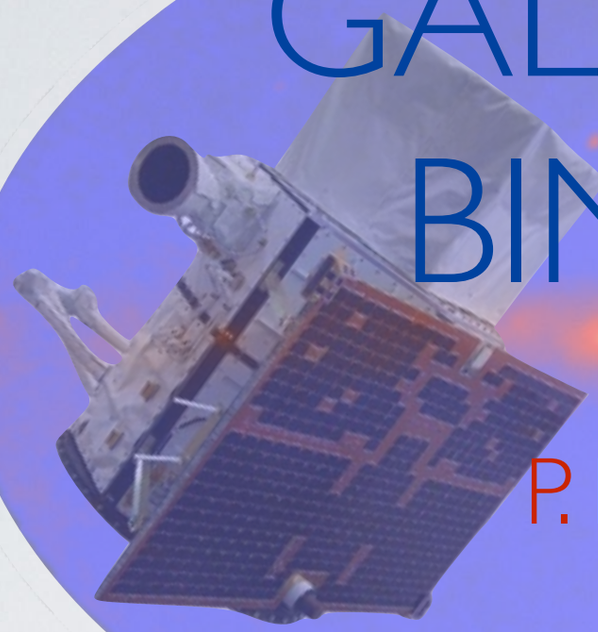
GALACTIC GAMMA-RAY BINARY TRANSIENTS



P. Munar-Adrover for the *AGILE* Team

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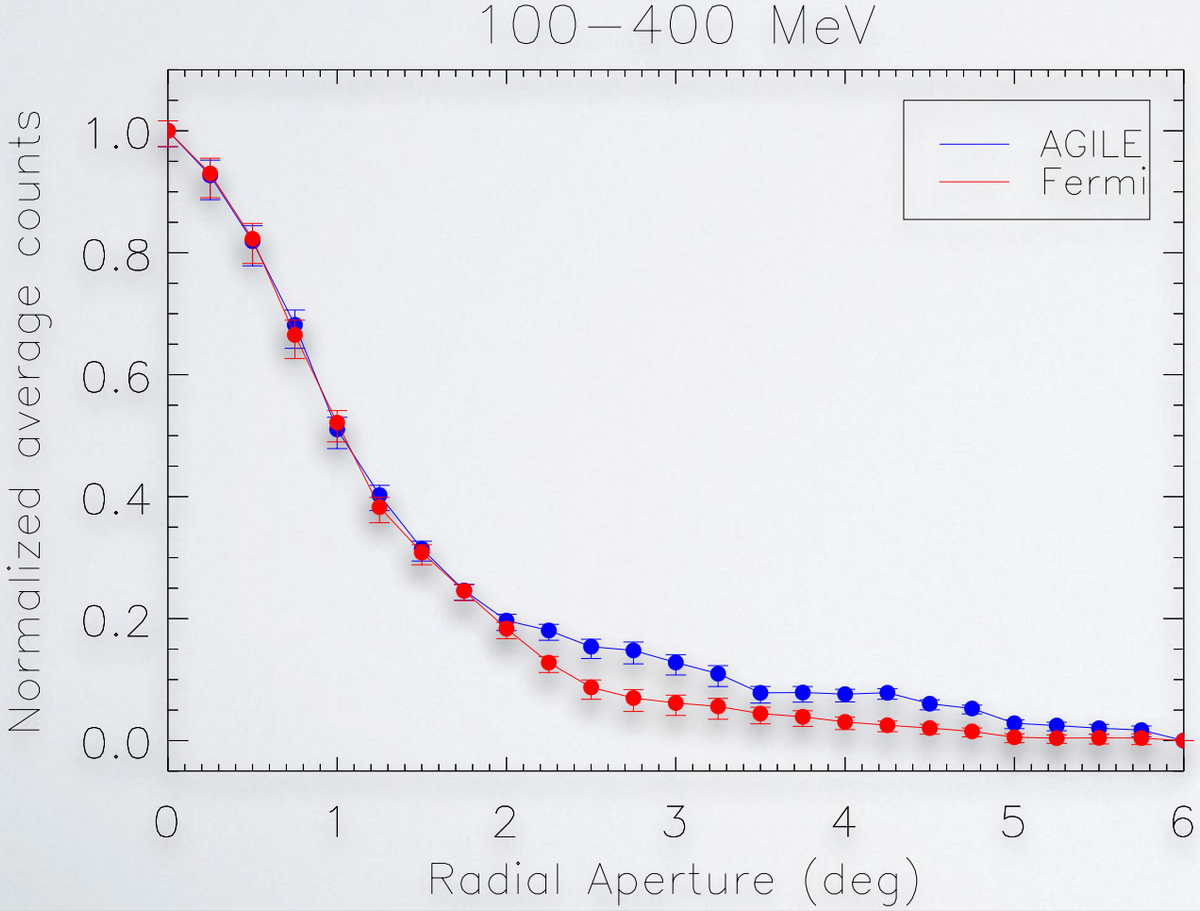
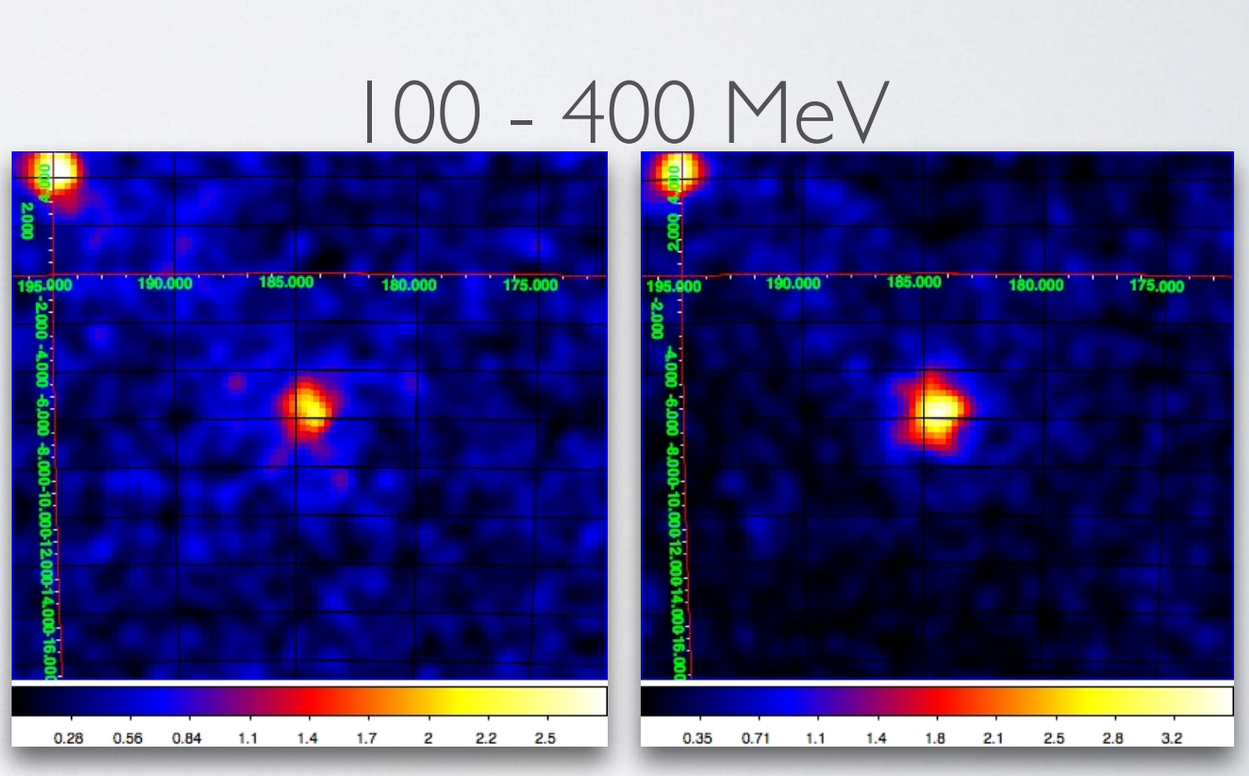
OUTLINE

- AGILE and transients
- Cygnus X-3
- MWC 656
- V404 Cygny

GALACTIC TRANSIENTS WITH *AGILE*

- Superb instrument to spot transient sources
  - Fast quick-look analysis (2 - 2.5 h)
  - Good PSF
  - Good sensitivity between 100 and 400 MeV
  - Spinning mode covers most of the sky every few hours





Sabatini et al. (2015)

GALACTIC TRANSIENTS WITH *AGILE*

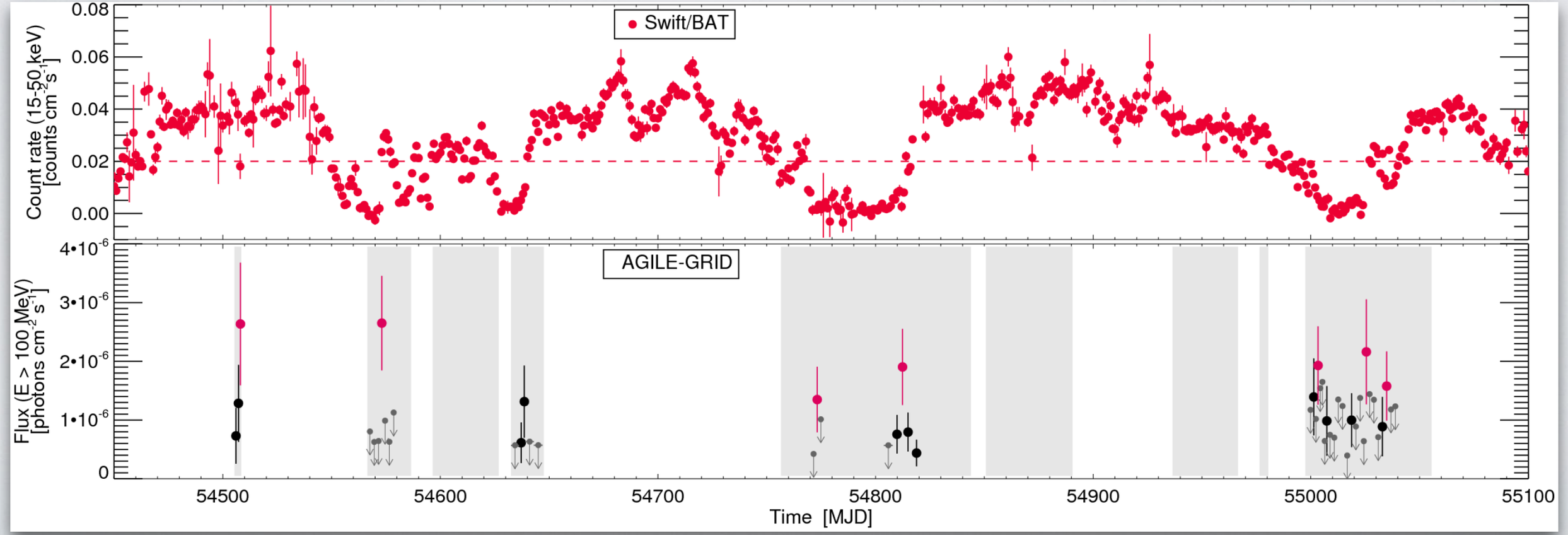
- Microquasars
  - Rare or undetectable transient gamma-ray emission

