

AGILE BINARIES

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ON BEHALF OF THE AGILE TEAM

“Variable Galactic Gamma-ray Sources”

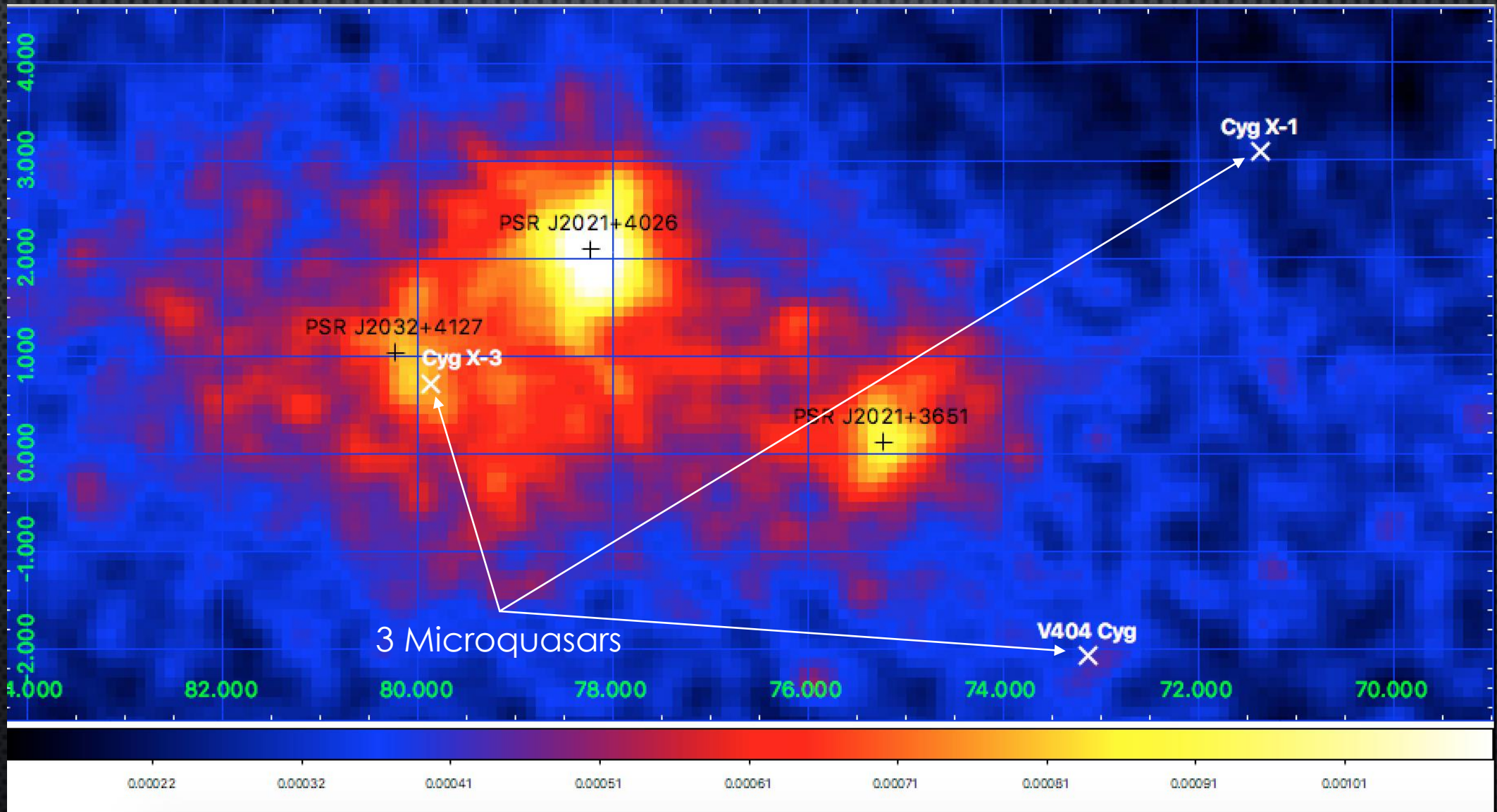
VGGRS V, Barcellona

September 4-6, 2019

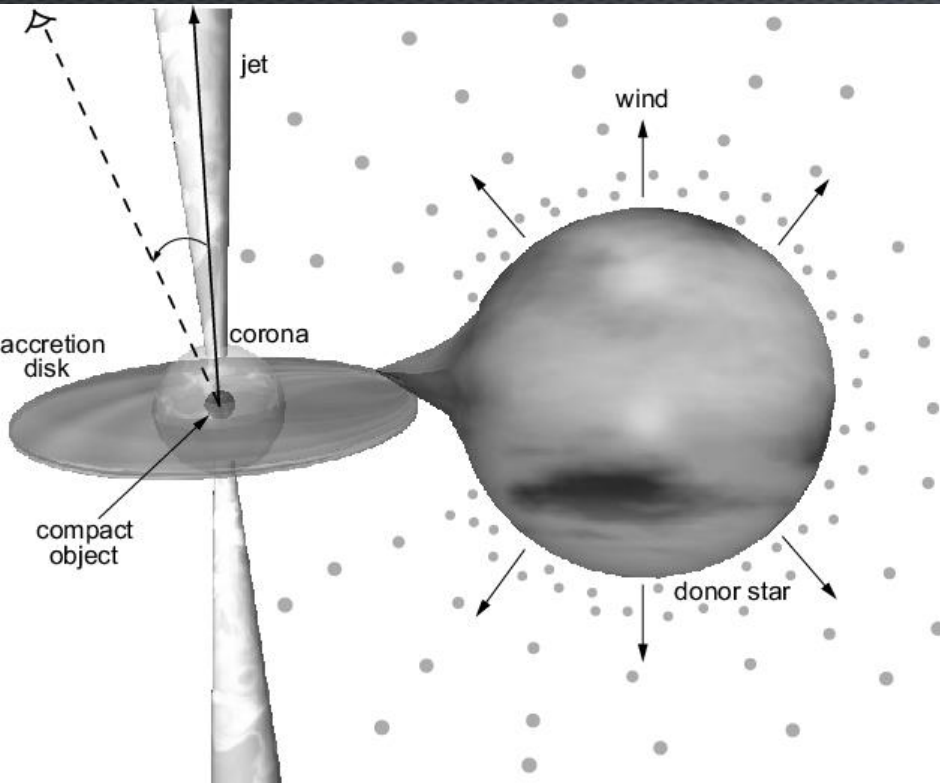
Outline

- MICROQUASARS IN THE CYGNUS REGION
 - CYGNUS X-1
 - CYGNUS X-3
 - V404 CYGNI
- η CARINAE: A COLLIDING WIND BINARY
- AGILE SOURCES POSSIBLY ASSOCIATED WITH BINARY SYSTEMS

THE CYGNUS REGION AS DETECTED BY AGILE ($E > 100$ MeV)



Microquasar



- X-ray binary systems: accreting NS or BH + jets
- Variable X-ray emission
- Radio emission: variable low-level flux + giant flares (Cyg X-3)
- Typically, correlated radio/soft X-ray/hard X-ray emission

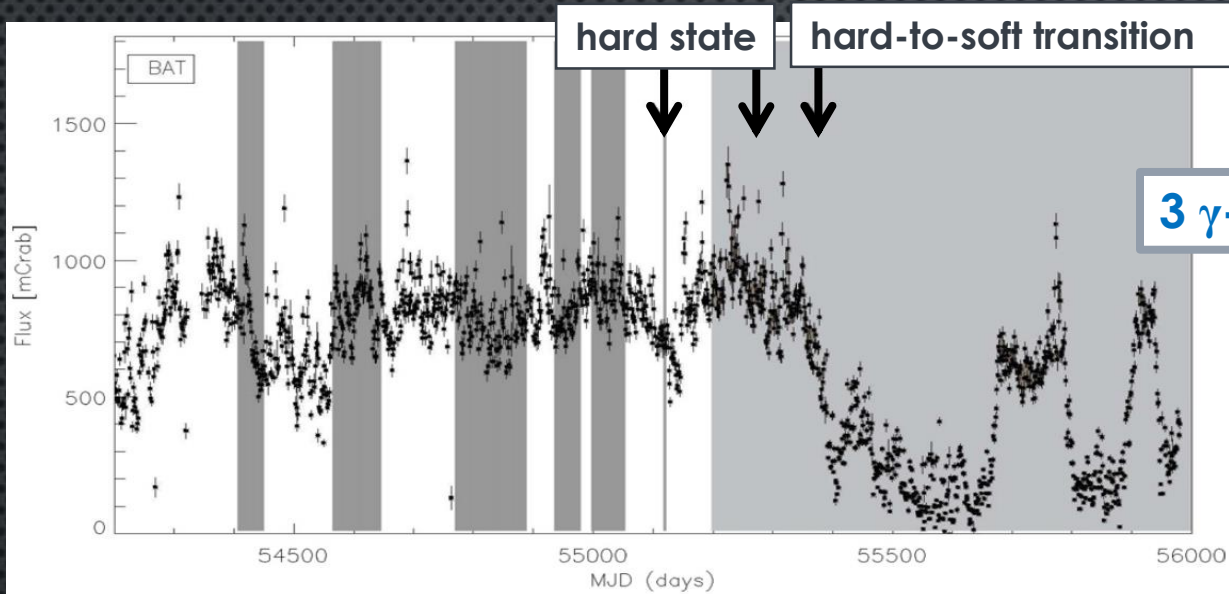
Open question (pre-AGILE/Fermi):

