MICROQUASARS IN THE CYGNUS REGION

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ON BEHALF OF THE AGILE TEAM

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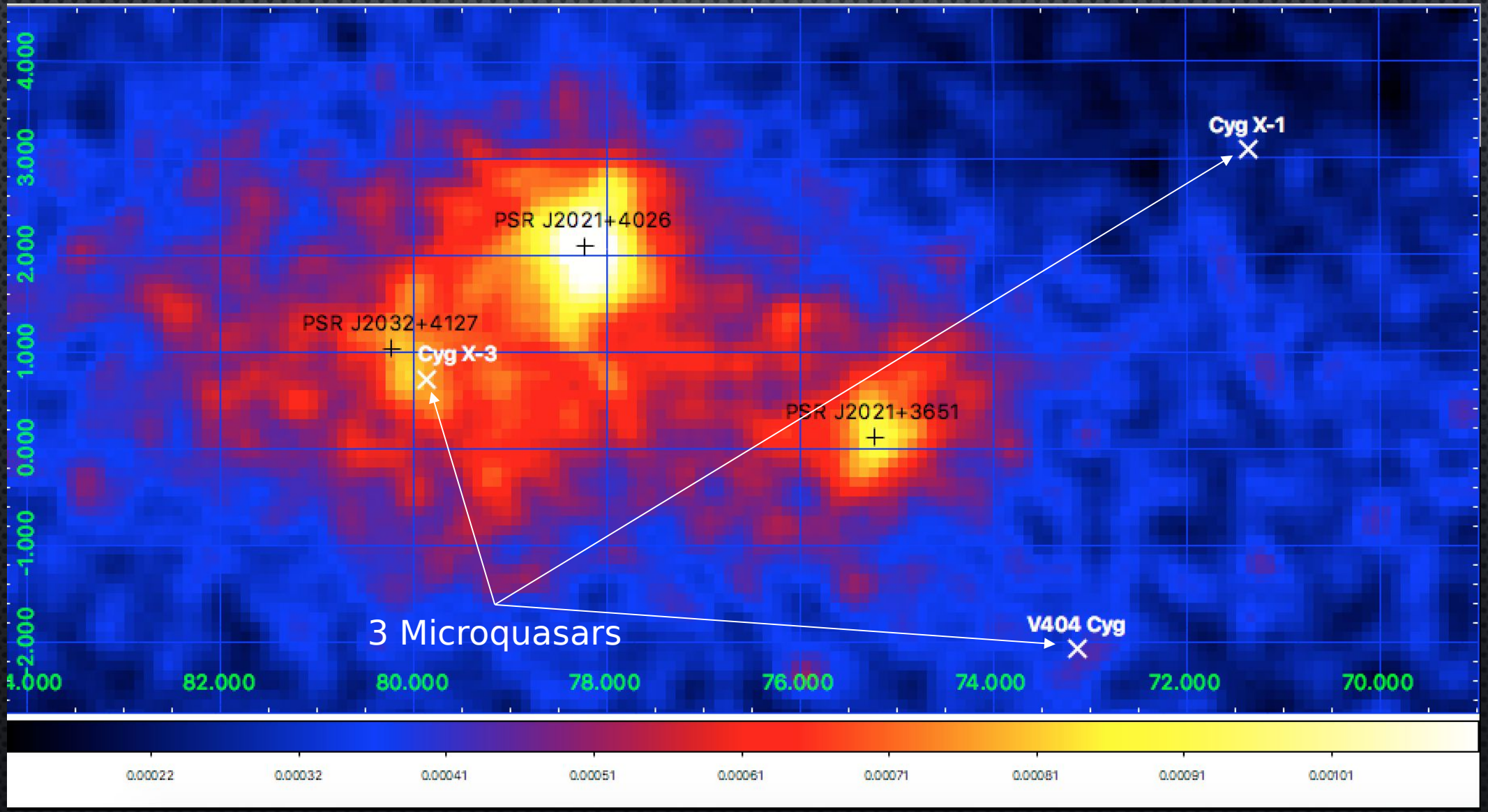
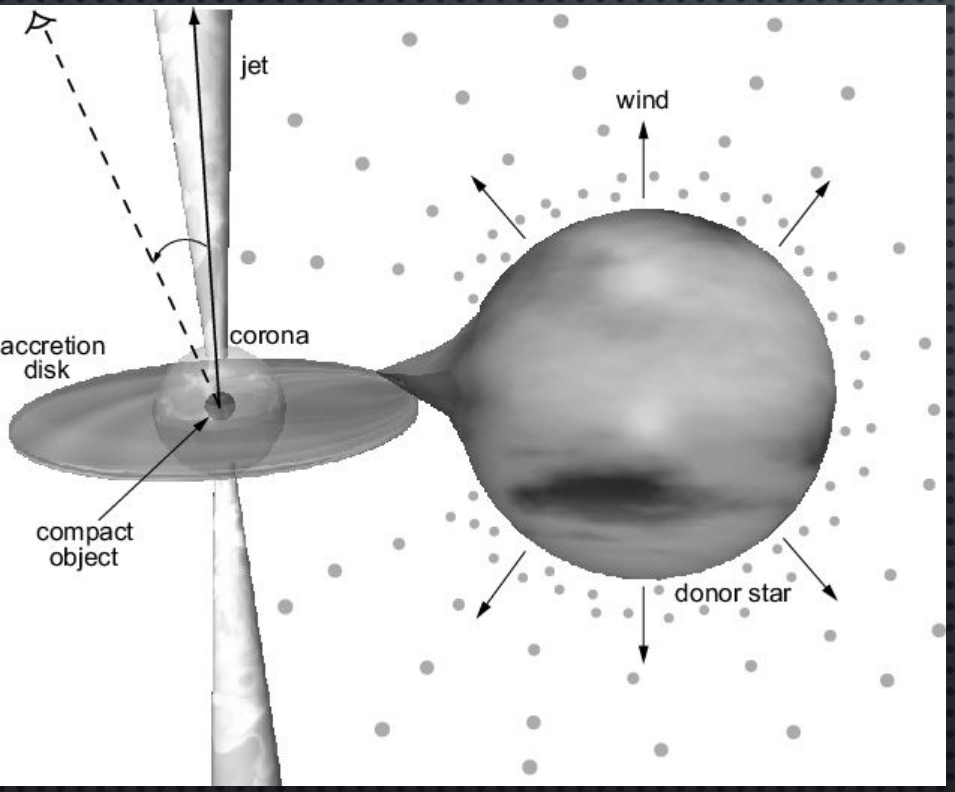
THE CYGNUS REGION AS DETECTED BY AGILE (E > 100 MeV)