Source	Regular	Radio	MeV/GeV	TeV
Cygnus X-3	✗	Persistent & Burst	✓	✗
V 404 Cygni	✗	Burst	✓ (?)	✗
MWC 656	✗	Burst	✓ (?)	✗

CYGNUS X-3

- Repetitive pattern:
  - Microquasar: WR star + unknown c.o. (NS or BH?)
  - 4.8h period
  - Soft-to-hard X-ray state transition
  - Preceeding strong radio flares
  - Clear phenomenological correlation

Adapted from Piano et al. (2012)



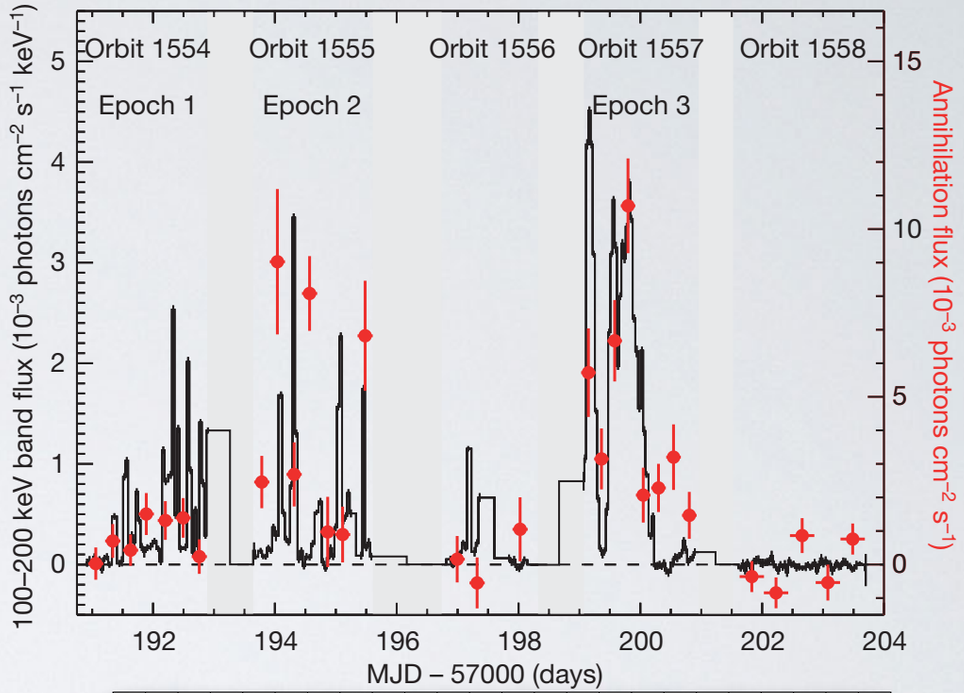
CYGNUS X-3

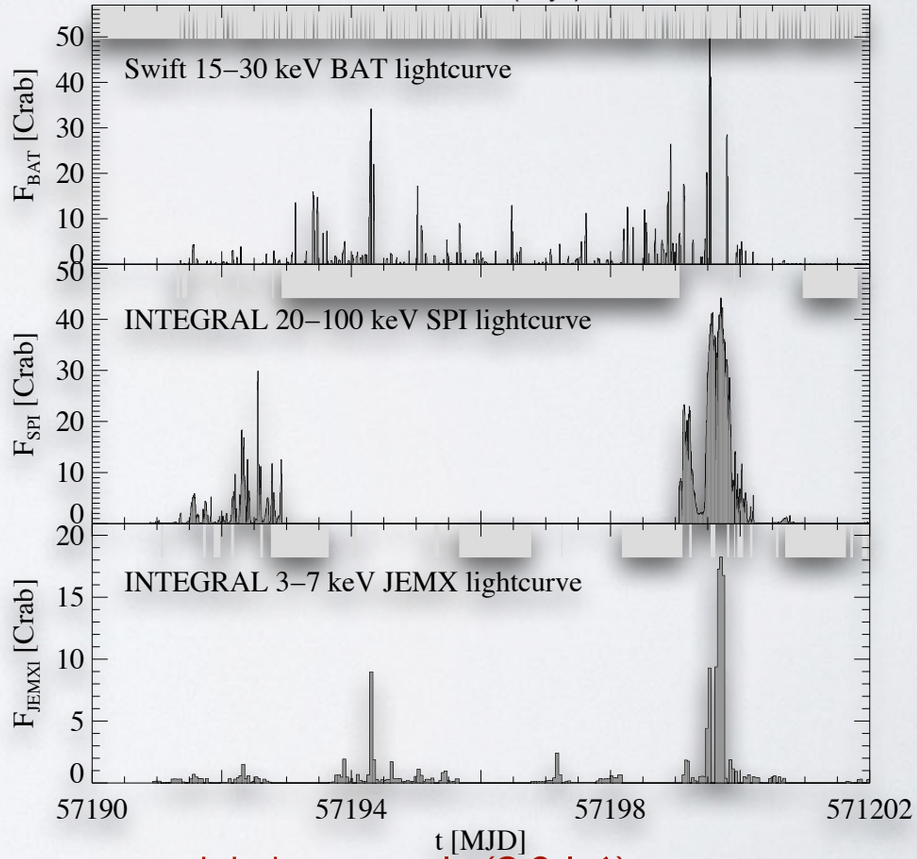
- Repetitive pattern:
  - January 2016 event
    - AGILE confirms the enhanced gamma-ray emission from Cygnus X-3 (Tavani et al. 2016, ATel #8597)
    - Flux(E > 100 MeV) = 2.8 x 10^{-6} ph cm^{-2} s^{-1}
    - Correlated with X-ray state transition

V404 CYGNI

- Microquasar with a 12 ± 3 $M_\odot$ black hole, 6.47d period
- Late G or K Companion with < 1 $M_\odot$
- June 2015 flare
  - First flaring activity since ~30 years
  - Seen by Swift, MAXI, INTEGRAL… from radio to gamma-rays (66 ATels!!!)
  - Excellent for studying massive accretion onto BHs

Siegert et al. (2016)