➤ **Can the jet emit γ -rays above 100 MeV?**

Microquasars in the Cygnus region

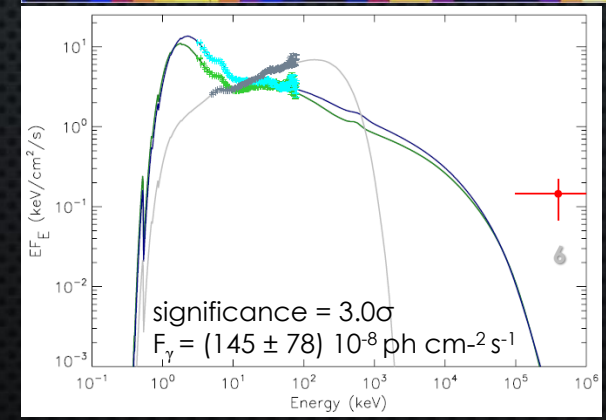
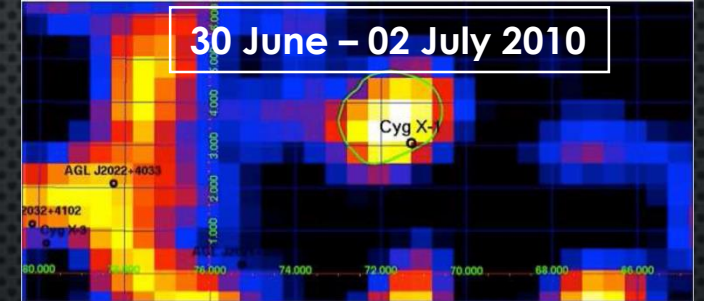
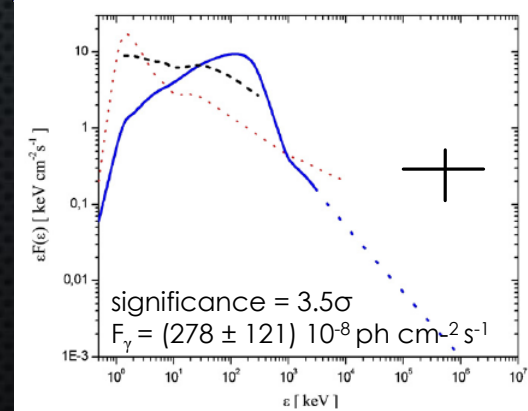
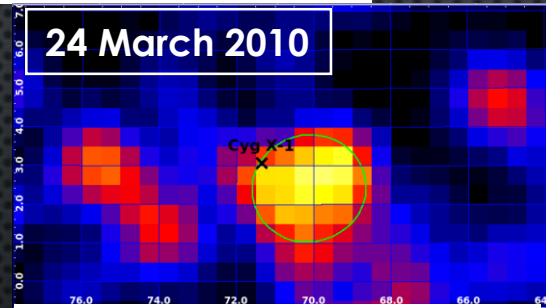
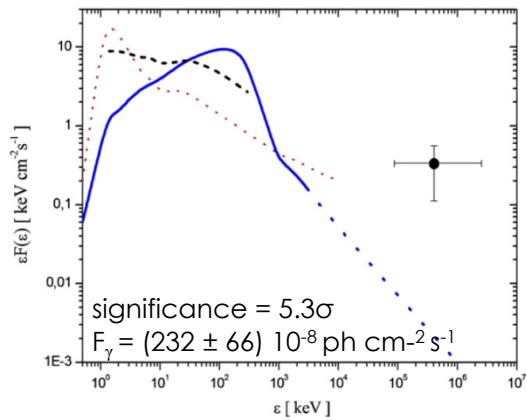
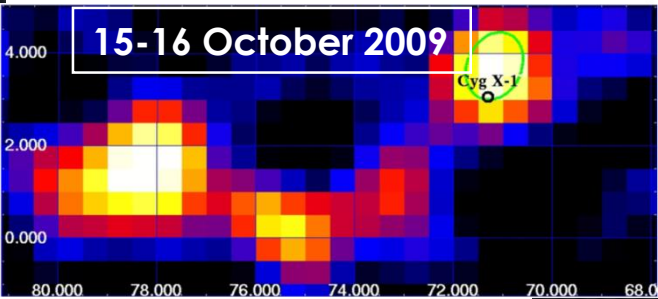
	Cygnus X-1	Cygnus X-3	V404 Cygni
type	HMXB	HMXB	LMXB
compact object	BH (4.8-14.8 M_{\odot})	BH or NS (?)	BH (9 M_{\odot})
companion star	O9.7 Iab (17-31 M_{\odot})	WR (> 7 M_{\odot})	K3 III (0.7 M_{\odot})
distance	1.9 kpc	7-10 kpc	2.39 kpc
orbital period	5.6 days	4.8 hours	6.47 days

Cygnus X-1: flaring activity - AGILE observations



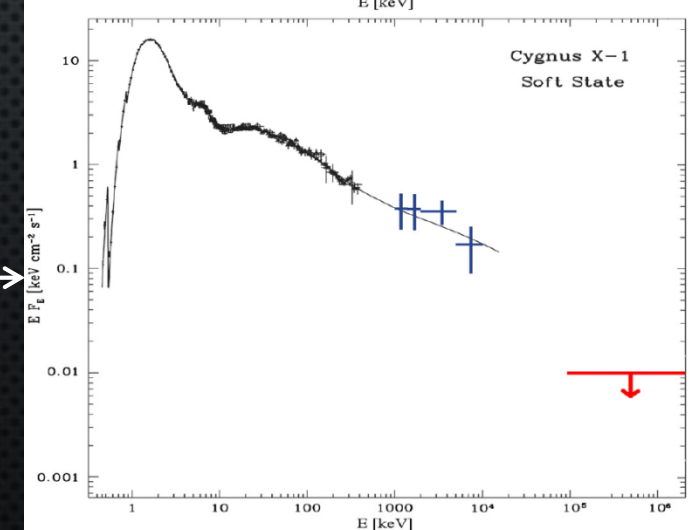
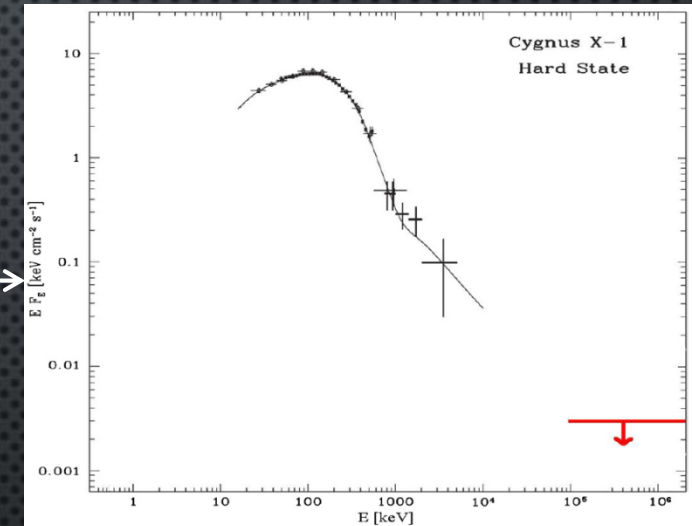
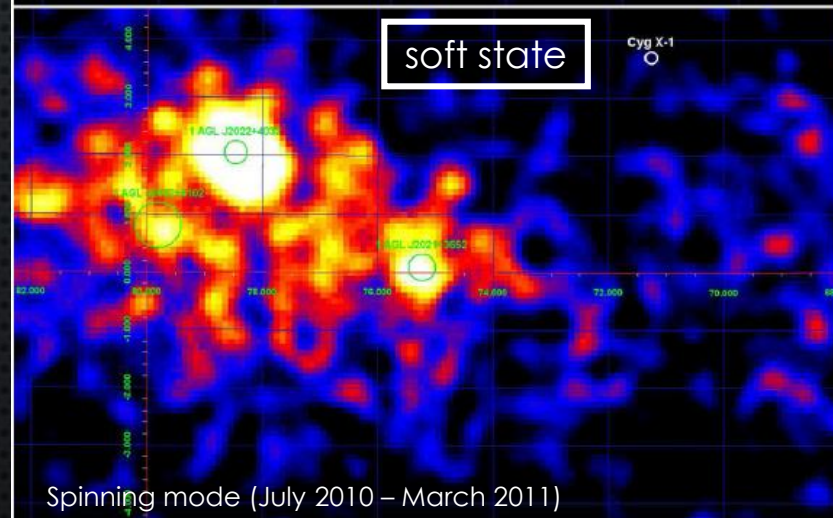
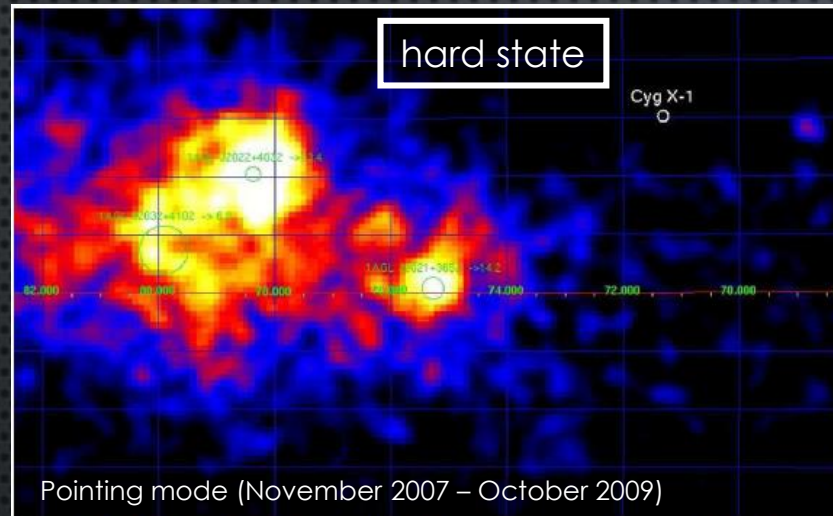
3 γ -ray flares detected by AGILE

