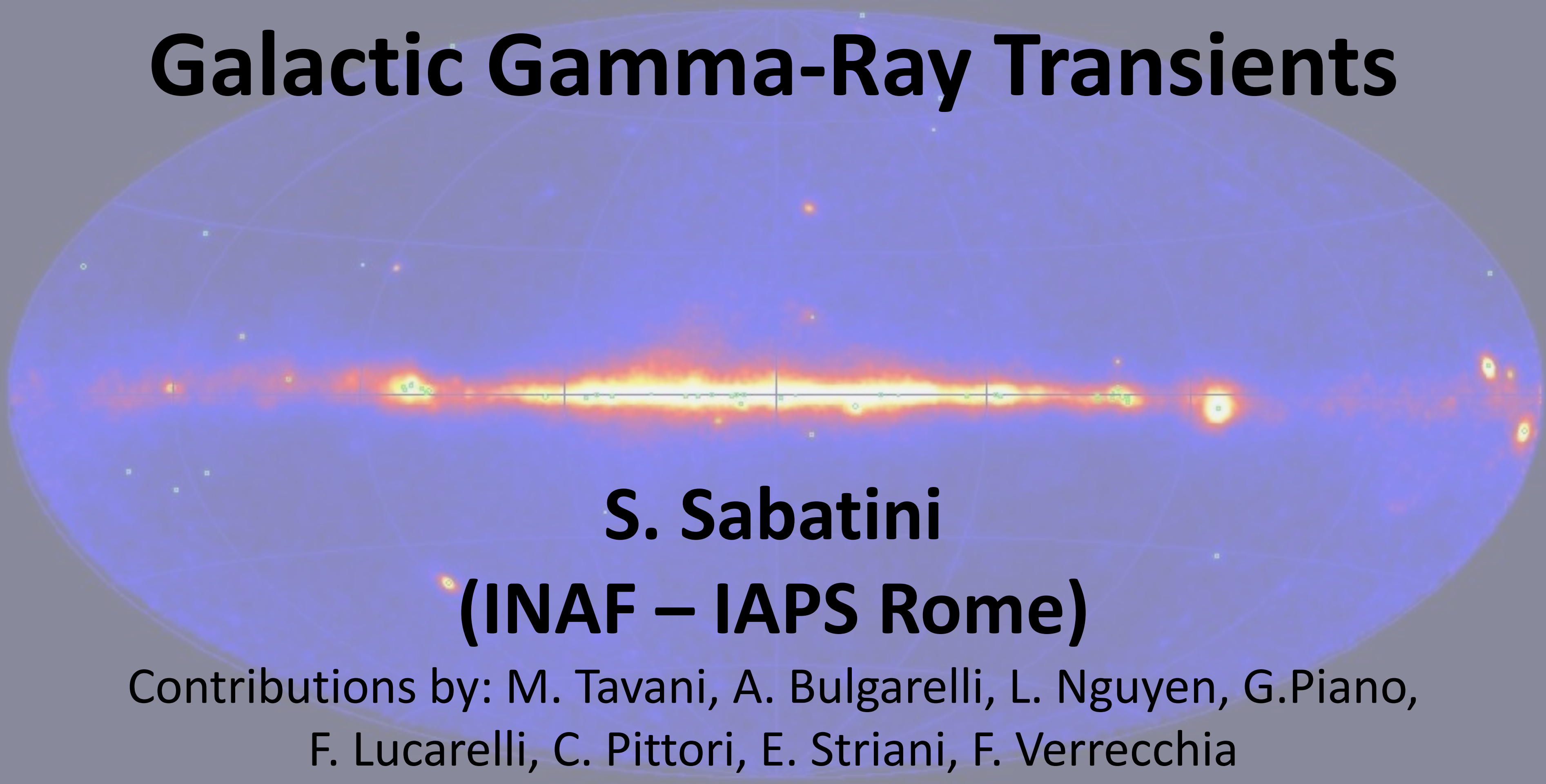
Galactic Gamma-Ray Transients



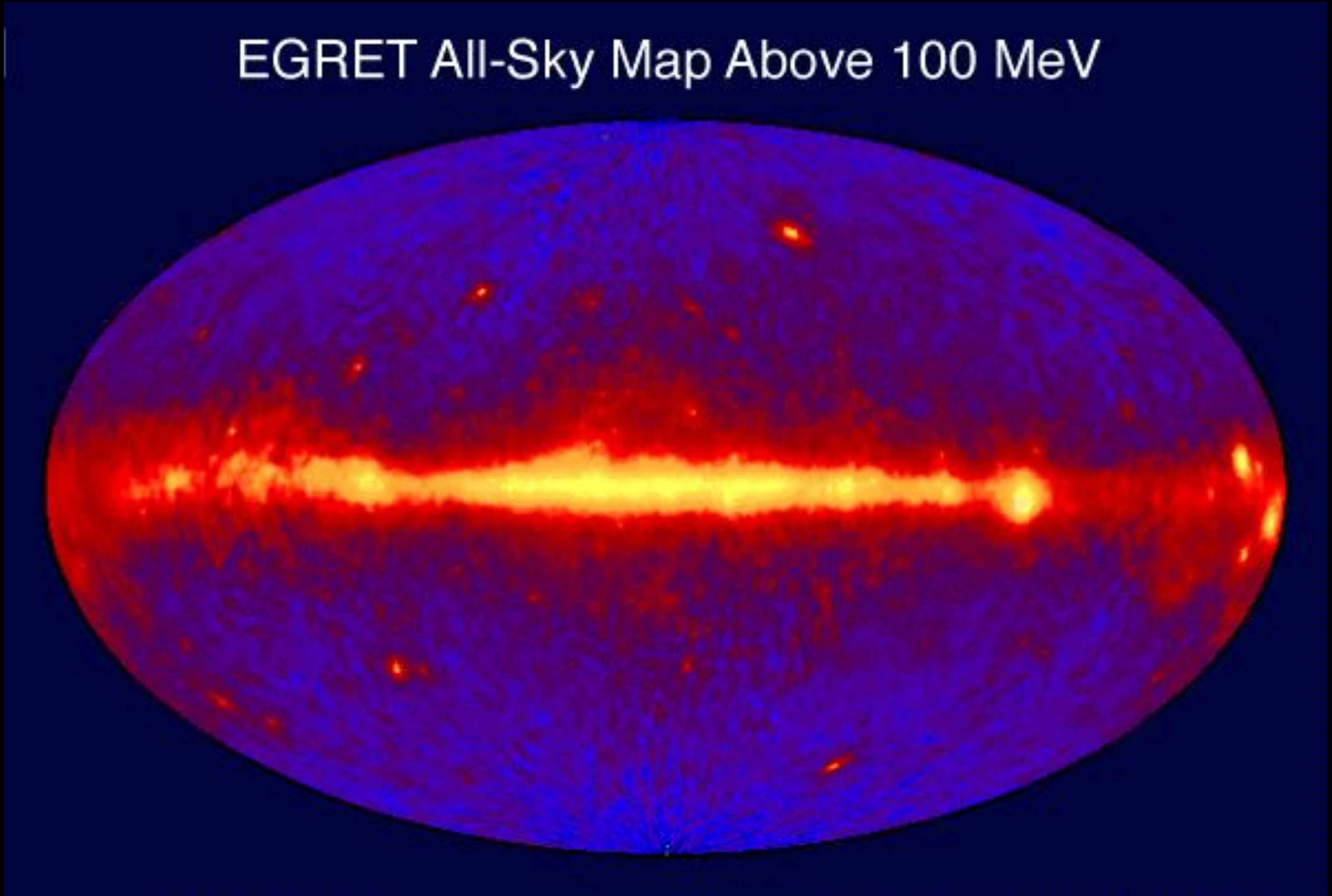
S. Sabatini

(INAF – IAPS Rome)

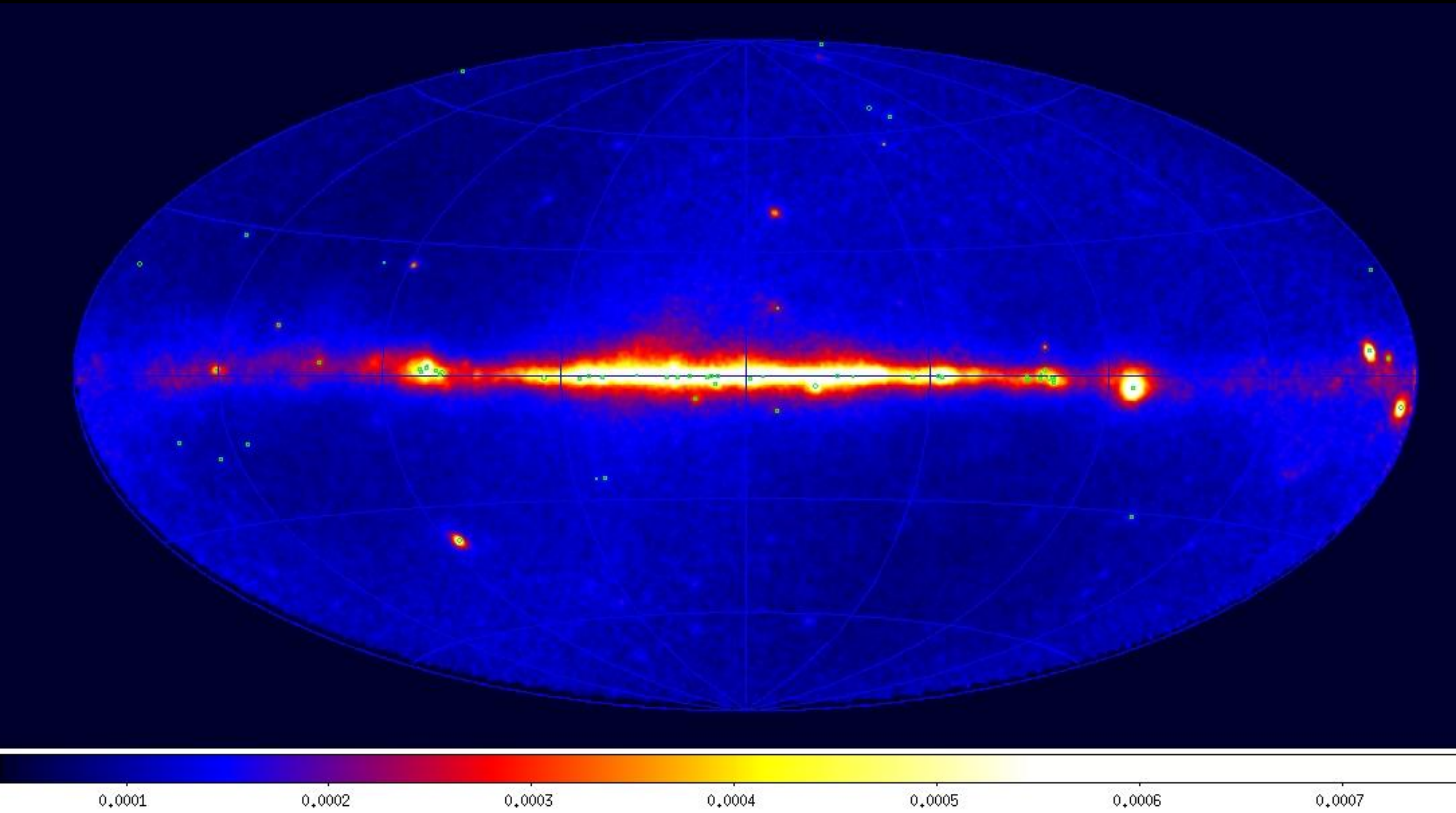
Contributions by: M. Tavani, A. Bulgarelli, L. Nguyen, G.Piano, F. Lucarelli, C. Pittori, E. Striani, F. Verrecchia

Gamma-Ray Galactic Transients

- **EGRET, some detection/hints**
  - one-time transient: e.g., GRO J1838-04 (Tavani et al. 1997)
  - variable emission from LSI 61 303, LS5039



AGILE 5.5 year all sky map



5.5-years exposure γ-ray sky (E > 100 MeV)
2007, July – 2012, Dec

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  - variable emission from LSI 61 303, LS5039
- AGILE detection of several candidates (usually low-energy)
  - Cygnus transients
  - Crux Region transients
  - Carina Region transients
  - Eta-Car
  - Galactic Center transients (March 09)
  - Unidentified (l= 17, l = 8 ....)