Microquasar



- X-ray binary systems
- 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

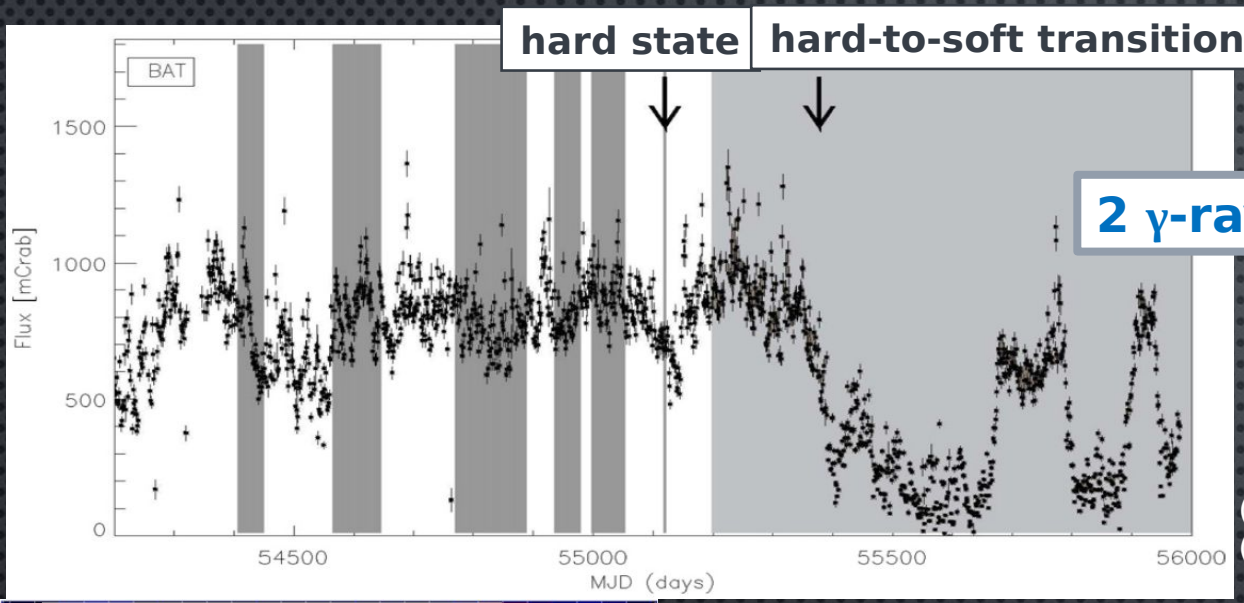
Open question (pre-AGILE/Fermi):

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

Microquasars in the Cygnus region

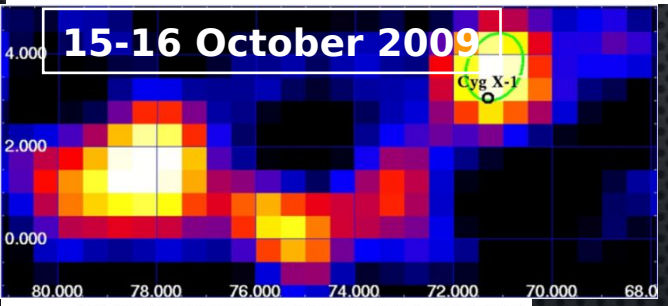
	Cygnus X-1	Cygnus X-3	V404 Cygni
type	HMXB	HMXB	LMXB
compact object	BH (4.8-14.8 $M_\odot$)	BH or NS (?)	BH (9 $M_\odot$)
companion star	09.7 Iab (17-31 $M_\odot$)	WR (> 7 $M_\odot$)	K3 III (0.7 $M_\odot$)
distance	1.9 kpc	7-10 kpc	2.39 kpc
orbital period	5.6 days	4.8 hours	6.47 days

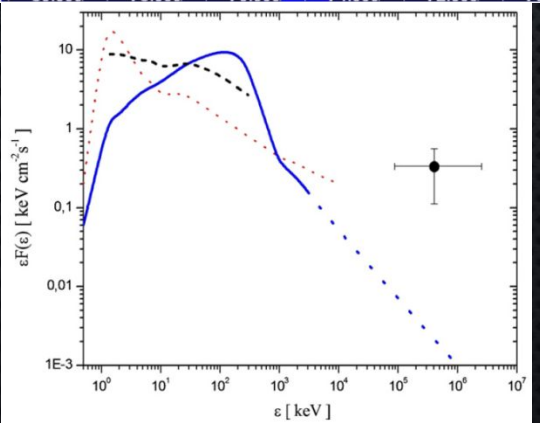
Cygnus X-1



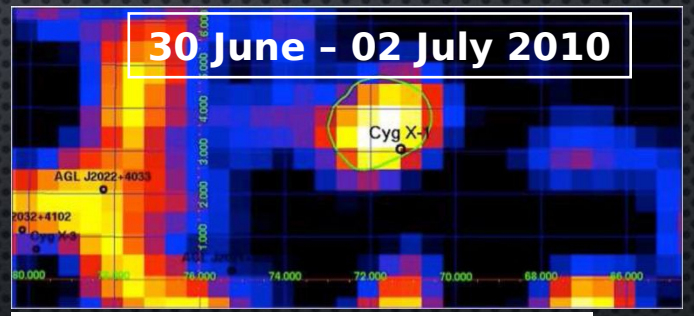
2 γ-ray flares detected by AGILE

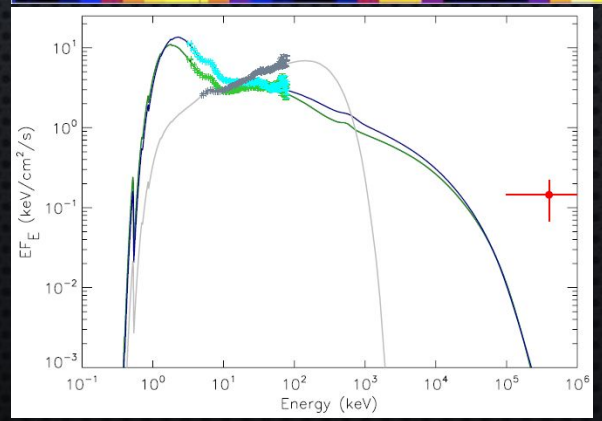
(Sabatini et al., 2010)
(Sabatini et al., 2013)





