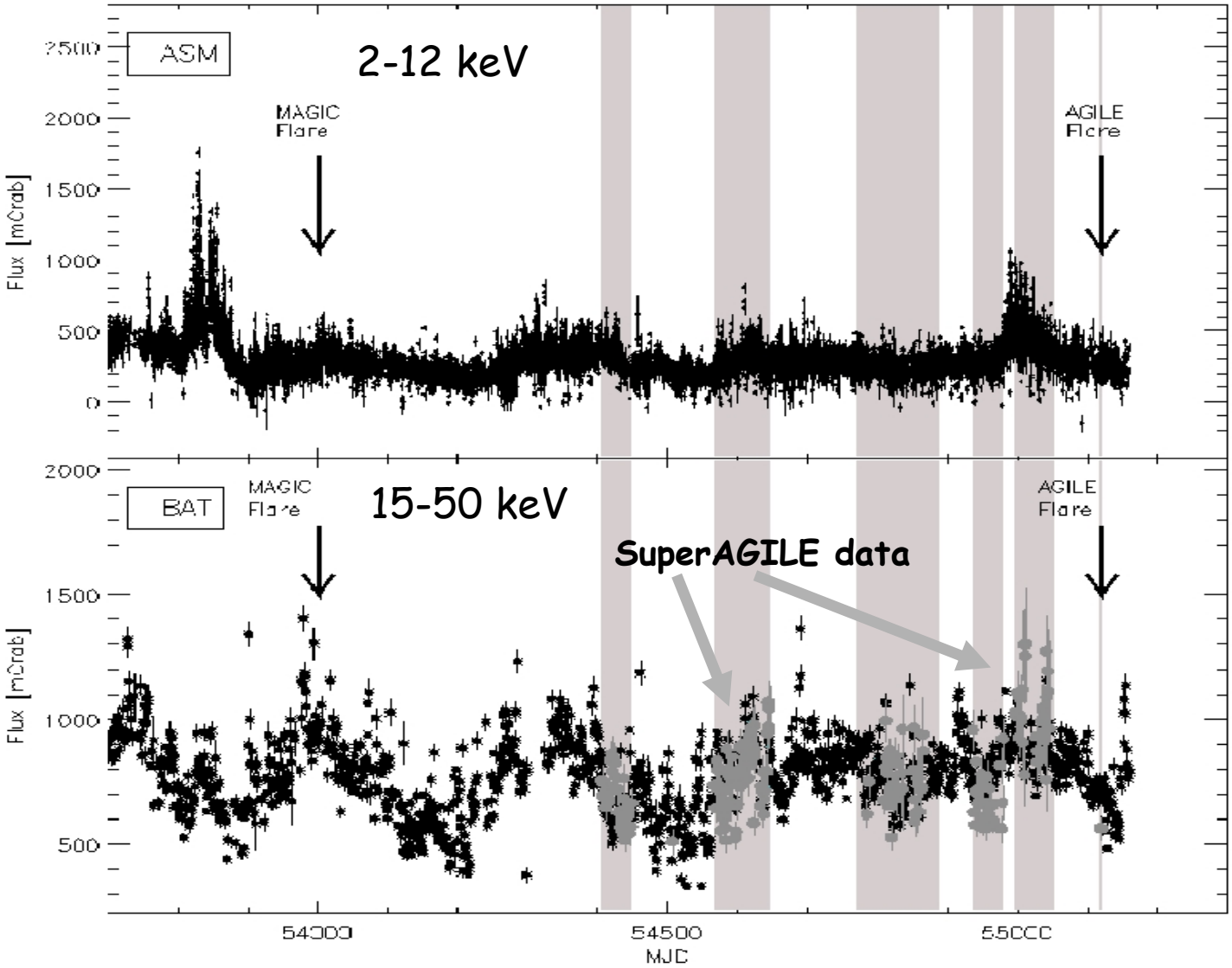
- **Cyg X-1: sporadic gamma-ray emission from (Sabatini et al., 2010, ApJL)**
- **Cygnus X-3: currently the most prolific above 100 MeV (Tavani et al., 2010, Nature)**
- **LSI +61 303, LS 5039: work in progress**
- **Non-detections (so far) of other microquasars despite many AGILE monitoring observations (hard X-rays and gamma-rays)**

AGILE observation of Cyg X-1

- **S.Sabatini, M.Tavani, E.Del Monte et al.**


deep integration
(> 2 yrs)
Cyg X-1
AGL J2022+4033
AGL J2032+4102
Cyg X-3
AGL J2021+3652
1 day flare
(15 October 2009)
Cyg X-1
6.000
4.000
2.000
0.000
-2.000
80.000
78.000
76.000
74.000
72.000
70.000
68.000
66.000
64.000
0.0003
0.0004
0.0005
0.0006
0.0007
0.0008

Flaring CygX-1
(Sabatini et al., 2010, ApJL)

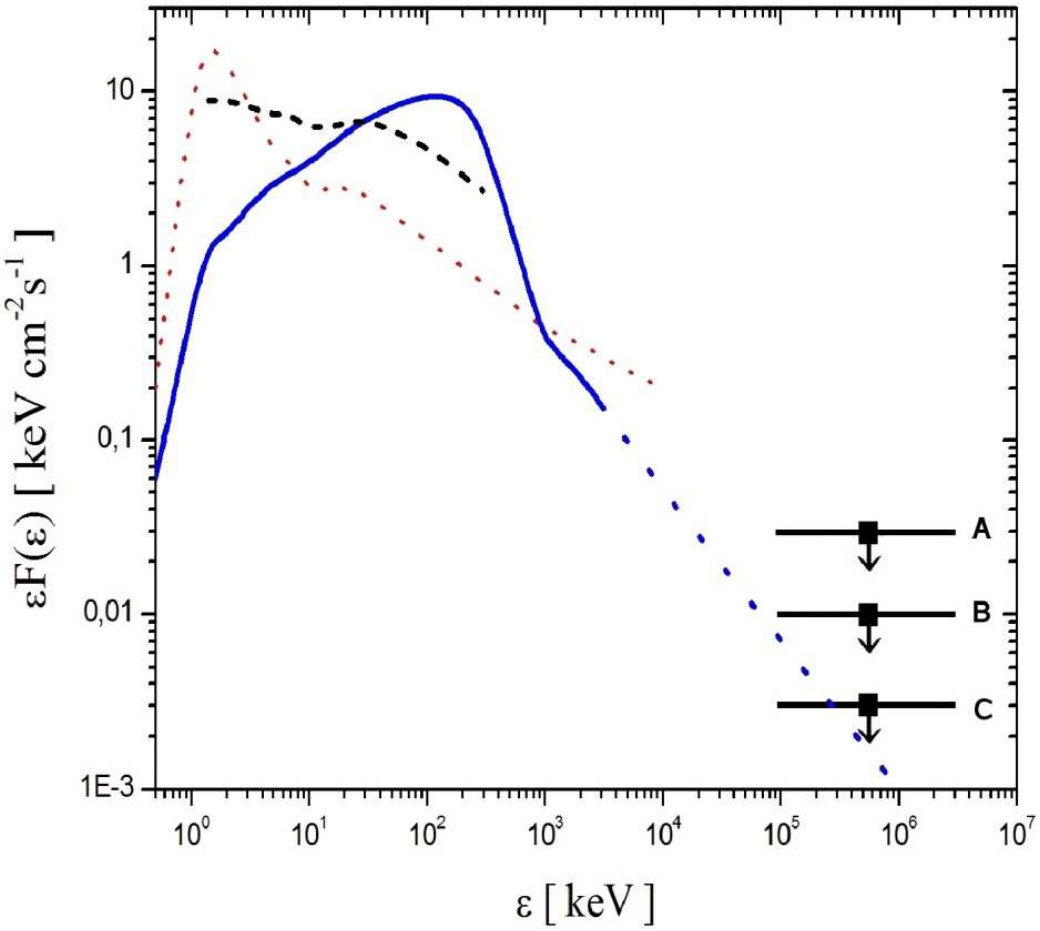


CygX-1 Spectral Energy Distribution
(Sabatini et al., 2010, ApJL)

Spectral energy distribution in tipical 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")**

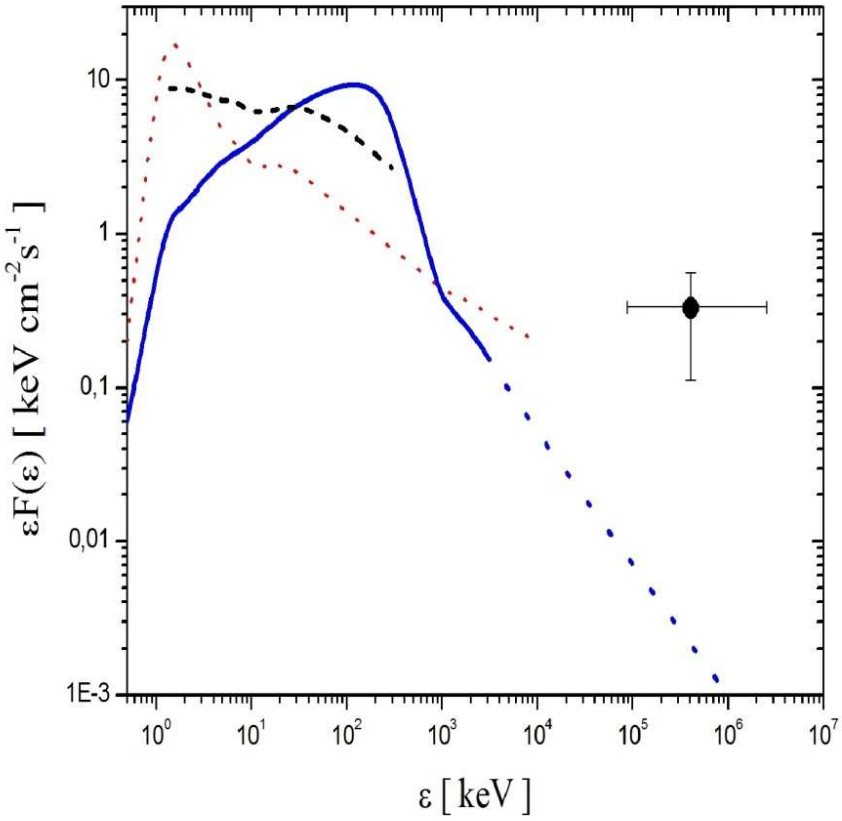
->average gamma-ray spectra in hard-state: a spectral cut-off