Gamma-Ray Galactic Transients

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  - example: GRO J1838-04 (Tav
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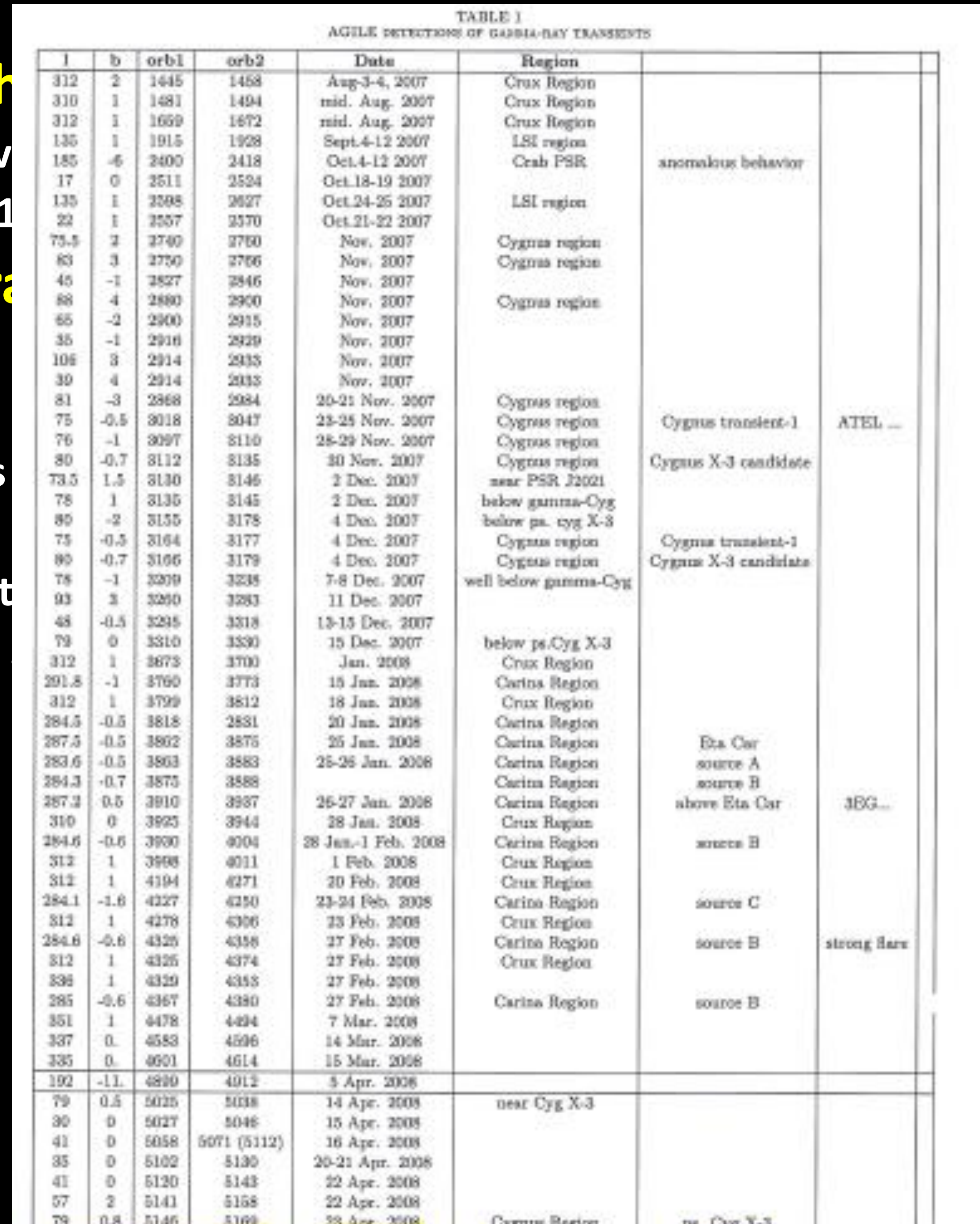

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AGILE detections of gamma-ray transients

l	b	orb1	orb2	Date	Region		
312	2	1445	1458	Aug-3-4, 2007	Crux Region		
310	1	1481	1494	mid. Aug. 2007	Crux Region		
312	1	1659	1672	mid. Aug. 2007	Crux Region		
135	1	1915	1928	Sept.4-12 2007	LSI region		
185	-6	2400	2418	Oct.4-12 2007	Crab PSR	anomalous behavior	
17	0	2511	2524	Oct.18-19 2007			
135	1	2598	2627	Oct.24-25 2007	LSI region		
22	1	2557	2570	Oct.21-22 2007			
73.5	2	2740	2760	Nov. 2007	Cygnus region		
83	3	2750	2766	Nov. 2007	Cygnus region		
45	-1	2827	2846	Nov. 2007			
88	4	2880	2900	Nov. 2007	Cygnus region		
65	-2	2900	2915	Nov. 2007			
35	-1	2916	2929	Nov. 2007			
106	3	2914	2933	Nov. 2007			
39	4	2914	2933	Nov. 2007			
81	-3	2868	2984	20-21 Nov. 2007	Cygnus region		
75	-0.5	3018	3047	23-25 Nov. 2007	Cygnus region	Cygnus transient-1	ATEL ...
76	-1	3097	3110	28-29 Nov. 2007	Cygnus region		
80	-0.7	3112	3135	30 Nov. 2007	Cygnus region	Cygnus X-3 candidate	
73.5	1.5	3130	3146	2 Dec. 2007	near PSR J2021		
78	1	3135	3145	2 Dec. 2007	below gamma-Cyg		
80	-2	3155	3178	4 Dec. 2007	below ps. cyg X-3		
75	-0.5	3164	3177	4 Dec. 2007	Cygnus region	Cygnus transient-1	
80	-0.7	3166	3179	4 Dec. 2007	Cygnus region	Cygnus X-3 candidate	
78	-1	3209	3238	7-8 Dec. 2007	well below gamma-Cyg		
93	3	3260	3283	11 Dec. 2007			
48	-0.5	3295	3318	13-15 Dec. 2007			
79	0	3310	3330	15 Dec. 2007	below ps.Cyg X-3		
312	1	3673	3700	Jan. 2008	Crux Region		
291.8	-1	3760	3773	15 Jan. 2008	Carina Region		
312	1	3799	3812	18 Jan. 2008	Crux Region		
284.5	-0.5	3818	2831	20 Jan. 2008	Carina Region		
287.5	-0.5	3862	3875	25 Jan. 2008	Carina Region	Eta Car	
283.6	-0.5	3863	3883	25-26 Jan. 2008	Carina Region	source A	
284.3	-0.7	3875	3888		Carina Region	source B	
287.2	0.5	3910	3937	26-27 Jan. 2008	Carina Region	above Eta Car	3EG...
310	0	3925	3944	28 Jan. 2008	Crux Region		
284.6	-0.6	3930	4004	28 Jan.-1 Feb. 2008	Carina Region	source B	
312	1	3998	4011	1 Feb. 2008	Crux Region		
312	1	4194	4271	20 Feb. 2008	Crux Region		
284.1	-1.6	4227	4250	23-24 Feb. 2008	Carina Region	source C	
312	1	4278	4306	23 Feb. 2008	Crux Region		
284.6	-0.6	4325	4358	27 Feb. 2008	Carina Region	source B	strong flare
312	1	4325	4374	27 Feb. 2008	Crux Region		
336	1	4329	4353	27 Feb. 2008			
285	-0.6	4367	4380	27 Feb. 2008	Carina Region	source B	
351	1	4478	4494	7 Mar. 2008			
337	0.	4583	4596	14 Mar. 2008			
335	0.	4601	4614	15 Mar. 2008			
192	-11.	4899	4912	5 Apr. 2008			
79	0.5	5025	5038	14 Apr. 2008	near Cyg X-3		
30	0	5027	5046	15 Apr. 2008			
41	0	5058	5071 (5112)	16 Apr. 2008			
35	0	5102	5130	20-21 Apr. 2008			
41	0	5120	5143	22 Apr. 2008			
57	2	5141	5158	22 Apr. 2008			
79	0.8	5146	5169	23 Apr. 2008	Cygnus Region	ps. Cyg X-3	

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...several pages of candidates!

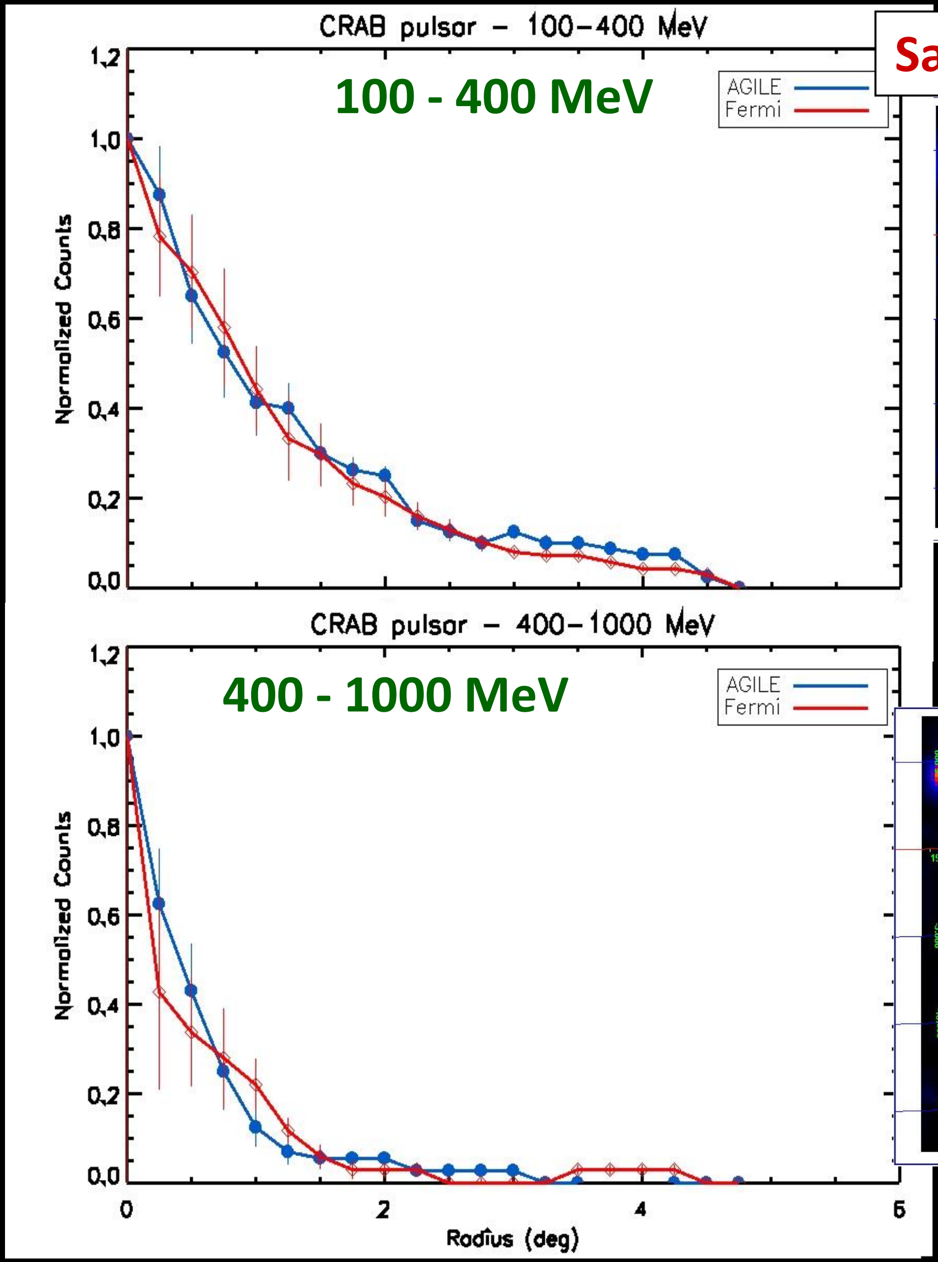
TABLE 3
AGILE DETECTIONS OF GAMMA-RAY TRANSIENTS