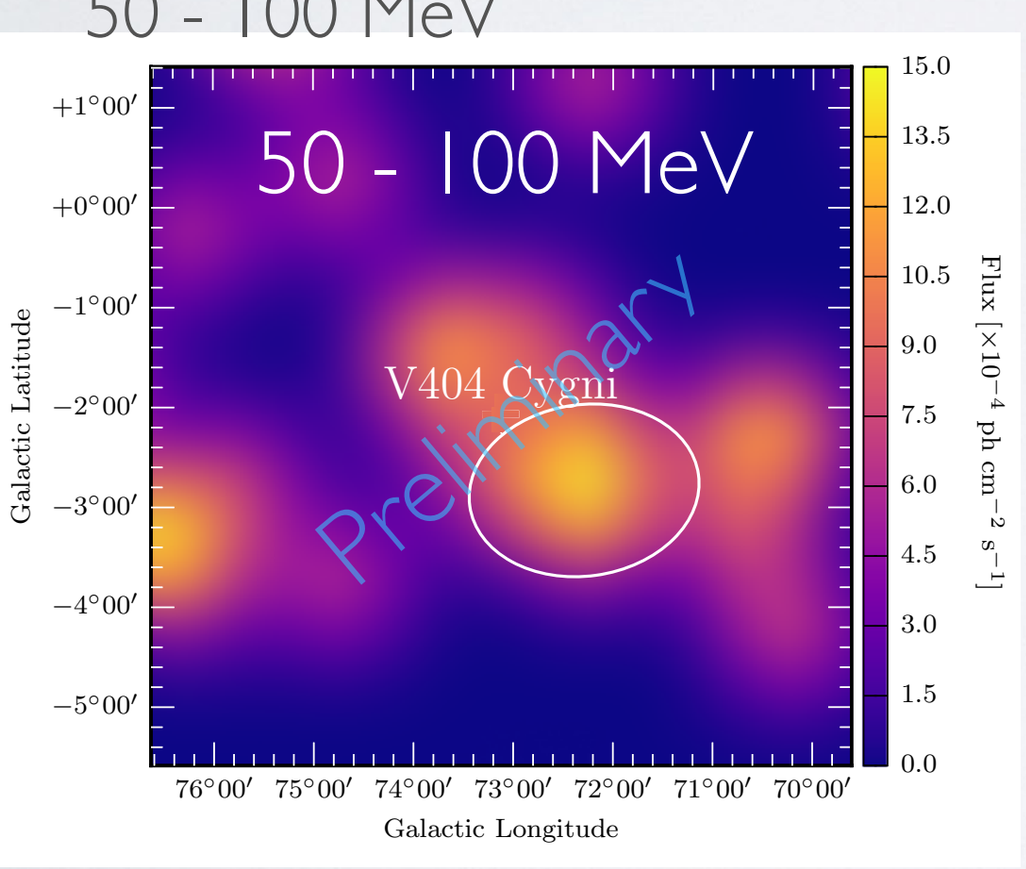


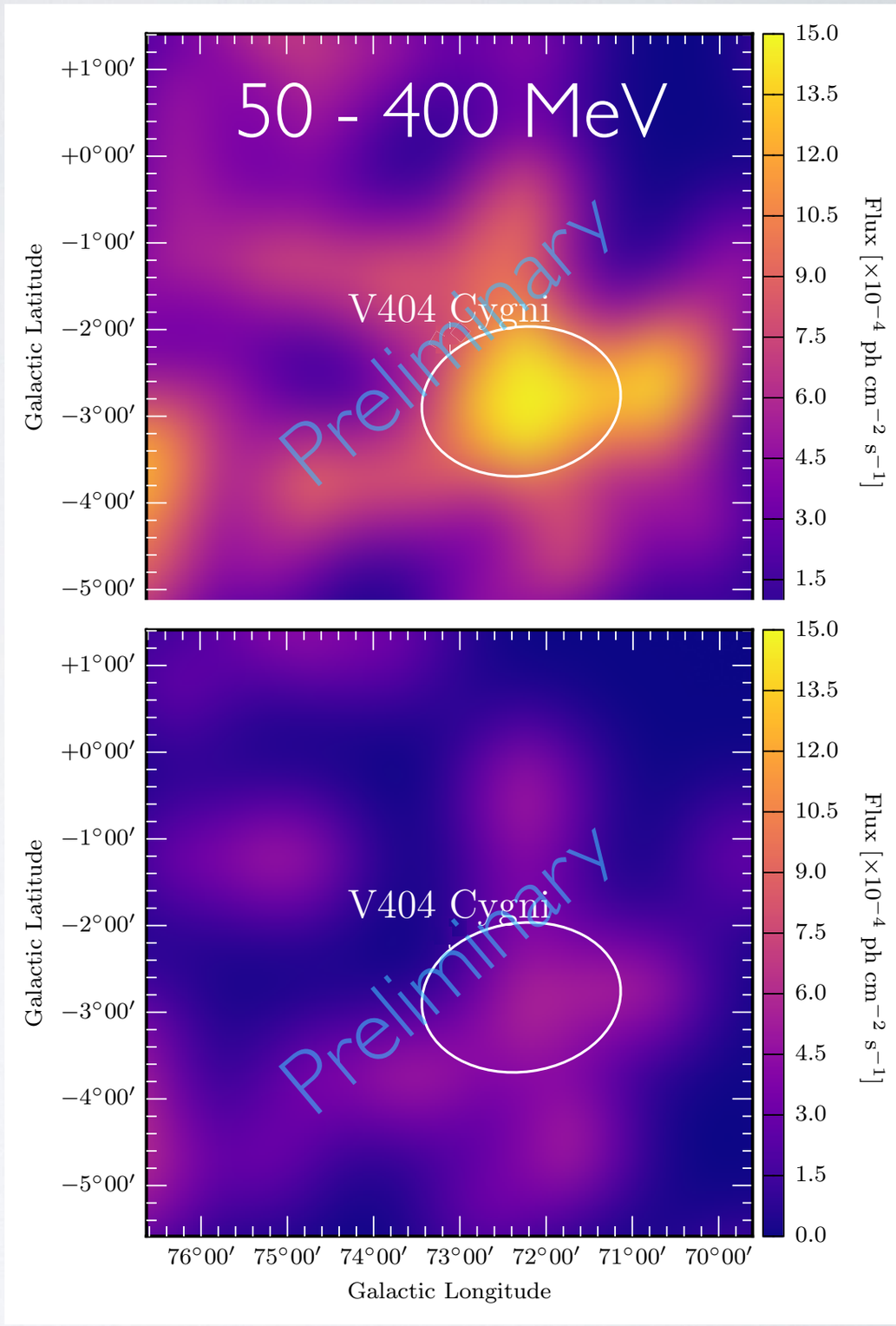


Heinz et al. (2016)

V404 CYGNI

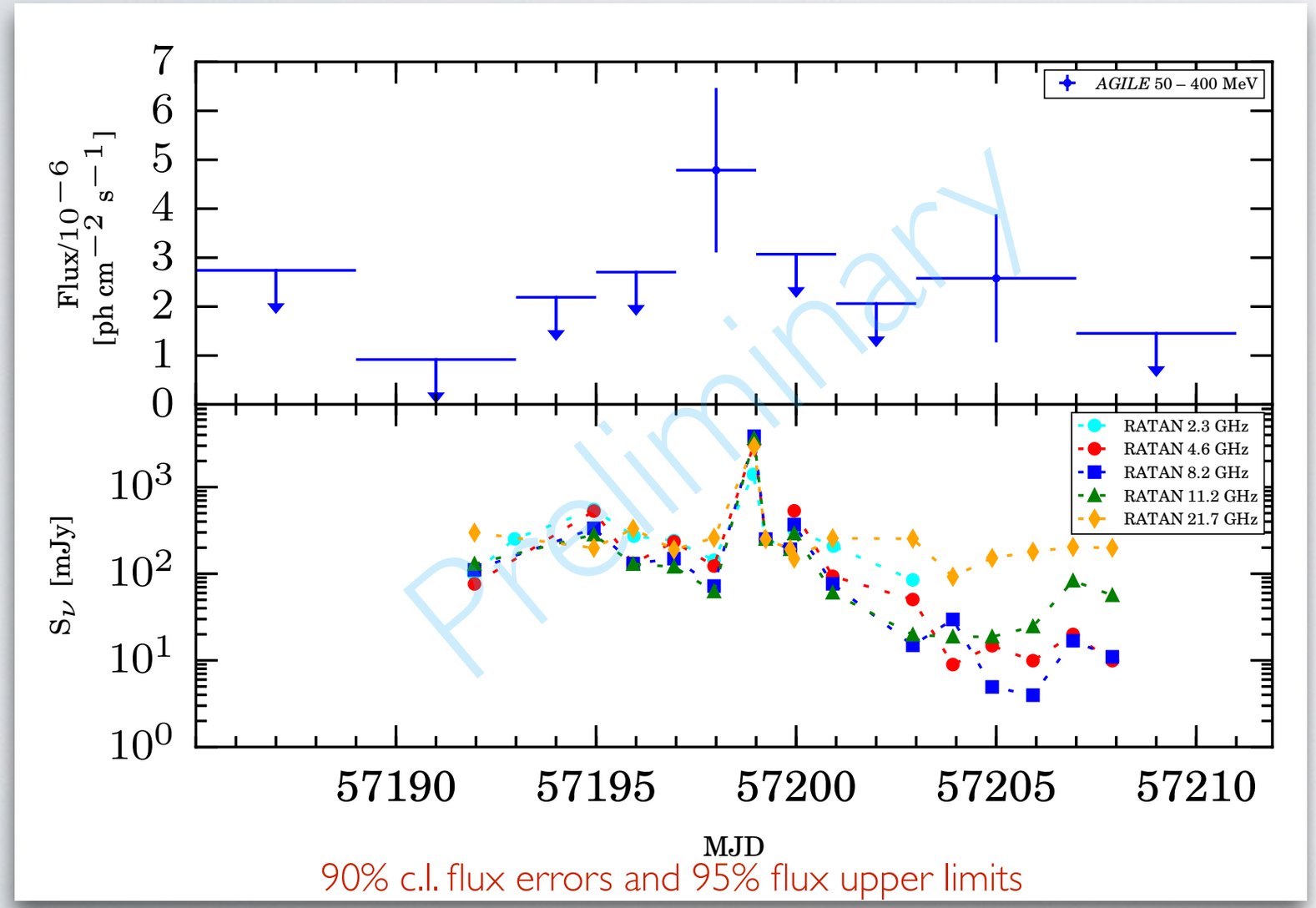
- *AGILE* observations
  - Activity between June 24 and 26
  - Soft gamma-ray emission (50 - 400 MeV), at 4.3σ
  - Most of the emisison between 50 - 100 MeV





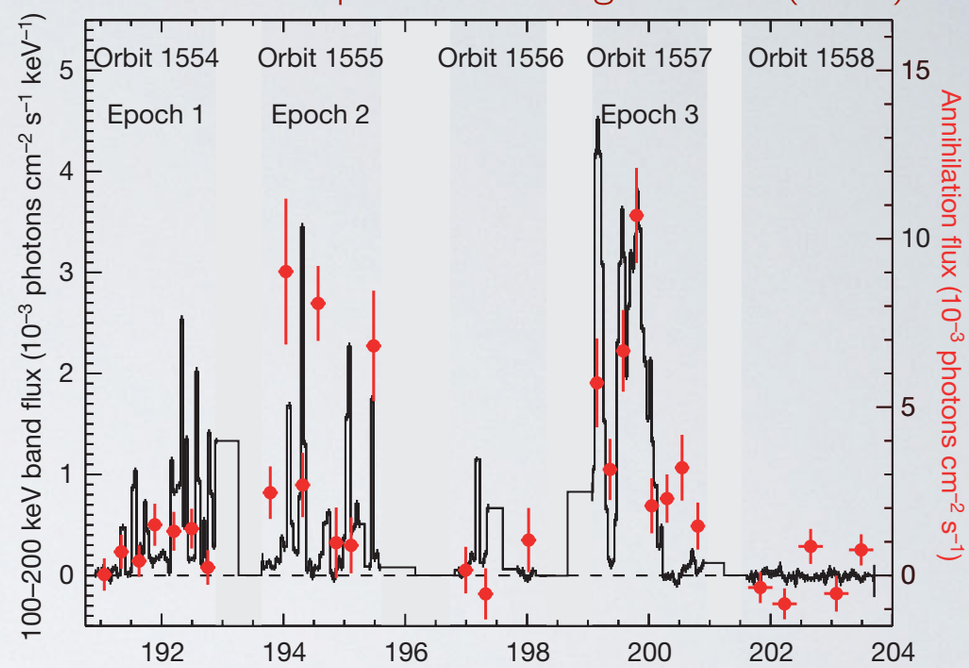
V404 CYGNI

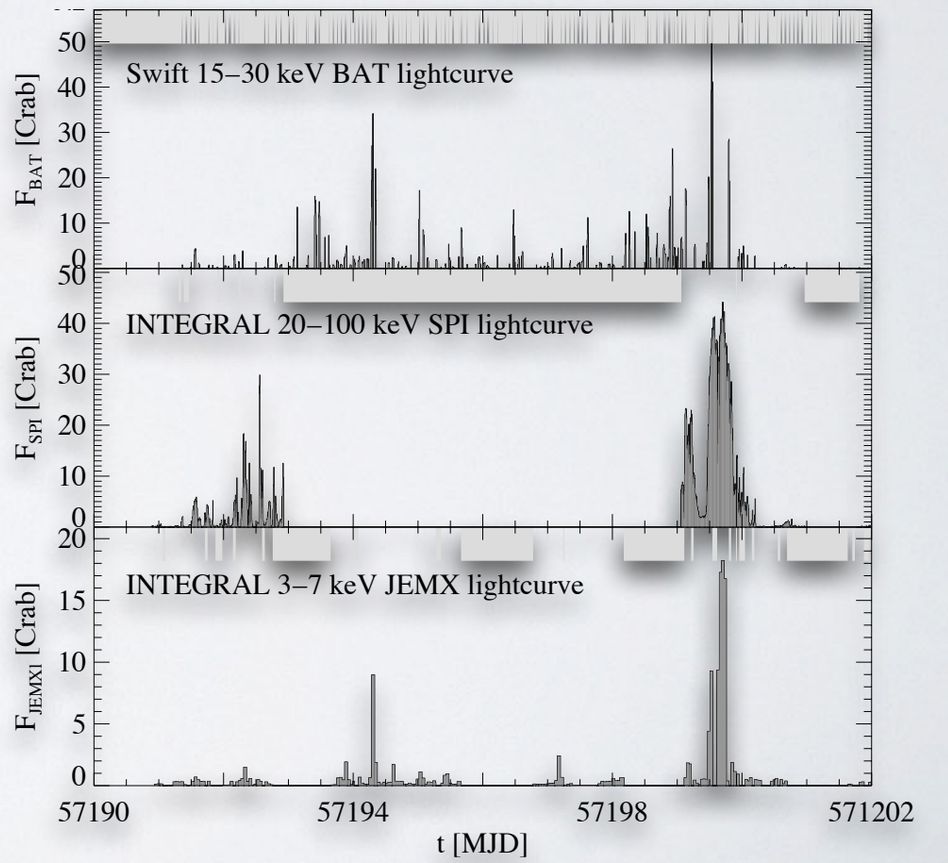
- *AGILE* observations
  - Soft gamma-ray emission (50 - 400 MeV)
  - No evidence for activity prior June 24-26
  - Hint of activity on July 2nd (2.7σ), in coincidende with radio enhancement