CygX-1 Spectral Energy Distribution

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*)

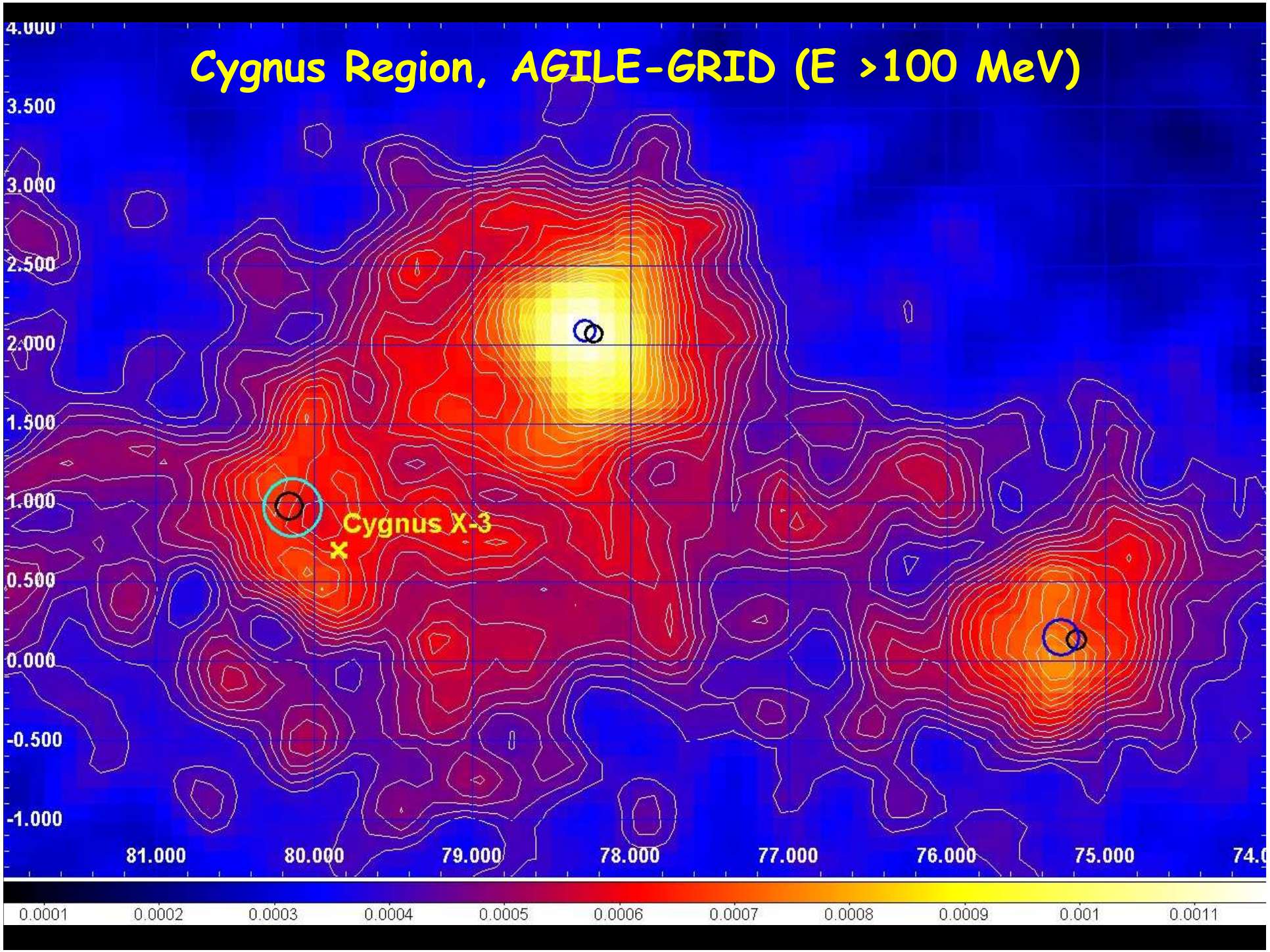
AGILE observation of Cyg X-3

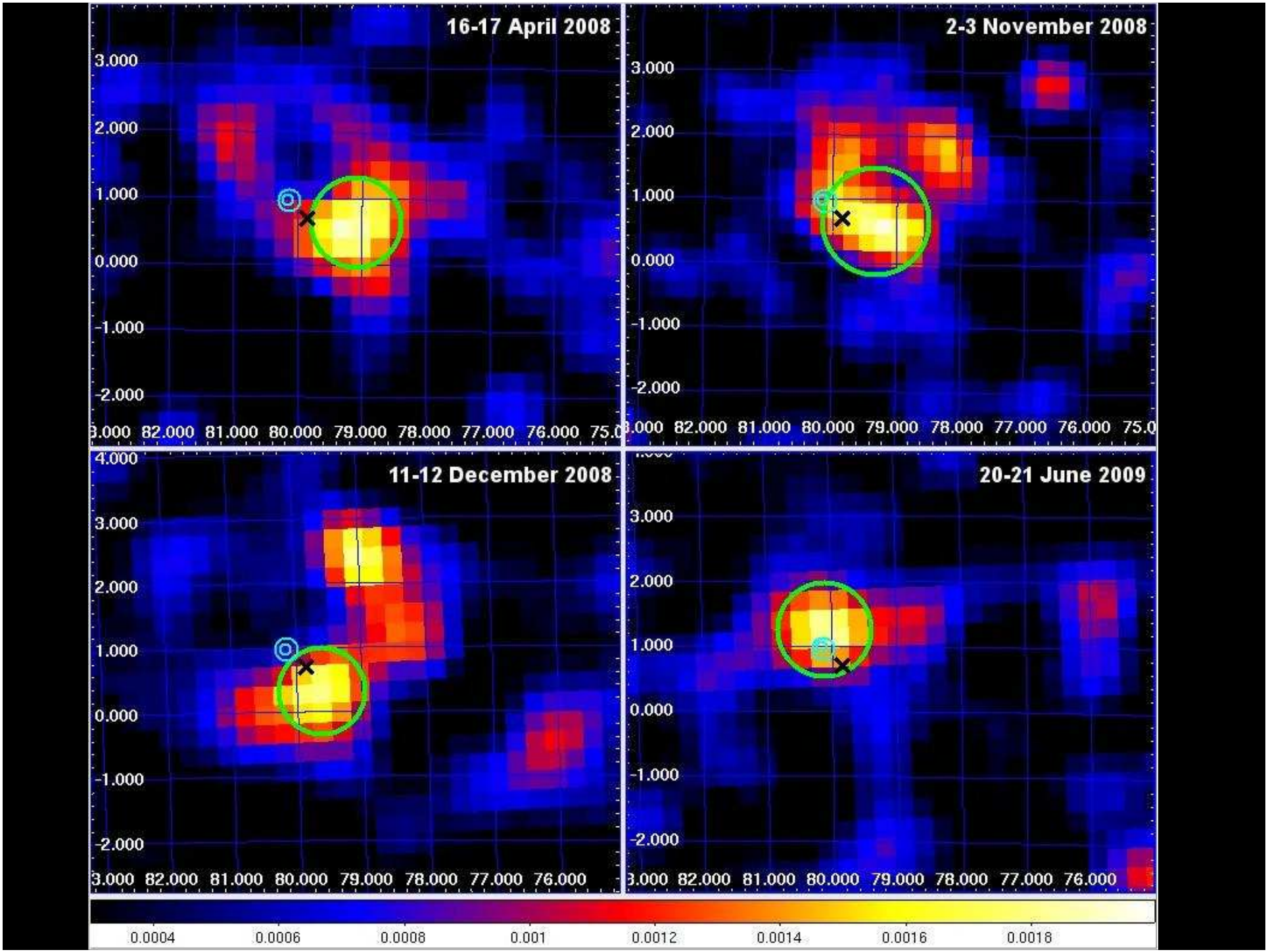
- **M.Tavani, A.Bulgarelli, S.Sabatini et al.**