l	b	orb1	orb2	Date	Region		
320	0	6456	6474	24 Jul. 2008			
284	- 1	6461	6478	24 Jul. 2008	Carina Region	source B	
136	1.2	6550	6574	29 Jul.-1 Ago. 2009		135+1	
135.5	1.	6623	6646	6 Ago. 2008		135+1	
135.5	1.	6707	6765	11-13 Ago. 2008		135+1	
312	0	6793	6815	17 Ago. 2008	Crux Region		
300	0	6809	6822	18 Ago. 2008			
286	0.3	6820	6836	19 Ago. 2008	Carina Region	right of PSR	
282	0.5	6825	6846	20 Ago. 2008	Carina Region		
288	-0.7	6827	6840	20 Ago. 2008	Carina Region	eta Car (?)	
284	-0.9	6832	6870	20-22 Ago. 2008	Carina Region	source B	
316	0	6838	6851	21 Ago. 2008	Crux Region		
286	0.3	6843	6856	21 Ago. 2008	Carina Region	right of PSR	
311	1	6849	6863	21 Ago. 2008	Crux Region		
288	-0.7	6851	6885	21-23 Ago. 2008	Carina Region	eta Car	
286.5	0.5	6862	6885	23 Ago. 2008	Carina Region	right of PSR (!)	
312	0	6871	6884	23 Ago. 2008	Crux Region		
248	-1.5	6877	6900	23-24 Ago. 2008	Carina Region	source C	
282	-1.	6877	6900	23-24 Ago. 2008	Carina Region	right of source B	
312.5	0	6904	6917	25 Ago. 2008	Crux Region	middle posit.	
310.	0	6914	6927	26 Ago. 2008	Crux Region		
301	1	6914	6927	26 Ago. 2008			
285	-1.7	6914	6927	26 Ago. 2008	Carina Region	left of source C	
285	-0.5	6926	6956	27 Ago. 2008	Carina Region	left of source B	
308	0	6944	6960	28 Ago. 2008			
283.6	-0.5	6965	6982	29 Ago. 2008	Carina Region	source A	
287.5	-0.7	6969	6982	30 Ago. 2008	Carina Region	eta Car	
327	2	6972	6992	30 Ago. 2008			
297.5	-2	6979	6992	30 Ago. 2008			
309	-1	6979	6995	30 Ago. 2008			
317	0	6979	6997	30 Ago. 2008			
283	-2	6980	6997	30 Ago. 2008	Carina Region	right of source C	
135.5	1.	7000	7023	2 Sept. 2008		135+1	
132	-5	7011	7024	2 Sept. 2008			
133.5	1.	7031	7044	3 Sept. 2008		right of 135+1	
160	- 6	7053	7073	5 Sept. 2008			
135	-1	7102	7115	8 Sept. 2008		below 135+1	
8	1	7159	7173	12 Sept. 2008			
22	0	7160	7173	12 Sept. 2008			
337	0	7160	7173	12 Sept. 2008			
356	2	7160	7180	12 Sept. 2008			
345	-2	7170	7183	12 sept. 2008		right of PSR B1706	
24	2	7193	7206	15 Sept. 2008			
349	-1	7193	7217	15-16 Sept. 2008			
8	1	7197	7217	15-16 Sept. 2008			
357	0.5	7207	7224	16 Sept. 2008			strong flare
352.5	-0.5	7210	7224	16 Sept. 2008			
25	0	7218	7246	17 Sept. 2008			
341	-1	7225	7238	17 Sept. 2008			
8	- 0.3	7230	7246	18 Sept. 2008			
326	-0.7	7233	7252	18 Sept. 2008			
17.5	0.	7244	7260	19 Sept. 2008			
35	0	7244	7288	19-20 Sept. 2008			
343.3	-1	7235	7274	19-20 Sept. 2008		above PSR B1706	
358	0	7261	7274	20 Sept. 2008			
328	0	7273	7295	21 Sept. 2008			
7	0	7270	7364	21-23 Sept. 2008			
25	0	7365	7378	27 Sept. 2008			
358	0	7350	7384	28 Sept. 2008			
335	-0.8	7350	7384	28 Sept. 2008			
343	-1.	7390	7408	29 Sept. 2008		near PSR B1706	

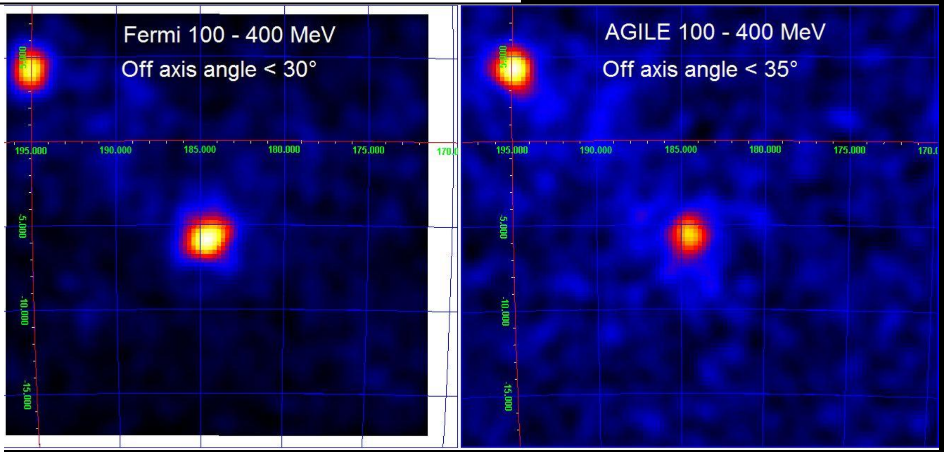
AGILE is optimal for the detection of transient sources:

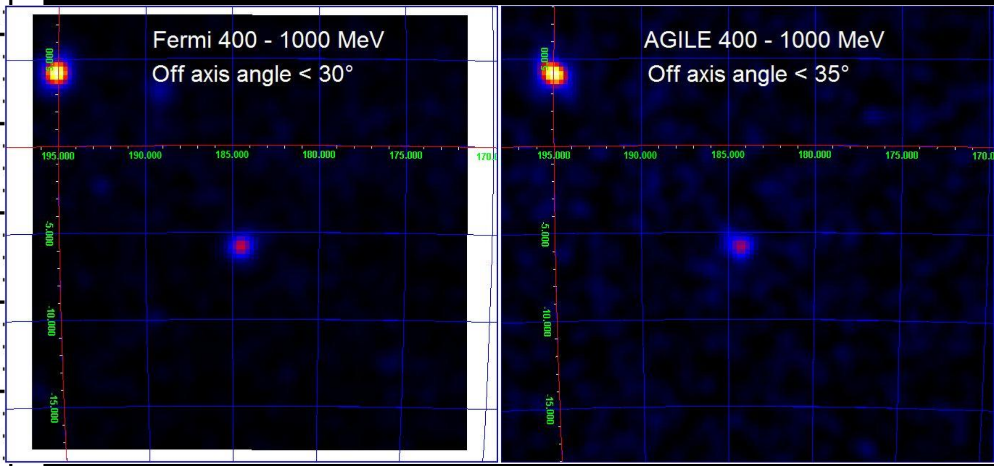
- fast quicklook analysis (2-2.5 hr)
- 2 different statistical approaches (Likelihood and False Discovery Rate)
- optimal PSF (crucial for galactic sources)
- good sensitivity

Gamma-Ray PSF: AGILE vs. Fermi (front-LAT) - Crab



Sabatini et al., in prep





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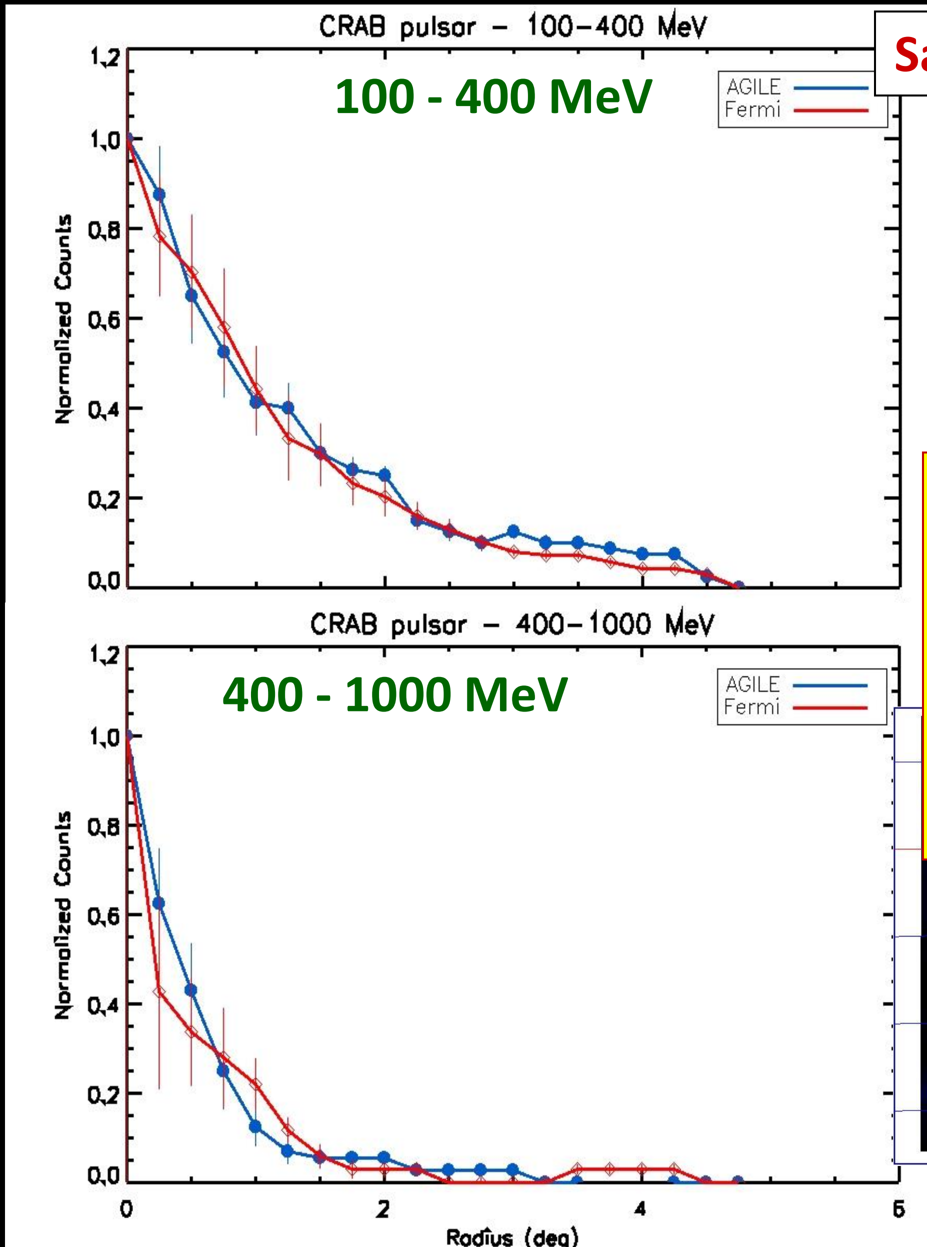

