Follow-up observations of the first Be/BH binary

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CNOC IX

Session: Buchi neri stellari

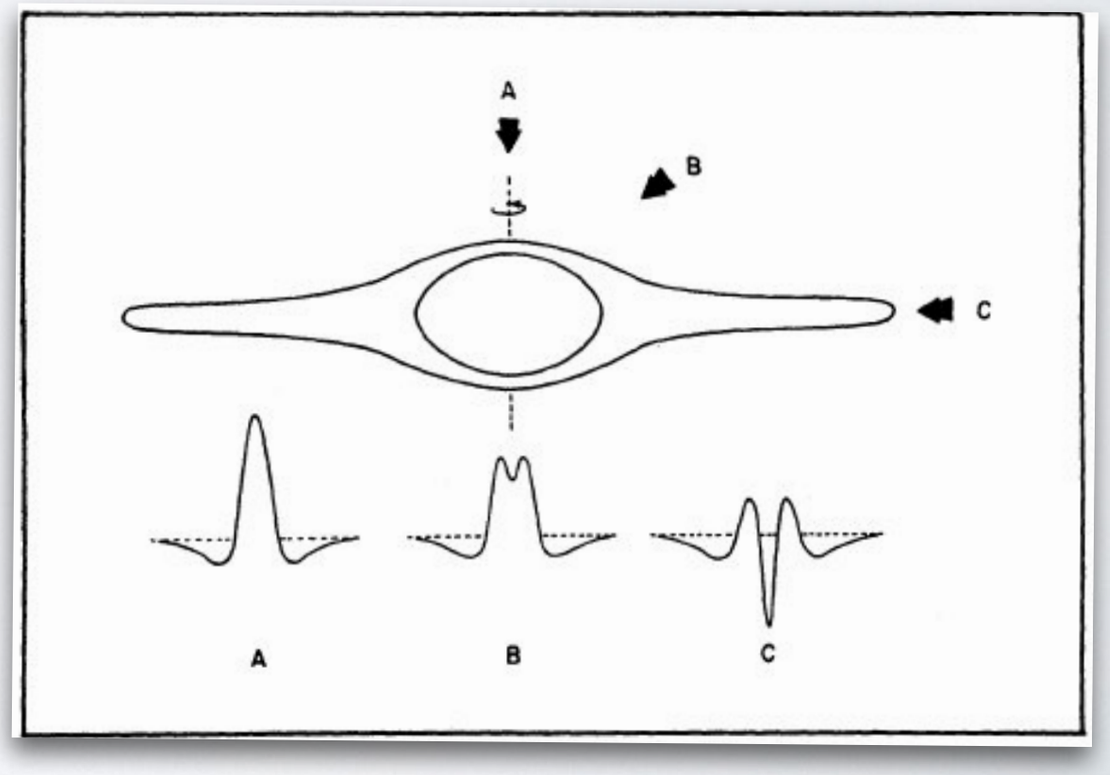
OUTLINE

- Introduction
- MWC 656
- X-ray observations
- Follow-up
  - *AGILE* data analysis
  - *Fermi* data analysis
  - Comparison *AGILE* vs *Fermi*
- Conclusions

INTRODUCTION

Be stars

- Be stars are B stars with spectral emission lines of hydrogen (Hα, Hβ, etc.) and a high projected rotational velocity (close to critical when de-projected).
- It is well established that Be stars have a circumstellar envelope in the form of a quasi-Keplerian deccretion disk surrounding the star

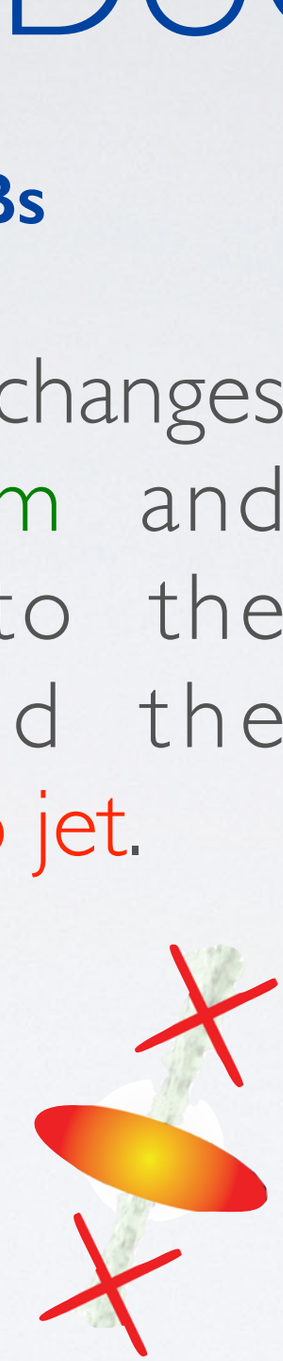


INTRODUCTION

Accretion-ejection coupling in XRBs

- Low-mass X-ray binaries: changes in their X-ray spectrum and luminosity associated to the accretion process and the presence/absence of a radio jet.

- Known as the accretion/ ejection coupling.



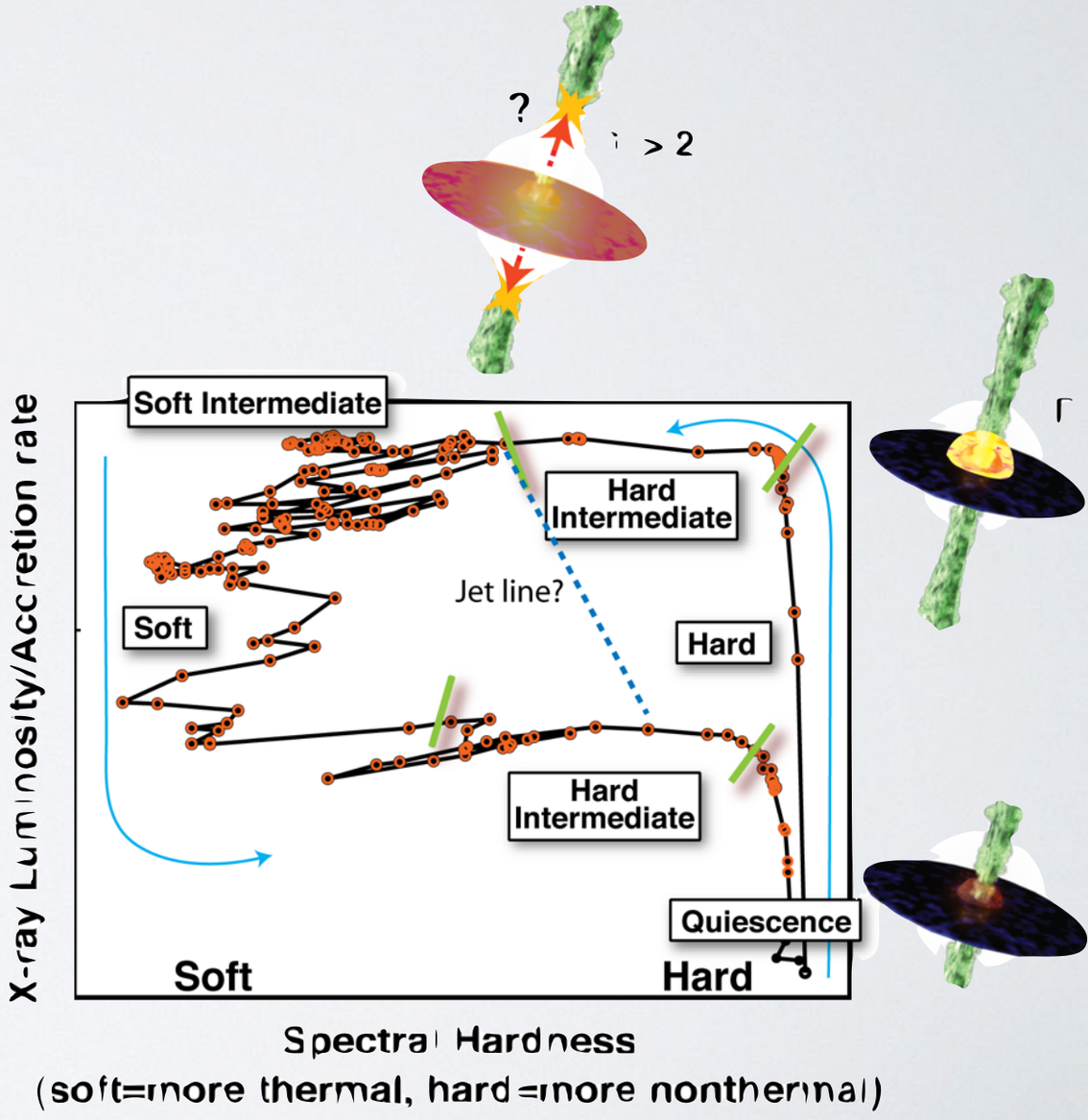


Image credit: Sera Markoff

MWC 656

- Discovered thanks to the *AGILE* detection of a gamma-ray flare (Lucarelli et al. 2010)
- *Fermi* could not confirm the detection (UL of 10^{-7} ph cm^{-2} s^{-1} at 95% c.l.)
- Confirmed as a binary system by Casares et al. (2012)
- Be star orbited by a BH (Casares et al. 2014) with a mass between 3.8 and 6.9 $M_\odot$
- MWC 656 is the **first known binary system of this class**