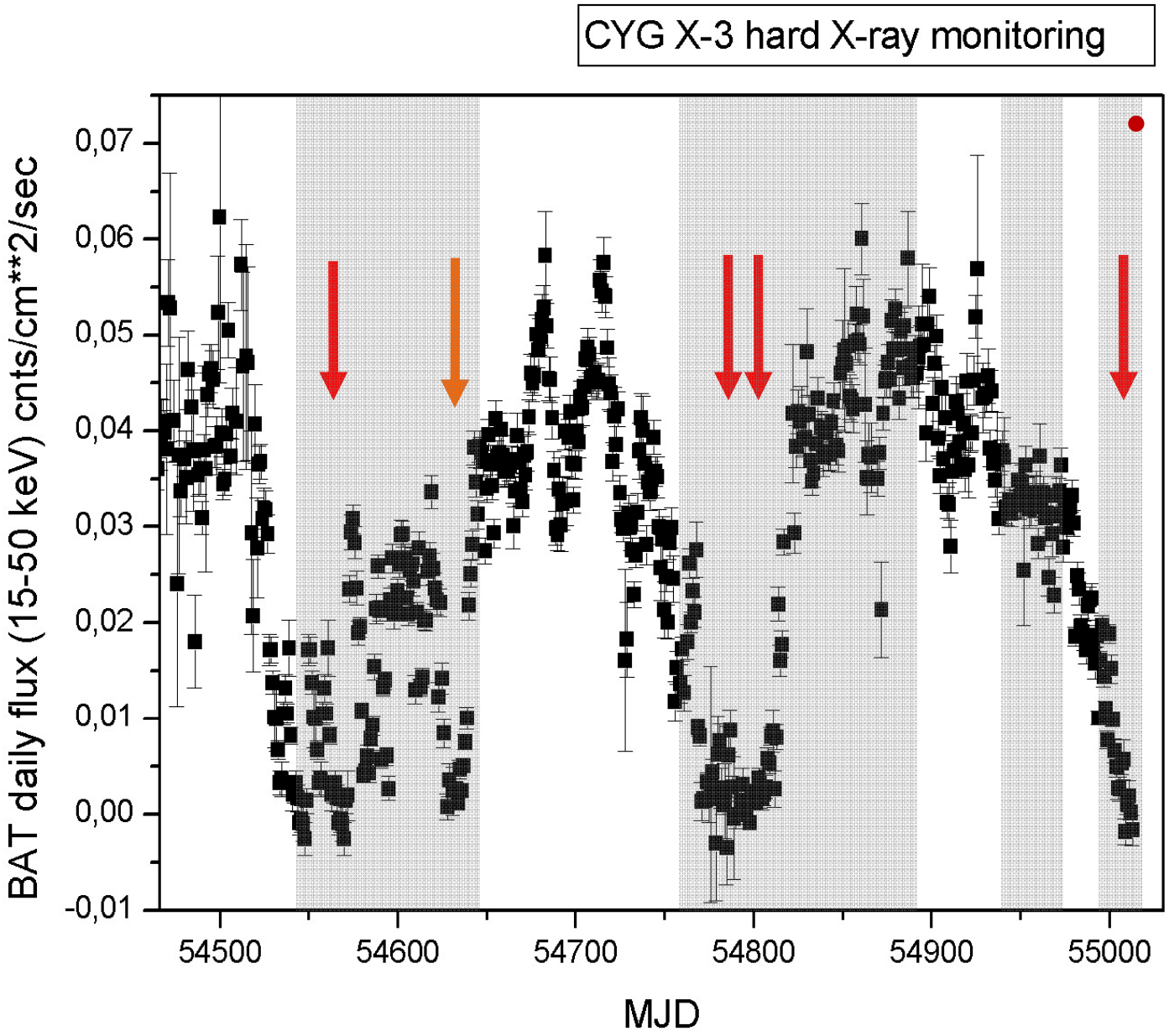
AGILE and Cygnus X-3

(Tavani et al., 2010, Nature)

- **AGILE detects weak persistent emission above 100 MeV and several gamma-ray flares from Cygnus X-3**
  - **16-17 Apr 2008**
  - **2-3 Nov 2008**
  - **11-12 Dec 2008**
  - **20-21 Jun 2009**
- **Flares are all associated with special CygX-3 radio and X-ray/hard X-ray states**
- **Gamma-ray flares usually *before* radio flares**


Cygnus Region, AGILE-GRID (E >100 MeV)
4.000
3.500
3.000
2.500
2.000
1.500
1.000
0.500
0.000
-0.500
-1.000
Cygnus X-3
81.000
80.000
79.000
78.000
77.000
76.000
75.000
0.0001
0.0002
0.0003
0.0004
0.0005
0.0006
0.0007
0.0008
0.0009
0.001
0.0011


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
4.000
82.000 81.000 80.000 79.000 78.000 77.000 76.000 75.0
0.0004 0.0006 0.0008 0.001 0.0012 0.0014 0.0016 0.0018



All gamma-ray flares occur either in coincidence with low hard-X-ray fluxes or during transitions from low hard-X-ray fluxes to high

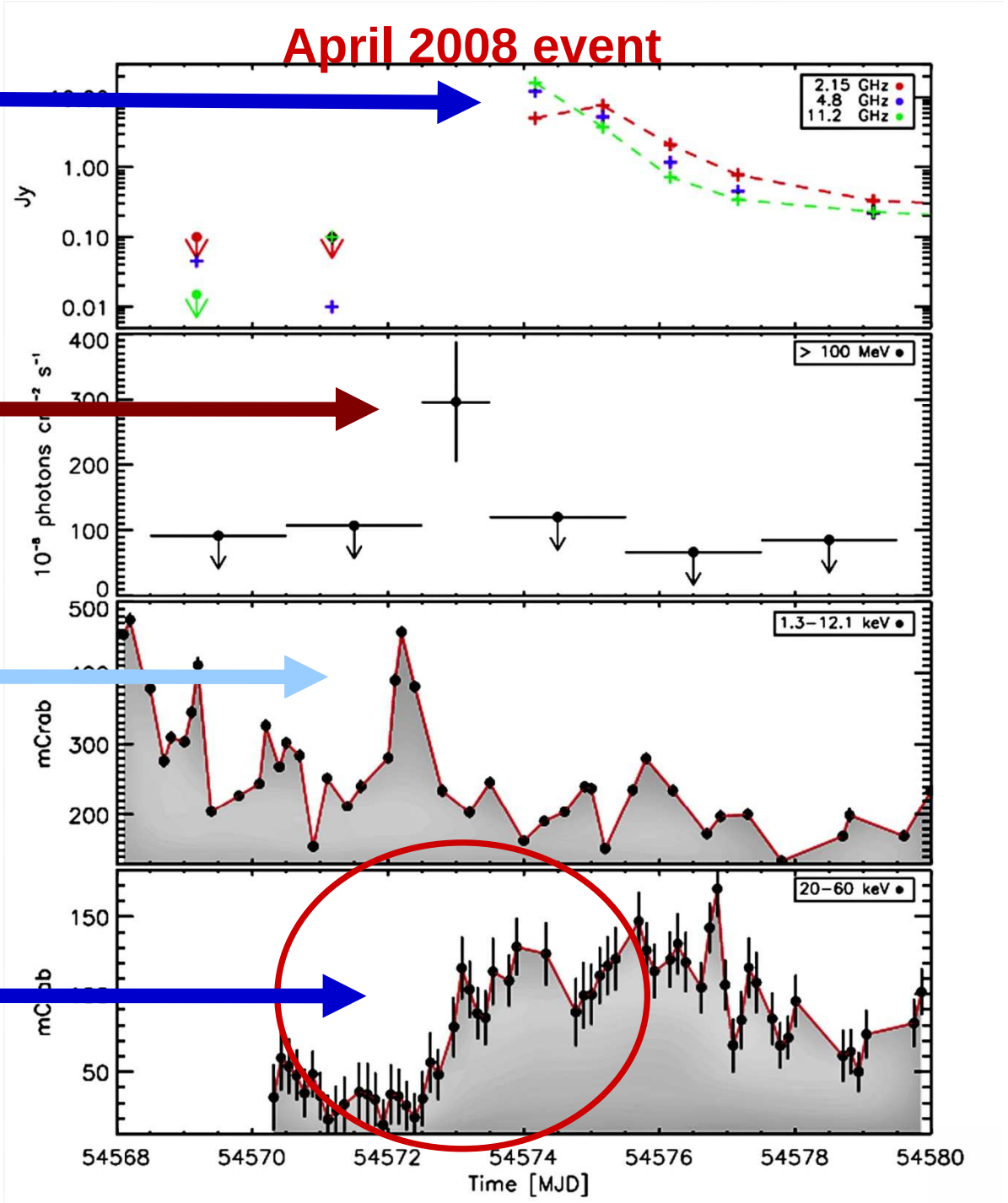
(Tavani et al., 2010, Nature)

very strong radio flare, presumably with jet ejection (~20 Jy)

Strong gamma-ray flare

X-ray (1-10 keV) flare

Hard X-ray flux state change (Super-A monitoring): from a soft X-ray to an intermediate hard X-ray



Gamma and Radio Flares

(Tavani et al., 2010, Nature)

Gamma-ray flares tend to occur in the **rare** low-flux/pre-flare radio states.