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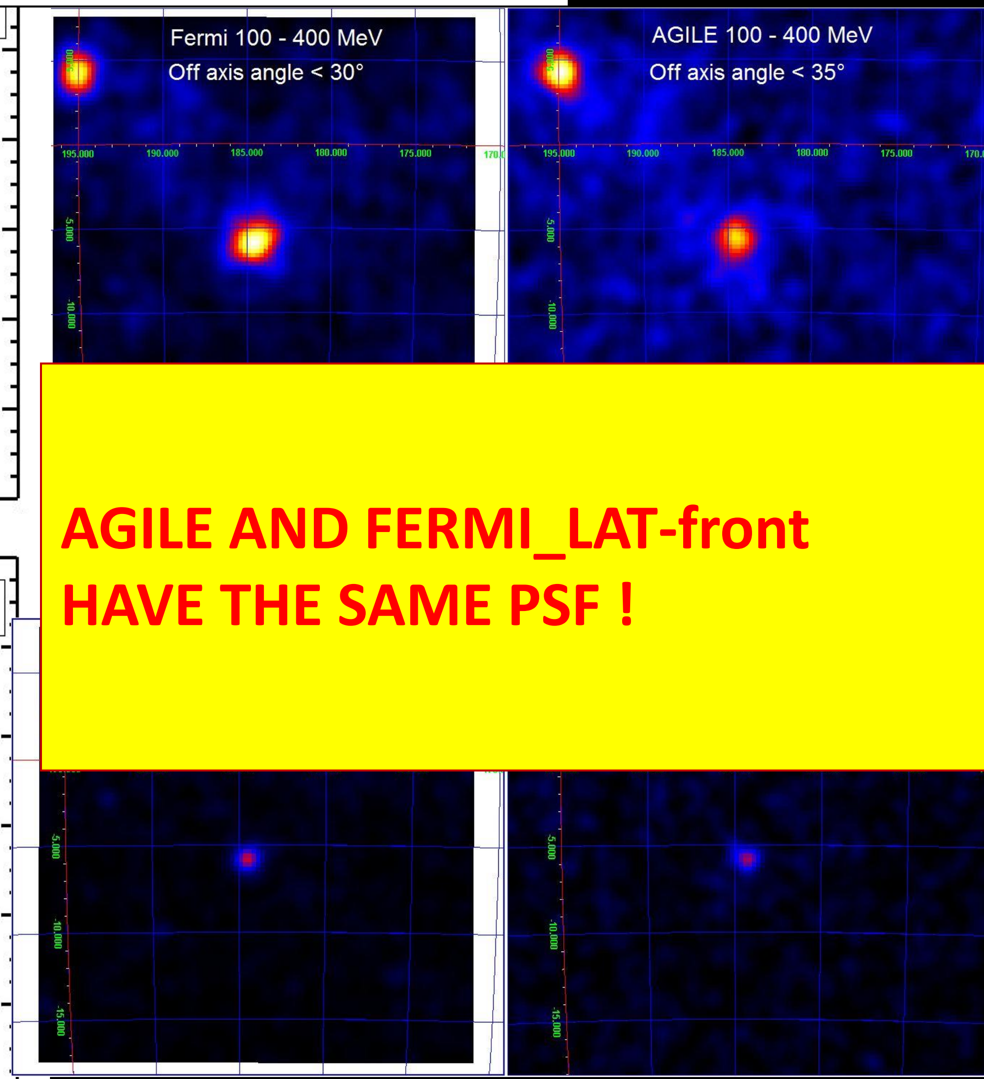
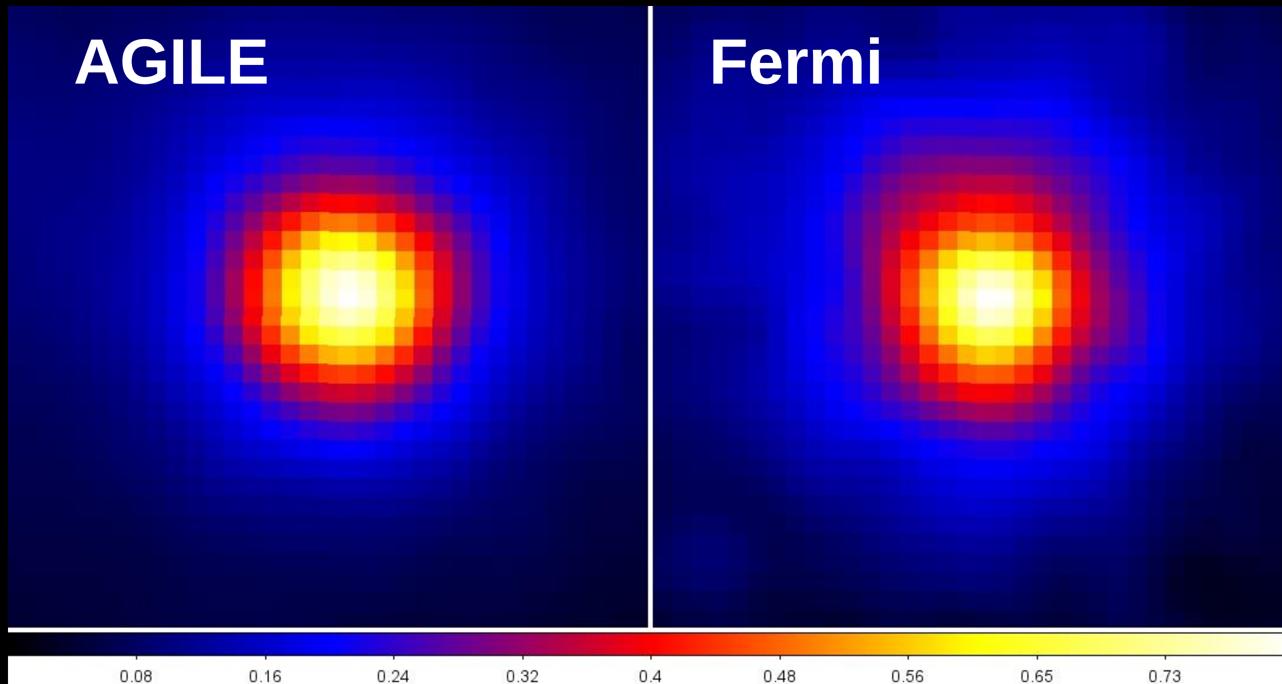
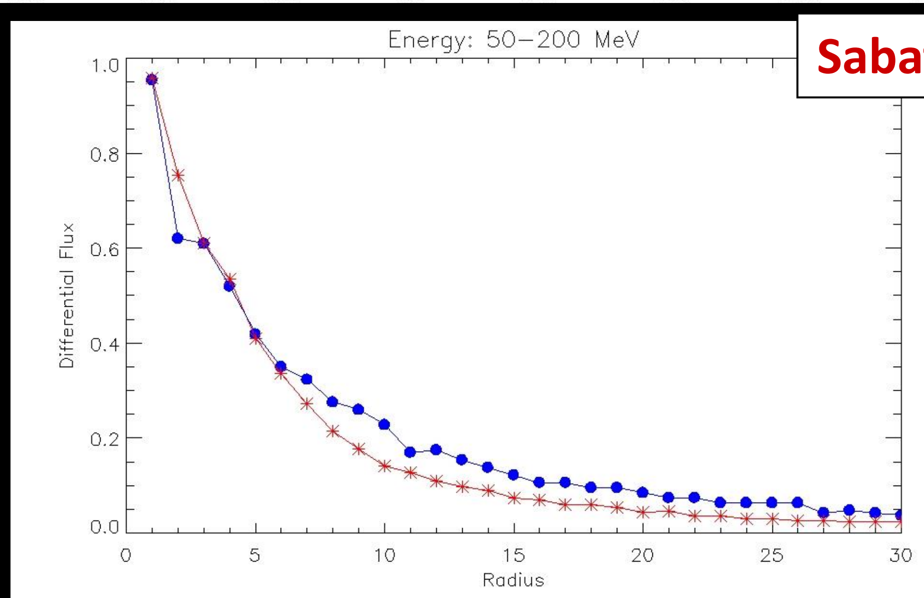


AGILE AND FERMI_LAT-front HAVE THE SAME PSF !

VELA





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  - Crux Region transients
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  - Eta-Car
  - Galactic Center transients (March 09)
  - Unidentified (l= 17, l = 8 ....)
- Fermi candidates:
  - Nova explosions (V407 Cyg, V745 Sco)
  - Low mass X-ray binary (XSS J12270-4859)
  - Galactic Centre (ATel 3162, 12 Feb 2011)
  - Gamma-ray binary 1FGL J1018.6-5856
  - Unidentified: J0639+0548, J1057-6027, J0910-5041

AGILE vs. Fermi: sometimes different results regarding gamma-ray transients

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- AGILE-GRID is optimized near 100 MeV, Fermi-LAT at E > 1 GeV

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- AGILE-GRID is optimized near 100 MeV, Fermi-LAT at E > 1 GeV

- 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 window

Main results on Gamma-Ray Galactic Transients

- **Microquasars**

- **Novae**

- **Gamma-ray binaries**

Main results on Gamma-Ray Galactic Transients

- **Microquasars:**
  - Gamma-ray emission is rare or undetectable in microquasars

	Θ (degrees)	β	Γ	L_X/L_E	γ/TeV
Cyg X-1	30?	?	?	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+105	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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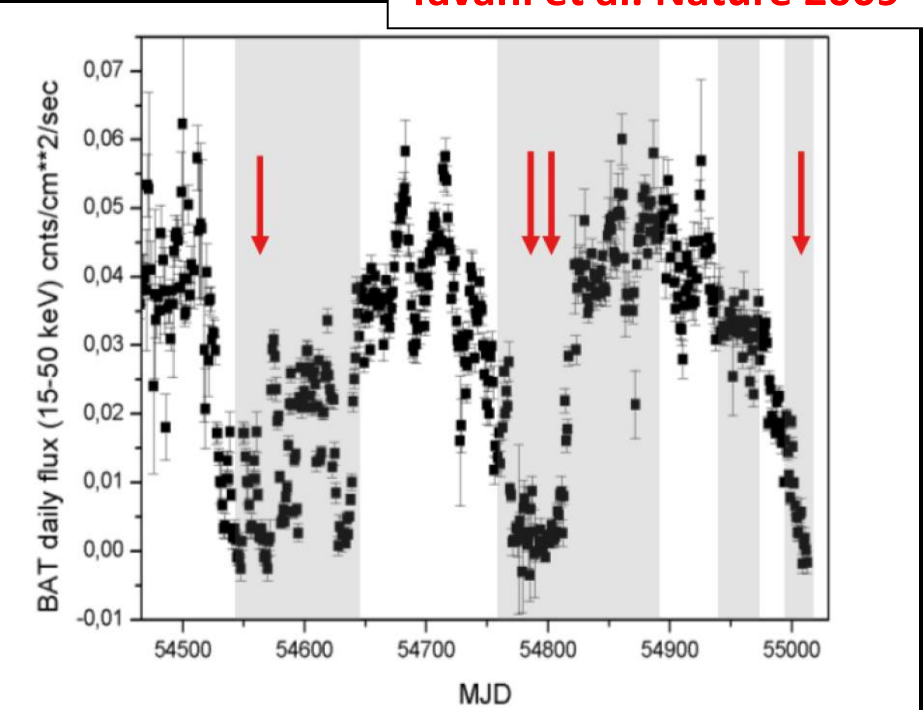
  - However Cyg X-3 and Cyg X-1 show transient activity in gamma-rays related to X-ray state transitions

Cygnus X-1 Cygnus X-3

Tavani et al. Nature 2009

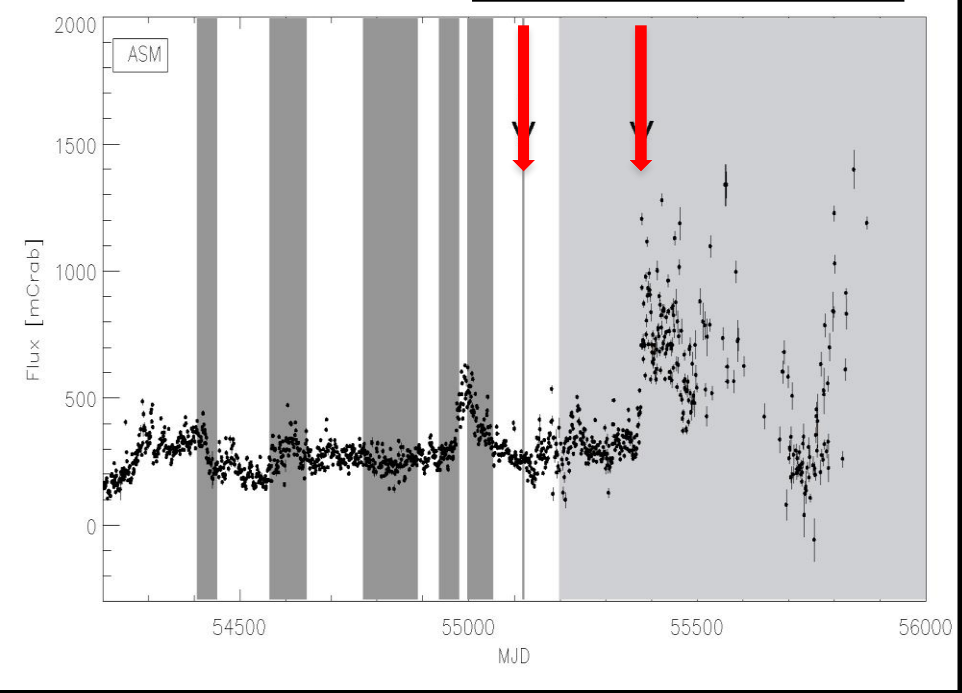


REPETITIVE PATTERN !!

- bright soft X-ray states (soft-to-hard state transitions)
- state preceeding strong radio flares.

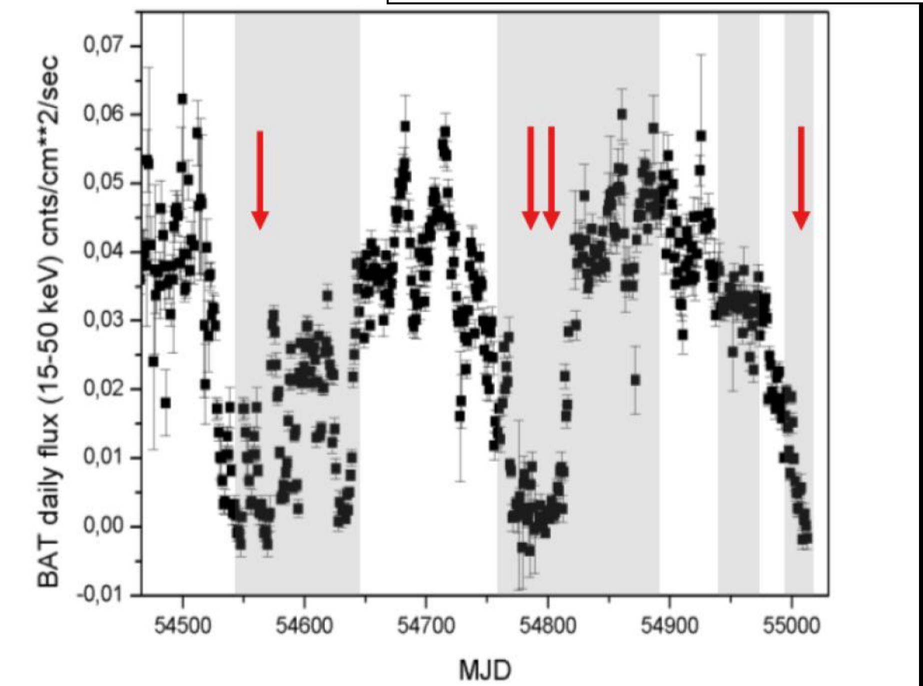
Cygnus X-1

Sabatini et al. 2012



Cygnus X-3

Tavani et al. Nature 2009



SPORADIC

2 episodes:

- Hard state
- Hard-to-soft transition

REPETITIVE PATTERN !!