Table 1 | Orbital elements for MWC 656

Parameter	Value
P_{orb} (days)	60.37 (fixed)
T_0 (HJD − 2,450,000)	3,243.70 ± 4.30
e	0.10 ± 0.04
ω (degrees)	163.0 ± 25.6
γ (km s^{-1})	−14.1 ± 2.1
K_1 (km s^{-1})	32.0 ± 5.3
K_2 (km s^{-1})	78.1 ± 3.2
$a_1 \sin i$ ($R_\odot$)	38.0 ± 6.3
$a_2 \sin i$ ($R_\odot$)	92.8 ± 3.8
$M_1 \sin^3 i$ ($M_\odot$)	5.83 ± 0.70
$M_2 \sin^3 i$ ($M_\odot$)	2.39 ± 0.48
M_2/M_1	0.41 ± 0.07
σ_f (km s^{-1})	16.7

Casares et al. (2014)

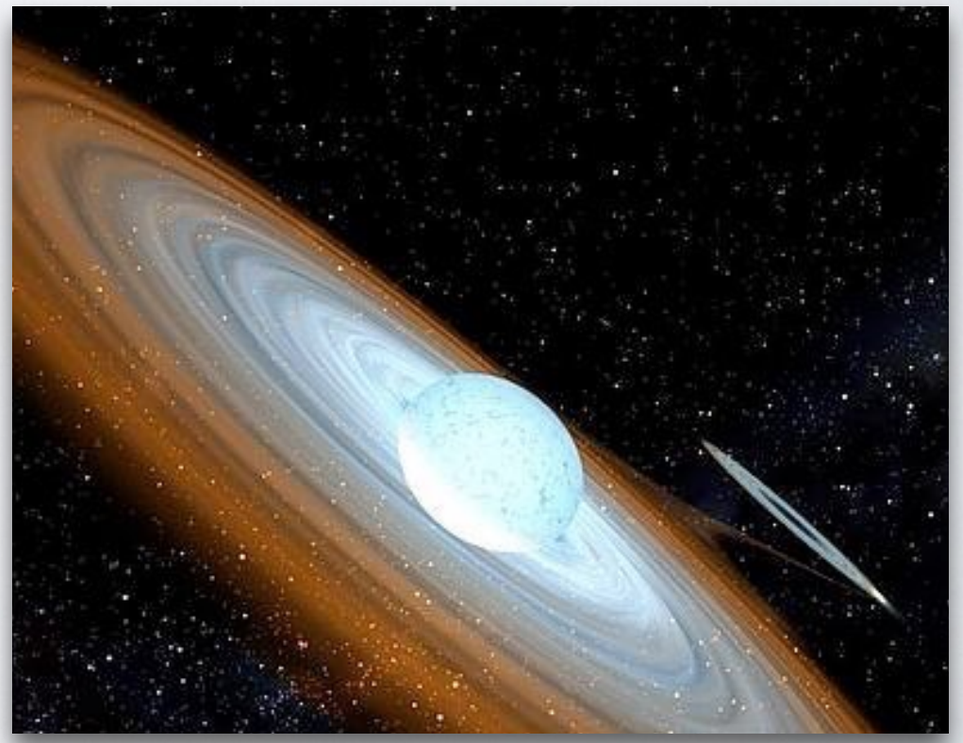
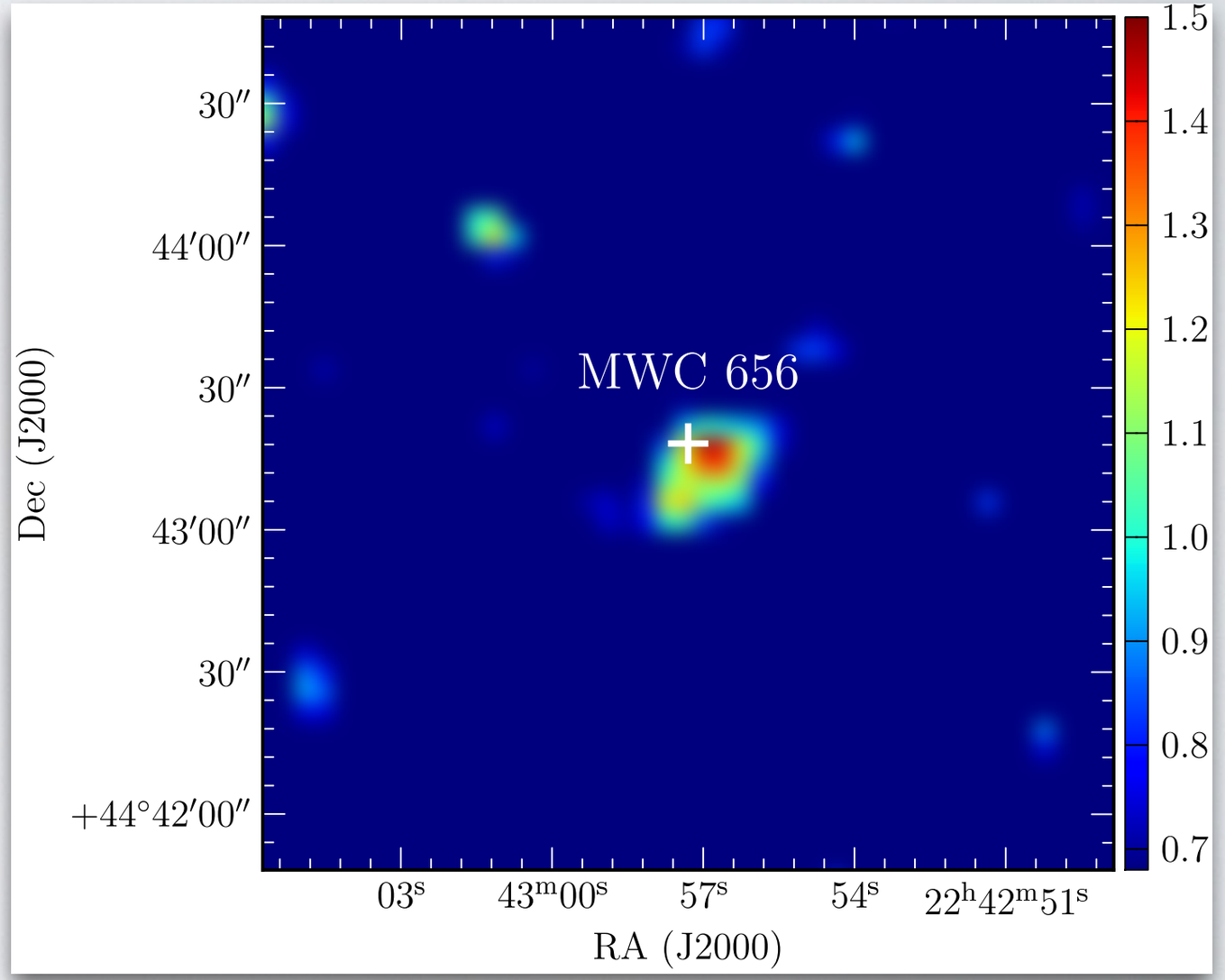


Image credit: Gabriel Pérez - SMM (IAC)

X-RAY DATA

- Observed with *XMM-Newton* (15 ks)
- We detect a faint source at 4σ c.l. coincident with the position of MWC 656
- X-ray source position compatible with the *Hipparcos* position of MWC 656 at 2.4σ
- Detected only in the 0.3-5.5 keV range
- Spectrum with low number of counts (0.3-5.5 keV energy range)



Munar-Adrover et al. (2014)