For all gamma-ray flaring episodes, the radio and hard-X-ray fluxes are low or very low, while the soft X-ray flux is large

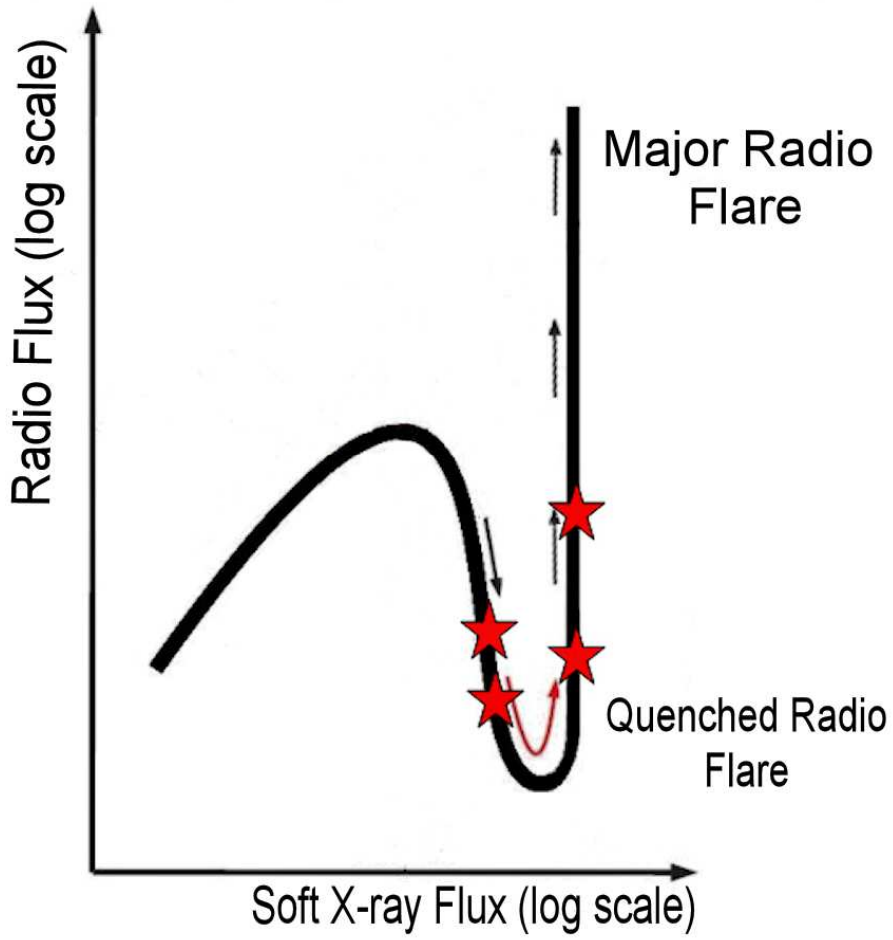


figure adapted from Szostek Zdziarski & McCollough (2008)

The mystery of Galactic Gamma-ray Transients

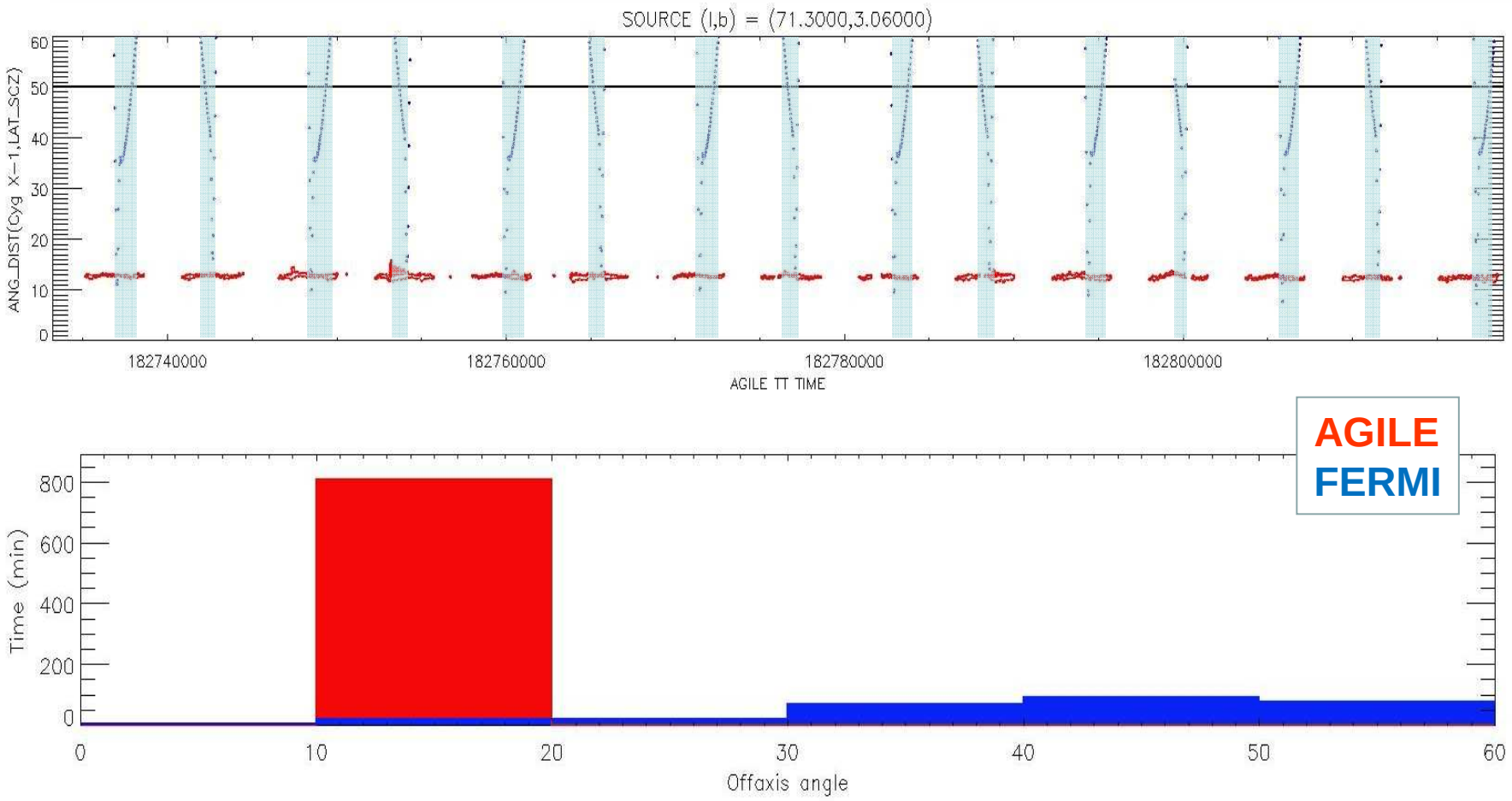
- **M.Tavani, A.Bulgarelli, S.Sabatini, A.Chen, G.Piano, F.Verrecchia et al.**

The Galactic Gamma-ray Transients

- **AGILE detects several candidates (usually low-energy), announced in several ATels**
  - **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**