significance = 5.3σ
$F_\gamma = (232 \pm 66)\ 10^{-8}$ ph cm^{-2} s^{-1}

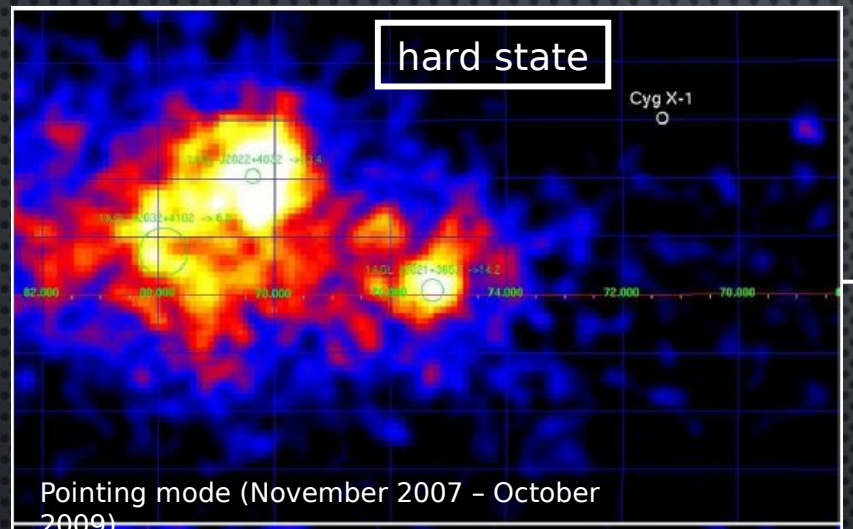




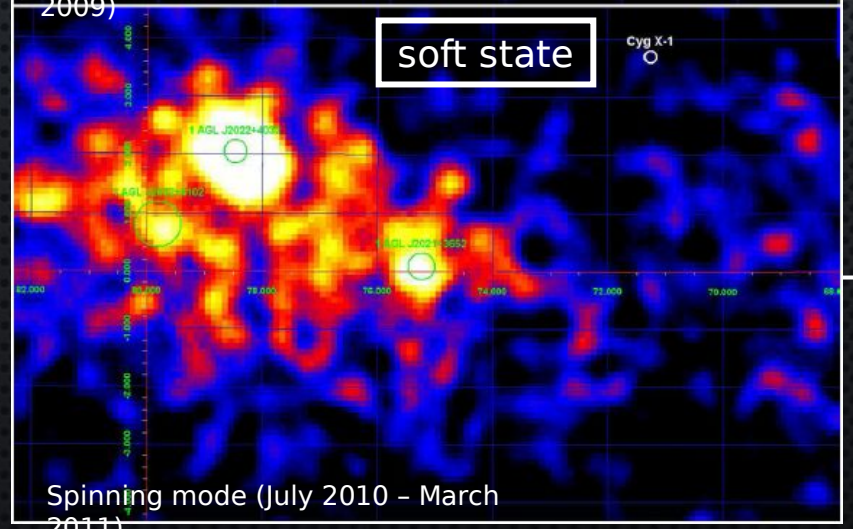
significance = 3.0σ
$F_\gamma = (145 \pm 78)\ 10^{-8}$ ph cm^{-2} s^{-1}

Cygnus X-1

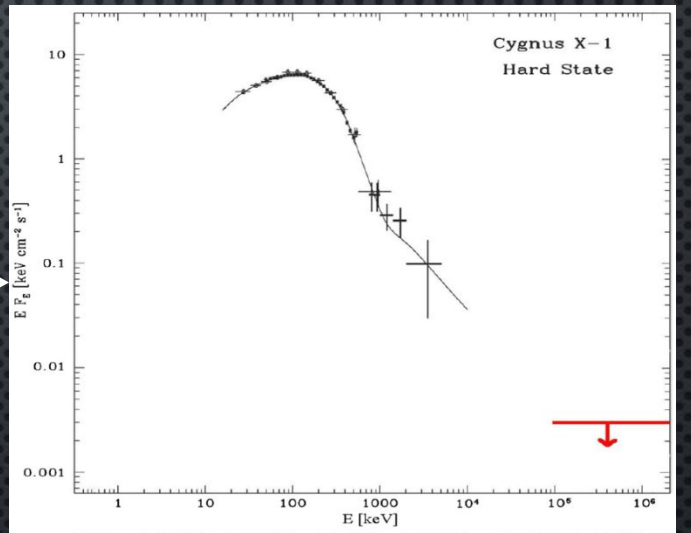
Comptonization models: spectral ULs from long-term integration in the γ-ray energy band both for hard and soft states

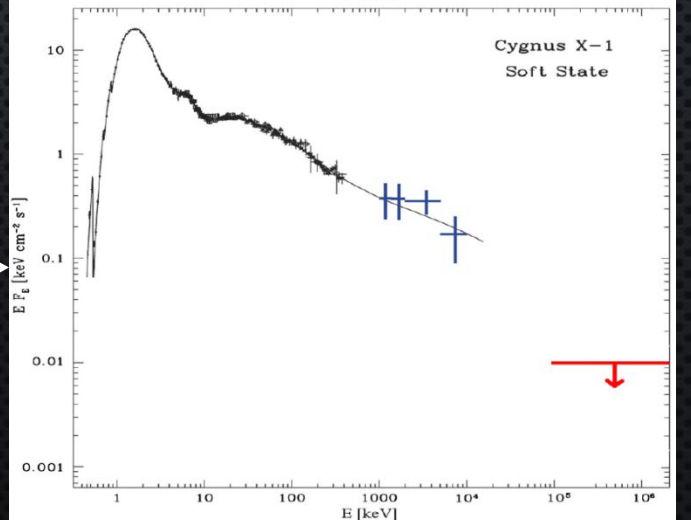


Pointing mode (November 2007 – October 2009)



Spinning mode (July 2010 – March 2011)





(Sabatini et al., 2013)