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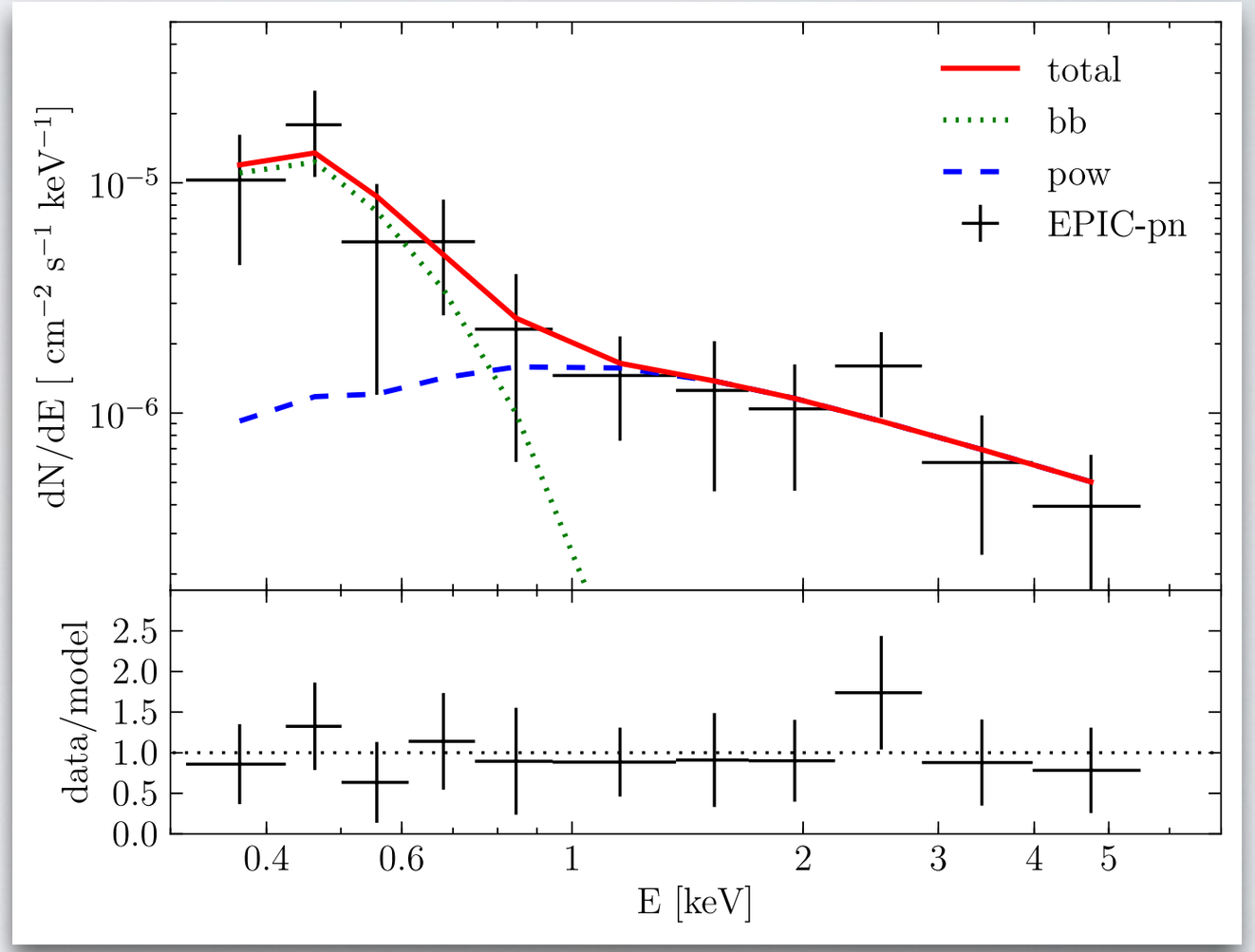
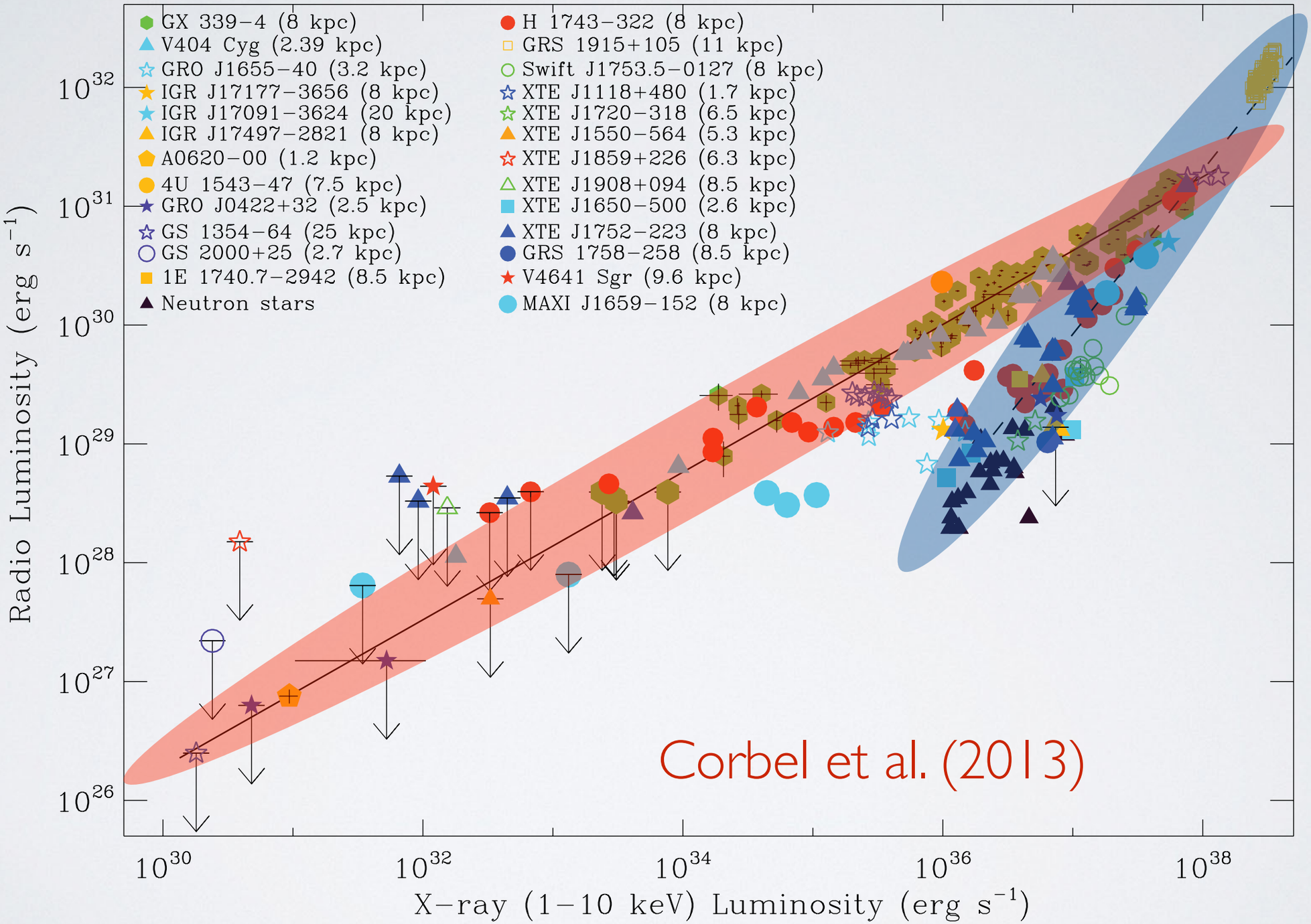


Munar-Adrover et al. (2014)

X-RAY LUMINOSITY vs RADIO LUMINOSITY CORRELATION



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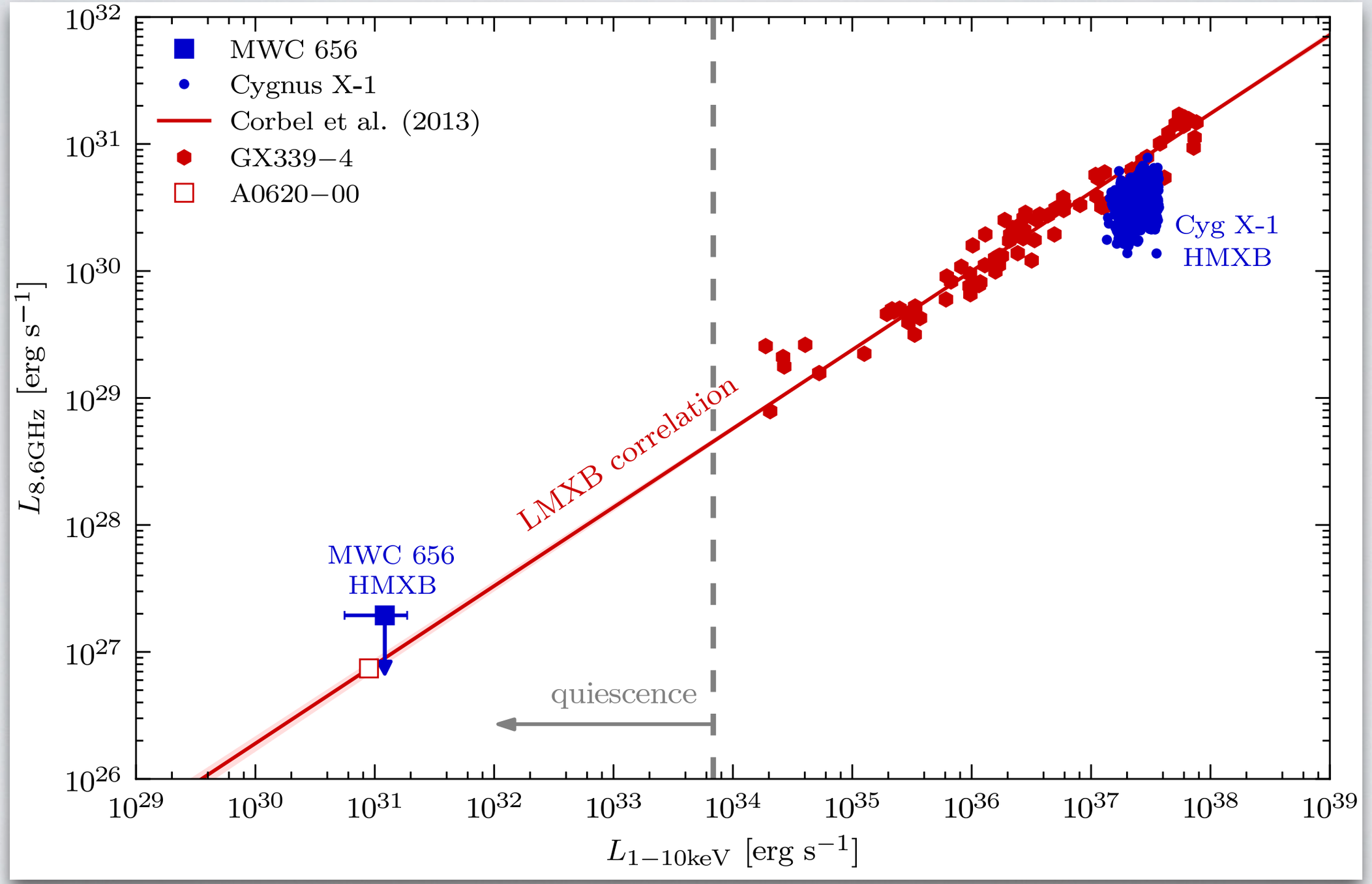