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	Cygnus X-1	Cygnus X-3
Compact Object	4-15 $M_\odot$ BH	1.4 $M_\odot$ NS or 10 $M_\odot$ BH
Companion	O9.7 Supergiant, L ~ 10^{39} erg/s	Wolf Rayet, L ~ 10^{39} erg/s
Companion wind	~ 10^{-6} $M_\odot$/yr, v ~ 2000 km/s	~ 10^{-5} $M_\odot$/yr, v ~ 1000 km/s
Period	5.6 days, orb. r. ~ 3.4 x 10^{12} cm	4.8 h, orb. r. ~ 3 x 10^{11} cm
Inclination Angle	30?	< 14

Cygnus X-3 is unique in orbital separation, luminosity of the companion star and inclination -> different behaviour can be expected in the two systems

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The nature of the emission (leptonic vs hadronic) is not clear yet.

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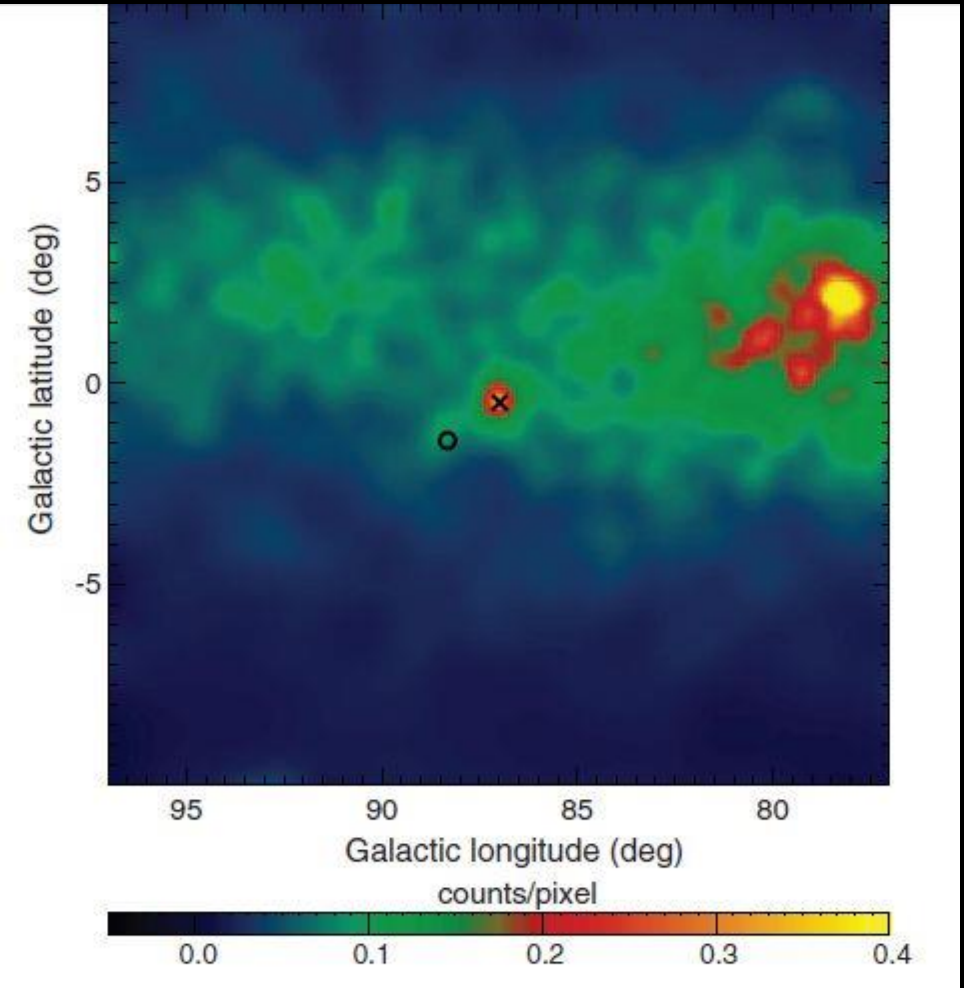
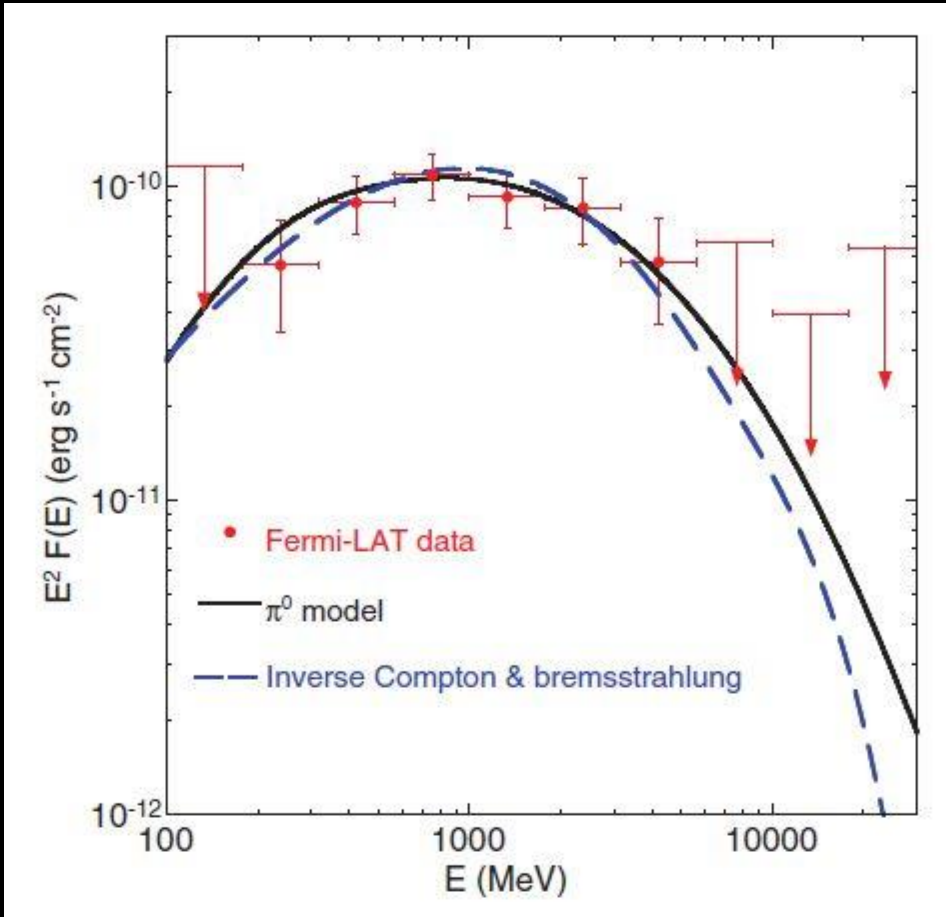
Fermi-LAT detection of the symbiotic system V407 Cygni (March 2009) Abdo et al. Science 2010





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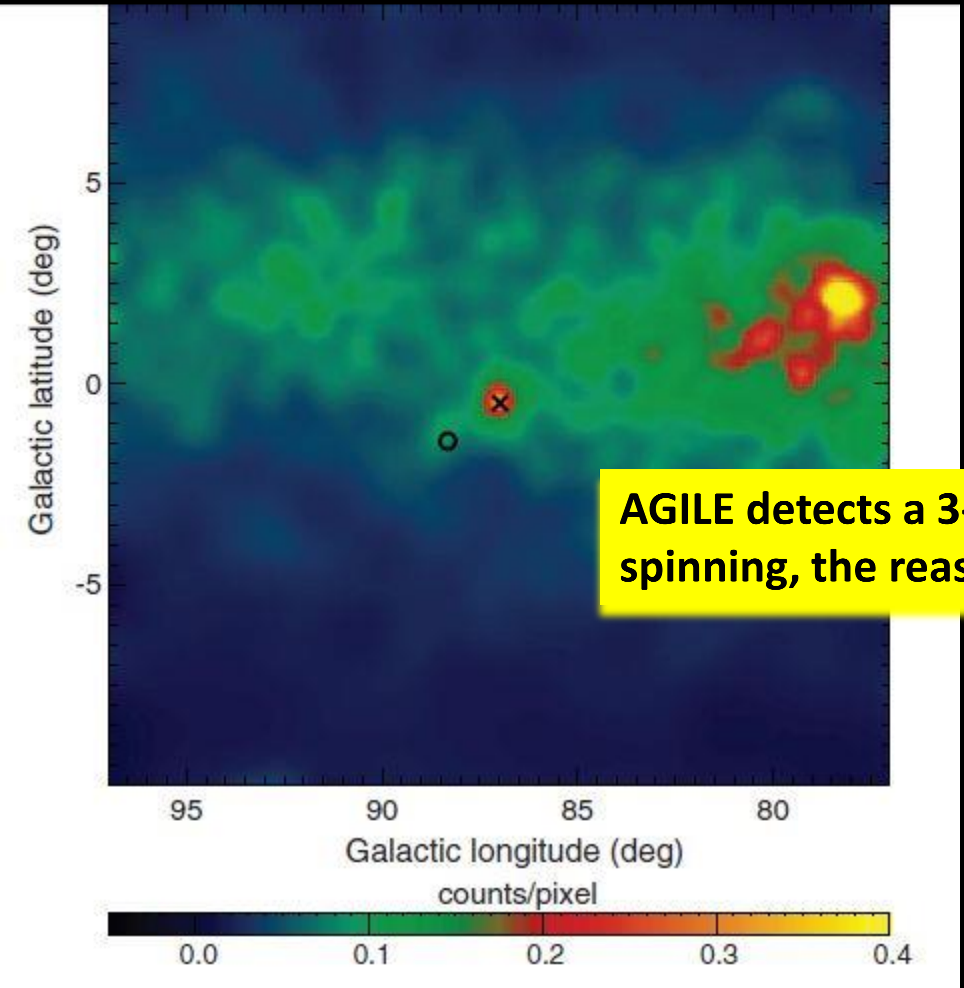

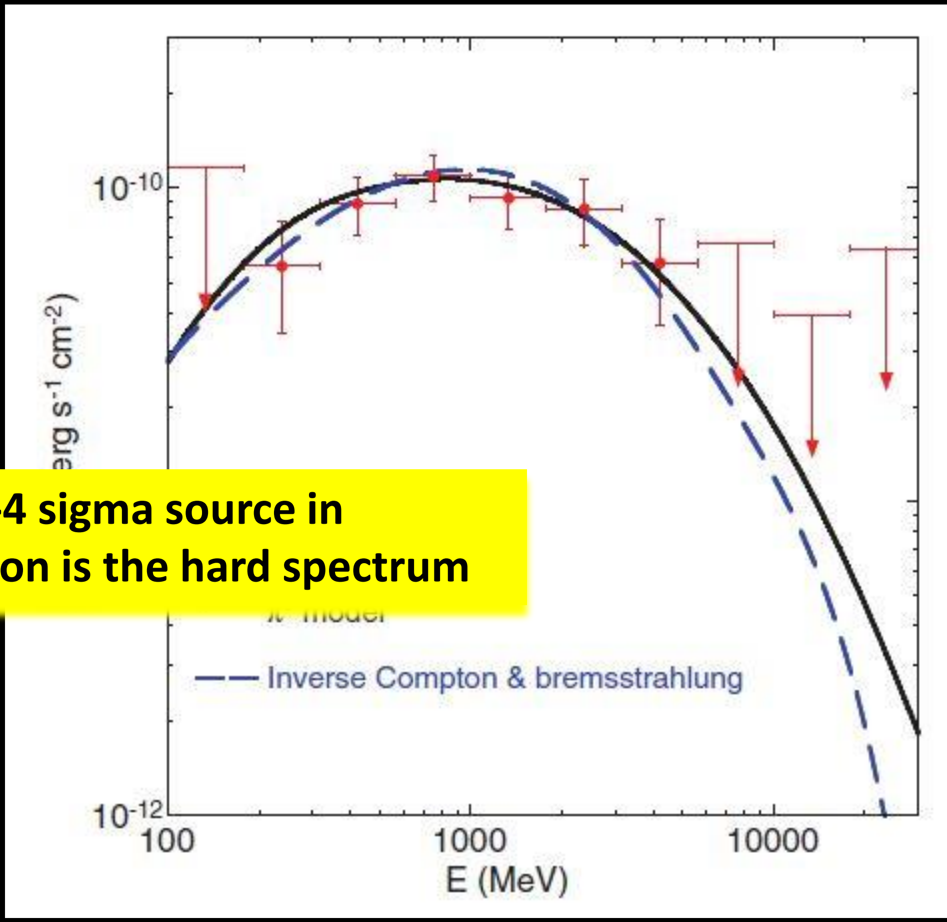

AGILE detects a 3-4 sigma source in spinning, the reason is the hard spectrum

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- **Gamma-ray binaries:**
  - Blind searches in gamma-ray data (modulation and/or transient emission) revealed the existence of a new population of binaries, e.g.:
    - 1FGL 1018.6-5856, discovered by Fermi (modulation)

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1FGL J1018.6-5856: a New Gamma-ray Binary

ATel #3221; R. H.D. Corbet (UMBC/NASA GSFC), C. C. Cheung (NRC, resident at NRL), M. Kerr (Stanford), R. Dubois (SLAC), D. Donato (UMCP/NASA GSFC), G. A. Caliandro (IEEC-CSIC), on behalf of the LAT collaboration, M. J. Coe (Southampton), P. G. Edwards (CSIRO), M. D. Filipovic (UWS), J. L. Payne (UWS), J. Stevens (CSIRO)
on 15 Mar 2011; 17:14 UT
Credential Certification: Robin Corbet (corbet@umbc.edu)

Subjects: Radio, Optical, X-ray, Gamma Ray, >GeV, Binary, Black Hole, Neutron Star, Star, Variables

Referred to by ATel #: 3228

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Fermi LAT observations of the gami
188, 405) obtained between MJD 54
show the presence of periodic modu
spectrum of the light curve the modi
power level, and the false alarm prol
Modulation at this period is not seen
be intrinsic to 1FGL J1018.6-5856 a
ray flux is MJD 55403.3 ± 0.4.