Cygnus X-3

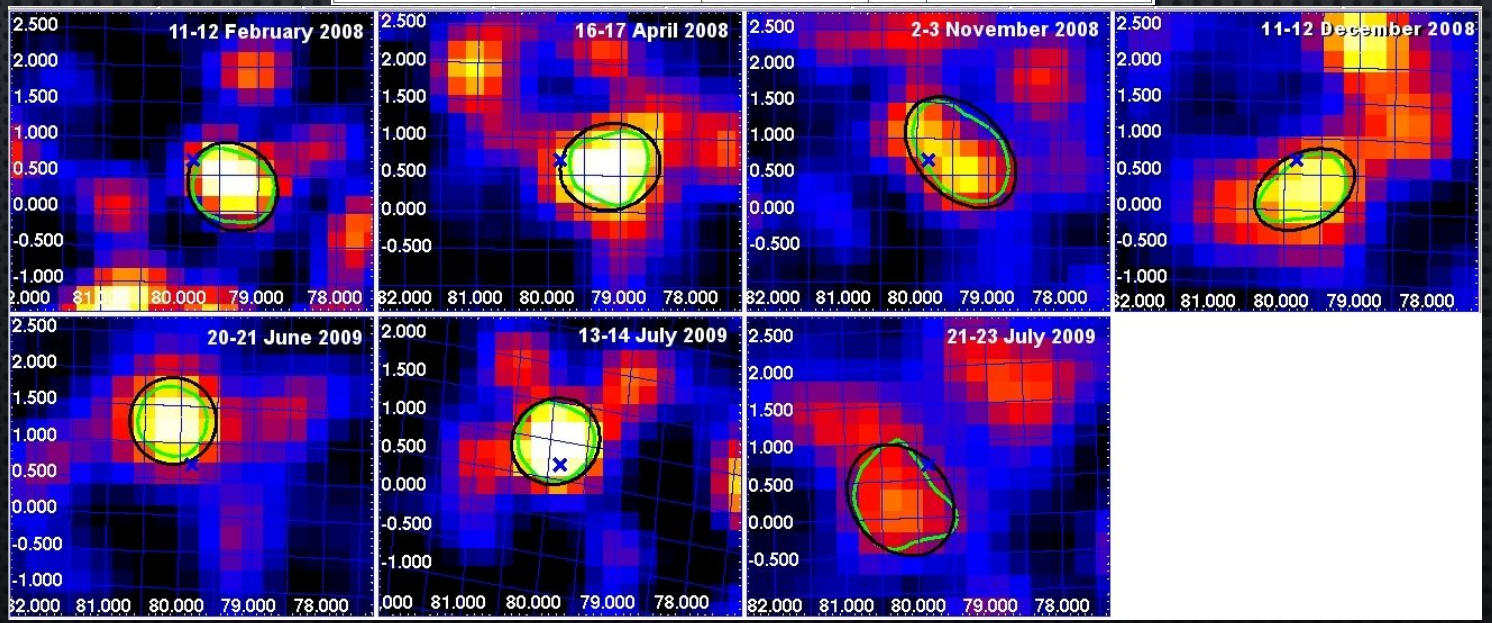
γ-ray activity discovered in late 2009

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

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

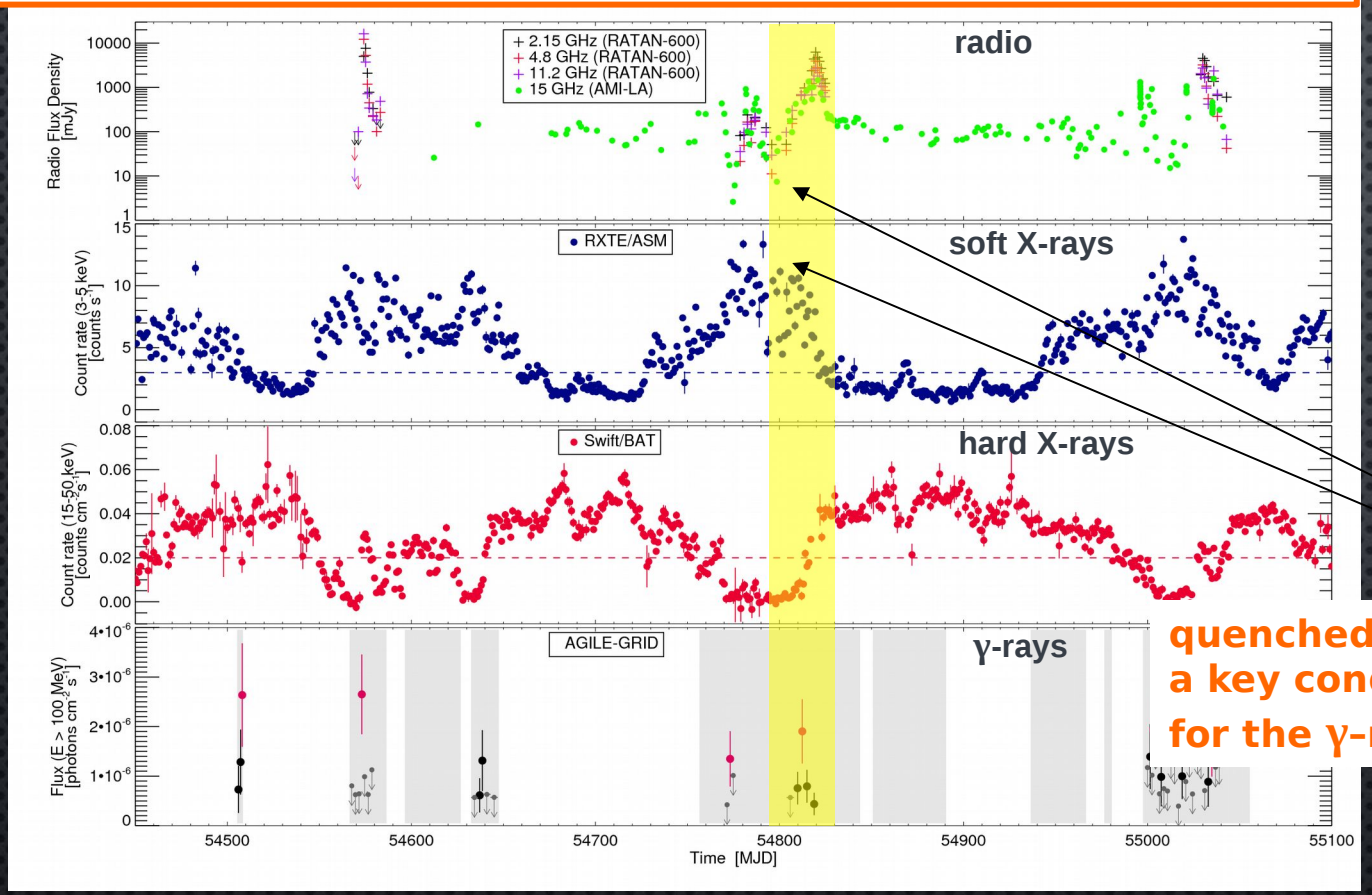
- significance ≥ 3σ
- γ-ray fluxes more than 10 times the steady flux [F_{steady} = (14 ± 3) x 10^{-8} ph cm^{-2} s^{-1}]

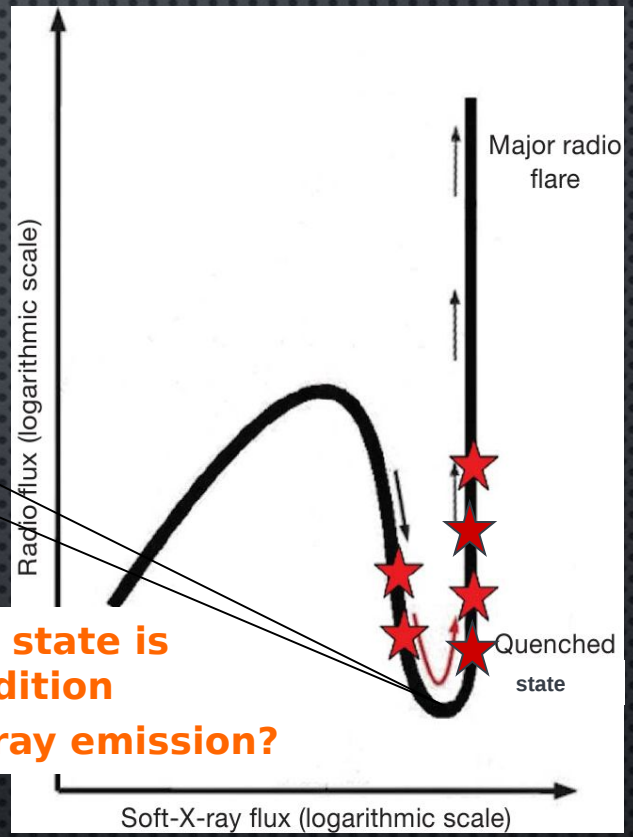
Period	MJD	√TS	Flux [10^{-8} photons cm^{-2} s^{-1}]
2008 Feb 11 (18:07:28) - 2008 Feb 12 (11:07:44)	54507.76 - 54508.46	3.7	264 ± 104
2008 Apr 16 (13:59:12) - 2008 Apr 17 (13:48:00)	54572.58 - 54573.58	4.5	265 ± 80
2008 Nov 2 (13:01:05) - 2008 Nov 3 (19:01:05)	54772.54 - 54773.79	3.1	135 ± 56
2008 Dec 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)





quenched state is a key condition for the γ-ray emission?