Munar-Adrover et al. (2014)

GAMMA-RAY OBSERVATIONS

- Analysis strategy (*AGILE* and *Fermi*/LAT):
  - Blind search in 2-days bins
  - Search for periodicity
  - Search for steady emission
  - Stack detected events to get a spectrum

AGILE DATA ANALYSIS

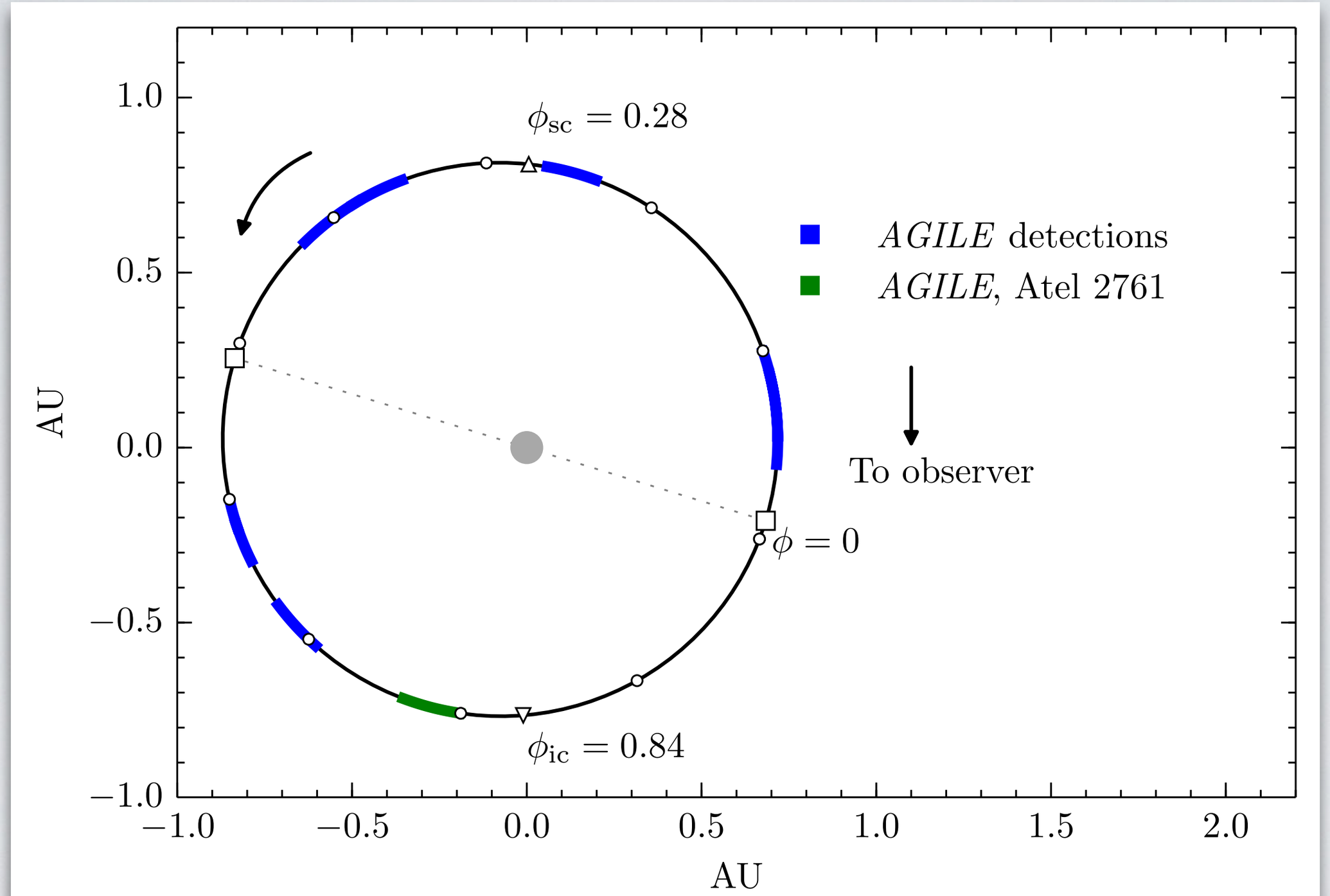
- Blind search: 10 flaring events registered by *AGILE* between 2007 and 2013

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

l [°]	b [°]	t_{start} [UT]	t_{end} [UT]	Flux [$\times 10^{-6}$ cm^{-2} s^{-1}]	$\sqrt{TS}$
100.28	-13.22	2007-11-23 UT00:02:10	2007-11-24 UT12:02:12	1.5 ± 0.5	4.5
100.22	-12.61	2008-06-28 UT12:03:15	2008-06-30 UT06:03:15	0.6 ± 0.3	3.2
101.74	-11.25	2009-01-04 UT12:02:12	2009-01-07 UT00:02:12	0.5 ± 0.2	3.1
100.94	-12.65	2010-06-13 UT12:01:06	2010-06-14 UT18:01:06	1.4 ± 1.1	3.2
99.27	-11.50	2010-06-30 UT00:01:06	2010-07-02 UT00:01:06	1.3 ± 0.6	3.1
99.96	-12.24	2010-07-25 UT00:02:12	2010-07-27 UT00:02:12	1.4 ± 0.6	3.8
99.94	-12.76	2011-10-08 UT00:02:12	2011-10-10 UT00:02:12	2.5 ± 1.1	3.4
101.70	-12.51	2011-04-09 UT00:02:12	2011-04-11 UT00:02:12	2.2 ± 1.1	3.1
100.38	-12.70	2013-07-10 UT00:00:00	2013-07-12 UT00:00:00	3.2 ± 1.6	3.5
100.34	-11.81	2013-03-07 UT00:00:00	2013-03-08 UT09:00:00	2.6 ± 1.4	3.1

from Le Hoang master thesis (2014)