Swift XRT observations of the vicin
R.A. = 10^h 18^m 55.54^s, decl. = -58°
with the location of the gamma-ray
between September 2009 and Febru
keV count rates ranging from appro
obtained so far are from times close

The DSS2 image of this region show
circle at R.A. = 10^h 18^m 55.6^s, decl.
with the SAAO 1.9m telescope indic
to that of the gamma-ray binary LS

Binary 1FGL J1018.6–5856

Science, 2012

The Fermi LAT Collaboration*

Gamma-ray binaries are stellar systems containing a neutron star or black hole, with gamma-ray emission produced by an interaction between the components. These systems are rare, even though binary evolution models predict dozens in our Galaxy. A search for gamma-ray binaries with the Fermi Large Area Telescope (LAT) shows that 1FGL J1018.6–5856 exhibits intensity and spectral modulation with a 16.6-day period. We identified a variable x-ray counterpart, which shows a sharp maximum coinciding with maximum gamma-ray emission, as well as an O6V((f)) star optical counterpart and a radio counterpart that is also apparently modulated on the orbital period. 1FGL J1018.6–5856 is thus a gamma-ray binary, and its detection suggests the presence of other fainter binaries in the Galaxy.

Two types of interacting binaries containing compact objects are expected to emit gamma rays (1): microquasars—accreting black holes or neutron stars with relativistic jets (2)—and rotation-powered pulsars interacting with the wind of a binary companion (3). Microquasars should typically be powerful x-ray sources when active, and hence such gamma ray–emitting systems may already be known x-ray binaries. Indeed, the bright x-ray source Cygnus X-3 is now known to be such a source (4, 5). The existence of pulsars interacting with stellar companions of early spectral types is predicted as an initial stage in the formation of high-mass x-ray binaries (HMXBs) containing neutron stars (6). These interacting pulsars are predicted to be much weaker x-ray emitters and may not yet be known or classified x-ray sources. Gamma-ray binaries may thus not be as rare as they appear to be, and many systems may await detection.

A gamma-ray binary is expected to show orbitally modulated gamma-ray emission due to a combination of effects, including changes in viewing angle and, in eccentric orbits, the degree of the binary interaction, both of which depend on binary phase. Periodic gamma-ray modulation has indeed been seen in LS 5039 (period 3.9 days), LS I +61° 303 (26.5 days), and Cygnus X-3 (4.8 hours) (4, 7, 8), and gamma-ray emission is at least orbital phase–dependent for the PSR B1259–63 system (3.4 years) (9). However, the putative gamma-ray binary HESS J0632+057, for which a 321-day x-ray period is seen, has not yet been shown to exhibit periodic gamma-ray emission (10). PSR B1259–63 contains a pulsar, and LS 5039 and LS I +61° 303 are suspected, but not proved, to contain pulsars, whereas Cygnus X-3 is a black hole candidate. A search for periodic modulation of gamma-ray flux from LAT sources may thus lead to the detection of further gamma-ray binaries, potentially revealing the predicted HMXB precursor population. The first Fermi LAT (11) catalog of gamma-ray sources ("1FGL") contains 1451 sources (12), a large fraction of which do not have confirmed counterparts at other wavelengths and thus are potentially gamma-ray binaries.

To search for modulation, we used a weighted photon method to generate light curves for all 1FGL sources in the energy range 0.1 to 200 GeV (13). We then calculated power spectra for all sources. From an examination of these, in addition to modulation from the known binaries LS I +61° 303 and LS 5039, we noted the presence of a strong signal near a period of 16.6 days from 1FGL J1018.6–5856 (Fig. 1). 1FGL J1018.6–5856 has a cataloged 1- to 100-GeV flux of 2.9 × 10^{-8} ...

... –58° 56.30′ (J2000; ±1.8′, 95% uncertainty) means that it lies close to the galactic plane (b = –1.7°), marking it as a good candidate for a binary system. 1FGL J1018.6–5856 has been noted to be positionally coincident with the supernova remnant G284.3–1.8 (12) and the TeV source HESS J1018–589 (14), although it has not been shown that these sources are actually related.

The modulation at a period of 16.6 days has a power more than 25 times the mean value of the power spectrum and has a false-alarm probability of 3 × 10^{-8}, taking into account the number of statistically independent frequency bins. From both the power spectrum itself (15) and from fitting the light curve, we derived a period of 16.58 ± 0.02 days. The folded light curve (Fig. 1) has a sharp peak together with additional broader modulation. We modeled this to determine the epoch of maximum flux T_{max} by fitting a function consisting of the sum of a sine wave and a Gaussian function, and obtained T_{max} = modified Julian date (MJD) 55403.3 ± 0.4.

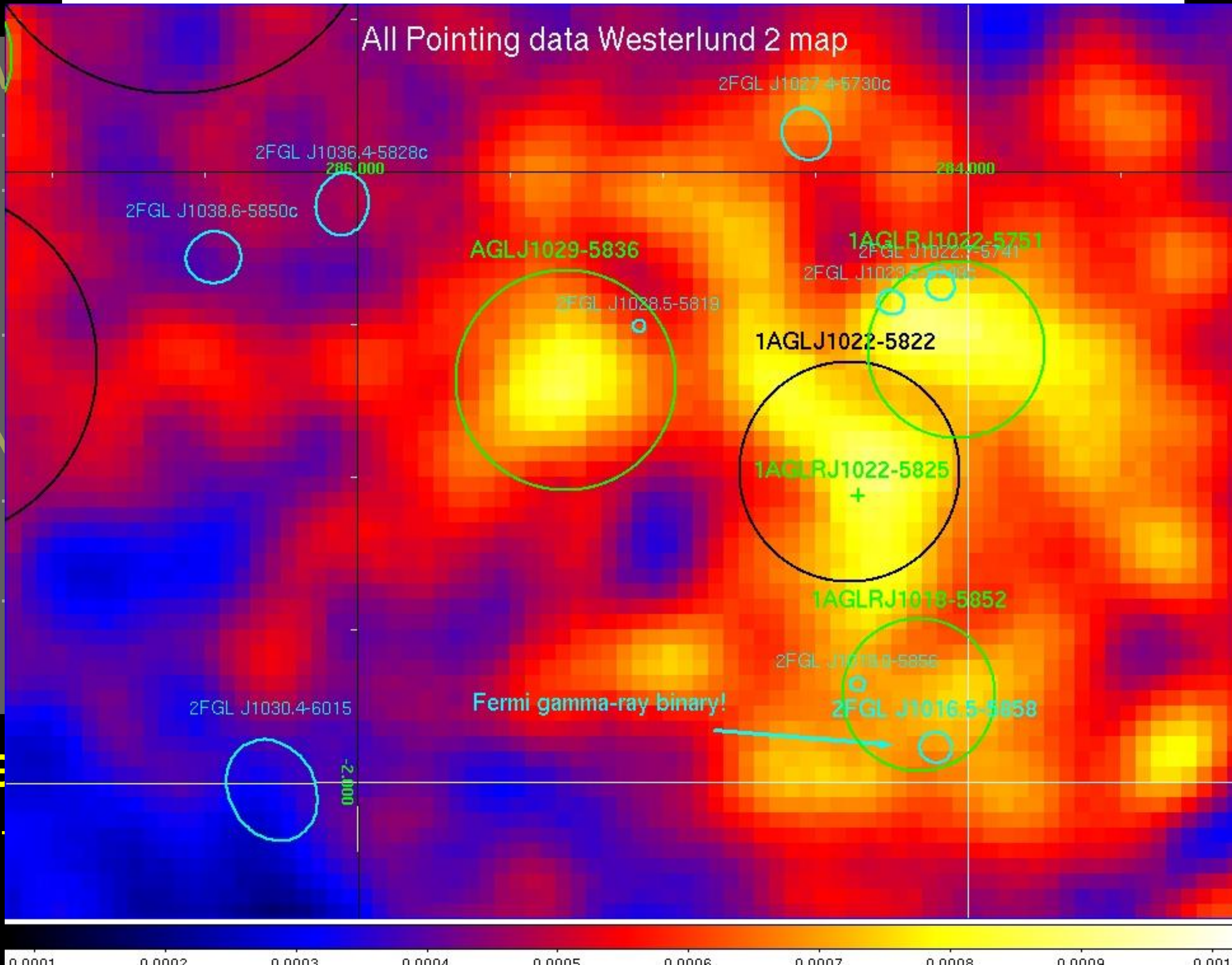
The gamma-ray spectrum of 1FGL J1018.6–5856 shows substantial curvature through the LAT passband. To facilitate discussion of the lower-energy (<1 GeV) and higher-energy (>1 GeV) gamma rays, we adopted as our primary model a broken power law with photon indices $\Gamma_{0.1-1}$ and Γ_{1-10} for energies below and above 1 GeV, respectively. The best-fit values (13) are $\Gamma_{0.1-1}$ = 2.00 ± 0.04_{stat} ± 0.08_{syst} and Γ_{1-10} = 3.09 ± 0.06_{stat} ± 0.12_{syst}, along with an integral energy flux above 100 MeV of (2.8 ± 0.1_{stat} ± 0.3_{syst}) × 10^{-10} erg cm^{-2} s^{-1}. A power law with exponential cutoff (7, 8), $dN/dE = N_0(E/\text{GeV})^{-\Gamma}\exp(-E/E_c)$, gives an acceptable fit with Γ = 1.9 ± 0.1 and E_c = 2.5 ± 0.3 GeV (statistical errors only). Although this spectral shape is qualitatively similar to that of pulsars and of LS I +61° 303 and LS 5039, so far no detection of pulsed gamma-ray emission has been reported (16).

To investigate variability on the 16.6-day period, we folded the data into 10 uniform bins in orbital phase and then refit the broken power-law parameters within each phase bin. The resulting ...

*All authors with their affiliations appear at the end of this paper.

Ma ... ents

1FGL J1018.6-5856: a New Gamma-ray Binary



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    - 1FGL 1018.6-5856, discovered by Fermi
    - AGL J2241+4454, discovered by AGILE (transient)

AGL J2241+4454 (MWC656?): AGILE ATel

AGILE detection of the new unidentified gamma-ray source AGL J2241+4454

ATel #2761; *F. Lucarelli, F. Verrecchia (ASDC), E. Striani (Univ. Roma Tor Vergata and INFN Roma), C. Pittori (ASDC), M. Tavani (INAF/IASF-Rm, and Univ. Tor Vergata), S. Vercellone (INAF/IASF-Pa), A. Bulgarelli, F. Gianotti, M. Trifoglio (INAF/IASF-Bo), A. Chen, A. Giuliani, S. Mereghetti, P. Caraveo, F. Perotti (INAF/IASF-Mi), I. Donnarumma (INAF/IASF-Rm), F. D'Ammando (INAF/IASF-Pa), E. Del Monte, Y. Evangelista, M. Feroci, F. Lazzarotto, L. Pacciani, P. Soffitta, E. Costa, I. Lapshov, M. Rapisarda, A. Argan, G. Piano, G. Pucella, S. Sabatini, A. Trois, V. Vittorini (INAF/IASF-Rm), F. Fuschino, M. Galli, C. Labanti, M. Marisaldi, G. Di Cocco (INAF/IASF-Bo), A. Pellizzoni, M. Pilia (INAF/OA-Cagliari), G. Barbiellini, F. Longo, E. Moretti, E. Vallazza (INFN Trieste), A. Morselli, P. Picozza (INFN and Univ. Roma Tor Vergata), M. Prest (Universita` dell'Insubria), P. Lipari, D. Zanello (INFN and Univ. Roma Sapienza), P. W. Cattaneo, A. Rappoldi (INFN Pavia), P. Santolamazza, S. Colafrancesco, P. Giommi (ASDC), L. Salotti (ASI)*