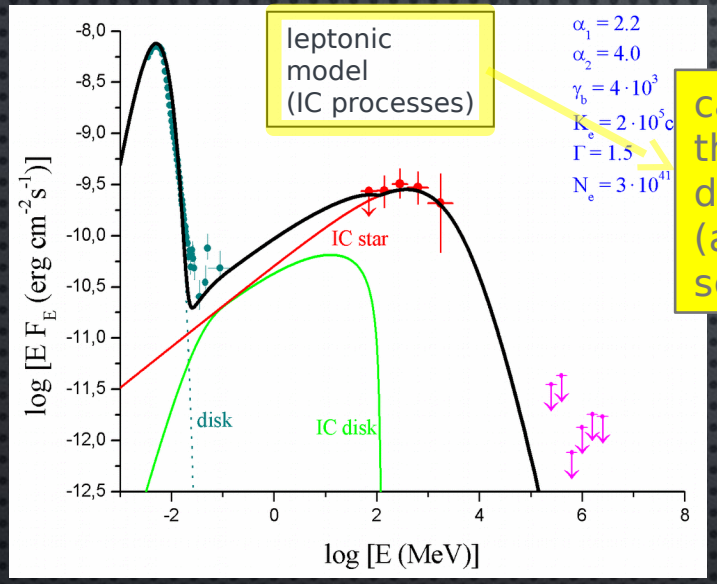
Repetitive multi-frequency emission pattern:

- **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

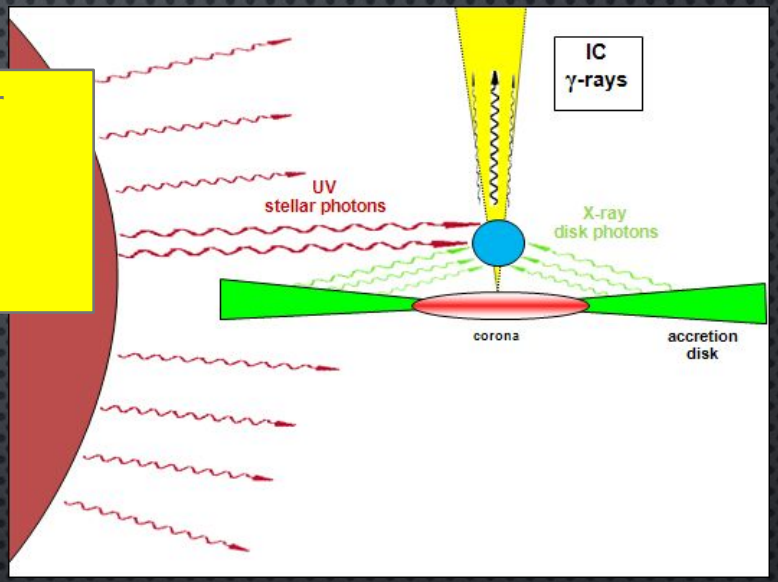
(Piano et al. 2012)

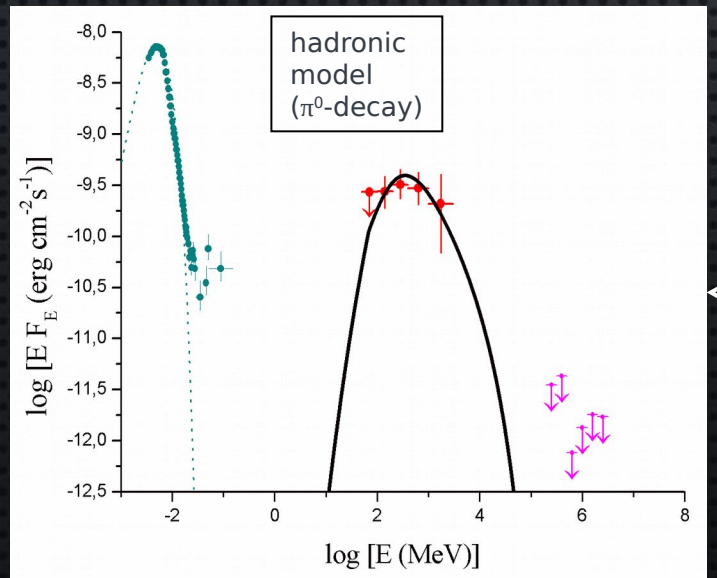
Cygnus X-3

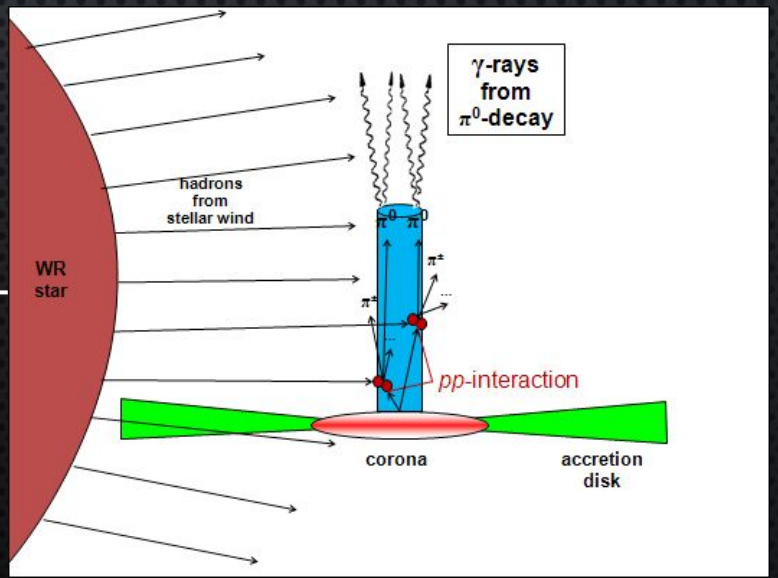
Both leptonic and hadronic emission models
can account for the γ-ray flaring spectrum detected by AGILE