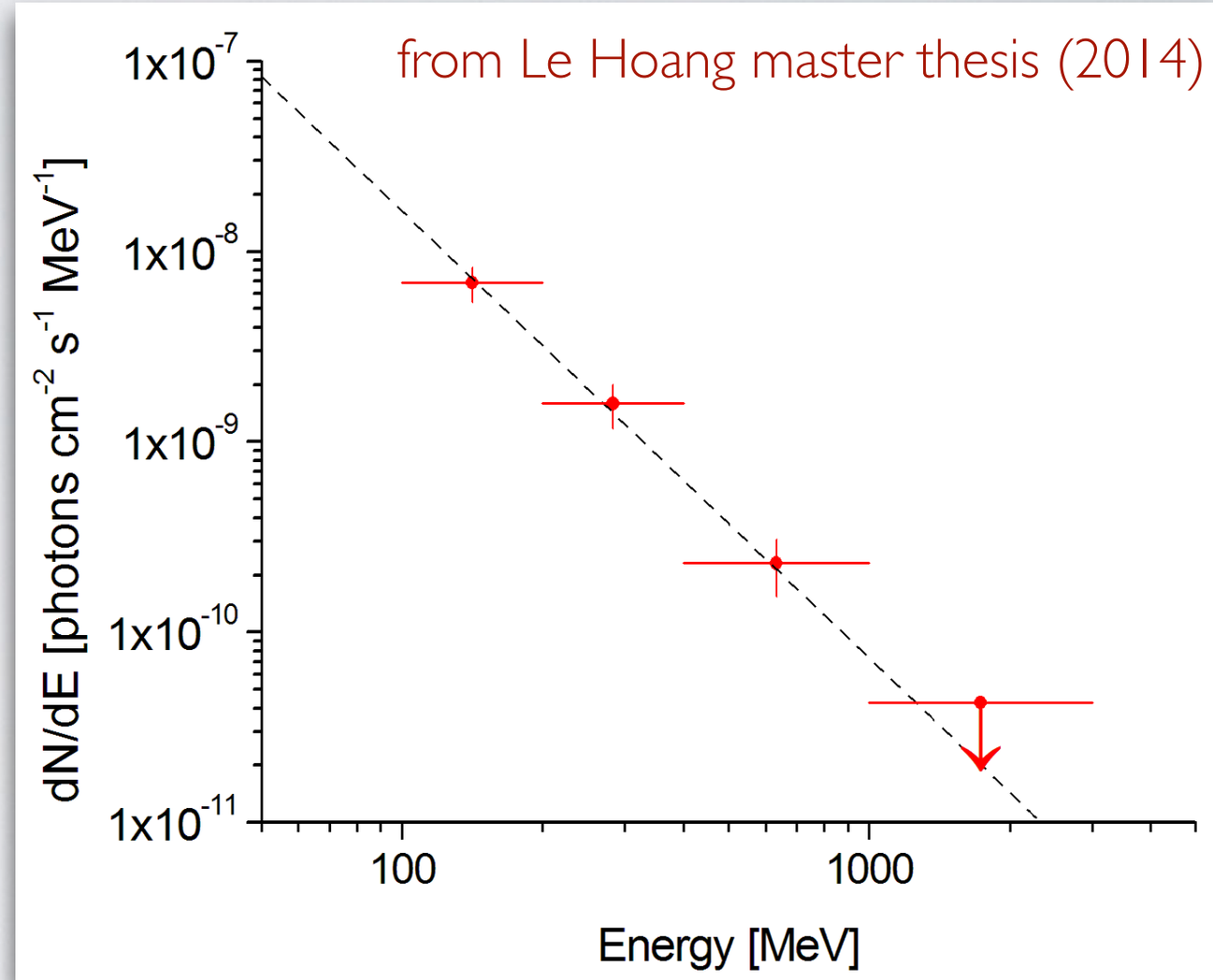
AGILE DATA ANALYSIS

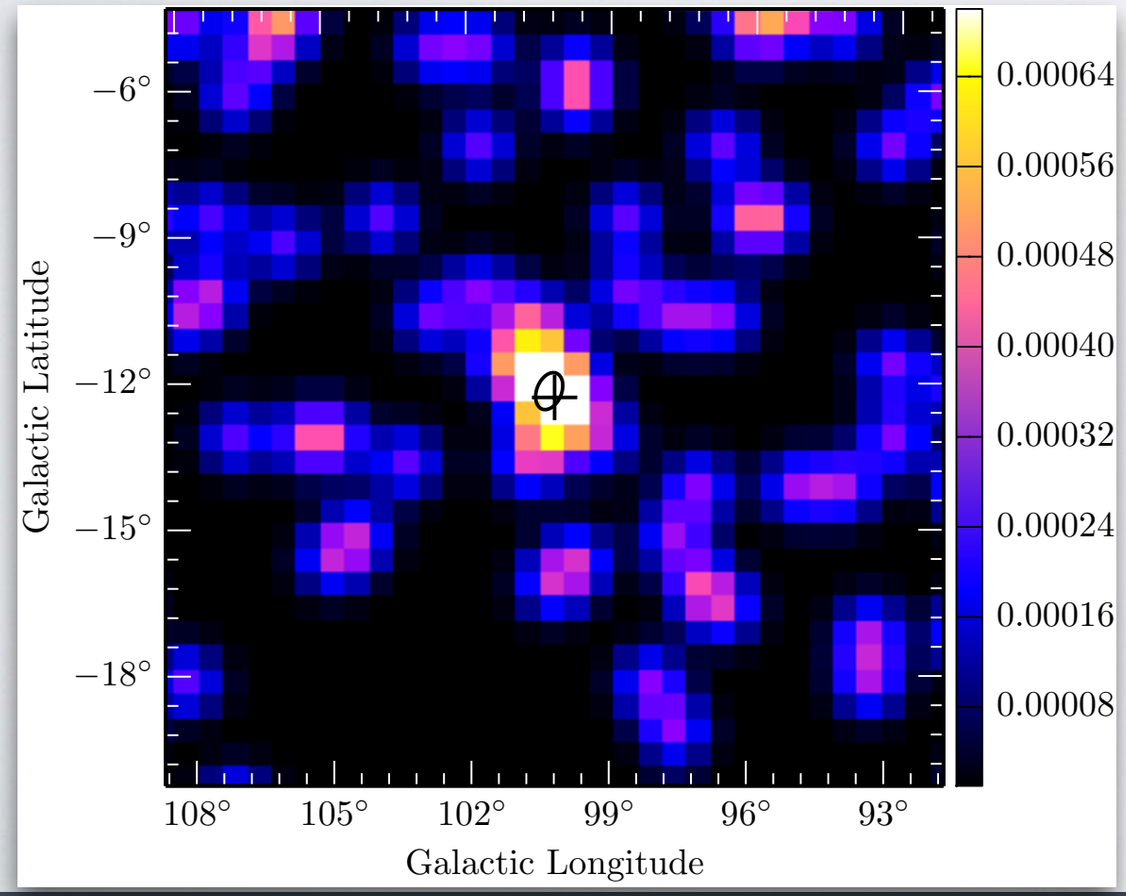


Ephemeris from Casares et al. (2014)

AGILE DATA ANALYSIS

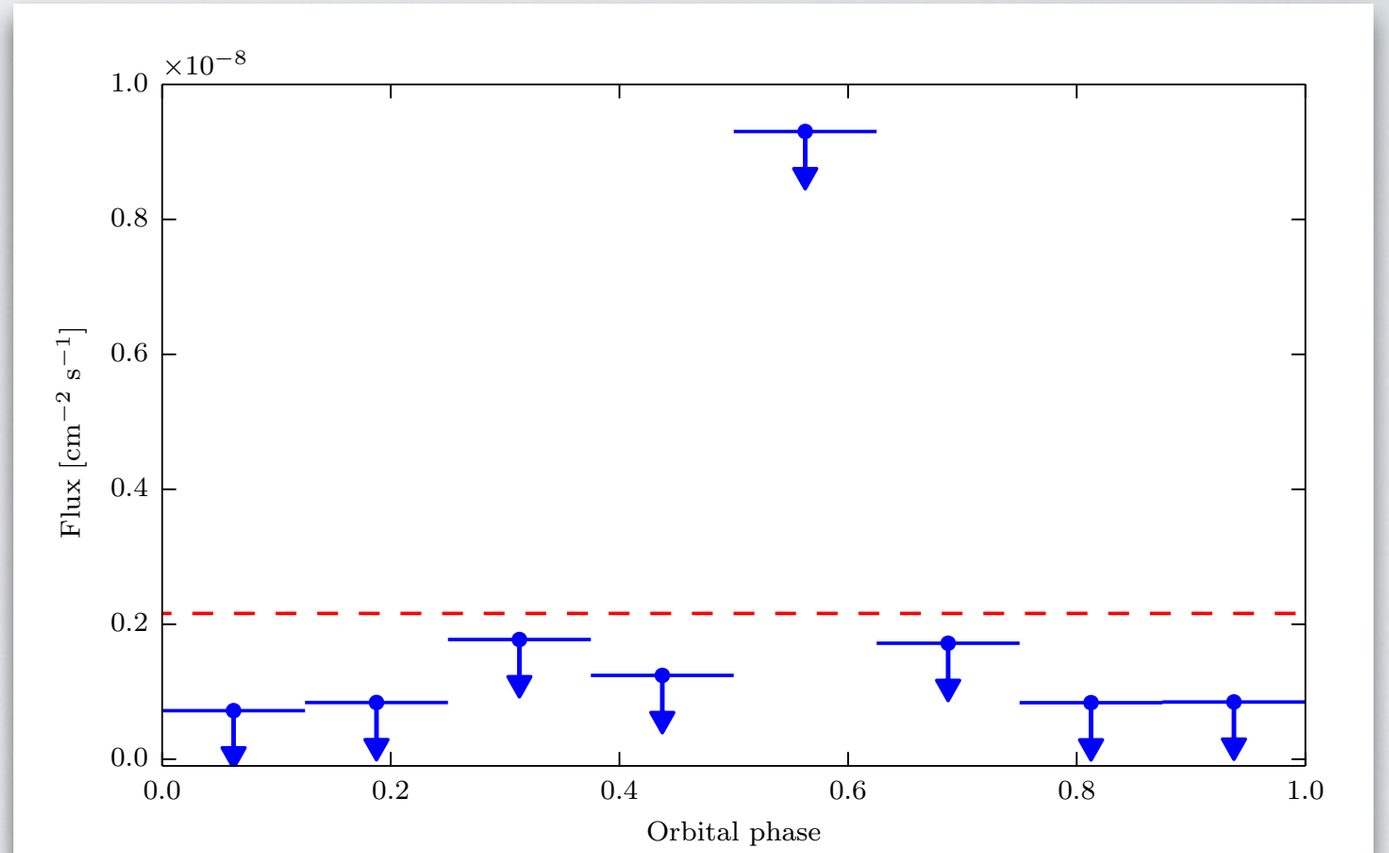
- *AGILE* spectrum between 100 MeV and 3 GeV
- Integrating over all detected gamma-ray flares
- Spectral fit with photon index $\Gamma = 2.35 \pm 0.16$