Sabatini et al., ApJL, 712, L10 (2010)
 Bulgarelli et al., ATel #2512 (2010)
 Sabatini et al., ApJ, 766, 83 (2013)



Cygnus X-1

Comptonization models: spectral ULs from **long-term integration** in the γ -ray energy band both for hard and soft states



Sabatini et al.,
ApJ, 766, 83 (2013)

Cygnus X-3

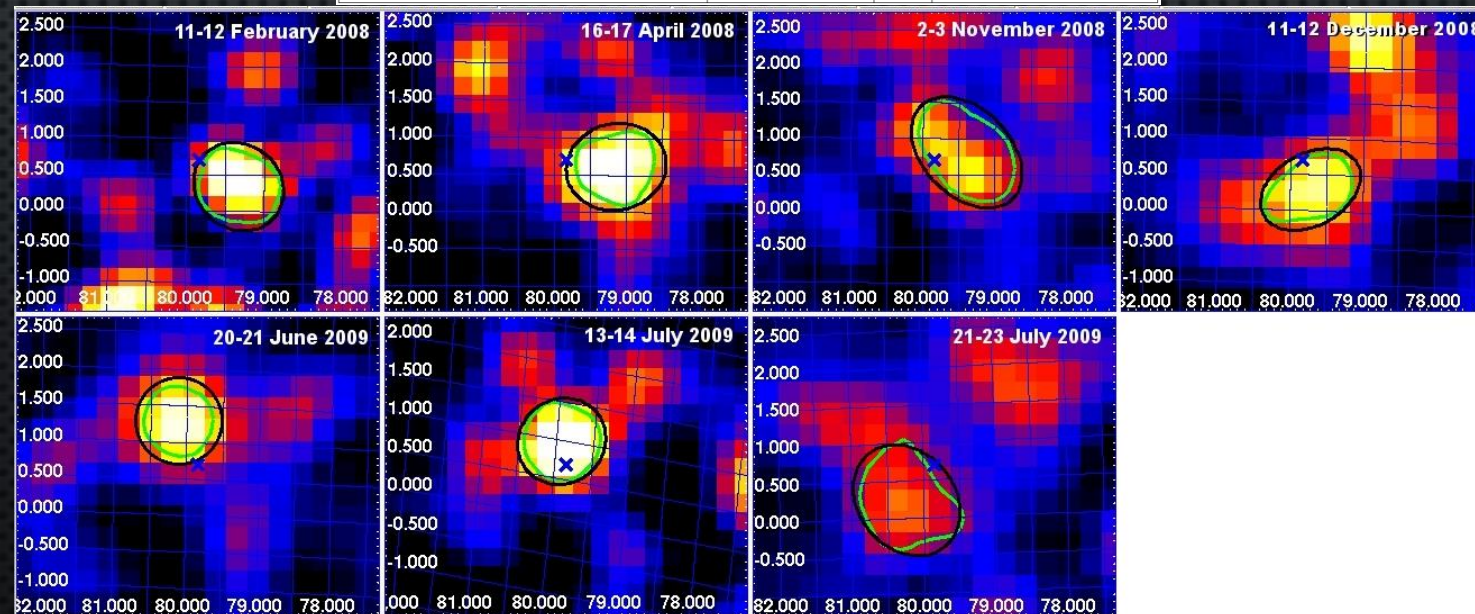
γ -ray activity discovered in late 2009

AGILE \rightarrow (Tavani et al, *Nature*, 2009); Fermi-LAT \rightarrow (Abdo et al., *Science*, 2009)

7 γ -ray flares have been detected between November 2007 and July 2009:

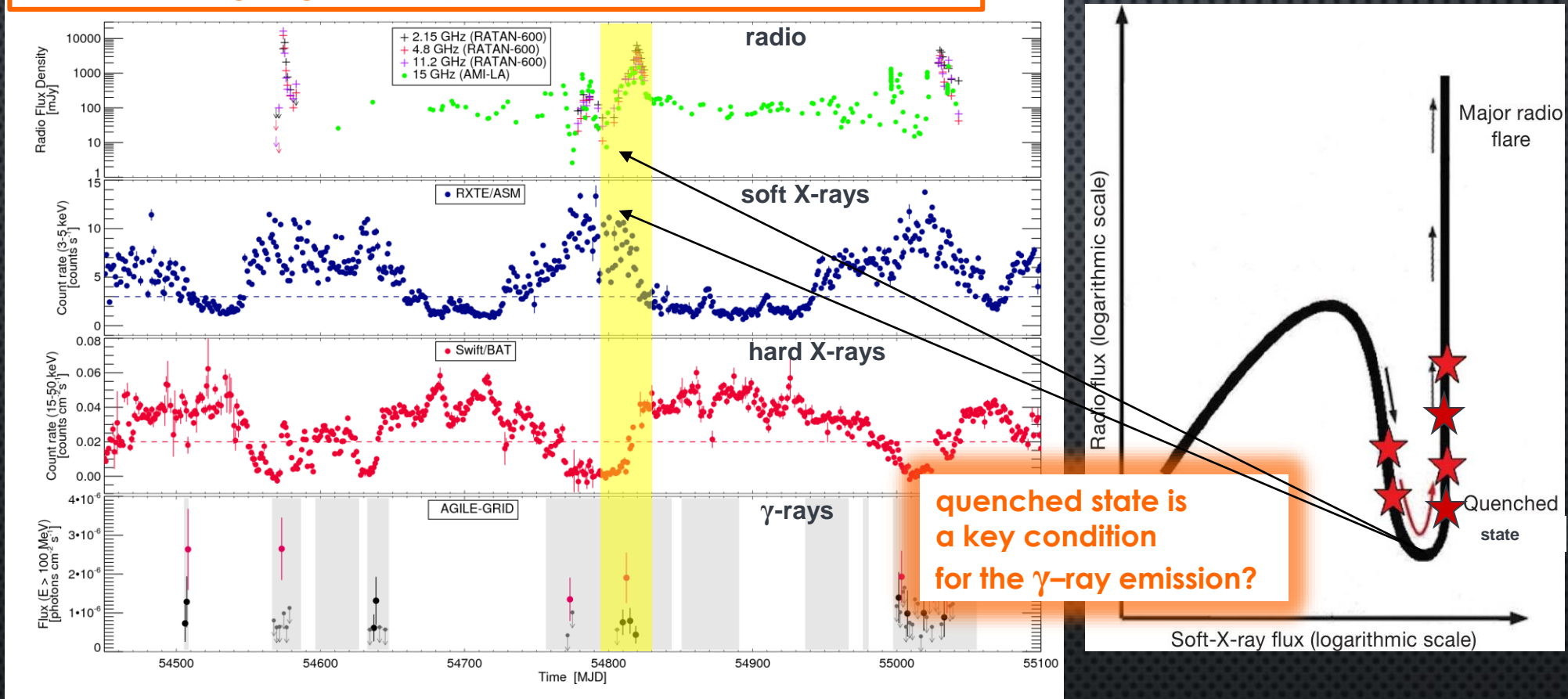
- significance $\geq 3\sigma$
- γ -ray fluxes more than 10 times the steady flux [$F_{\text{steady}} = (14 \pm 3) \times 10^{-8} \text{ ph cm}^{-2} \text{ s}^{-1}$]

Period	MJD	\sqrt{TS}	Flux [$10^{-8} \text{ photons cm}^{-2} \text{ s}^{-1}$]
2008 Feb 11 (18:07:28) - 2008 Feb 12 (11:07:44)	54507.76 - 54508.46	3.7	264 ± 104
2008 Apr 16 (13:59:12) - 2008 Apr 17 (13:48:00)	54572.58 - 54573.58	4.5	265 ± 80
2008 Nov 2 (13:01:05) - 2008 Nov 3 (19:01:05)	54772.54 - 54773.79	3.1	135 ± 56
2008 Dec 11 (19:50:40) - 2008 Dec 12 (23:02:40)	54811.83 - 54812.96	4.0	190 ± 65
2009 Jun 20 (21:04:48) - 2009 Jun 21 (20:53:04)	55002.88 - 55003.87	3.8	193 ± 67
2009 Jul 13 (01:11:60) - 2009 Jul 14 (00:59:44)	55025.05 - 55026.04	3.2	216 ± 89
2009 Jul 21 (21:07:12) - 2009 Jul 23 (21:07:12)	55033.88 - 55035.88	3.6	158 ± 59



Cygnus X-3

Multi-wavelength light curve (December 2007 → September 2009)

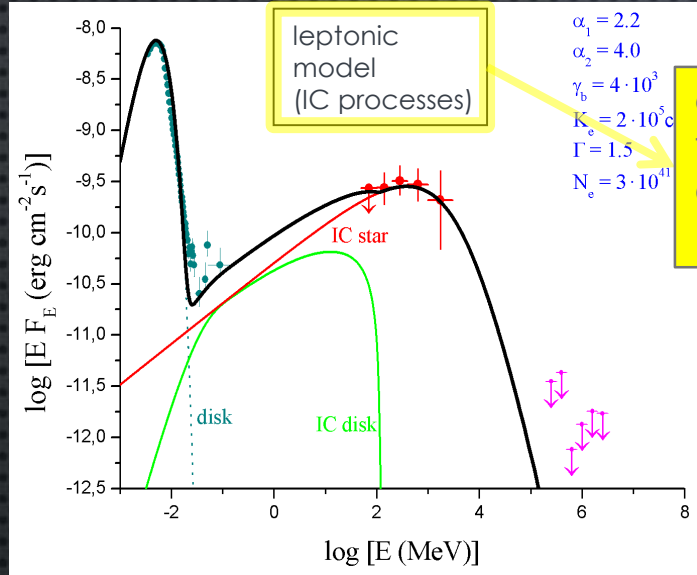


Repetitive multi-frequency emission pattern:

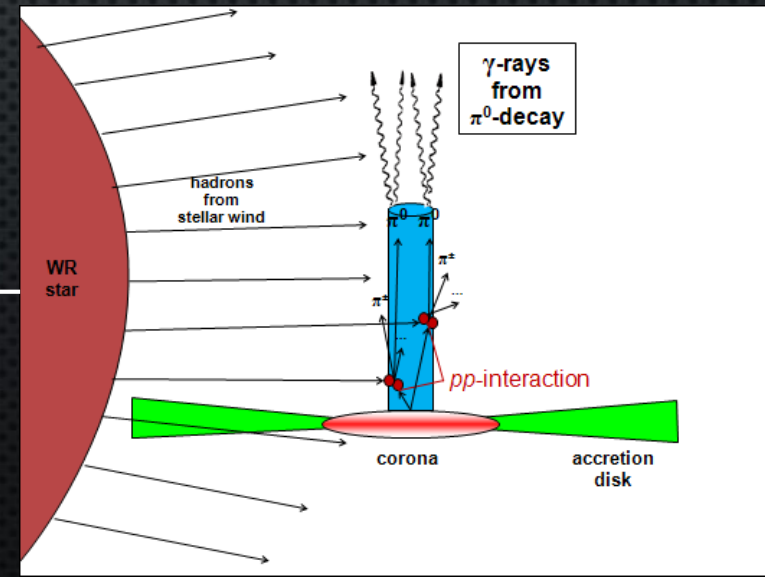
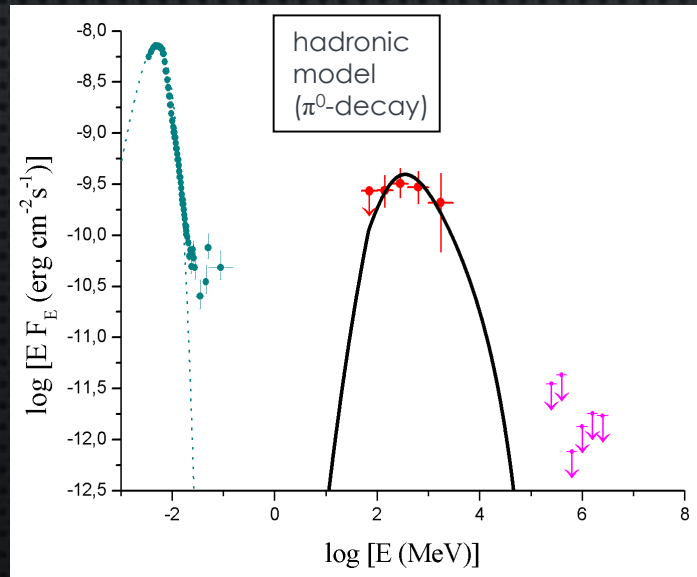
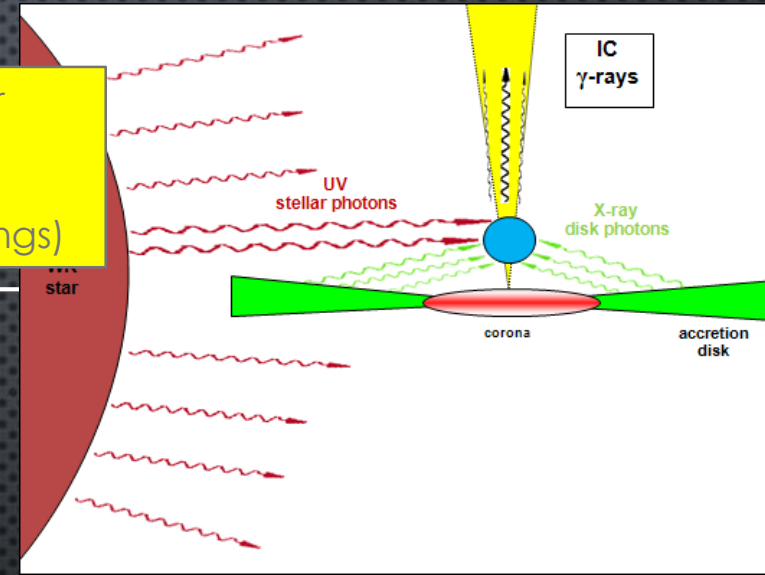
- **STRONG ANTICORRELATION** between hard X-ray and γ -ray emission: γ -ray activity associated with sharp/local minima in the hard X-ray light curve (*Swift*/BAT count rate ≤ 0.02 counts cm⁻² s⁻¹)
- γ -ray flares coincident with **soft spectral states** (*RXTE*/ASM count rate ≥ 3 counts s⁻¹)
- γ -ray flares around hard-to-soft or soft-to-hard spectral transitions
- γ -ray flares a few days before major radio flares

Cygnus X-3

Both **leptonic** and **hadronic** emission models can account for the γ -ray flaring spectrum detected by AGILE



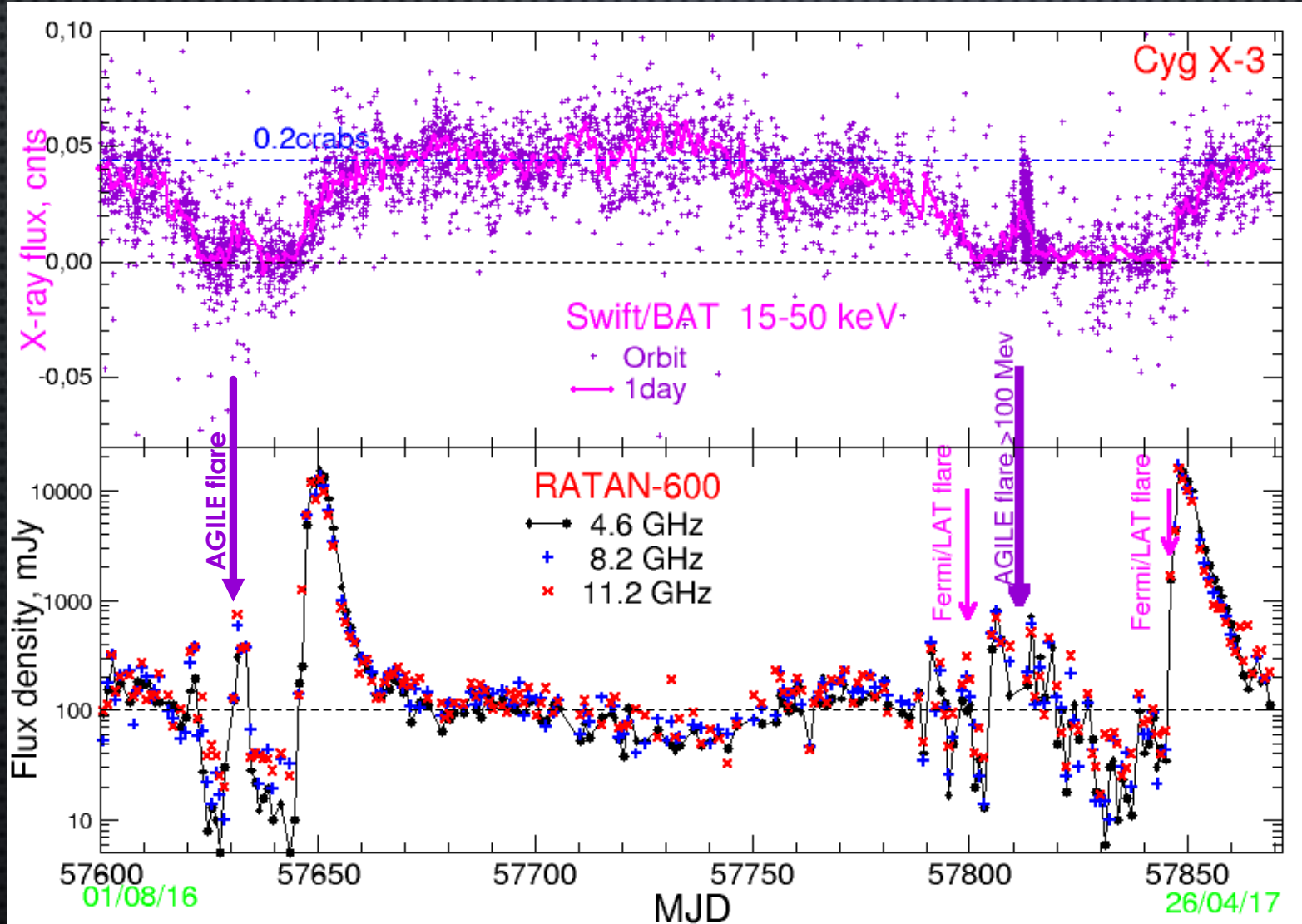
can easily accounts for the γ -ray modulation detected by *Fermi*-LAT (anisotropic IC scatterings)



Piano et al.,
A&A, 545, A110 (2012)