90% c.l. flux errors and 95% flux upper limits

Adapted from Siegert et al. (2016)





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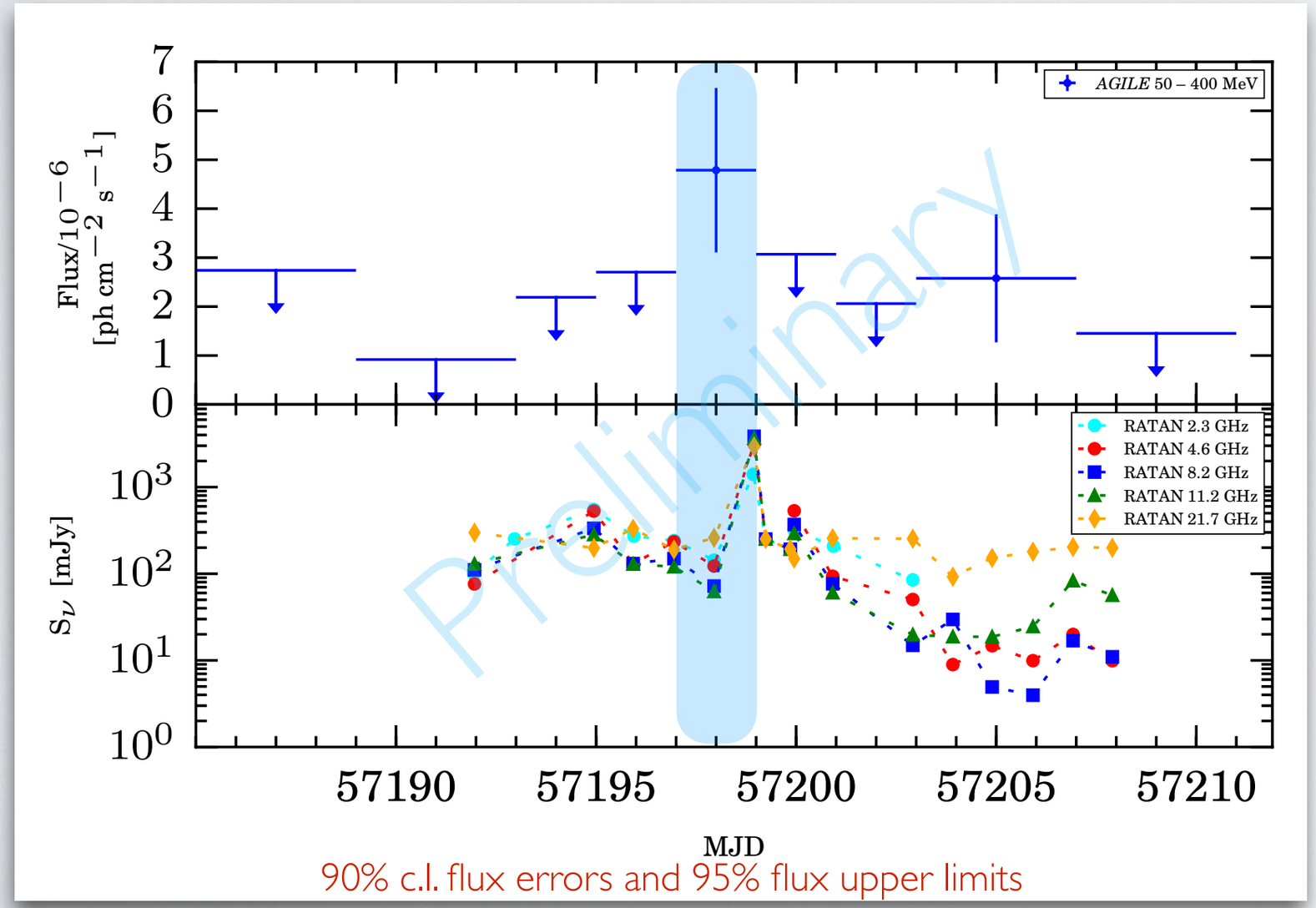

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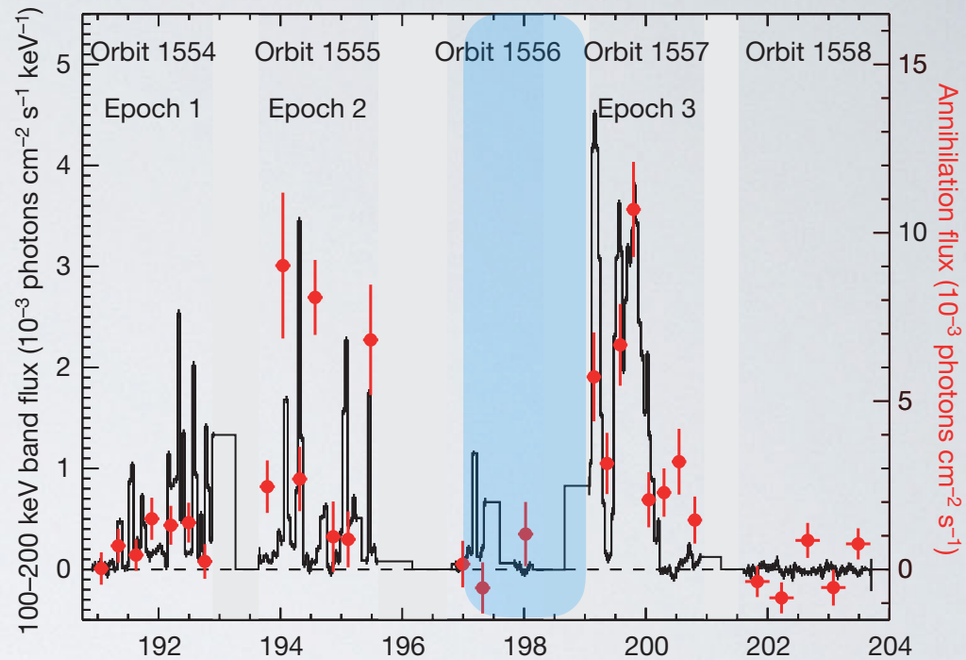
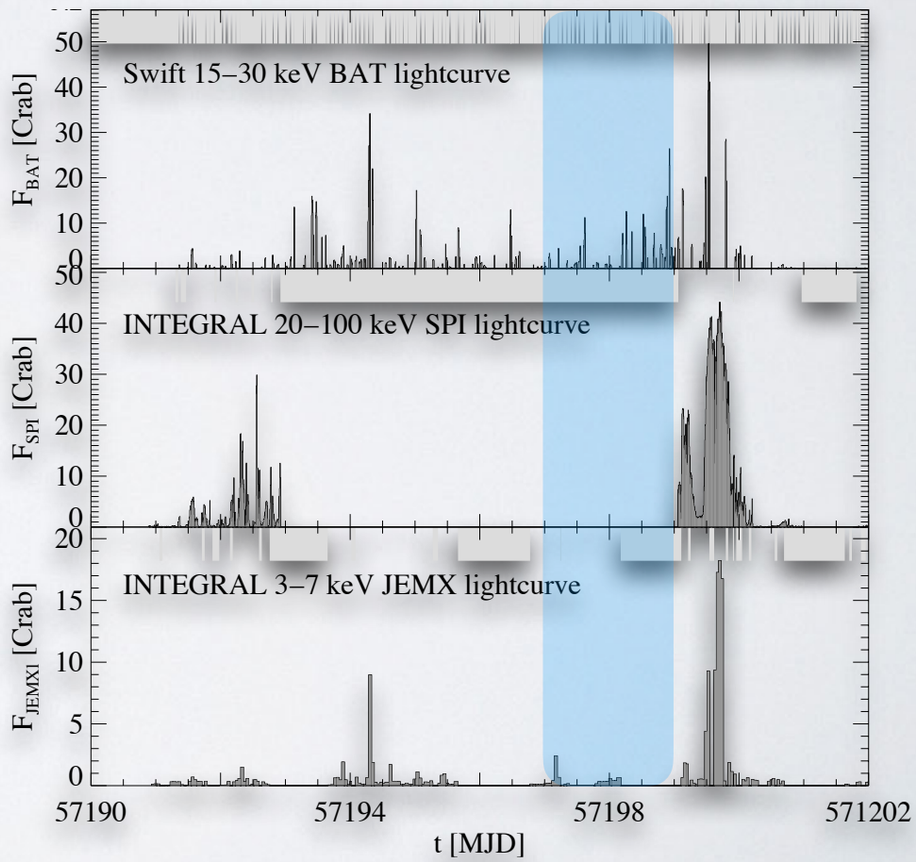
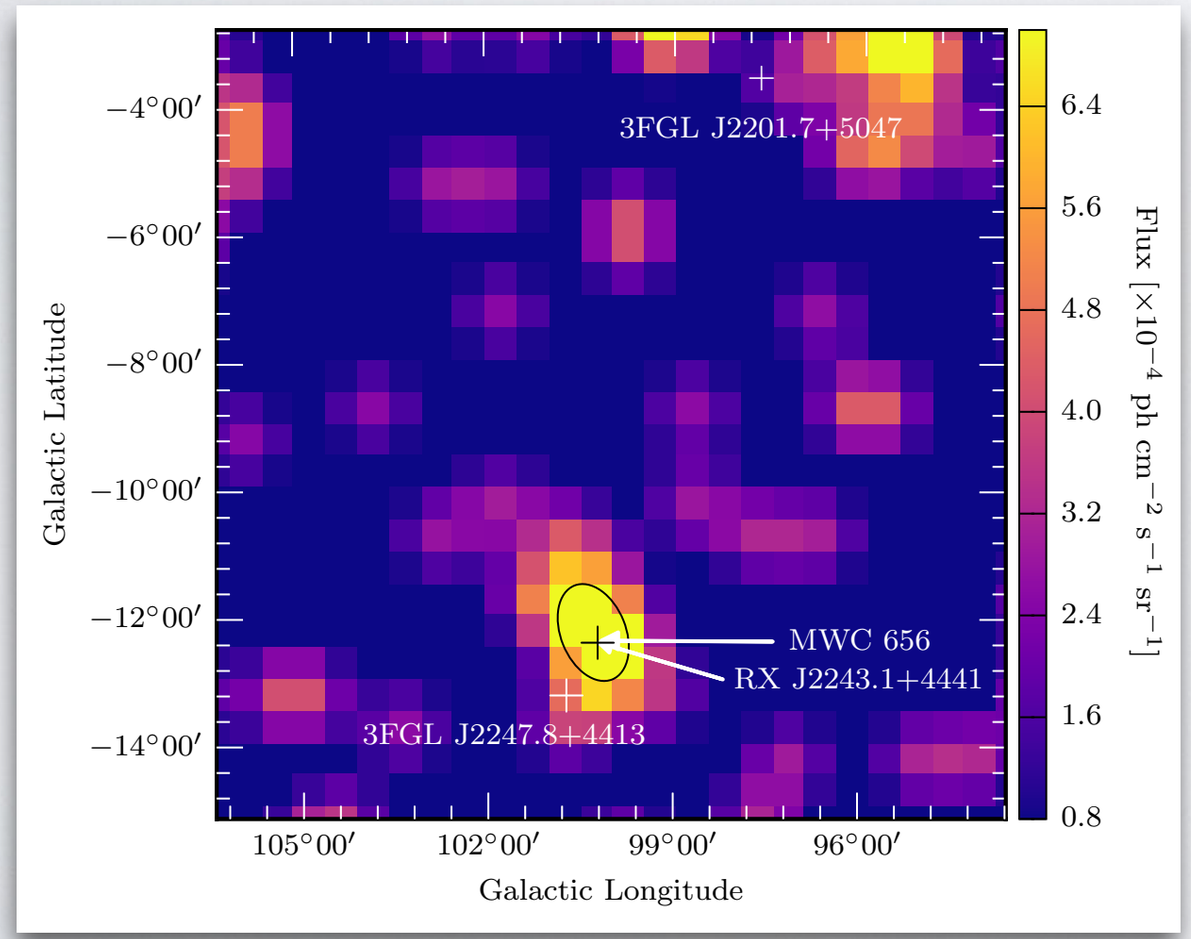