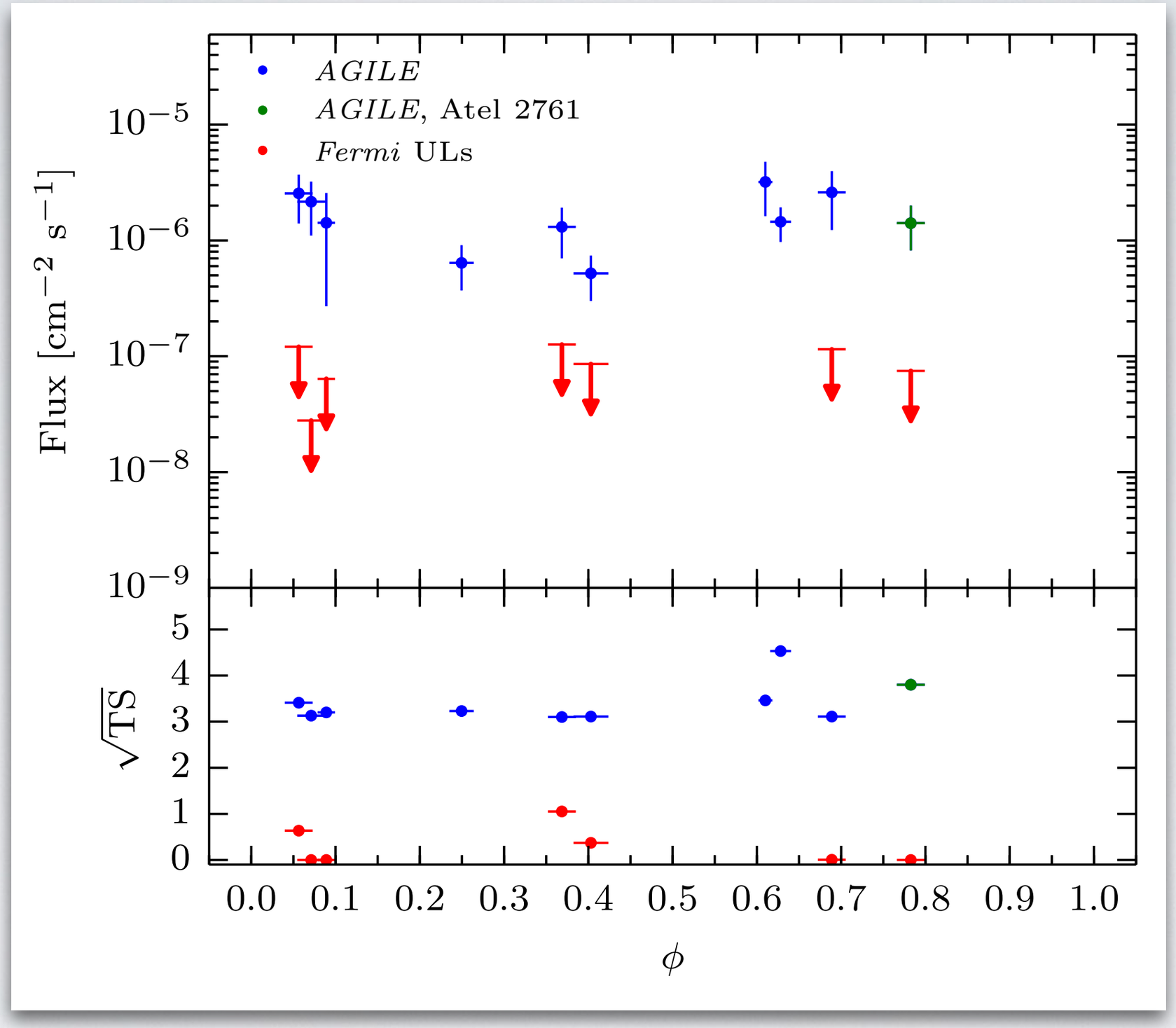


FERMI/LAT DATA ANALYSIS

- Blind search not ready yet…
- Steady emission: UL for 6 years integration: 8.0×10^{-10} cm^{-2} s^{-1}
- Stacking of *AGILE* detected flares: UL integrating all flares: 3.0×10^{-8} cm^{-2} s^{-1}
- Search for periodic emission