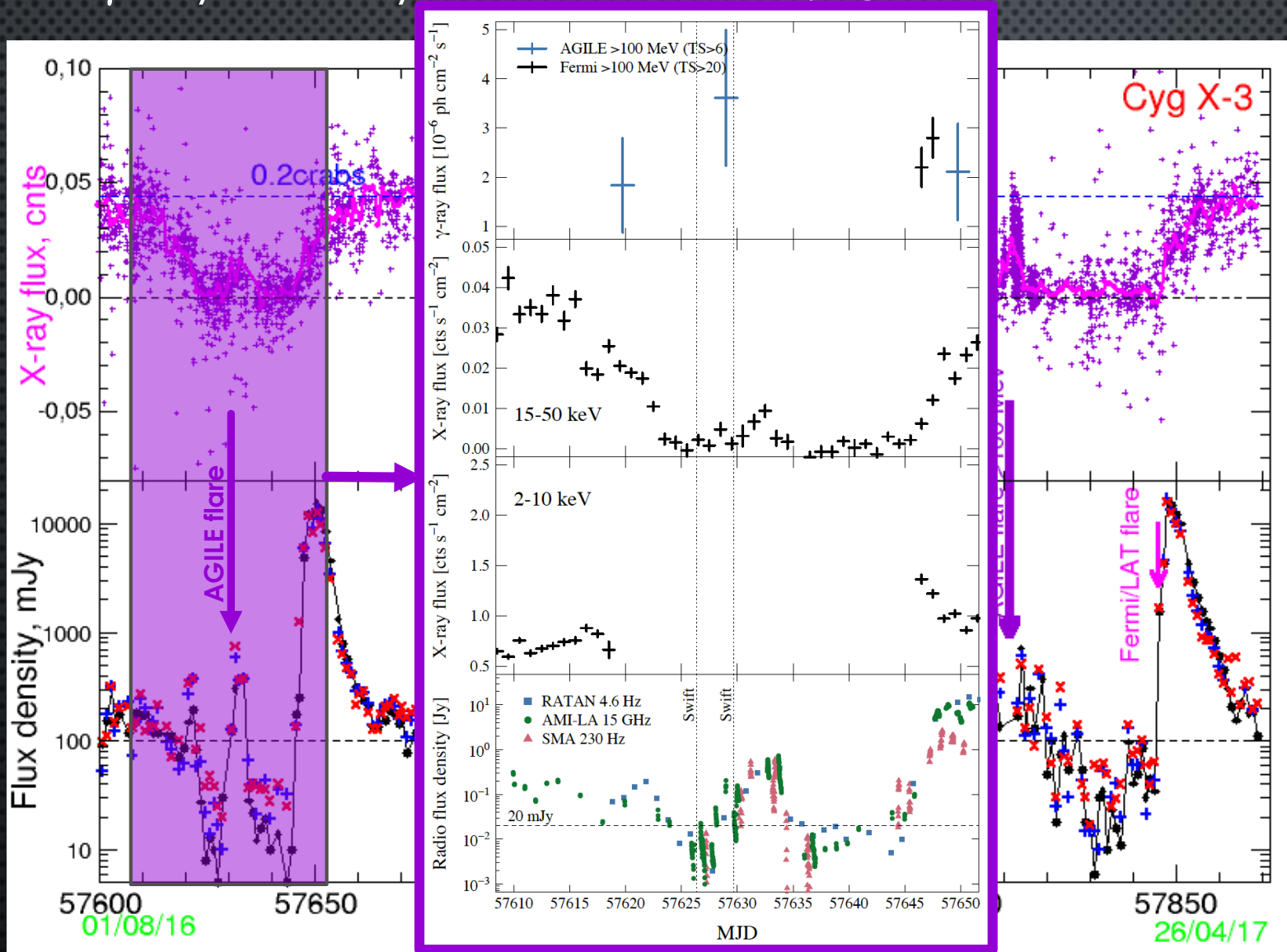
Cygnus X-3

Recent γ -ray activity \rightarrow 2016 – 2017 (Koljonen et al., 2017, submitted to A&A)



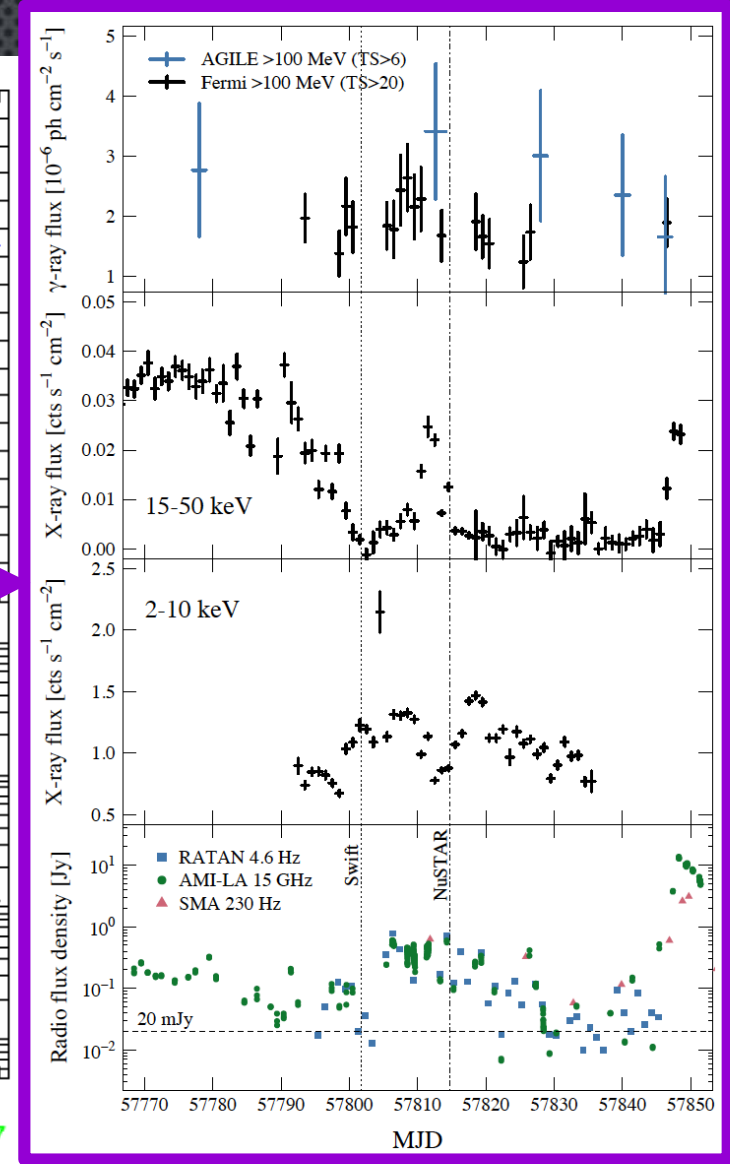
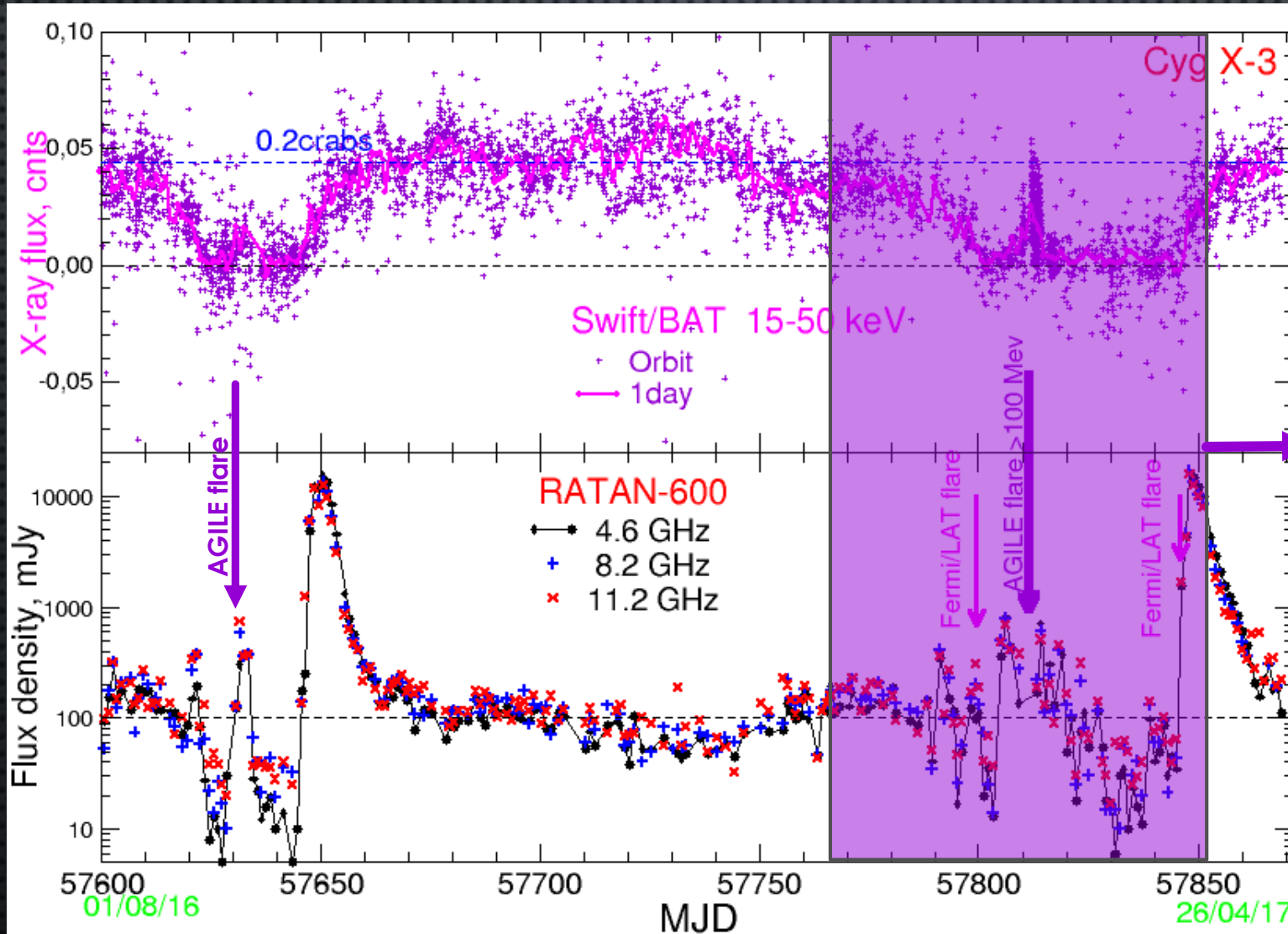
Cygnus X-3