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



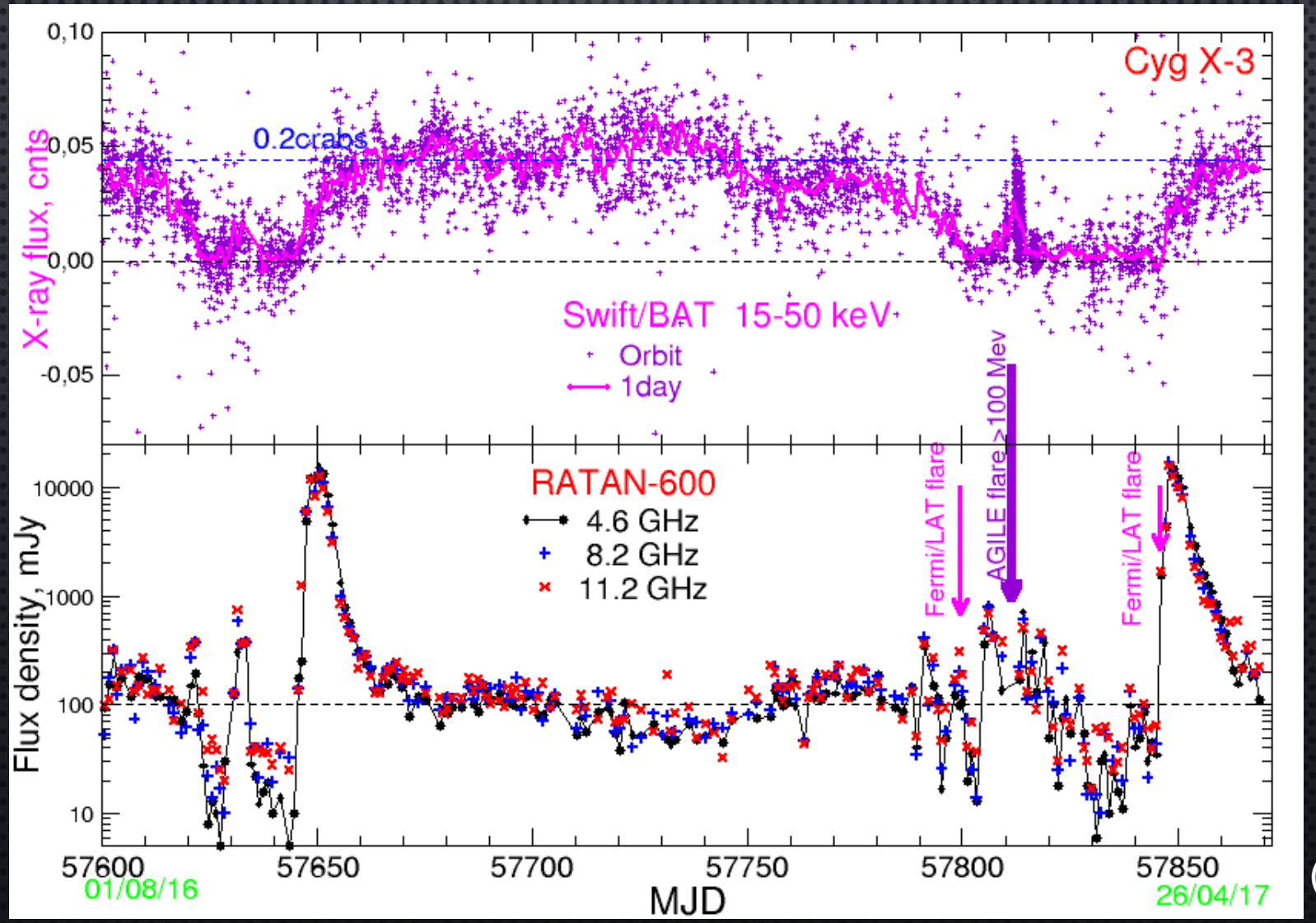




(Piano et al., A&A, 545 A110, 2012)

Cygnus X-3

Recent γ-ray activity ⎵ February-April 2017



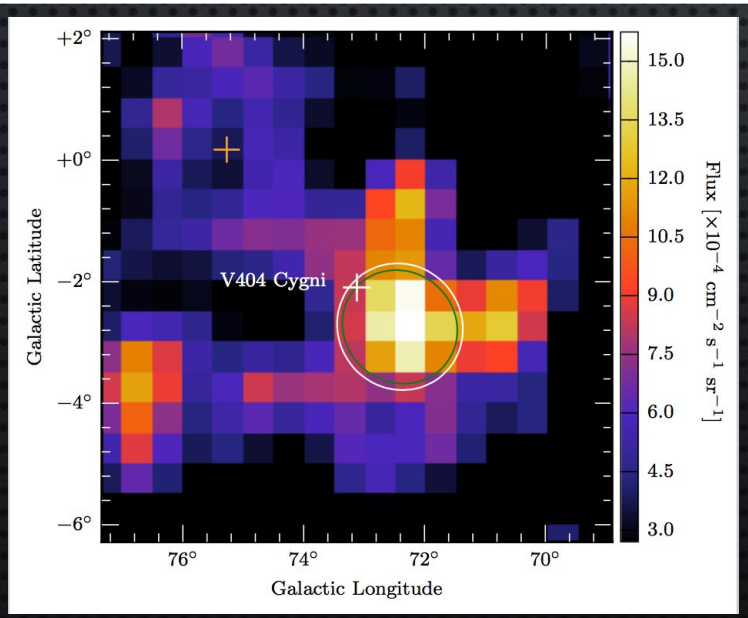
(see E. Egron's talk)