AGILE and Fermi time coverage and off-axis angle

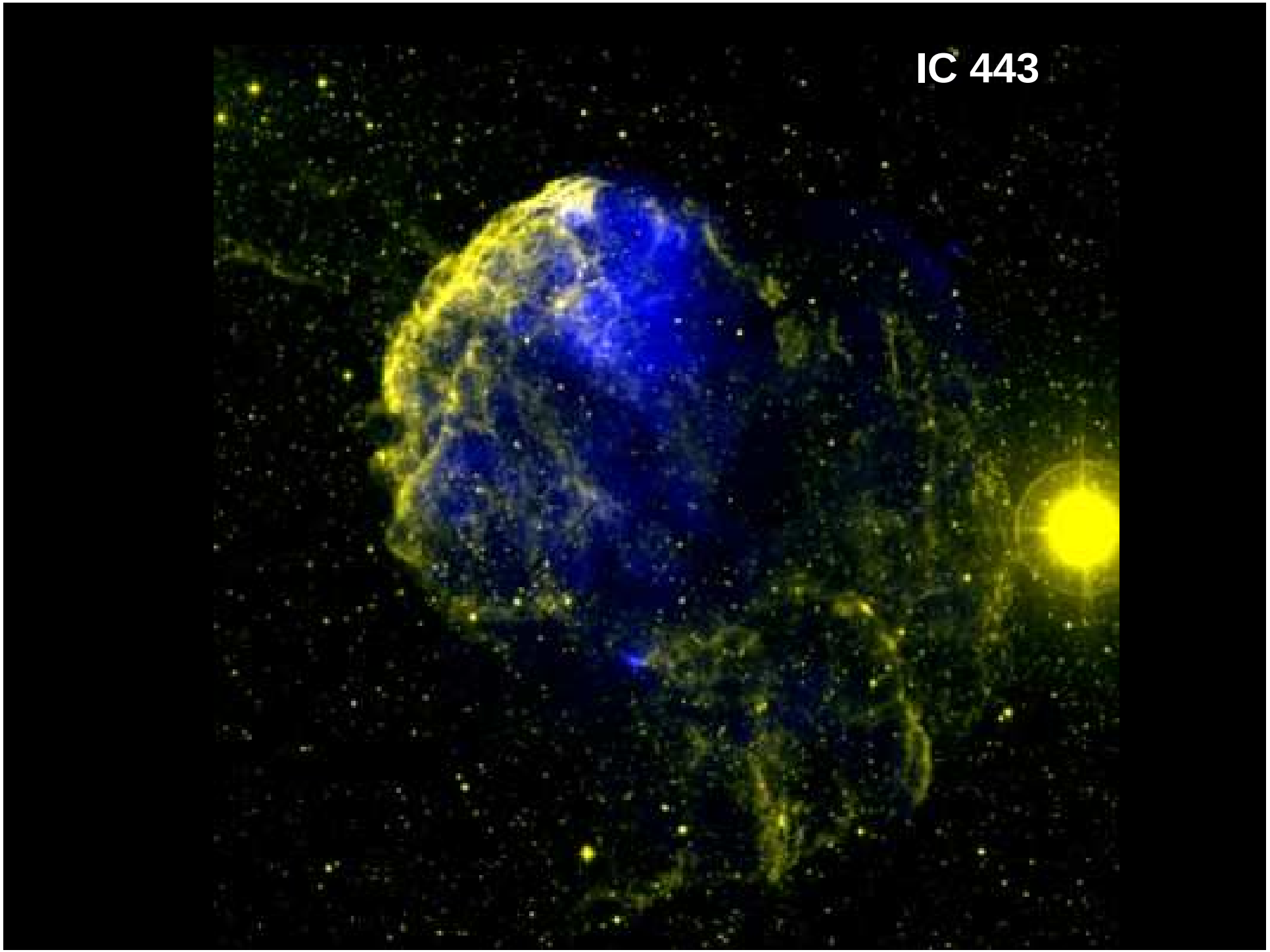
Orbit-by-orbit <u>SOURCE VISIBILITY</u>



Example of Cyg-X1 flare, 15-16 October 2009

Supernova Remnants and Molecular Clouds

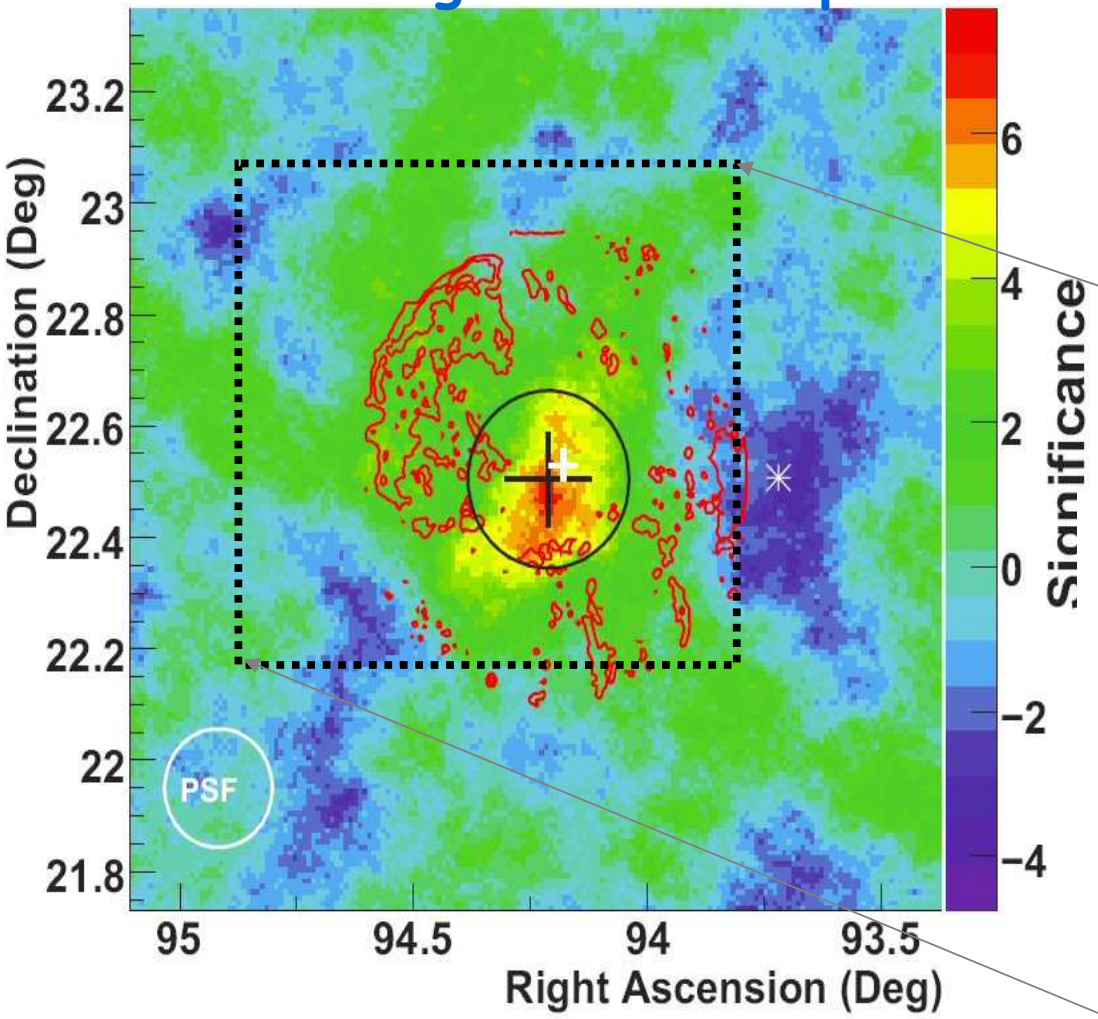
- **A.Giuliani, M.Tavani, A.Chen, G.Piano et al.**


IC 443

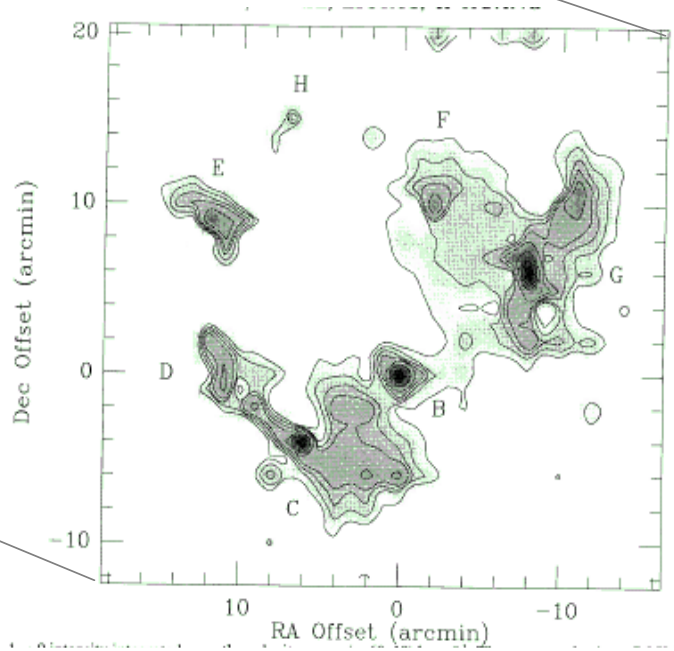
IC 443 – SNR and molecular clouds

(Tavani et al., 2010, ApJL)