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Cygnus X-3

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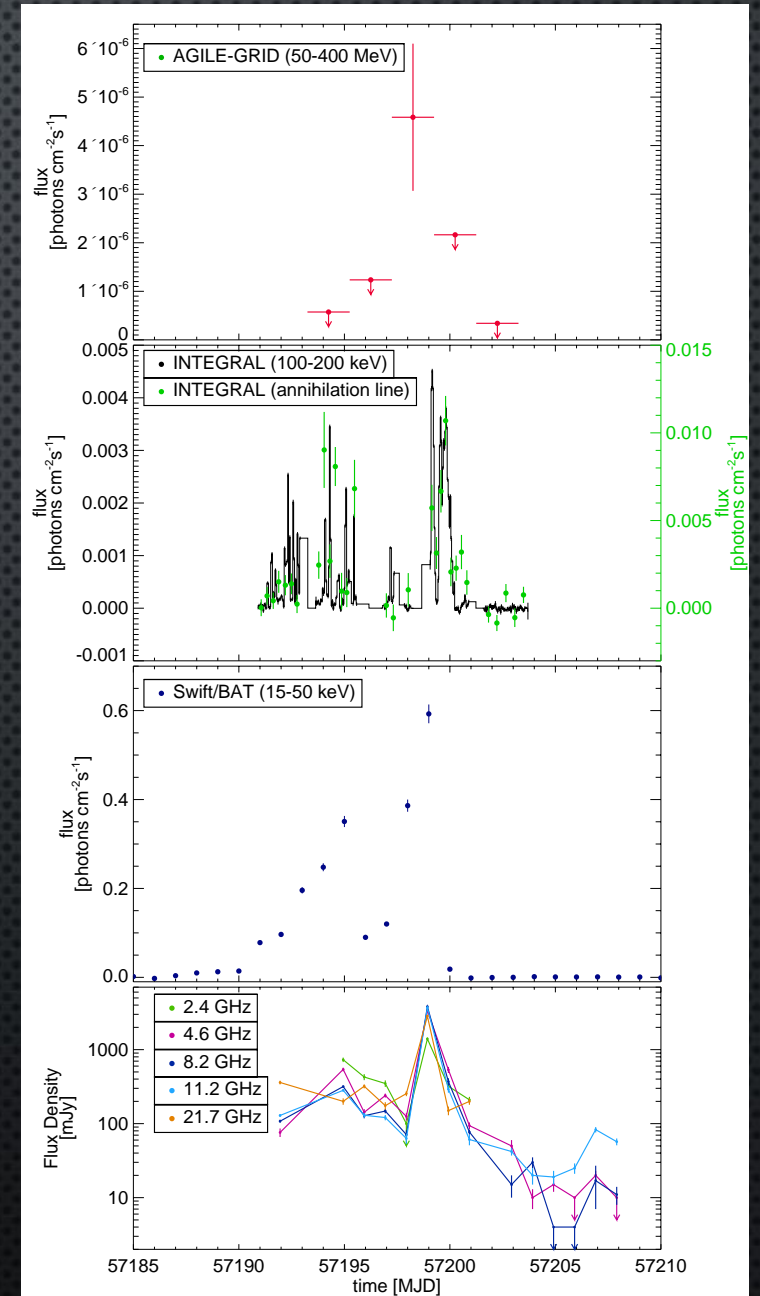
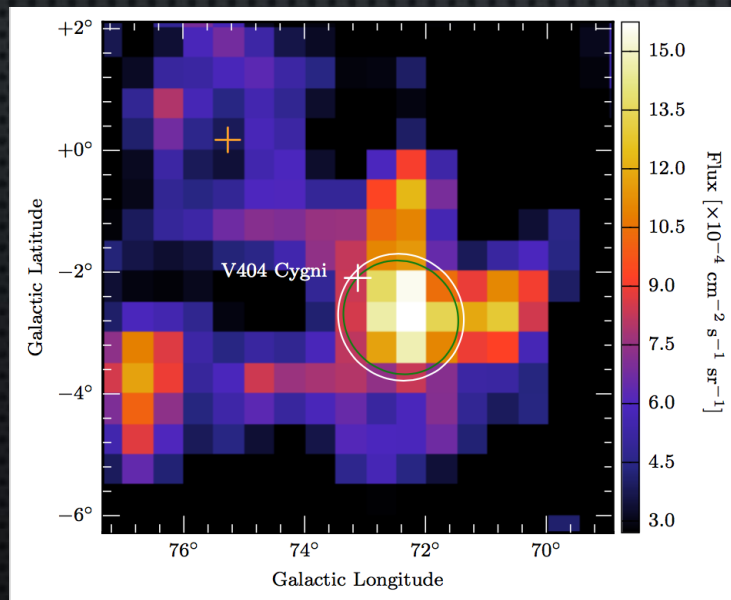


V404 Cygni

After ~26 years of quiescence → active phase in June 2015

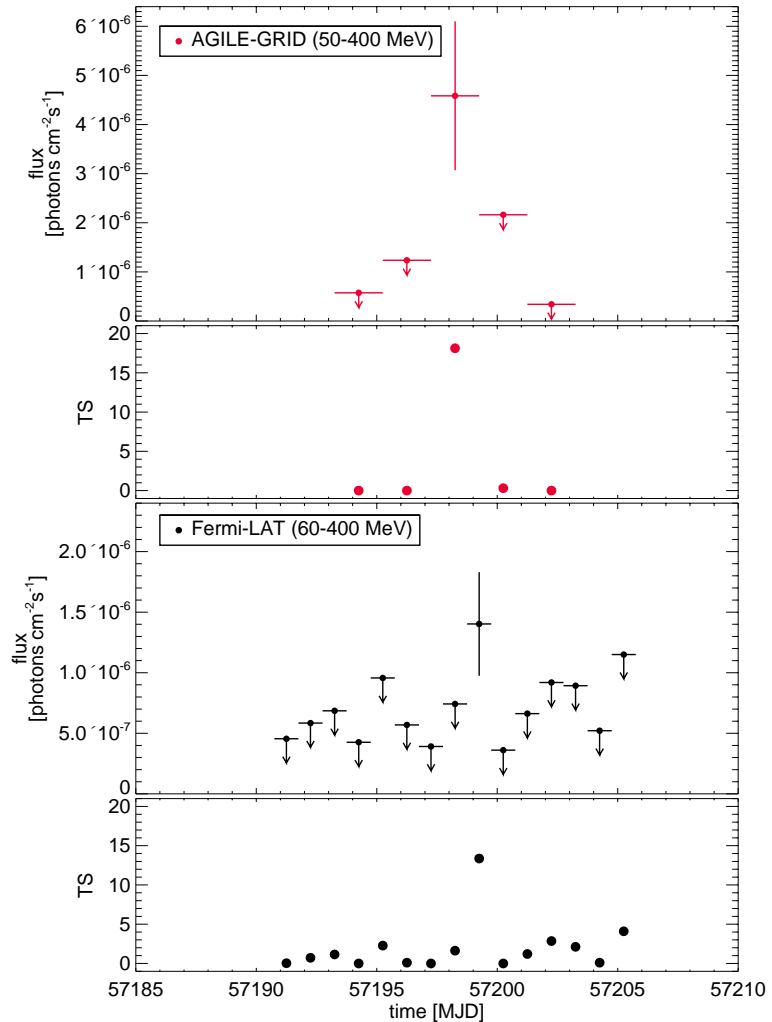
High Energy γ -ray flare (50-400 MeV) coincident with outbursts in:
radio
X-ray
soft γ -rays (continuum & 511 keV annihilation line)

AGILE 2-day intensity map (50-400 MeV)