*on **27 Jul 2010; 17:21 UT***

Distributed as an Instant Email Notice Request For Observations

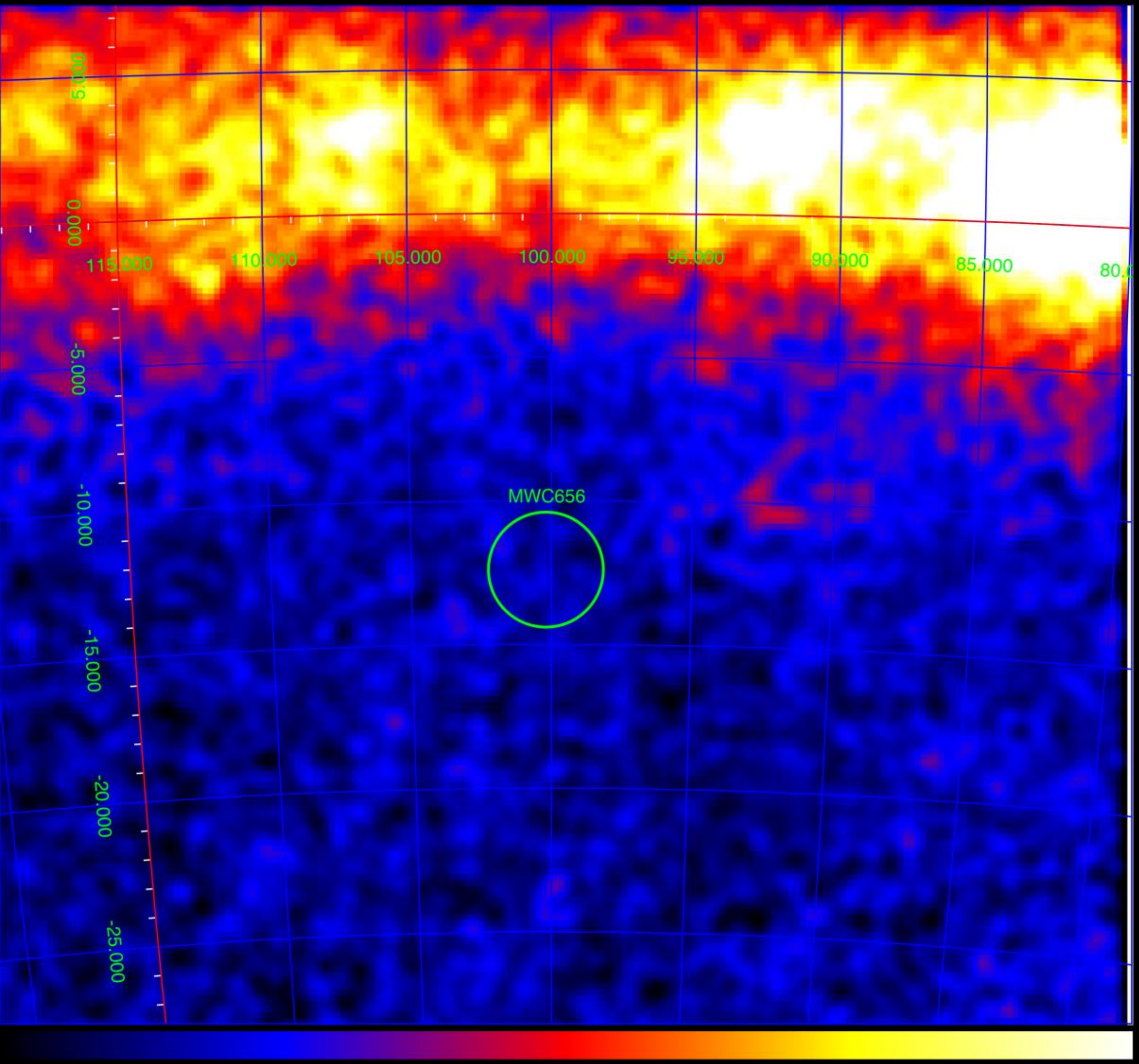
Credential Certification: Fabrizio Lucarelli (fabrizio.lucarelli@asdc.asi.it)

Subjects: Gamma Ray, >GeV, Request for Observations, Transient

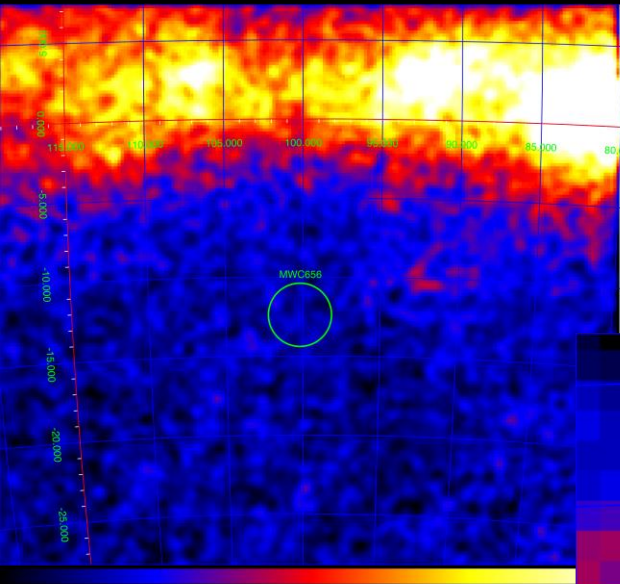
AGILE is detecting intense gamma-ray emission above 100 MeV from a new unidentified source, AGL J2241+4454, with Galactic coordinates (l, b) = (100.0, -12.2) Â± 0.6 deg (95% stat.) Â± 0.1 deg (syst.) (R.A.=340.3, Dec.=44.9, J2000).

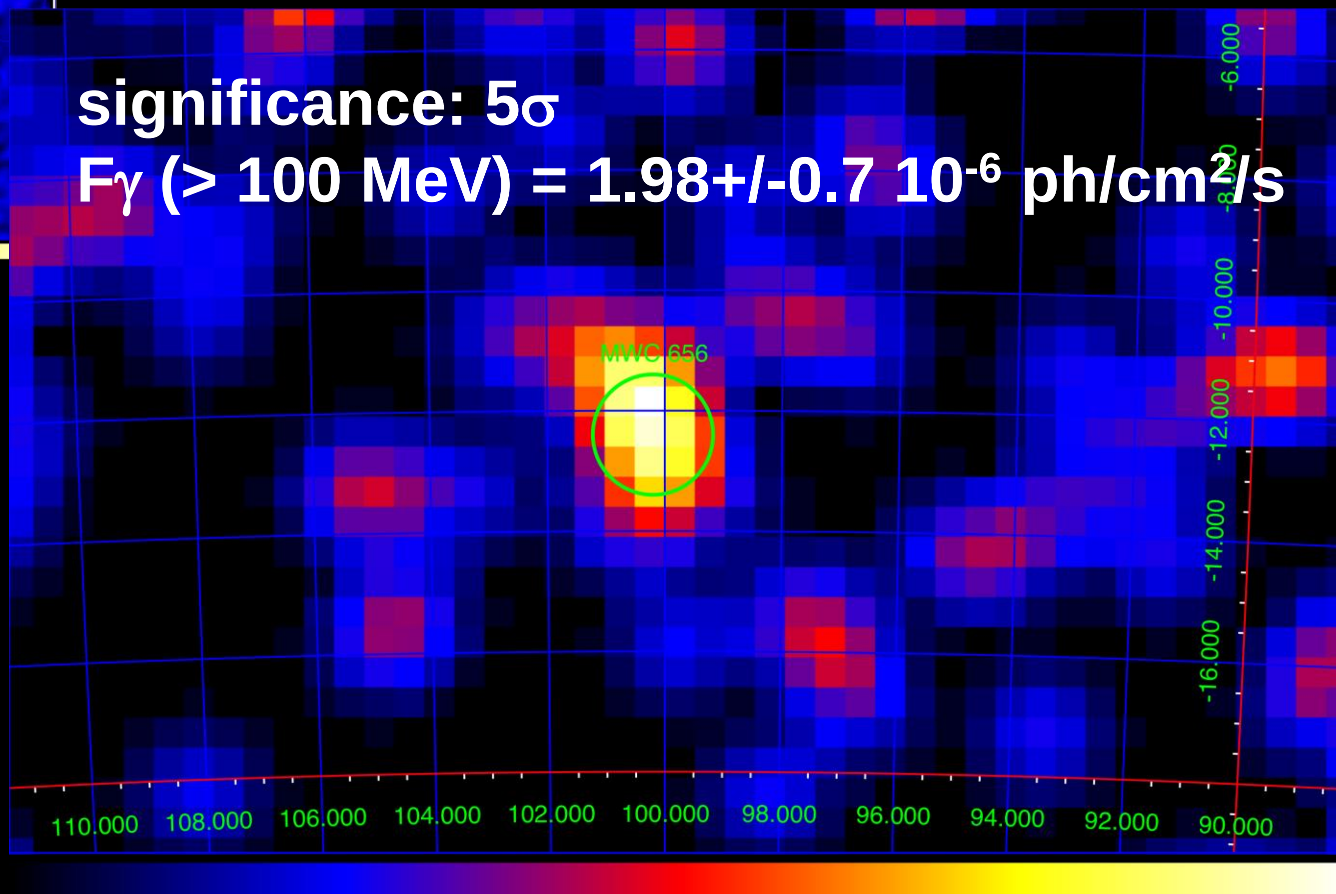
Integrating from 2010-07-25 01:00 UT to 2010-07-26 23:30 UT, a maximum likelihood analysis yields a detection at a significance level larger than 5 sigma, and a flux above 150 x 10E-8 ph/cm2/s (E > 100 MeV).

AGL J2241+4454 (MWC656?): AGILE deep field



AGL J2241+4454 (MWC656?): AGILE ATel 2671





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Follow up analysis triggered by the AGILE ATel and carried out by Casares et al., led to

the discovery of the **first Be-BH binary system** **(MWC656)**

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A Be-type star with a black-hole companion

Nature, 2014

J. Casares[1,2], I. Negueruela[3], M. Ribó[4], I. Ribas[5], J. M. Paredes[4], A. Herrero[1,2] & S. Simón-Díaz[1,2]

Stellar-mass black holes have all been discovered through X-ray emission, which arises from the accretion of gas from their binary companions (this gas is either stripped from low-mass stars or supplied as winds from massive ones). Binary evolution models also predict the existence of black holes accreting from the equatorial envelope of rapidly spinning Be-type stars[1–3] (stars of the Be type are hot blue irregular variables showing characteristic spectral emission lines of hydrogen). Of the approximately 80 Be X-ray binaries known in the Galaxy, however, only pulsating neutron stars have been found as companions[2–4]. A black hole was formally allowed as a solution for the companion to the Be star MWC 656 (ref. 5; also known as HD 215227), although that conclusion was based on a single radial velocity curve of the Be star, a mistaken spectral classification[6] and rough estimates of the inclination angle. Here we report observations of an accretion disk line mirroring the orbit of MWC 656. This, together with an improved radial velocity curve of the Be star through fitting sharp Fe II profiles from the equatorial disk, and a refined Be classification (to that of a B1.5–B2 III star), indicates that a black hole of 3.8 to 6.9 solar masses orbits MWC 656, the candidate counterpart of the γ-ray source AGL J2241+4454 (refs 5, 6). The black hole is X-ray quiescent and fed by a radiatively inefficient accretion flow giving a luminosity less than 1.6×10^{-7} times the Eddington luminosity. This implies that Be binaries with black-hole companions are difficult to detect in conventional X-ray surveys.

B-type stars. Further, the He II profile is double-peaked, which is the signature of gas orbiting in a Keplerian geometry[11]. Gaussian fits to the He II profiles in the Liverpool telescope spectra reveal that the centroid of the line is modulated with the 60.37-day orbital period, reaching maximum velocity at photometric phase 0.06 (see Methods and Extended Data Fig. 1). This is approximately in antiphase with the radial velocity curve of the Be star[5], a strong indication that the He II emission arises from gas in an accretion disk around the invisible companion and not from the Be disk. We can therefore use its radial velocity curve to trace the orbit of the Be companion. An eccentric orbital fit to the He II velocities was performed using the Spectroscopic Binary Orbit Program (SBOP[12]), fixing the period to 60.37 days (Methods); the resulting orbital elements are given in Extended Data Table 2. The orbital evolution of the He II line is presented in Fig. 2. The line flux is also found to be modulated with the orbital period (Methods and Extended Data Fig. 1), owing to the presence of an S-wave component swinging between the double peak (see Fig. 2).