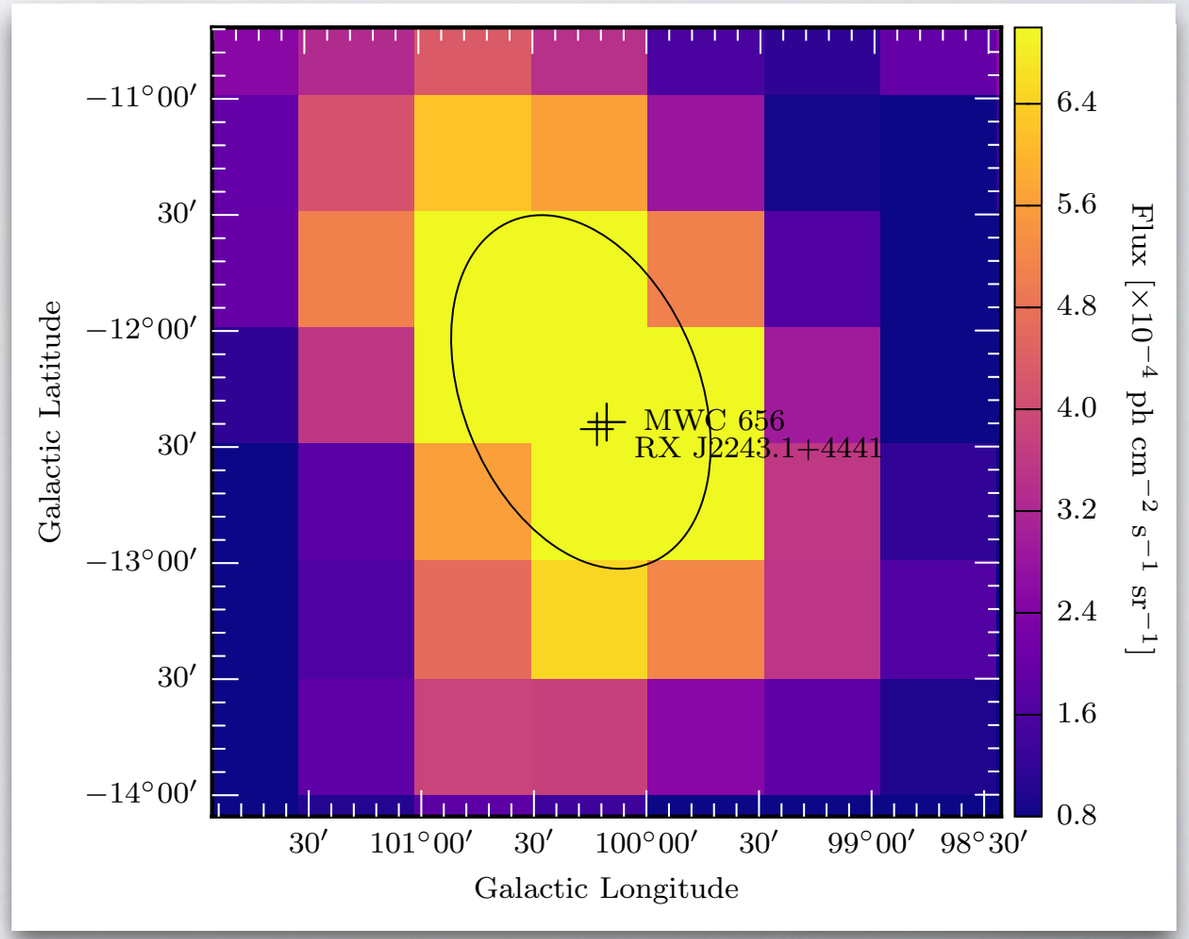


Adapted from Heinz et al. (2016)

AGL J2241+4454

- *AGILE* detection of a gamma-ray flare (Lucarelli et al. 2010)
- *Fermi* did not confirm the detection (UL of 10^{-7} ph cm^{-2} s^{-1} at 95% c.l.)





Munar-Adrover et al. (2016), under review

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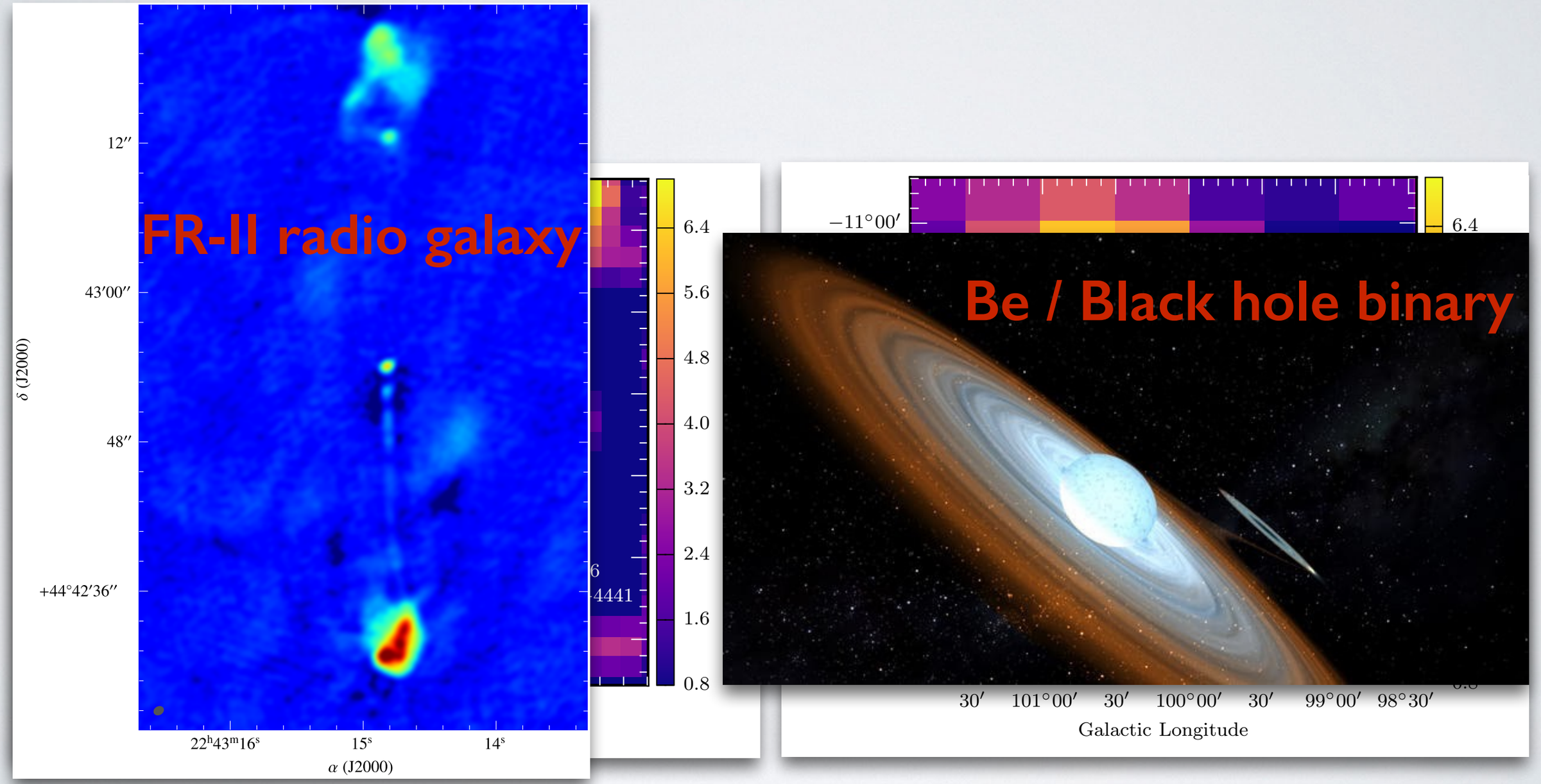
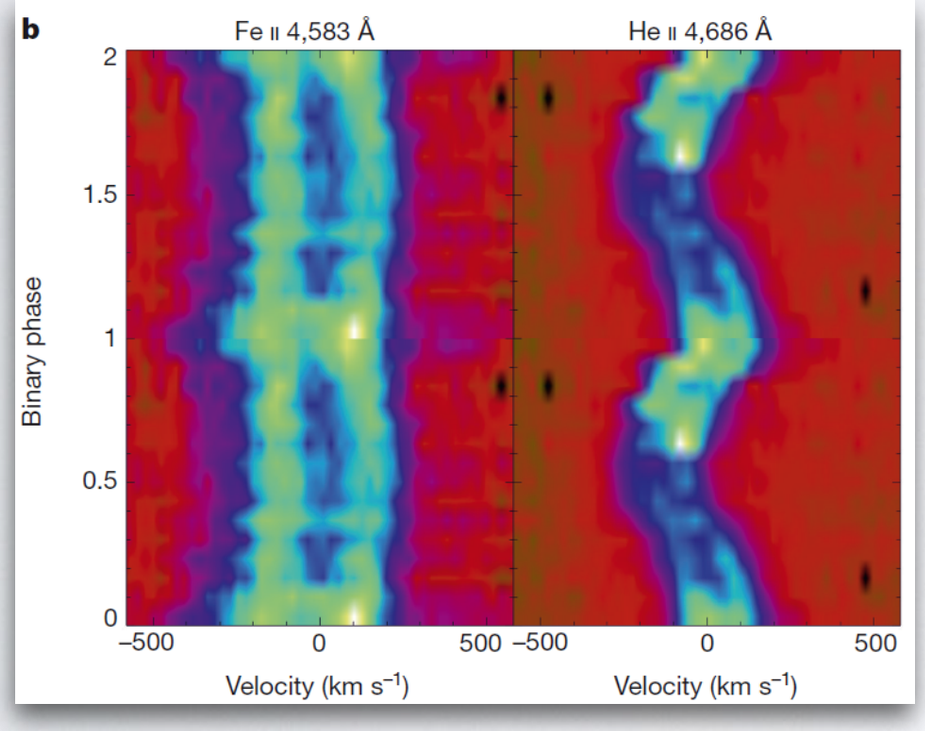