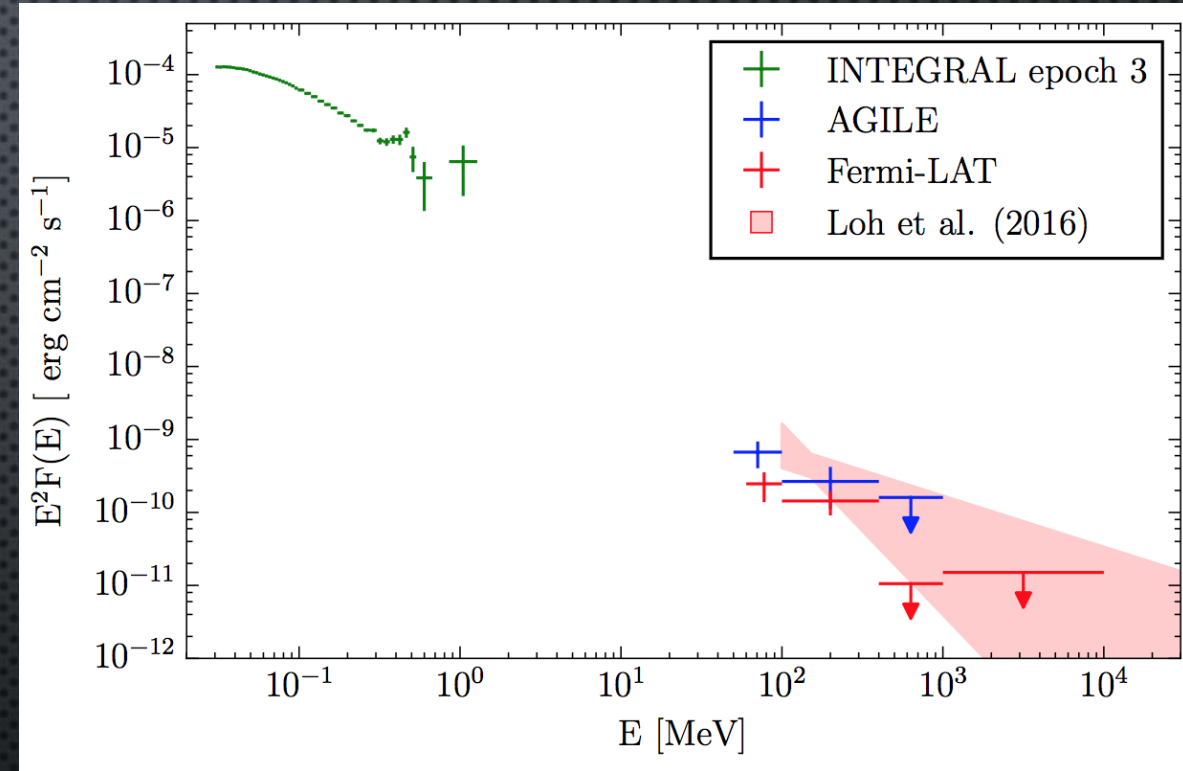


V404 Cygni

AGILE (50-400 MeV) simultaneous
with Fermi-LAT (60-400 MeV)



Simultaneous flaring SED



Soft emission in HE γ -rays:
no detected activity above 400 MeV

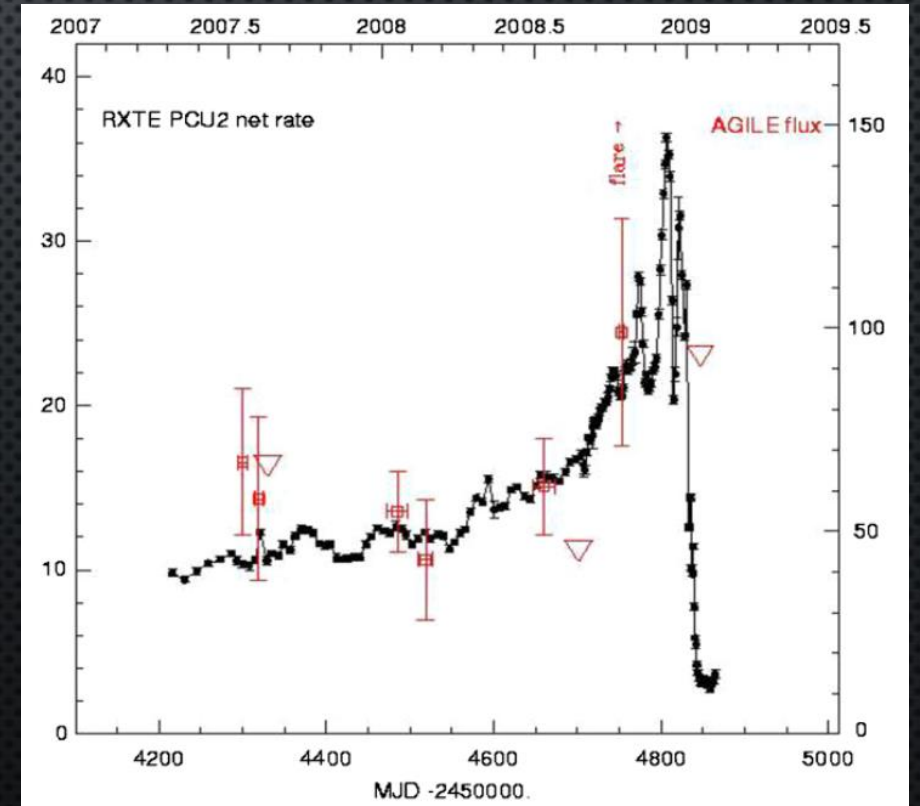
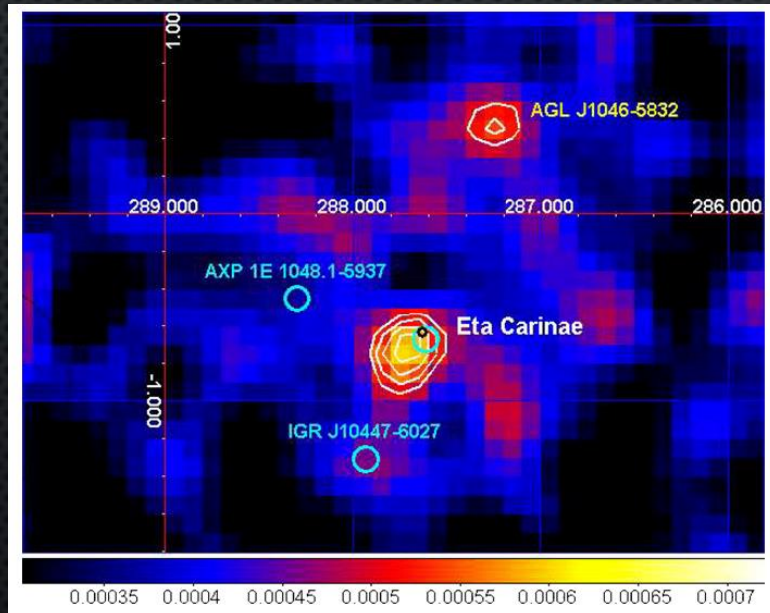
Microquasars in the Cygnus region: evidences

- The HE γ -ray emission is related to a new component in the multiwavelength spectrum (not coronal emission)
 - Acceleration processes in the jet
 - Leptonic/hadronic scenario?
- *Cygnus X-1* → ULs to persistent HE γ -ray emission → constraints to coronal emission
- *Cygnus X-3* → repetitive pattern of emission in a multifrequency context
- *V404 Cygni* → HE γ -ray emission correlated with radio and 511 keV annihilation line → all-leptonic scenario with a strong antimatter (positron) component?

η Carinae

- Luminous Blue Variable + O Star
- Orbital period ~ 5.54 years
- First detection of a Colliding Wind Binary in γ -rays ($E > 100 \text{ MeV}$; Tavani et al., ApJ, 698, L142, 2009)
- Shock acceleration mechanism in a wind-wind interaction scenario
($\dot{M}_1 \approx 2 \times 10^{-4} M_{\odot} \text{ yr}^{-1}$, $\dot{M}_2 \approx 2 \times 10^{-5} M_{\odot} \text{ yr}^{-1}$, $v_1 \approx 600 \text{ km/s}$, $v_2 \approx 3000 \text{ km/s}$)

AGILE map
(July 2007 – October 2008)



AGILE AND GALACTIC GAMMA-RAY SOURCES POSSIBLY ASSOCIATED WITH BINARY SYSTEMS

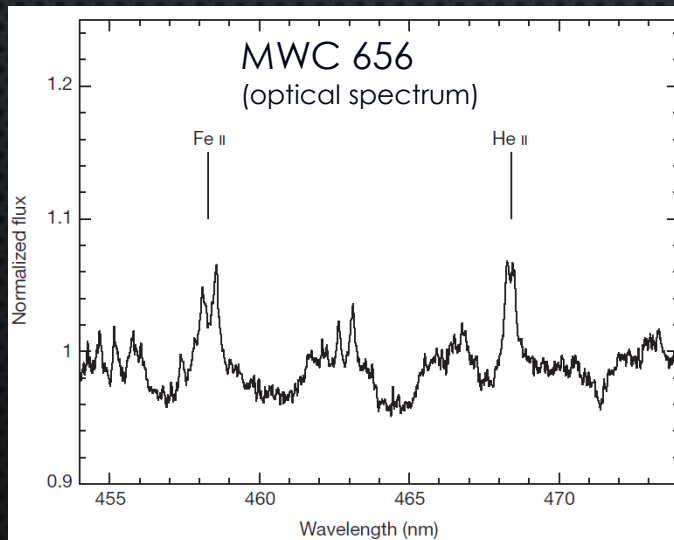
AGILE source	binary system	binary type	orbital period
1AGL J0242+6111	LS I +61 303	Be + ? (HMXB)	26.5 days
1AGLR J1822-1456	LS 5039	O + ? (HMXB)	3.9 days
AGL J1734-3310	IGR J17354-3255	SFXT (HMXB)	8.45 days (Sguera et al., 2011)
AGL J2022+3622	IGR J20188+3647	SFXT (HMXB) ?	? (ATel #1313; Sguera et al., 2006)
AGL J1037-5708	4U 1036-56	Be-NS (HMXB)	61.0 days (Cusumano et al., 2013)
AGL J2241+4454	MWC 656	Be-BH (HMXB)	60.37 days (Casares et al., 2014; P. Munar-Adrover et al., 2016)