To improve on the radial velocity curve of the Be star previously reported[5], we fitted the sharp double-peaked profile of the Fe II 4,583 Å emission line with a two-Gaussian model (Methods). Fe II lines are known to arise from the innermost regions of the circumstellar disk[13,14], and therefore reflect the motion of the Be star much more accurately

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big discovery potential for blind searches in gamma-ray data

AGL MWC656: gamma-ray follow up analysis

- Further search for transient emission in our database, revealed 10 other (low significance) candidates of gamma-ray activity

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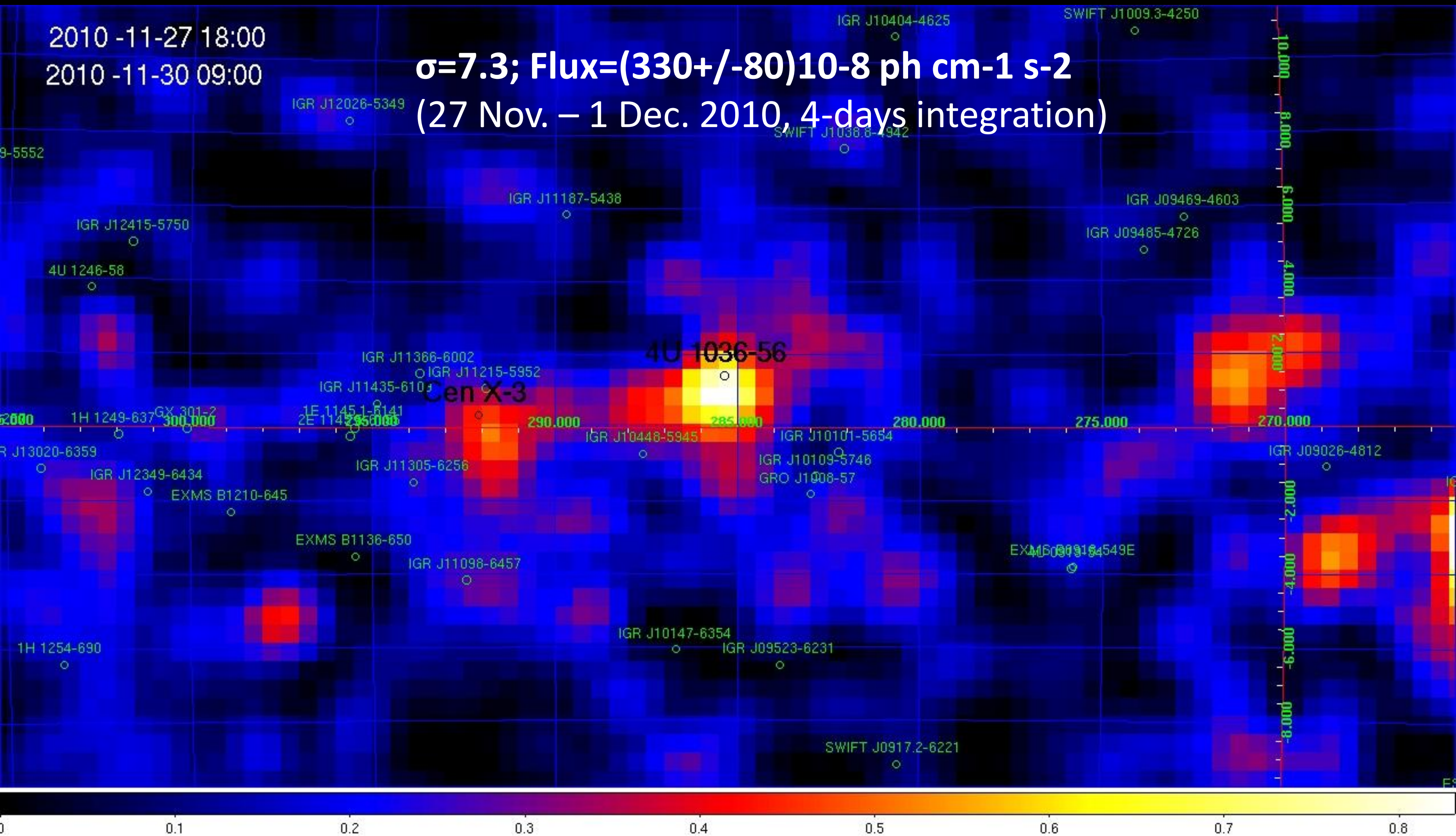
- most of them seems to be related to a specific orbital phase.

- a systematic search for similar systems has now started thanks to the collaboration with the Casares (Paredes, Ribo') group

Other prominent candidates:
Unidentified transient sources

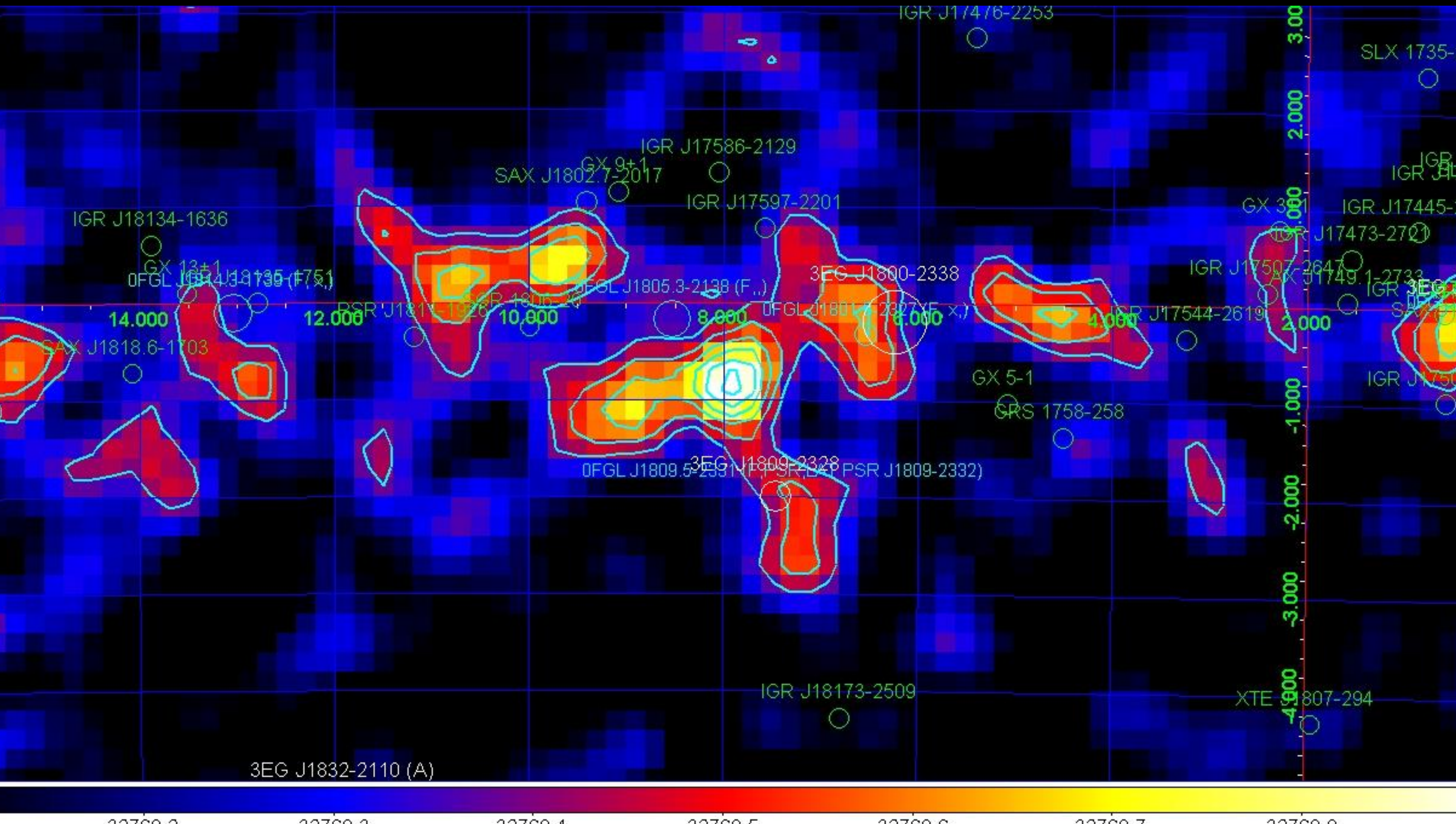
Unidentified transient sources



ATEL n. 3059, Bulgarelli et al. (2010)

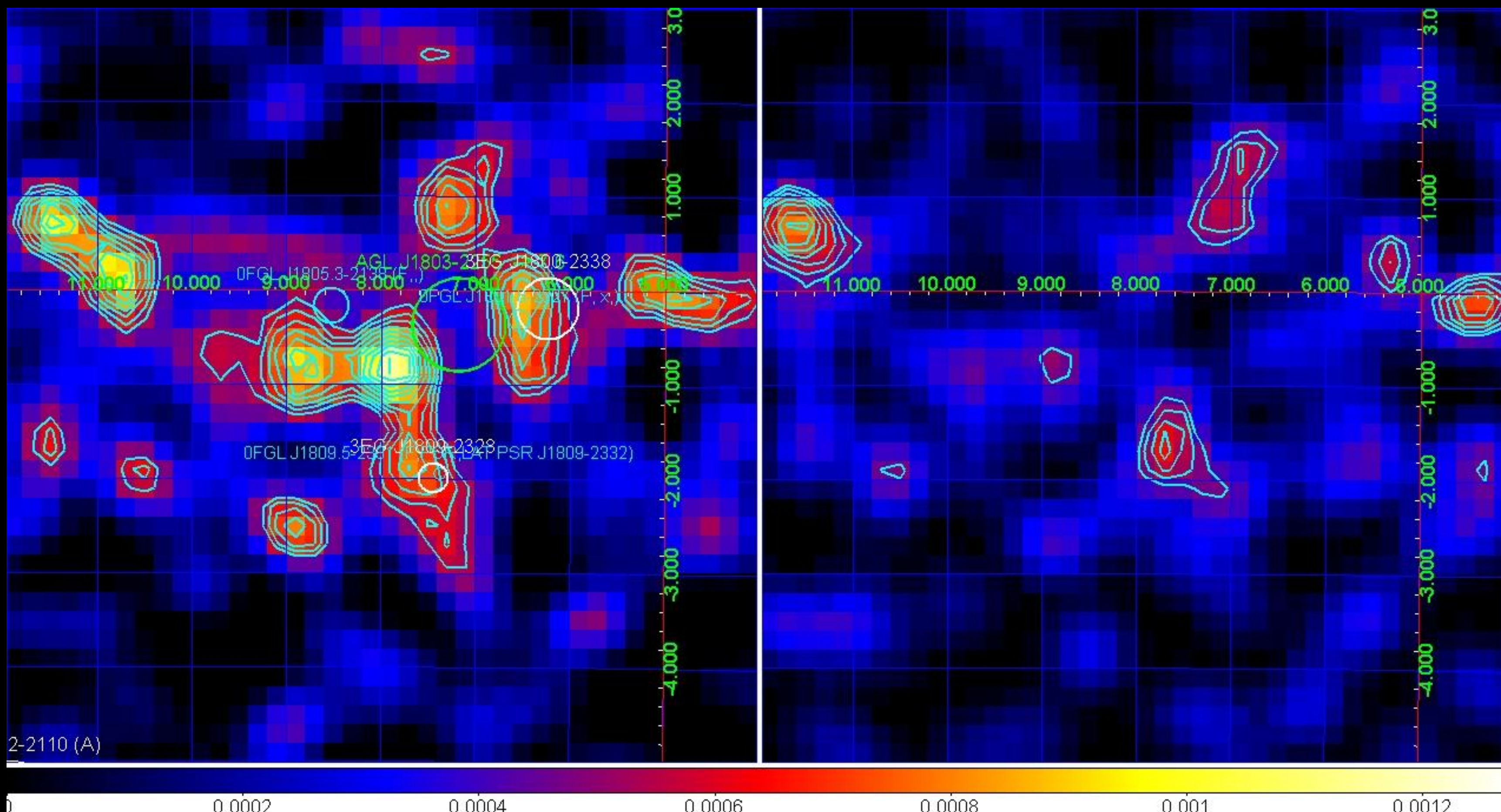
Unidentified transient sources

l=8 transient: 10-13 April 2009, 10143-10180, bin =0.2, B16, FM, E>100 MeV



Unidentified transient sources

l=8 transient: 10-13 April 2009, 10143-10180, bin =0.2, B17b, FT



E > 100 MeV **E > 400 MeV**

Consolidated results and surprises

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  ->Several other candidates in Be star binaries
- no obvious LMXB or INTEGRAL sources

CONCLUSIONS II – lots to do...

• 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 fields, high diffuse emission Galactic plane regions -> pointing data are still a 'gold mine' to discover (see e.g. MWC656). PSF in spinning mantains nominal performance and allows to carry out crucial studies of galactic soft transients (quicklook alerts in 2-2.5 hr).

• The nature of the gamma-ray emission (leptonic vs hadronic) is still not clear in galactic transients: improving sensitivity below 100 MeV is crucial for this.

• New blind searches in our database can populate the new class of gamma-ray binaries and give a crucial contribute to the study of these sources in the 100-400 MeV range.

THANKS FOR YOUR ATTENTION