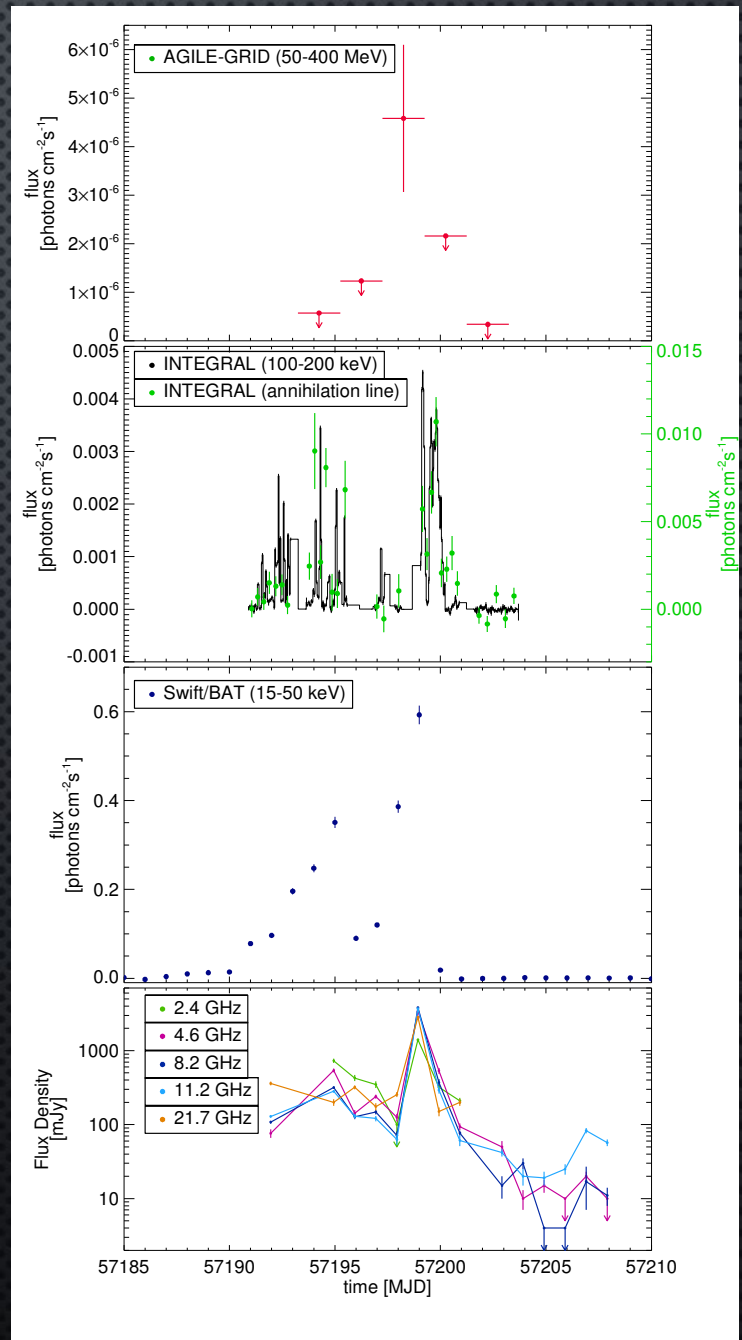
V404 Cygni

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)

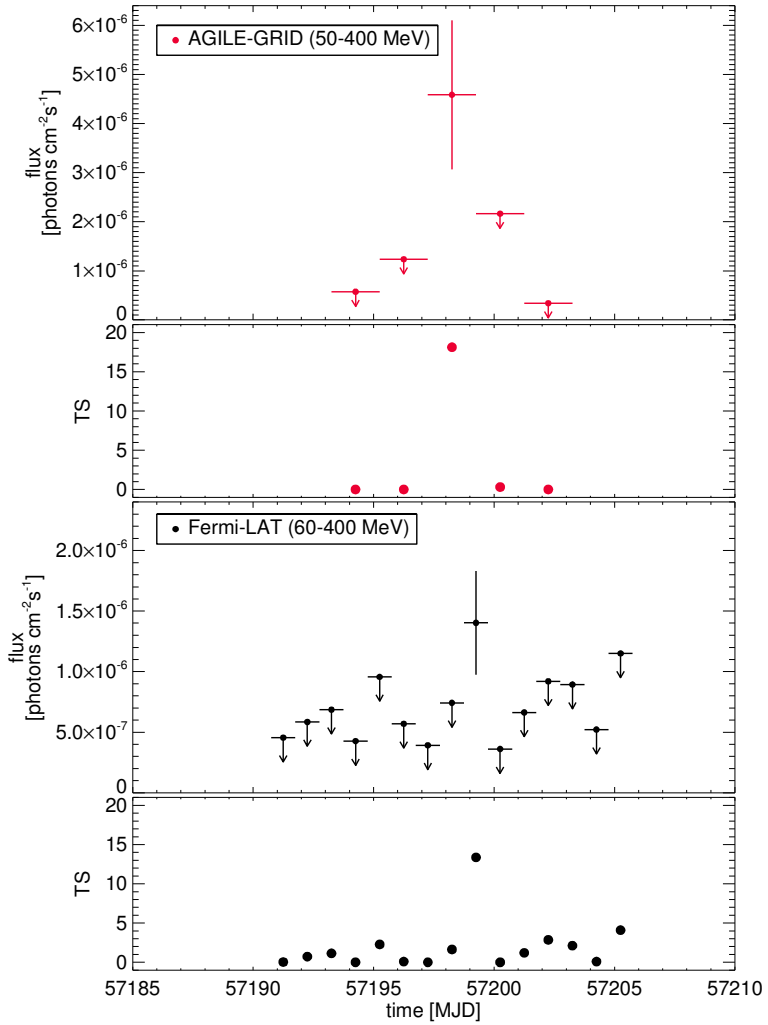
AGILE 2-day intensity map (50-400 MeV)