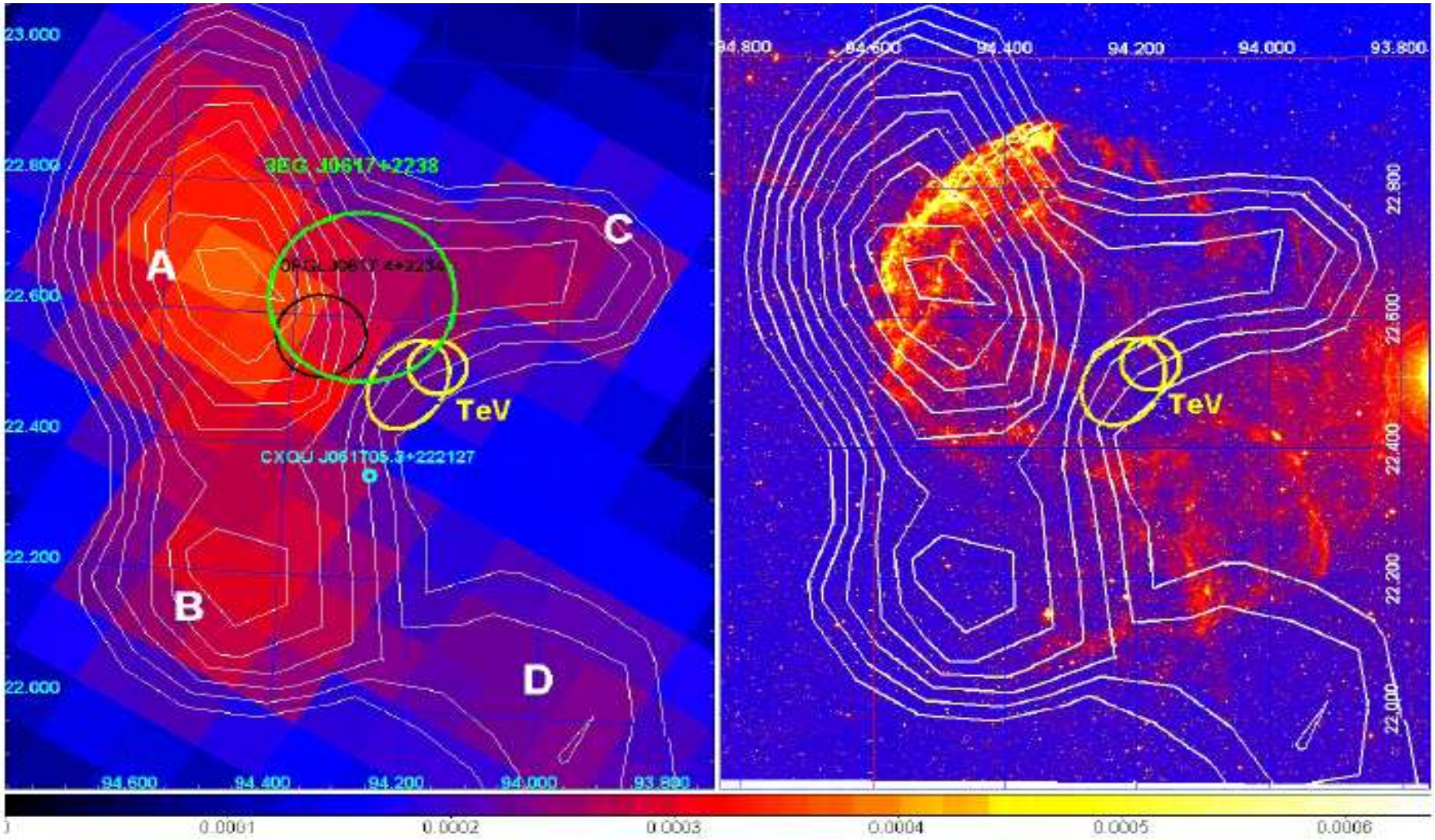
TeV significance map



Asymmetric shape: NE rim, SE shell, dense very massive central molecular cloud

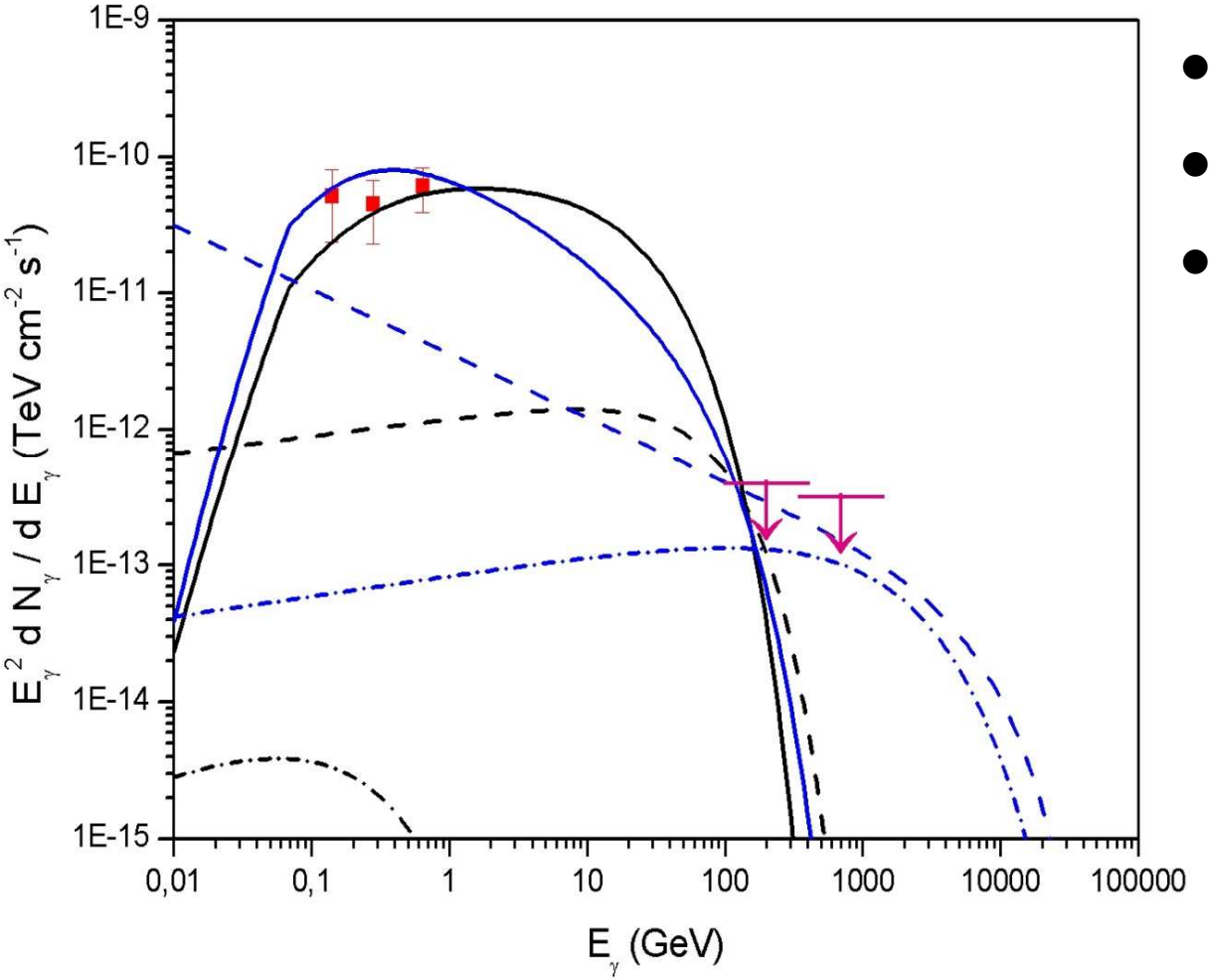


IC 443 imaged by AGILE (2009)



Hadronic models for IC 443

(Tavani et al., 2010, ApJL)