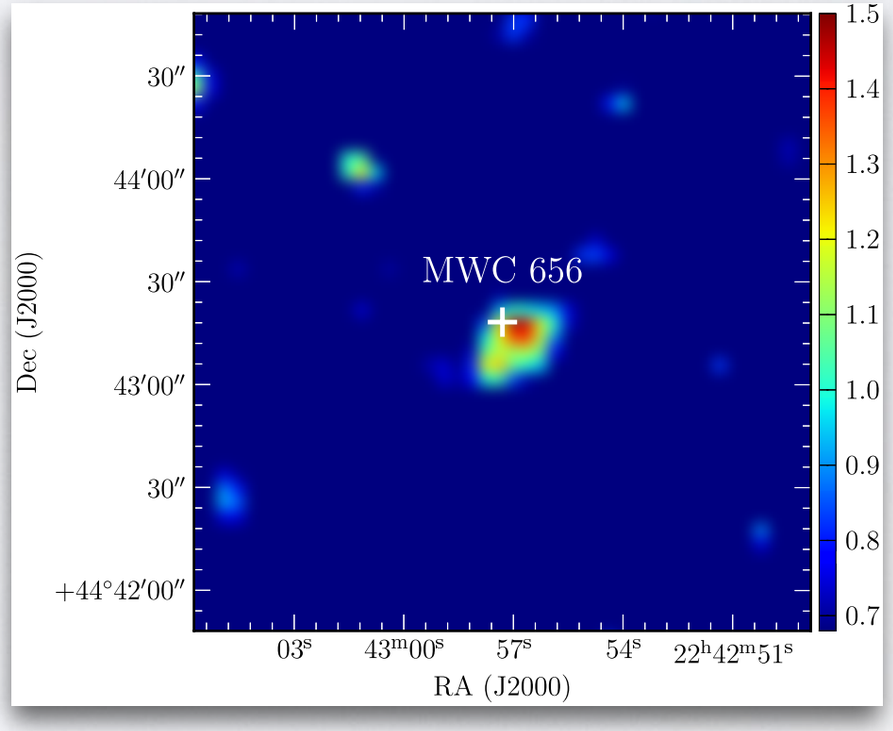
Munar-Adrover et al. (2016), under review

AGL J2241+4454

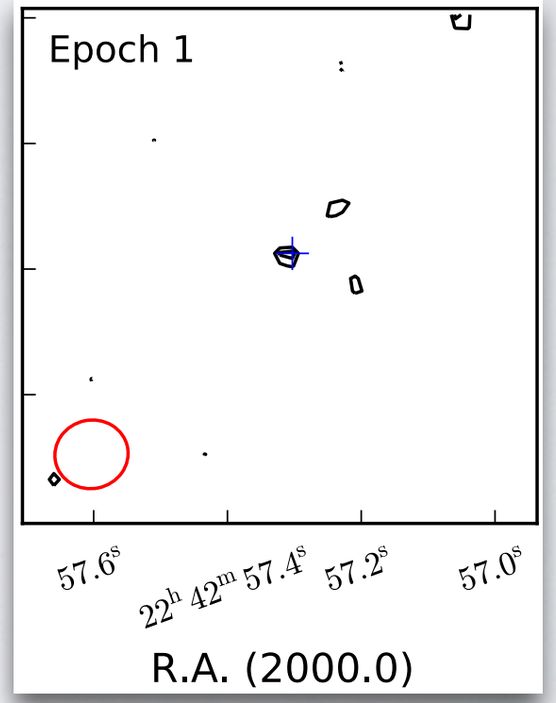
- Might be associated to MWC 656, which was confirmed as a binary system by Casares et al. (2012)
- MWC 656: Be star orbited by a BH (Casares et al. 2014) with a mass between 3.8 and 6.9 $M_{\odot}$. The **first known binary system of this class.** Confirmed as a high-mass X-ray binary (Munar-Adrover et al. 2014)
- Radio detection at GHz (Dzib et al. 2015). Proof of variable nature and emission of high-energy particles



Casares et al. (2014)



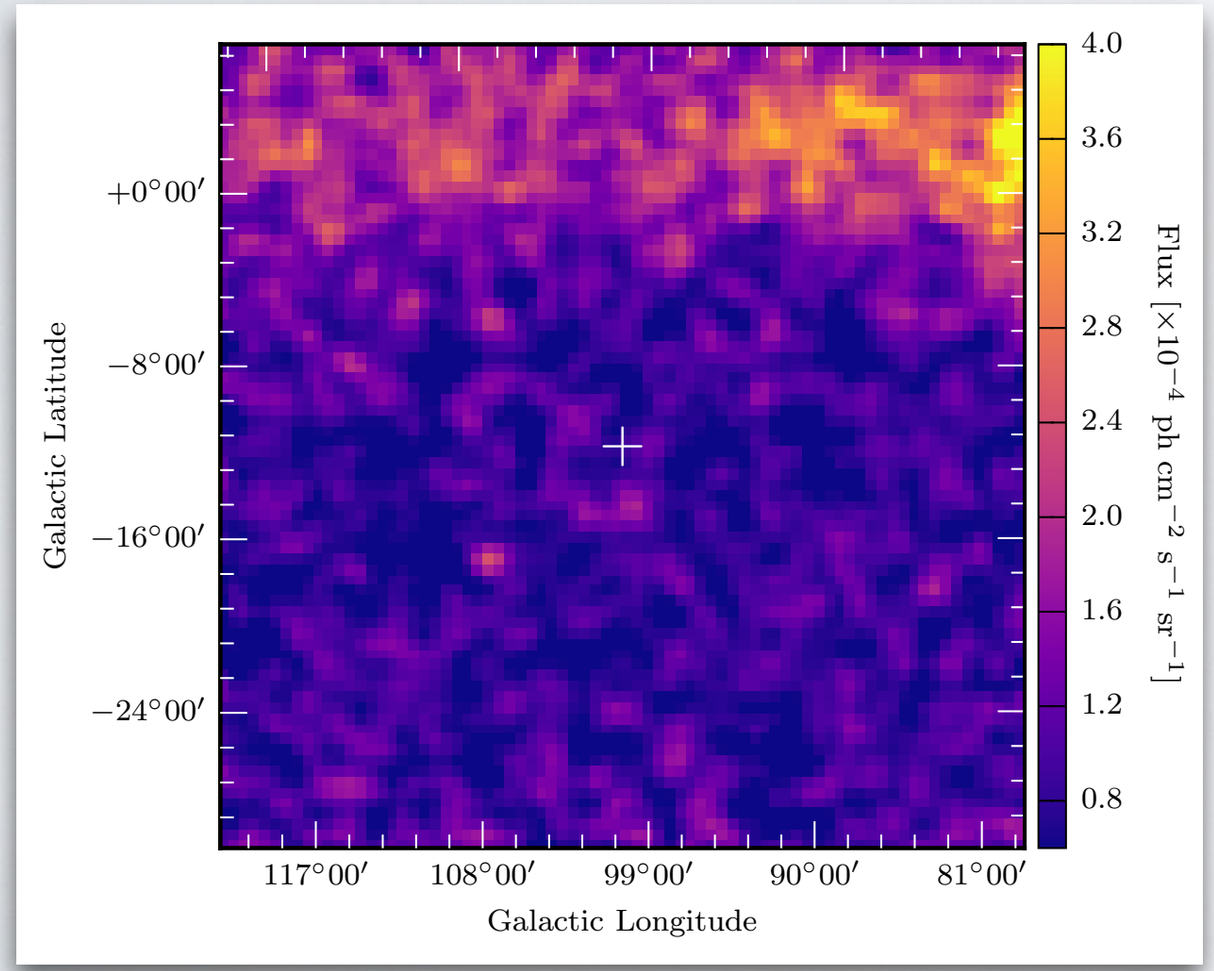
Munar-Adrover et al. (2014)