AGILE AND GALACTIC GAMMA-RAY TRANSIENTS: AGL J2241+4454

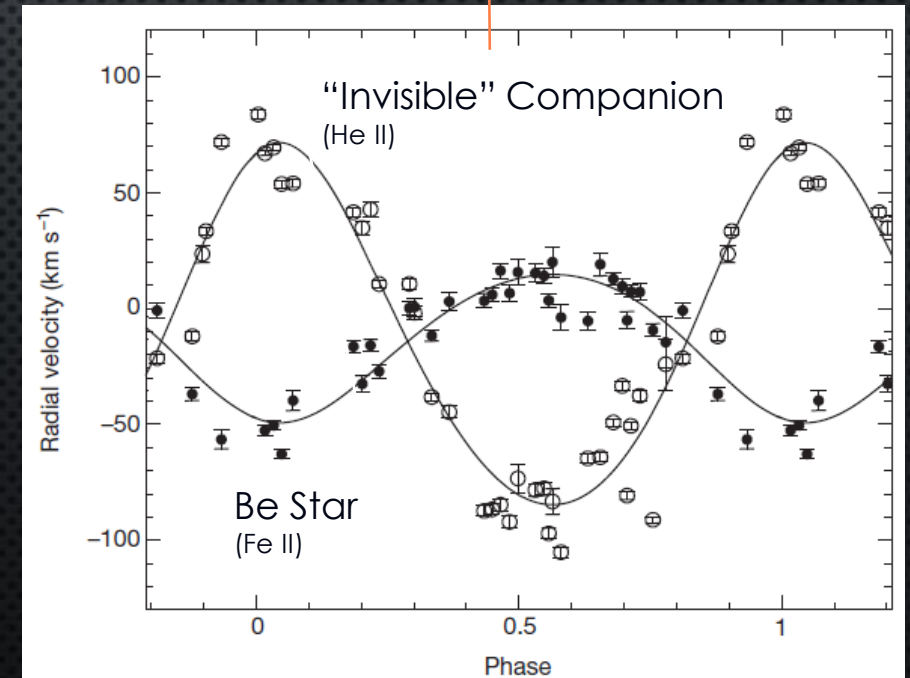
- Transient γ -ray activity detected in July 2010 (ATel #2761).
- AGILE detection \rightarrow discovery of the first Be-HMXB hosting a Black Hole: MWC 656 (Casares et al., 2014 \rightarrow optical data)



Casares et al.,
"A Be-type star with a black-hole companion",
Nature 505, 378 (2014)



Black Hole
($M = 3.8 - 6.9 M_{\odot}$)



AGL J2241+4454: AGILE OBSERVATIONS

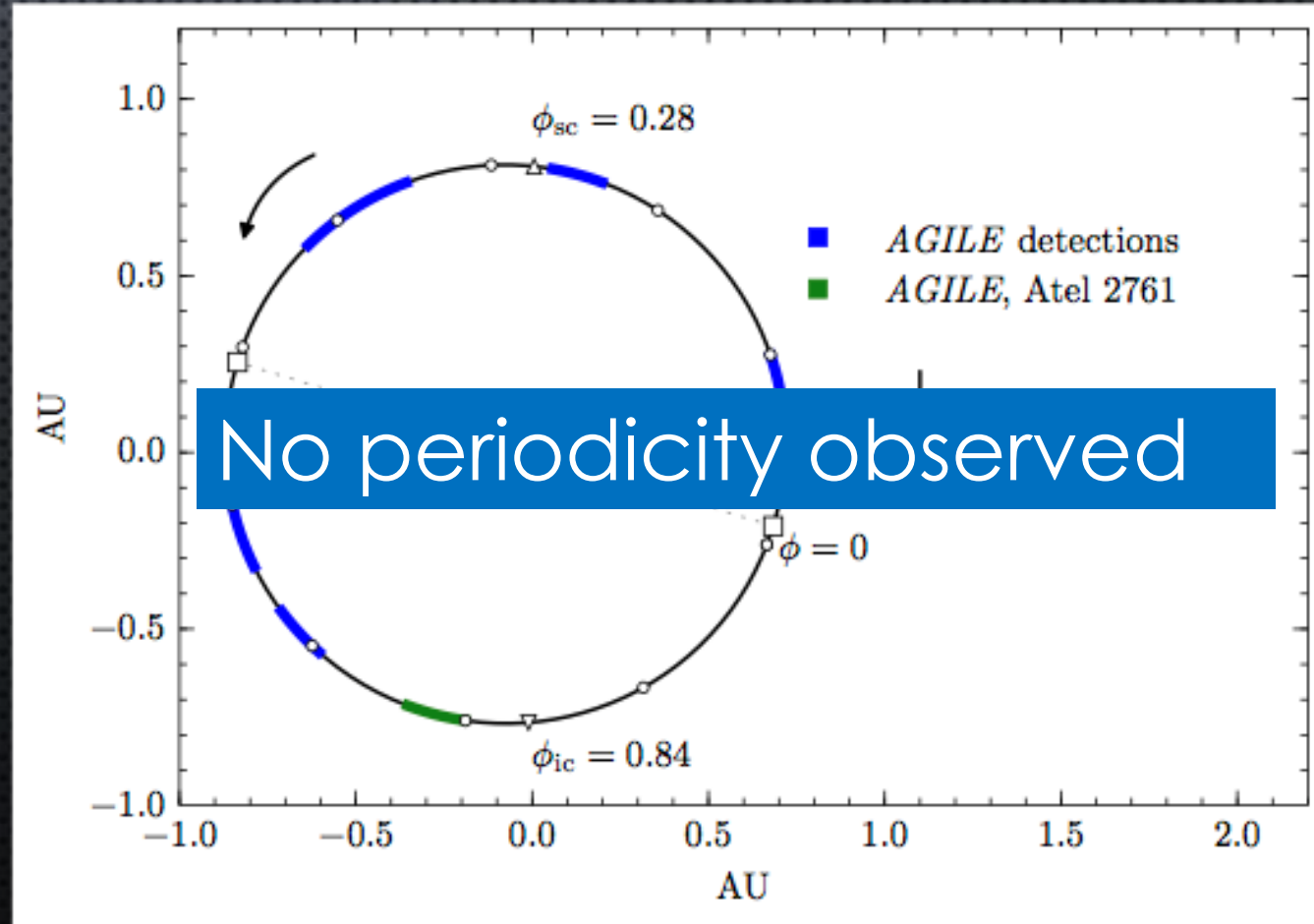
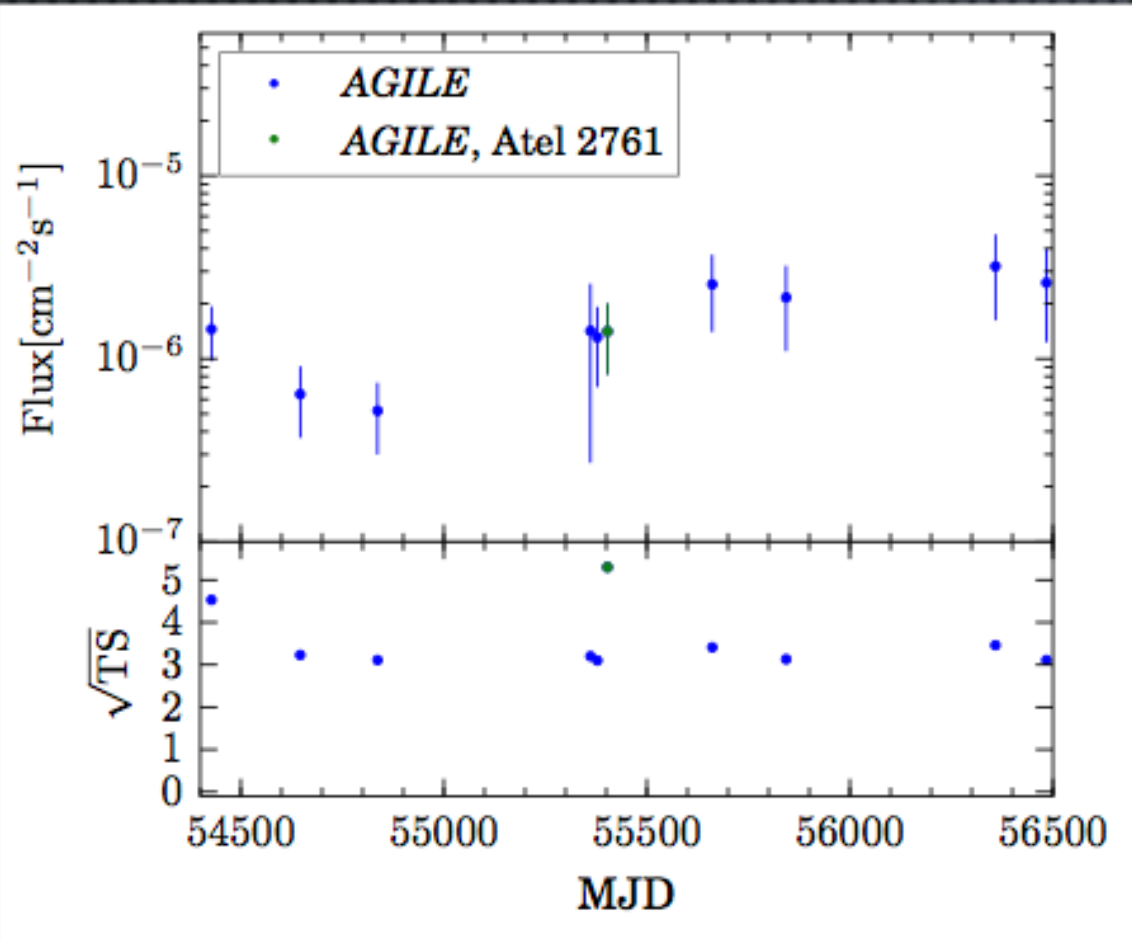
- Blind search in 2-day bin lightcurve (Pointing and Spinning)
- 10 flaring events observed by AGILE between 2007 and 2013

AGILE gamma-ray transient detections around the position of MWC 656.

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

AGL J2241+4454: AGILE OBSERVATIONS

- Searching for periodic γ -ray emission
- Folding data with 60.37 day period



AGILE AND GALACTIC GAMMA-RAY SOURCES POSSIBLY ASSOCIATED WITH BINARY SYSTEMS

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Ongoing analysis...

Thanks for your attention