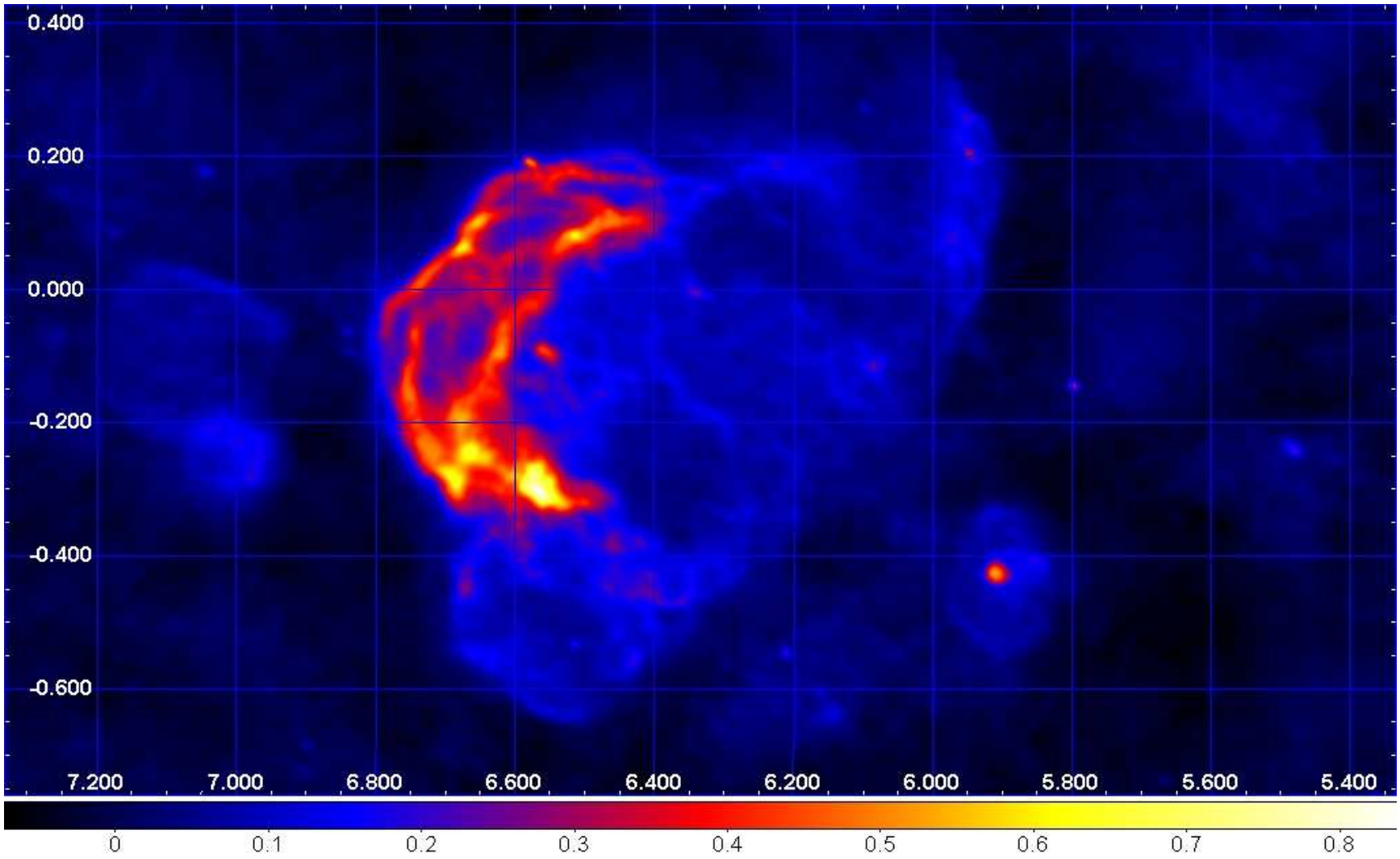


- solid: hadronic model
- dashed: bremm. by e^-
- short dashed: e^- IC

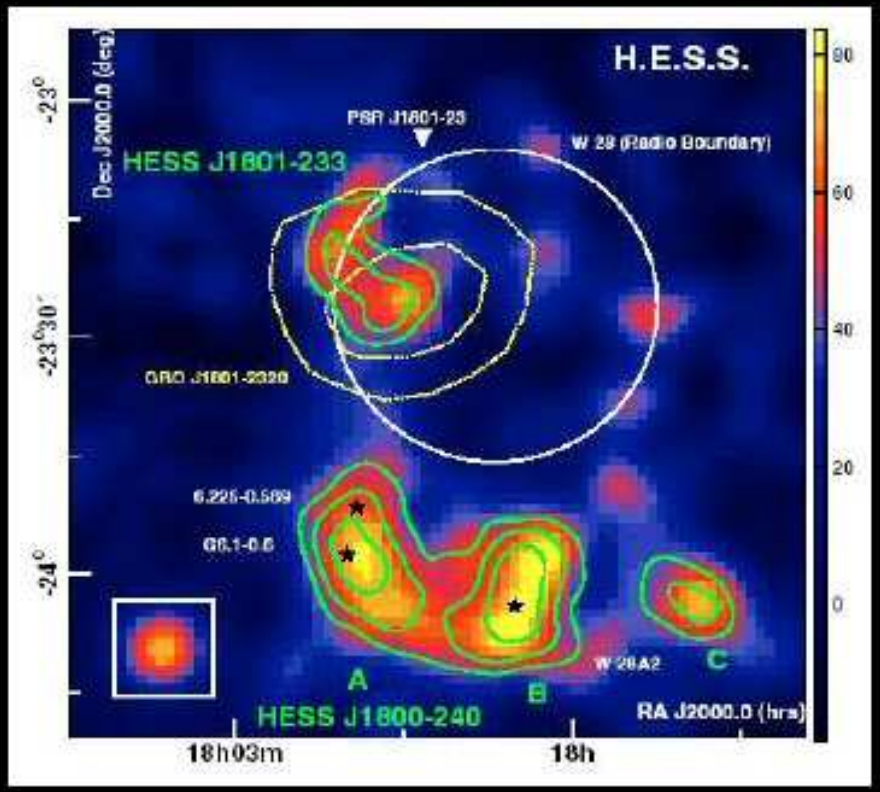
Facts on IC 443

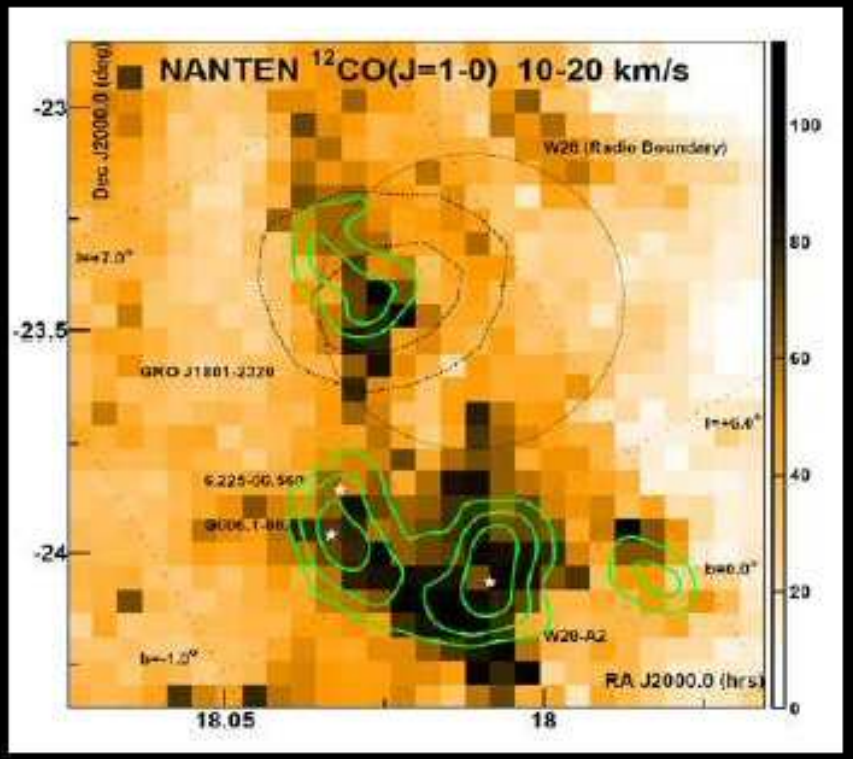
- **~100 MeV source and TeV source are non coincident**
- **absence of IC emission above 10-100 GeV at cloud "E":**
  - **electron/proton ratio ~10^{-2} (see also Gaisser et al. 1998)**
- **absence of prominent TeV emission along the SN shock front (and of non-thermal X-ray emission):**
  - **electron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

W 28, VLA radio imaging, 90 cm
(Brogan et al.)