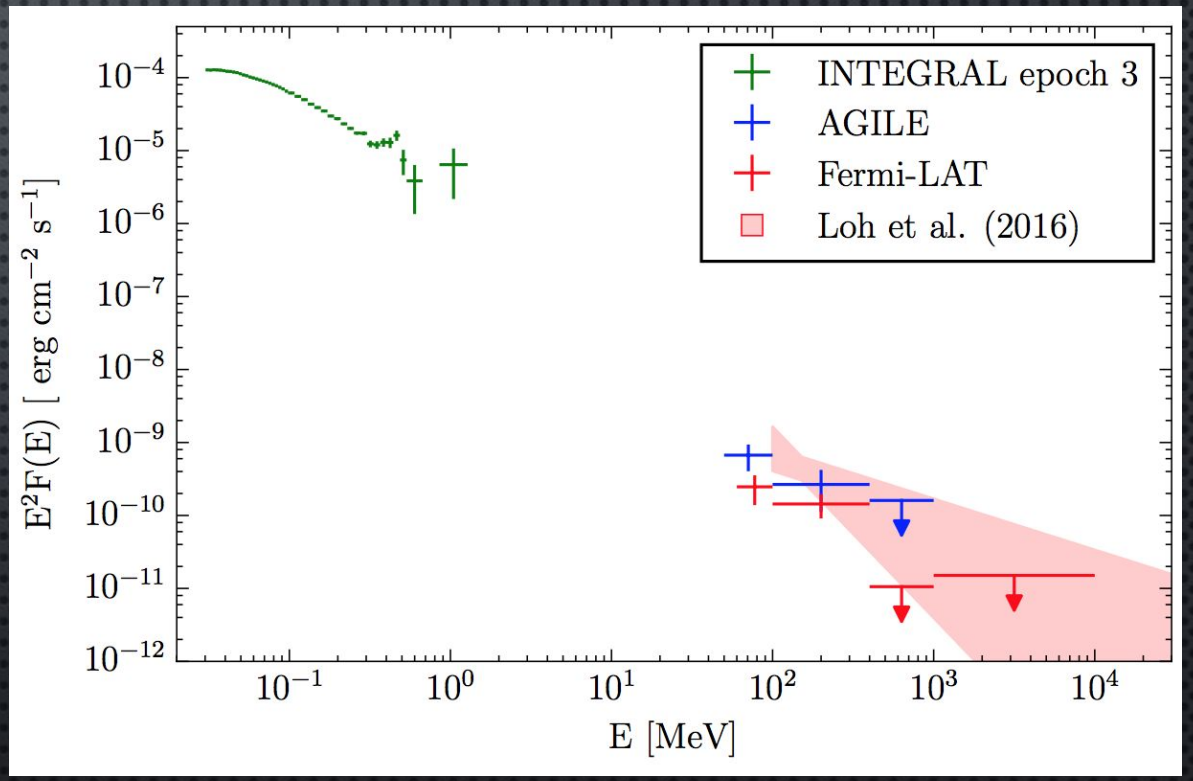


V404 Cygni

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

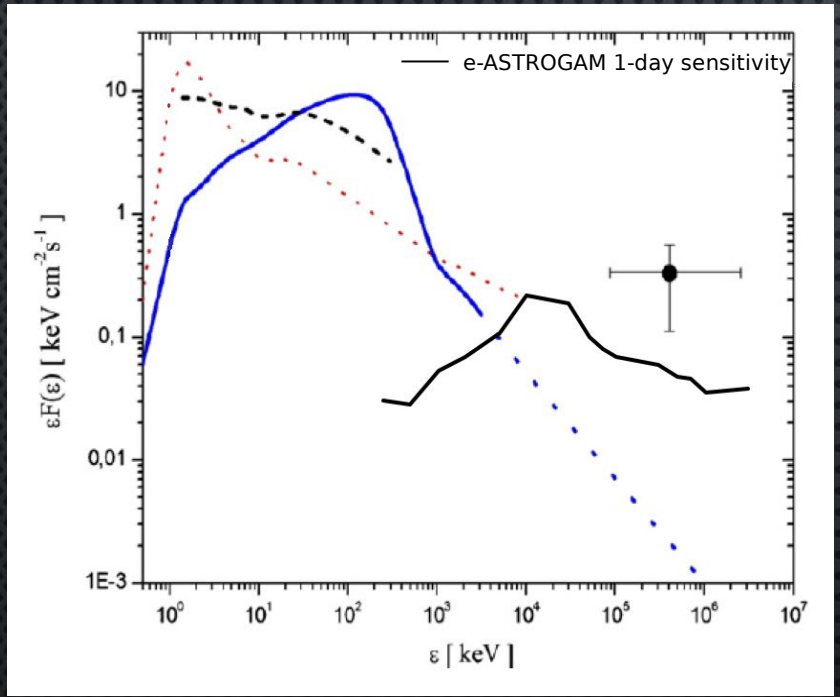
(Piano et al. ApJ 839, 84, 2017)

Evidences

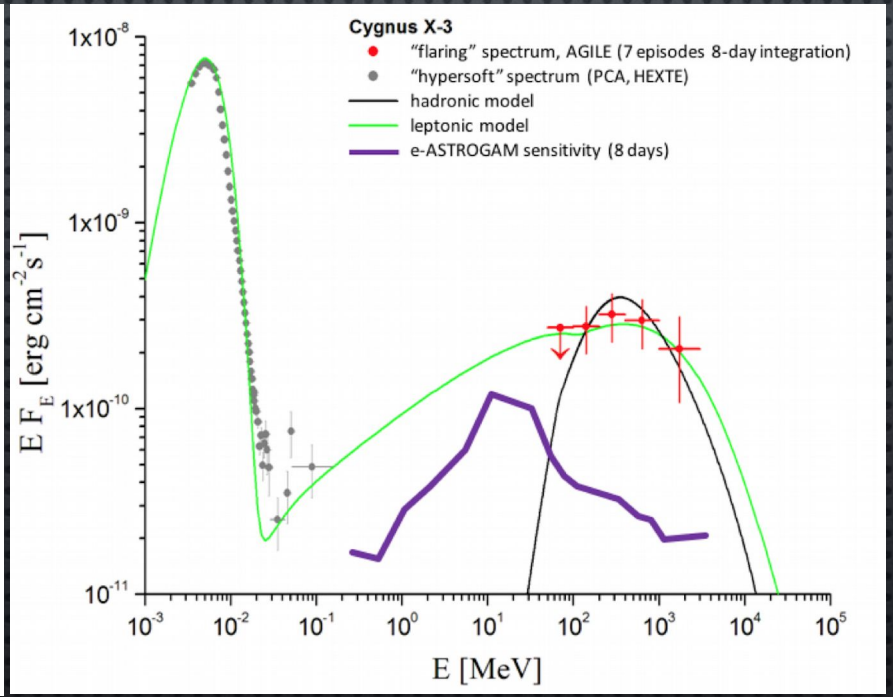
- The HE γ-ray emission is related to a new component in the multiwavelength spectrum (not coronal emission)
  - Acceleration processes in the jet
  - Leptonic/hadronic scenario?
- Cygnus X-1 ▭ ULs to persistent HE γ-ray emission ▭ constraints to coronal emission
- Cygnus X-3 ▭ repetitive pattern of 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?

Perspectives with **e-ASTROGAM**

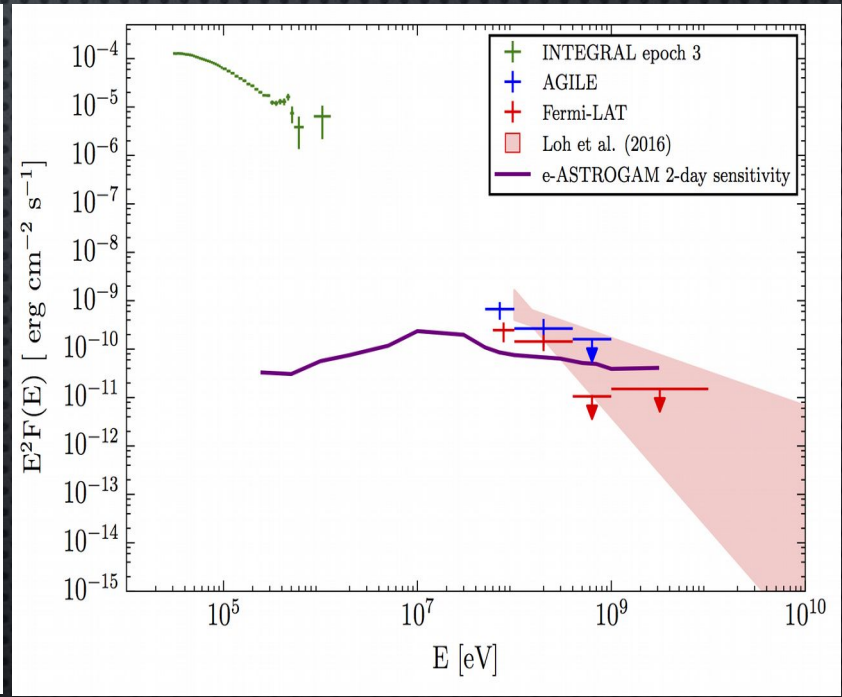
Cygnus X-1
(1day)



Cygnus X-3
(8 days)



V404 Cygni
(2 days)



Thanks for your attention