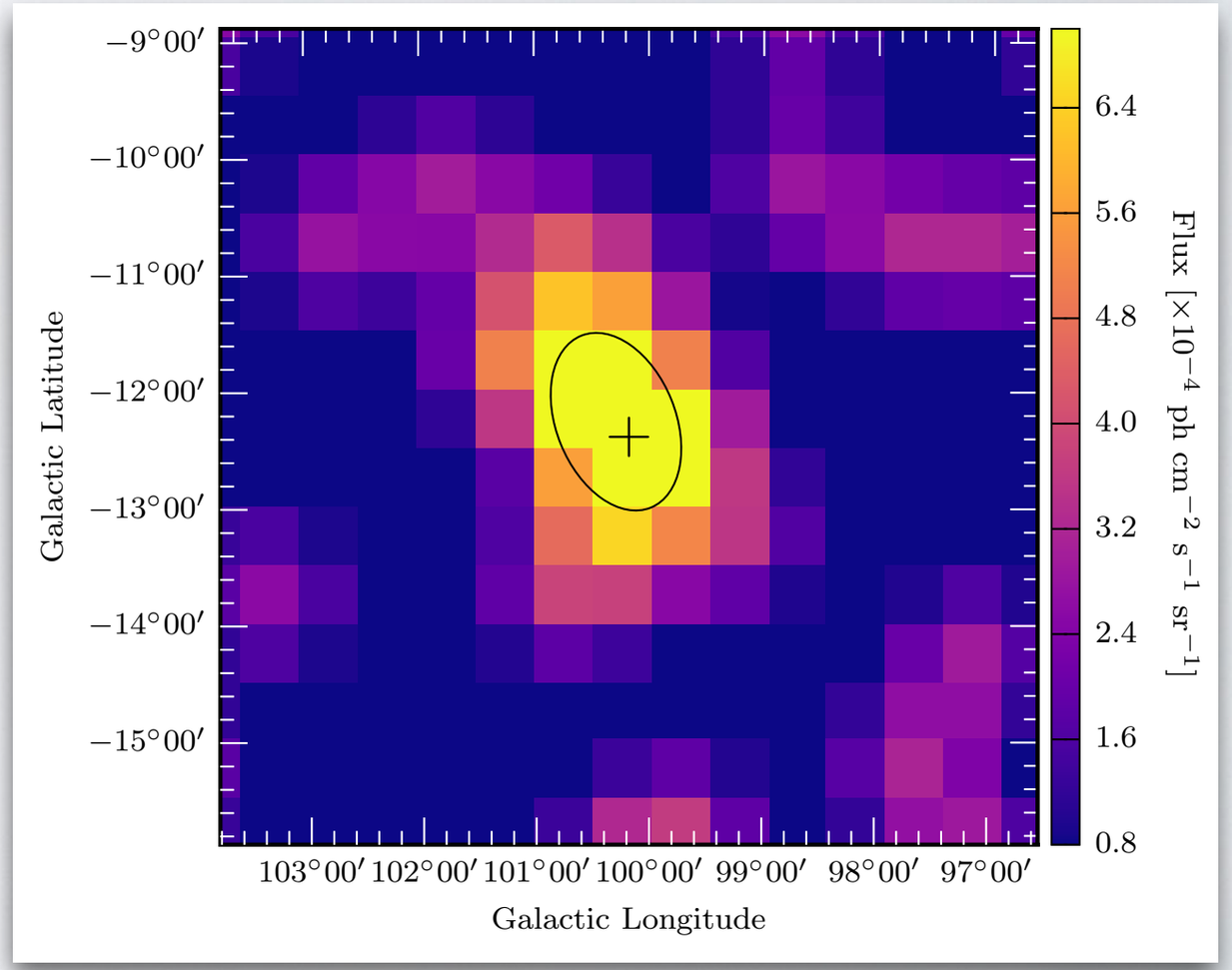


Adapted from Dzib et al. (2014)

AGL J2241+4454

- Searching for transient gamma-ray emission
  - Blind search in 2-day bins (spinning and pointing)





Munar-Adrover et al. (2016), under review

AGL J2241+4454

- 10 flaring events registered by AGILE between 2007 and 2013
- follow up of the source

AGILE GAMMA-RAY TRANSIENT DETECTIONS AROUND THE POSITION OF MWC 656.

t_{start} [UT]	t_{end} [UT]	Flux [$\times 10^{-6}$ cm^{-2} s^{-1}]	$\sqrt{TS}$
2007-11-23 UT00:00:00	2007-11-24 UT00:00:00	1.5 ± 0.5	4.5
2008-06-28 UT00:00:00	2008-06-30 UT00:00:00	0.6 ± 0.3	3.2
2009-01-04 UT00:00:00	2009-01-07 UT00:00:00	0.5 ± 0.2	3.1
2010-06-13 UT00:00:00	2010-06-14 UT00:00:00	1.4 ± 1.1	3.2
2010-06-30 UT00:00:00	2010-07-02 UT00:00:00	1.3 ± 0.6	3.1
2010-07-25 UT00:00:00	2010-07-27 UT00:00:00	1.4 ± 0.6	5.3
2011-04-09 UT00:00:00	2011-04-11 UT00:00:00	2.2 ± 1.1	3.1
2011-10-08 UT00:00:00	2011-10-10 UT00:00:00	2.5 ± 1.1	3.4
2013-03-07 UT00:00:00	2013-03-08 UT09:00:00	2.6 ± 1.4	3.1
2013-07-10 UT00:00:00	2013-07-12 UT00:00:00	3.2 ± 1.6	3.5

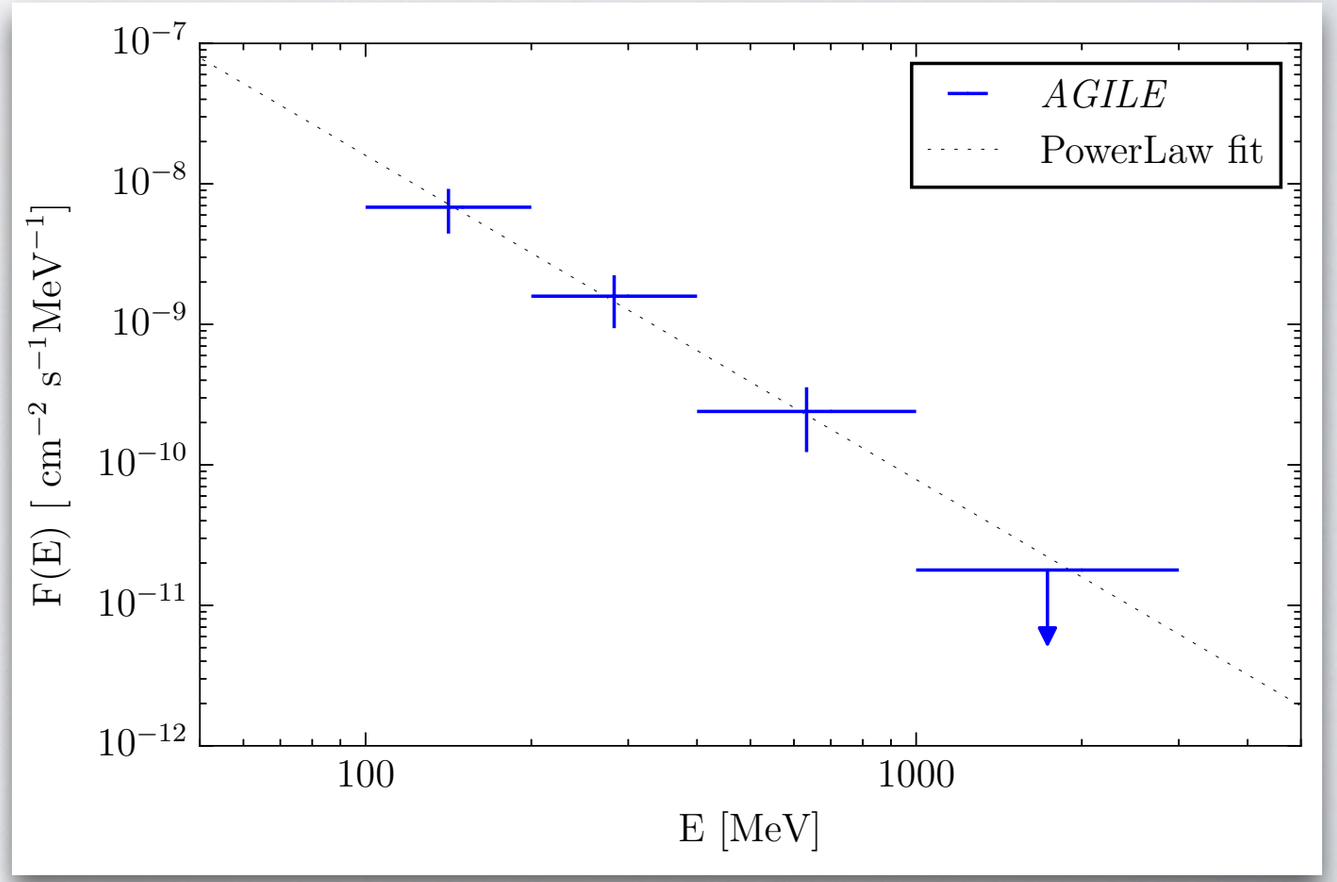
Munar-Adrover et al. (2016), under review

AGL J2241+4454

- Spectral analysis stacking all the events:
  - *AGILE* spectrum between 100 MeV and 3 GeV
  - Integrating over all detected gamma-ray flares
  - Spectral fit with photon index $\Gamma = 2.35 \pm 0.16$
  - Best fit position:

    (l, b) = (100°.37, -12°.39) ± 0°.35
- Post trial analysis:
  - 909 2-day bins, min TS = 9
  - $$P(N,k) = 1 - \sum_{j=0}^{k-1} \binom{N}{j} p^j (1-p)^{N-j}$$