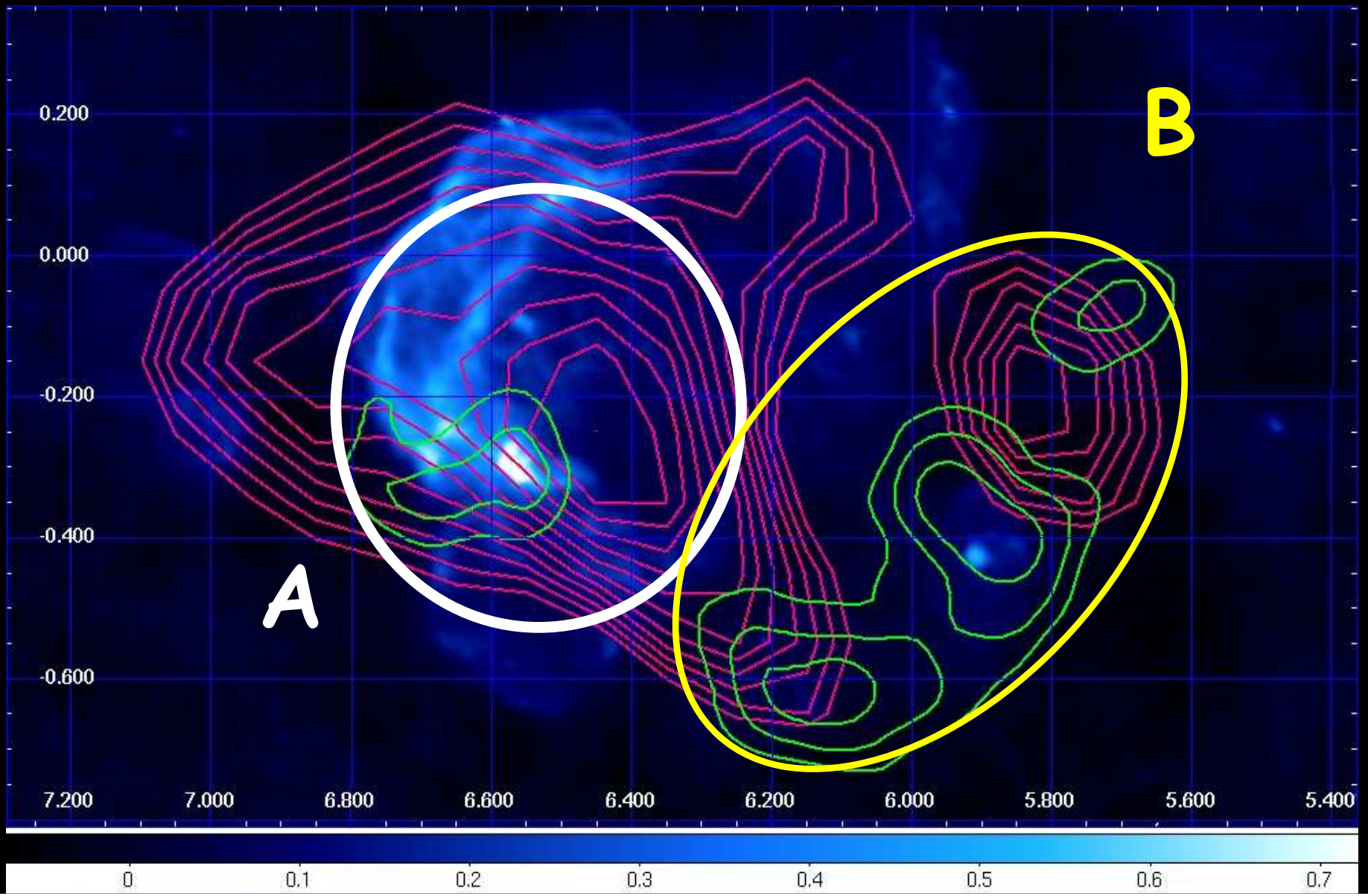


SNR W28:
HESS TeV emission



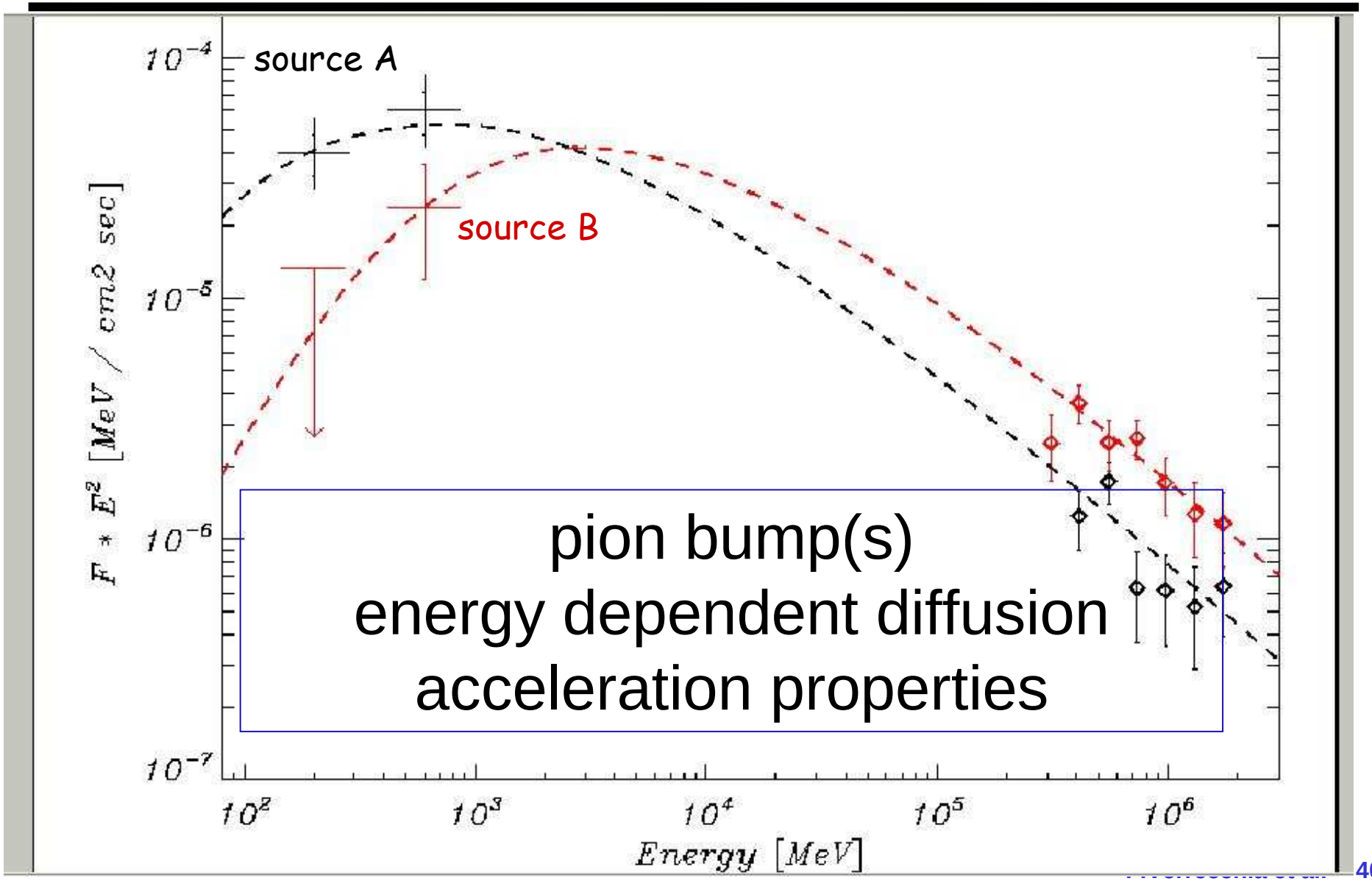


W 28, gamma-ray emission
(AGILE, E > 400 MeV) + TeV contours



W 28, High Energy Spectrum

(Giuliani et al., 2010, accepted by A&A)



SuperAGILE long term monitoring of the HMXB GX 301-2

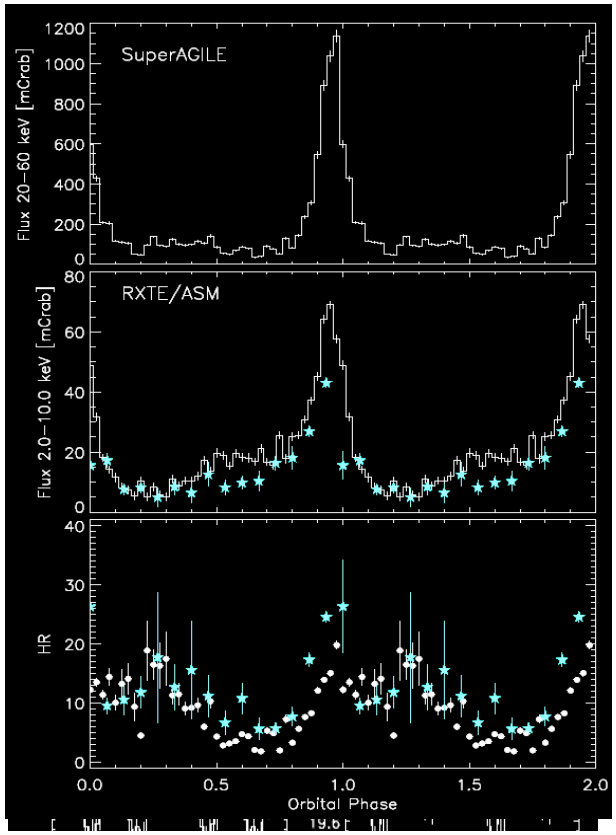
Evangelista et al., ApJ, 708, 1663, 2009

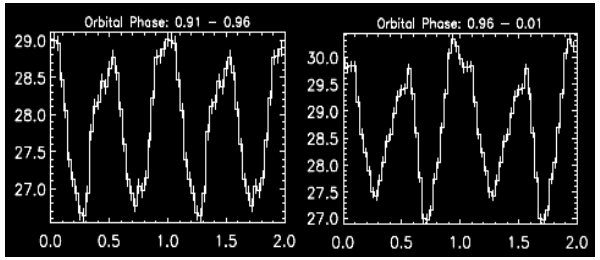
SuperAGILE has monitored the source quite continuously for a total **net exposure time of 3.7 Ms. All orbital phases covered**

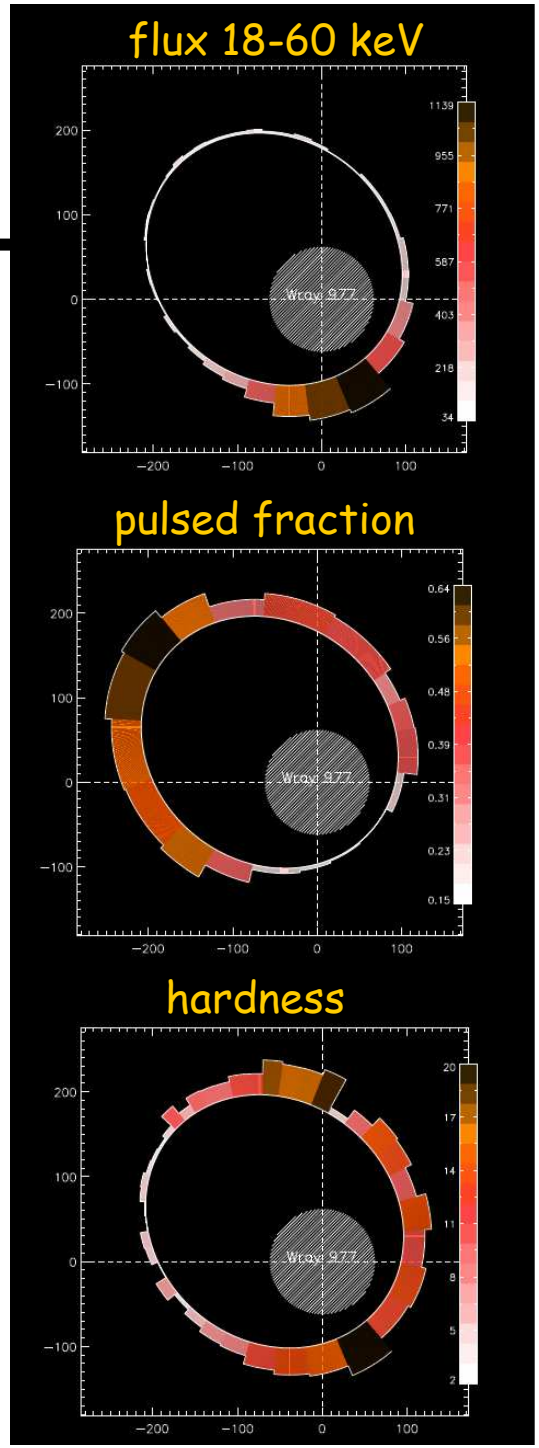
We perform spectral and timing analysis

Spectral analysis:
Behavior of the **hardness-ratio as a function of the orbital phase** and comparison with Leahy stream+wind model

Timing analysis:
Pulse shape profile and **pulsed fraction** variation **during the whole** system **orbital period.**







Conclusions

- **Very exciting time for Galactic gamma-ray source studies, with AGILE and FERMI**
- **AGILE has a good sensitivity near 100 MeV, a crucial energy range to study the evidence of proton acceleration (“pion bump”); good results also in studies of other source classes (PSRs)**
- **Promising Searches for PWNe using detailed PSR tools**
- **Remarkable Cyg X-3 detection: a “clock” with a clear pattern of gamma-ray emission; Cyg X-1 also detected and more sporadic**
- **AGILE has direct evidence of (hadronic) CR acceleration in IC 443 and W28, others are being studied.**

Thank you