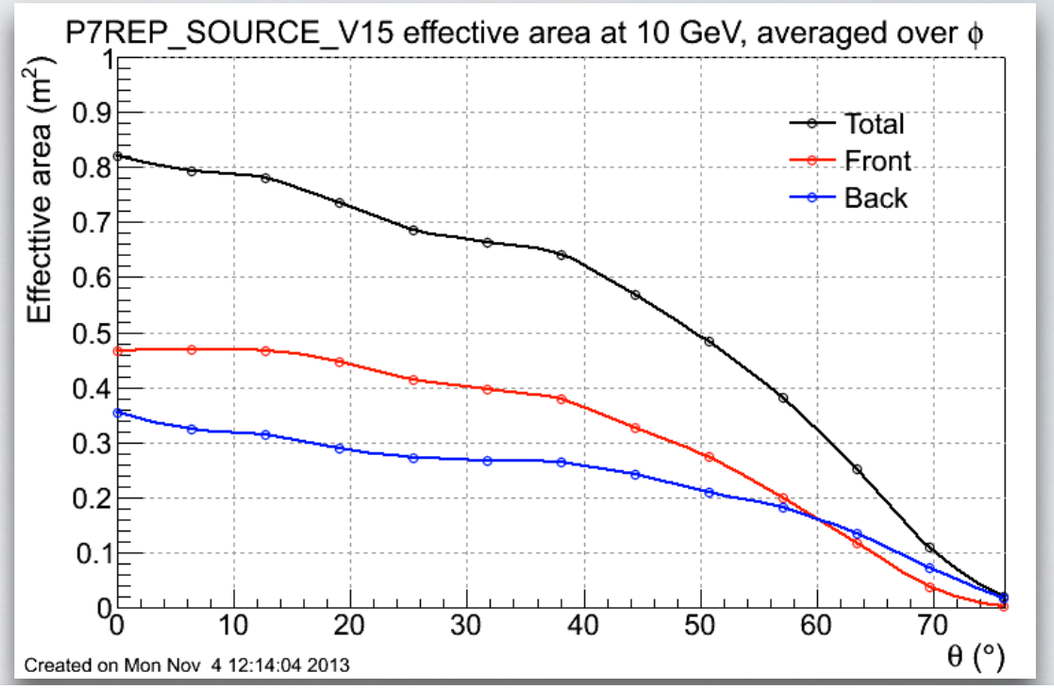


COMPARISON: *AGILE* vs *FERMI*

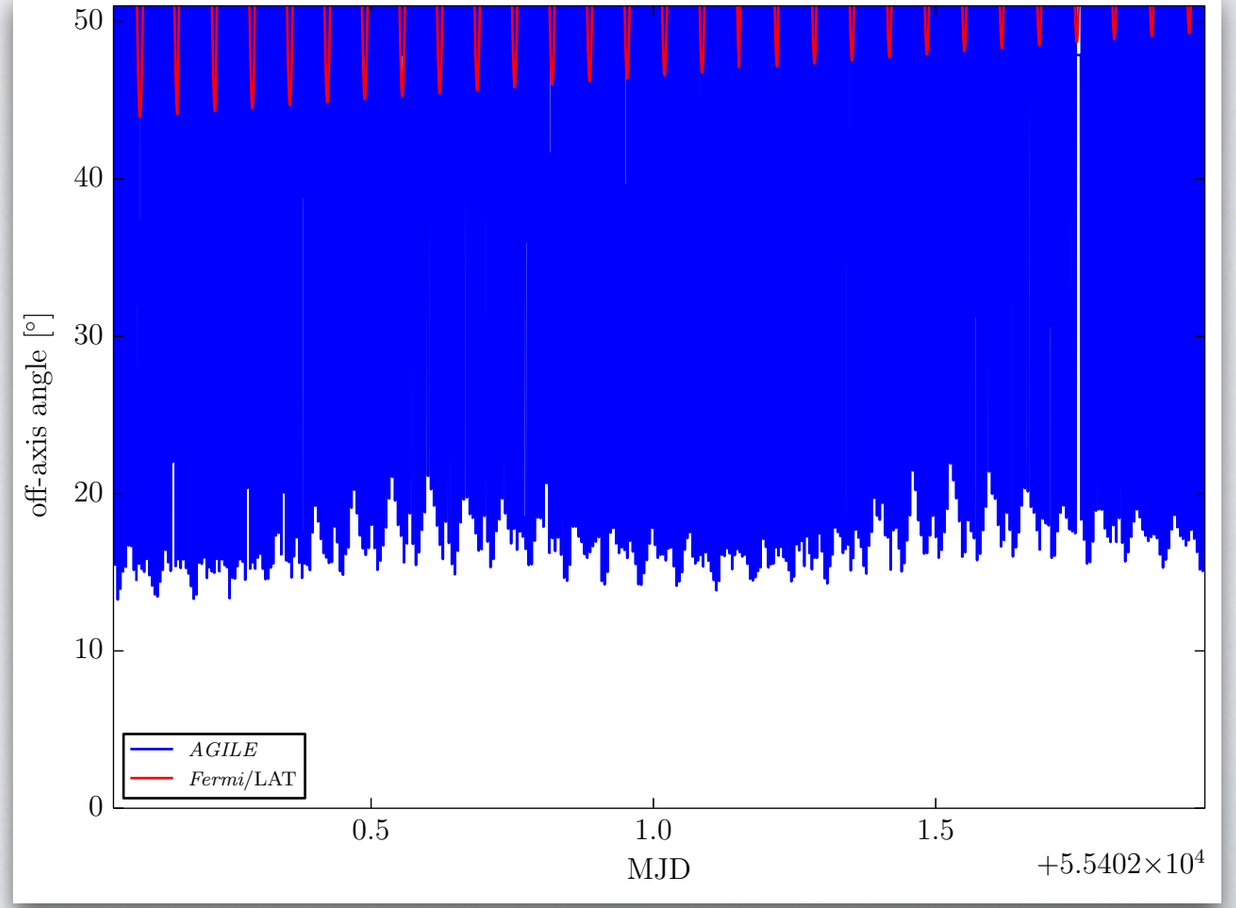


COMPARISON: *AGILE* vs *FERMI*

- *Fermi* and *AGILE* effective area decrease with zenith distance (ZD), specially above 50°

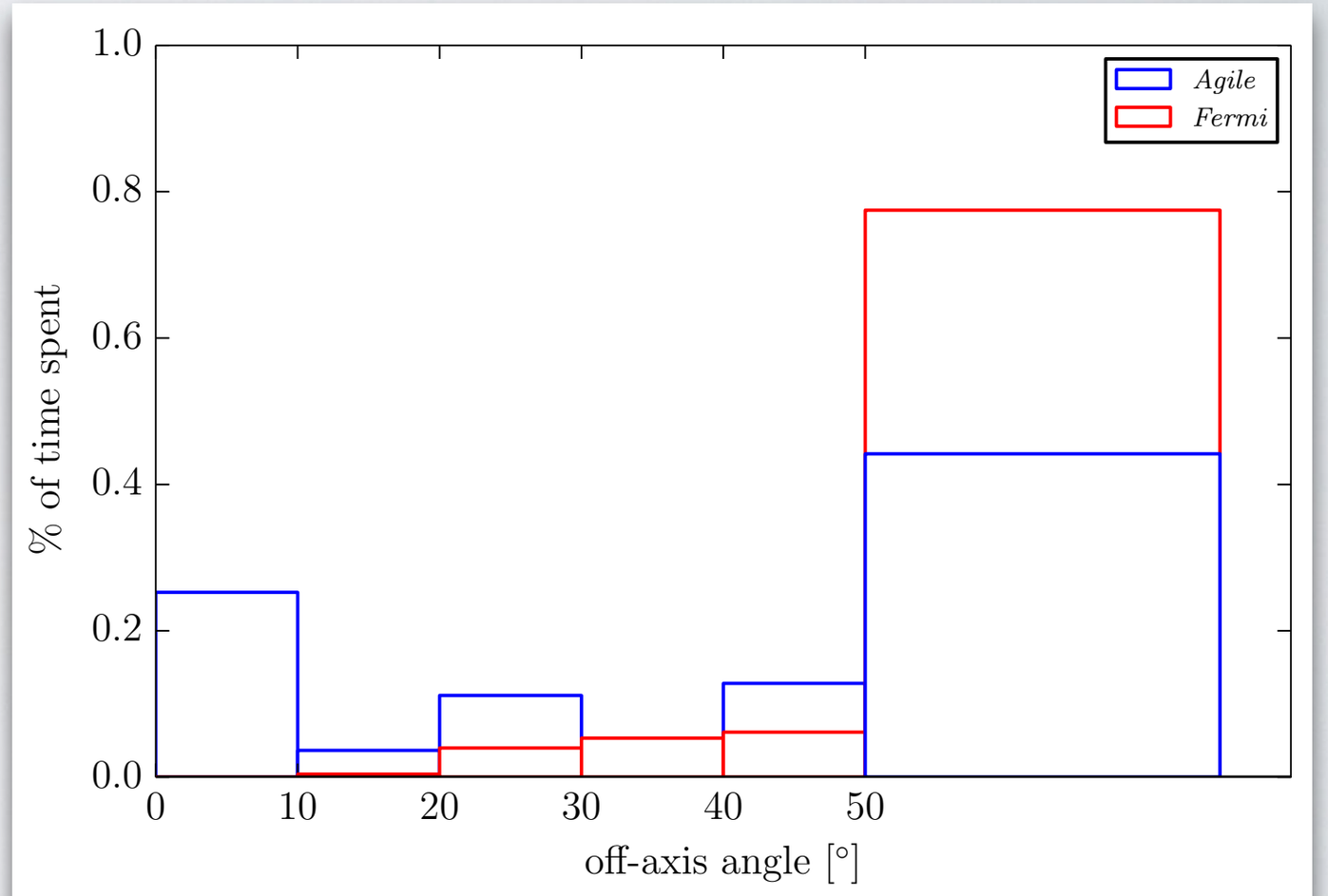


- We checked the source ZD at any given moment for the entire *Fermi* and *AGILE* missions
- During *AGILE* 2010 flare, MWC 656 is almost always at ZD > 50° for *Fermi*



COMPARISON: *AGILE* vs *FERMI*

- Time spent by *AGILE* and *Fermi*/LAT observing MWC 656 at diferent ZD
- Flares:
  - *AGILE*: more than 50% of time at ZD < 50°
  - *Fermi*/LAT: only 20% of time at ZD < 50°
- Rest of time:
  - *AGILE*: on average 30% of time spent at ZD < 50°
  - *Fermi*/LAT: on average 12% of time spent at ZD < 50°