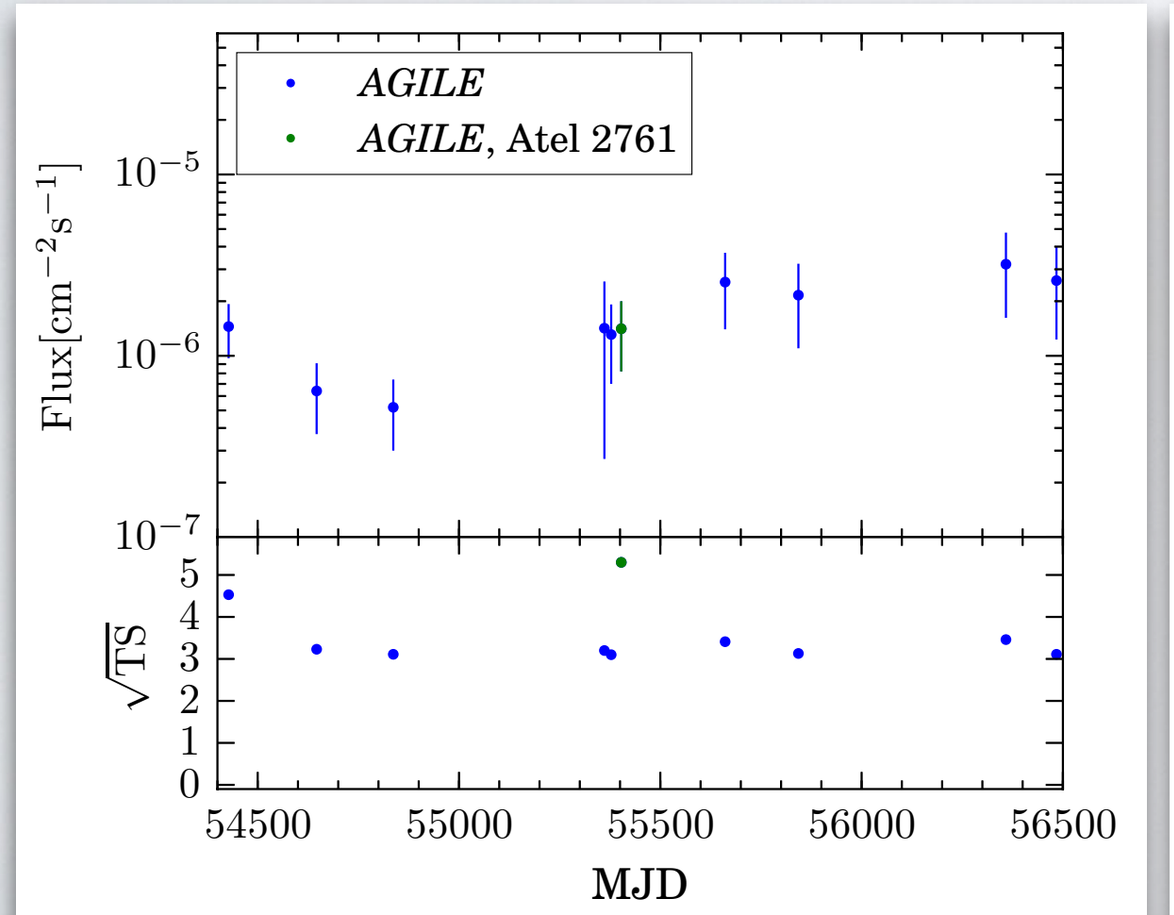
    from Bulgarelli et al. (2012)
  - P = 6.8 x 10^{-7}

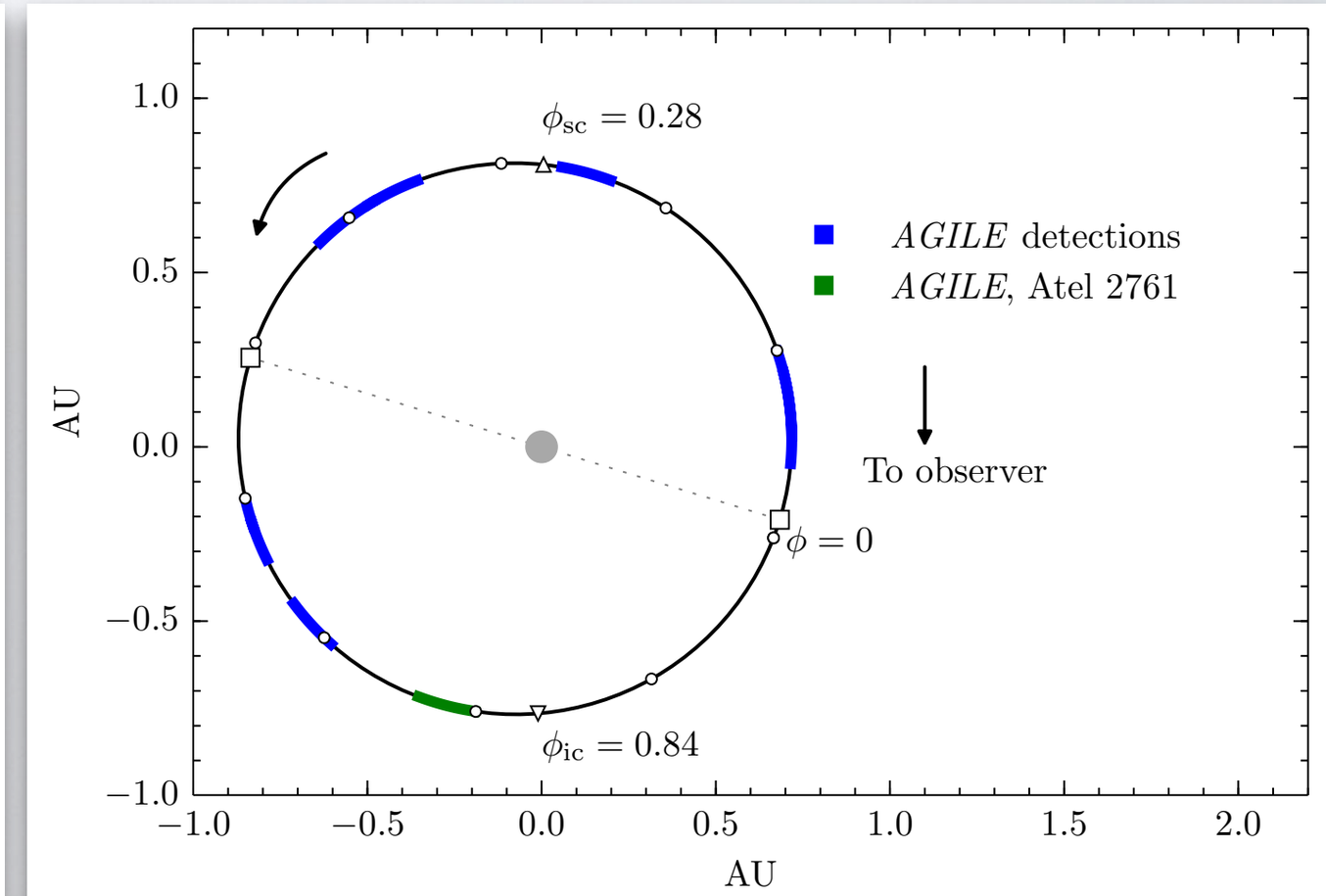


Munar-Adrover et al. (2016), under review

AGL J2241+4454

- Searching for periodic gamma-ray emission
  - Folding data with the 60.37 d period





Munar-Adrover et al. (2016), under review

CONCLUSSIONS

- AGILE is a superb instrument for the study of galactic transient sources
- Cygnus X-3 has been detected in 2016 during a state transition correlated with X-rays
- V404 Cygni 2015 outburst was observed by AGILE and a possible detection has been proposed. This allows to study strong accretion episodes onto black holes
- AGL J2241+4454 might be associated to the Be/BH binary system MWC 656. AGILE reveals 10 flares that allow for a spectral characterization of the gamma-ray source. No periodic or persistent emission is observed
- Emission mechanisms are still not clear for these systems. Improve in sensitivity at 100 MeV is crucial to distinguish between hadronic and leptonic models

BACK UP

AGILE FLARES

- *Fermi* likelihood analysis of each flaring event:

Start	Stop	TS	UL $[\mathrm{cm^{-2}s^{-1}}]$
2009-01-04 12:02:12	2009-01-07 00:02:12	0.4	8.6×10^{-8}
2010-06-13 12:01:06	2010-06-14 18:01:06	-2.5×10^{-5}	6.4×10^{-8}
2010-06-30 00:01:06	2010-07-02 00:01:06	1.05	1.3×10^{-7}
2010-07-25 00:02:12	2010-07-27 00:02:12	-2.6×10^{-6}	7.5×10^{-8}
2011-04-09 00:02:12	2011-04-11 00:02:12	-6.4×10^{-5}	2.8×10^{-8}
2011-10-08 00:02:12	2011-10-10 00:02:12	0.6	1.2×10^{-7}
2013-03-07 00:00:00	2013-03-08 09:00:00	0.005	1.1×10^{-7}
2013-07-10 00:00:00	2013-07-12 00:00:00	–	–

- *Fermi* likelihood phase folded analysis:

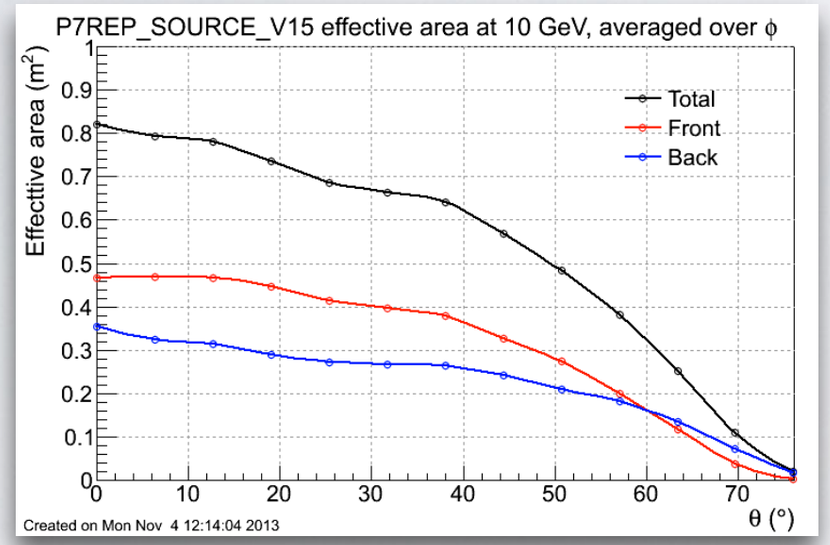
ϕ	UL $[\mathrm{ph\ cm^{-2}\ s^{-1}}]$	TS
0.063	2.85×10^{-9}	-0.0008
0.188	1.16×10^{-8}	0.19
0.313	8.50×10^{-9}	-9.9×10^{-5}
0.438	1.24×10^{-9}	-0.0019
0.563	9.50×10^{-0}	-0.003
0.688	1.77×10^{-9}	-0.0014
0.813	2.19×10^{-9}	1.72
0.938	2.19×10^{-9}	1.72

- *Fermi* likelihood analysis of stacking of the events:

UL = 3×10^{-7} $\mathrm{cm^{-2}\ s^{-1}}$

WHY *FERMI* DID NOT SEE THE FLARES?

- *Fermi's* effective area decreases fast for zenith distance (ZD) > 50°



http://www.slac.stanford.edu/exp/glast/groups/canda/lat_Performance.htm

- We checked the source ZD at any given moment for the whole *Fermi* mission
- During *AGILE* flares, MWC 656 is almost always at ZD > 50°