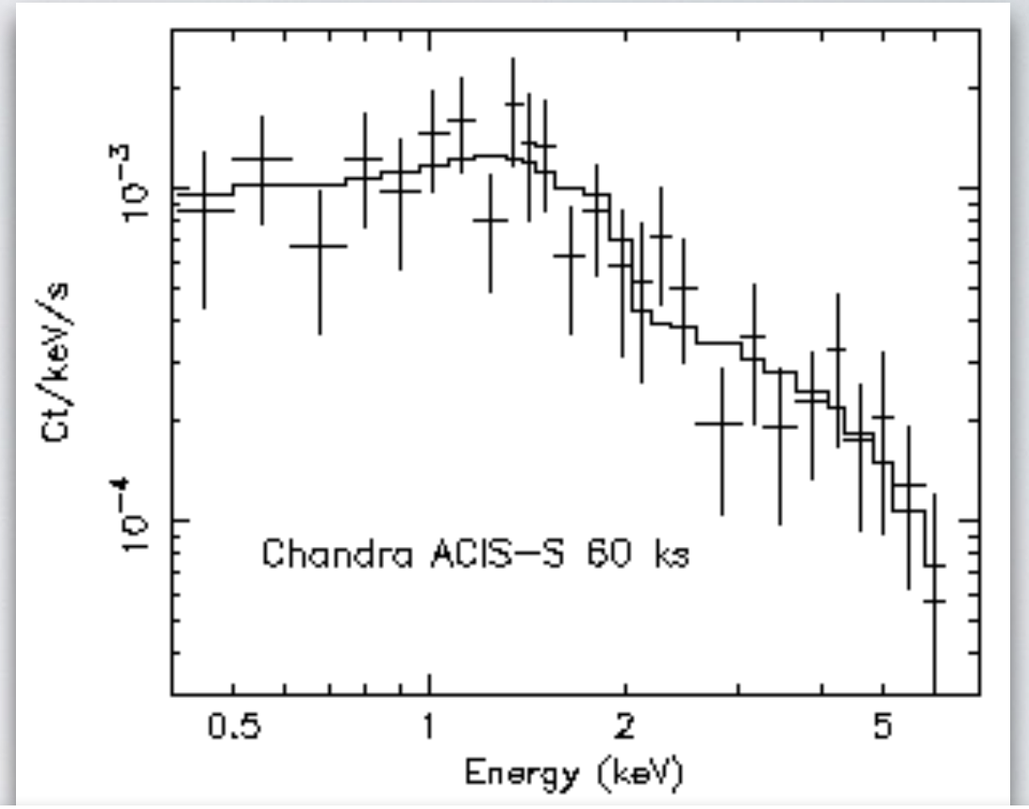
CONCLUSIONS

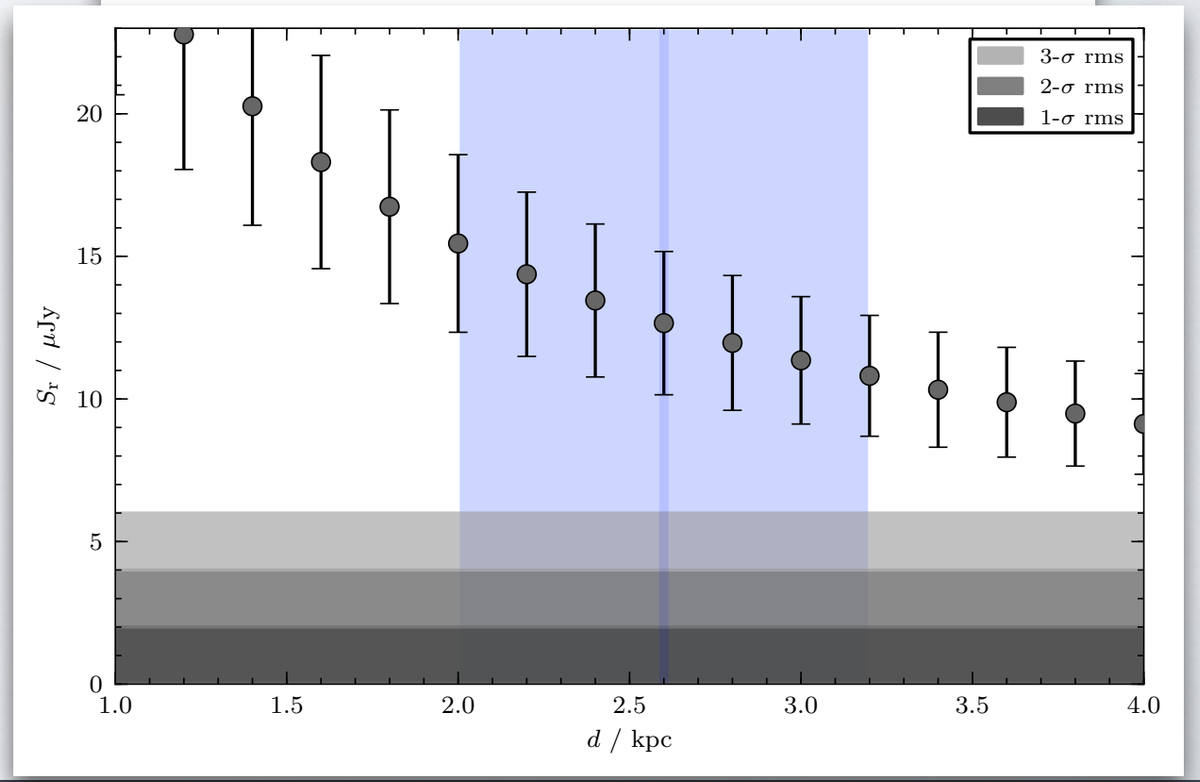
- The first Be/BH system was discovered thanks to the *AGILE* detection of a transient gamma-ray flare (Lucarelli et al. 2010)
- Munar-Adrover et al. (2014) discovered the X-ray counterpart of MWC 656. It is a high-mass X-ray binary. Two spectral components: thermal and non thermal. System at the quiescent state with very low luminosity
- *AGILE* detected 10 flares. Spectrum derived by stacking them. No sign of periodicity or recurrence
- *Fermi*/LAT does not detect the flares or any other episode of activity from MWC 656 field
- Reason of discrepancy might be diferences in off-axis position of MWC 656 between *AGILE* and *Fermi*/LAT during the occurence of the flares

Thank you

WORK IN PROGRESS: JOINT *CHANDRA*-VLA OBSERVATION

- Joint *Chandra*/VLA observations to:
  - Obtain good X-ray position and spectrum
  - Detect the source in radio
  - Check accretion/ejection coupling in the first quiescent HMXB
- 60 ks obs with *Chandra* + 6 h obs with VLA (8 -12 GHz)
- Expected radio flux density between 9 and 18 μJy





X-RAY DATA ANALYSIS

- The non thermal luminosity in the 0.3-5.5 keV range is $L_X=(1.6^{+1.0}_{-0.9})\times10^{31}$ erg $s^{-1} \equiv (3.1\pm2.3)\times10^{-8}\, L_{Edd}$

- The value of non thermal luminosity is well below the threshold of $10^{-5}\, L_{Edd}$ set by Plotkin et al. (2013) to indicate the quiescent state of XRBs, making our results compatible with MWC 656 being in quiescence

- This is the first case of a detection of a HMXB with a BH in quiescence

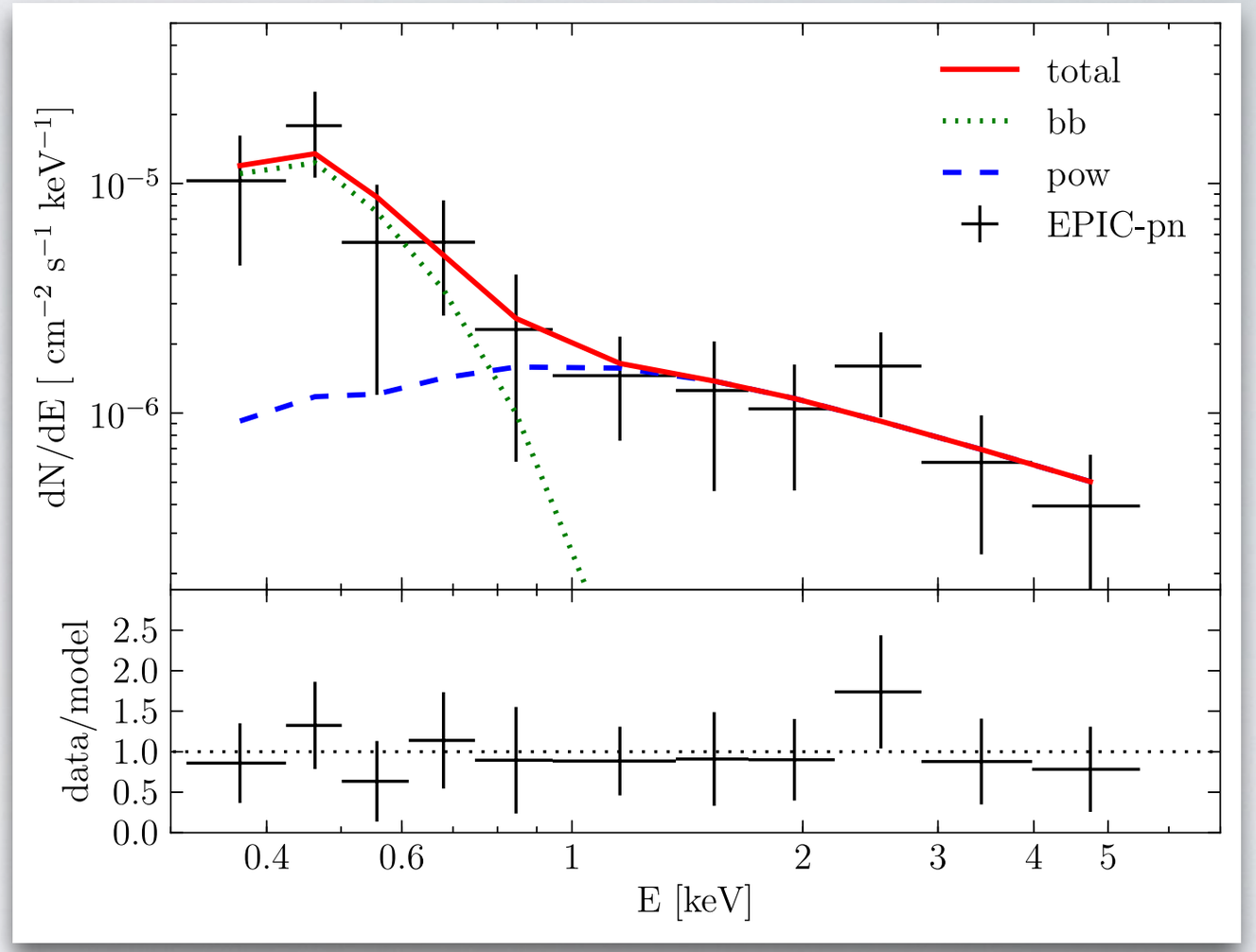
- Might be interpreted as an ADAF which leads to the low X-ray luminosity

X-RAY DATA ANALYSIS

- Thermal component

  -Might be arising from the hot wind of the Be star

  -The luminosity of this component is compatible with the $L_X/L_{Bol} \sim 10^{-7}$ relation from Cohen et al. (1997). Our results are $L_X/L_{Bol} \sim 3 \times 10^{-7}$



- Non thermal component

  -Photon index $\Gamma = 1.0 \pm 0.8$ compatible with Plotkin et al. (2013)

  -Possible origin in the vicinity of the black hole

  -The non thermal luminosity in the 0.3-5.5 keV range is $L_X = (1.6^{+1.0}) \times 10^{31}$ erg s^{-1} $\equiv (3.1 \pm 2.3) \times 10^{-8} L_{Edd}$