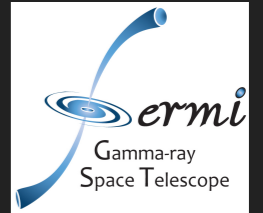




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# V404 Cyg High-Energy Gamma-ray emission detected with Fermi-LAT

A. Loh; S. Corbel; G. Dubus; J. Rodriguez; I. Grenier;  
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Fermi-LAT Collaboration

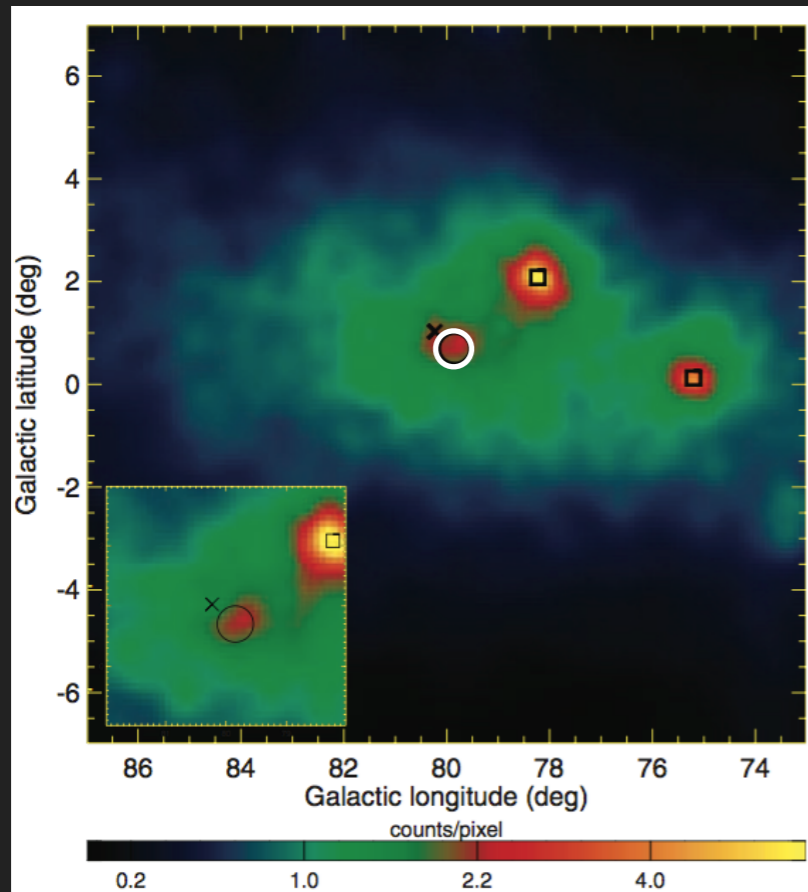
# Microquasars at High-Energy Gamma-rays

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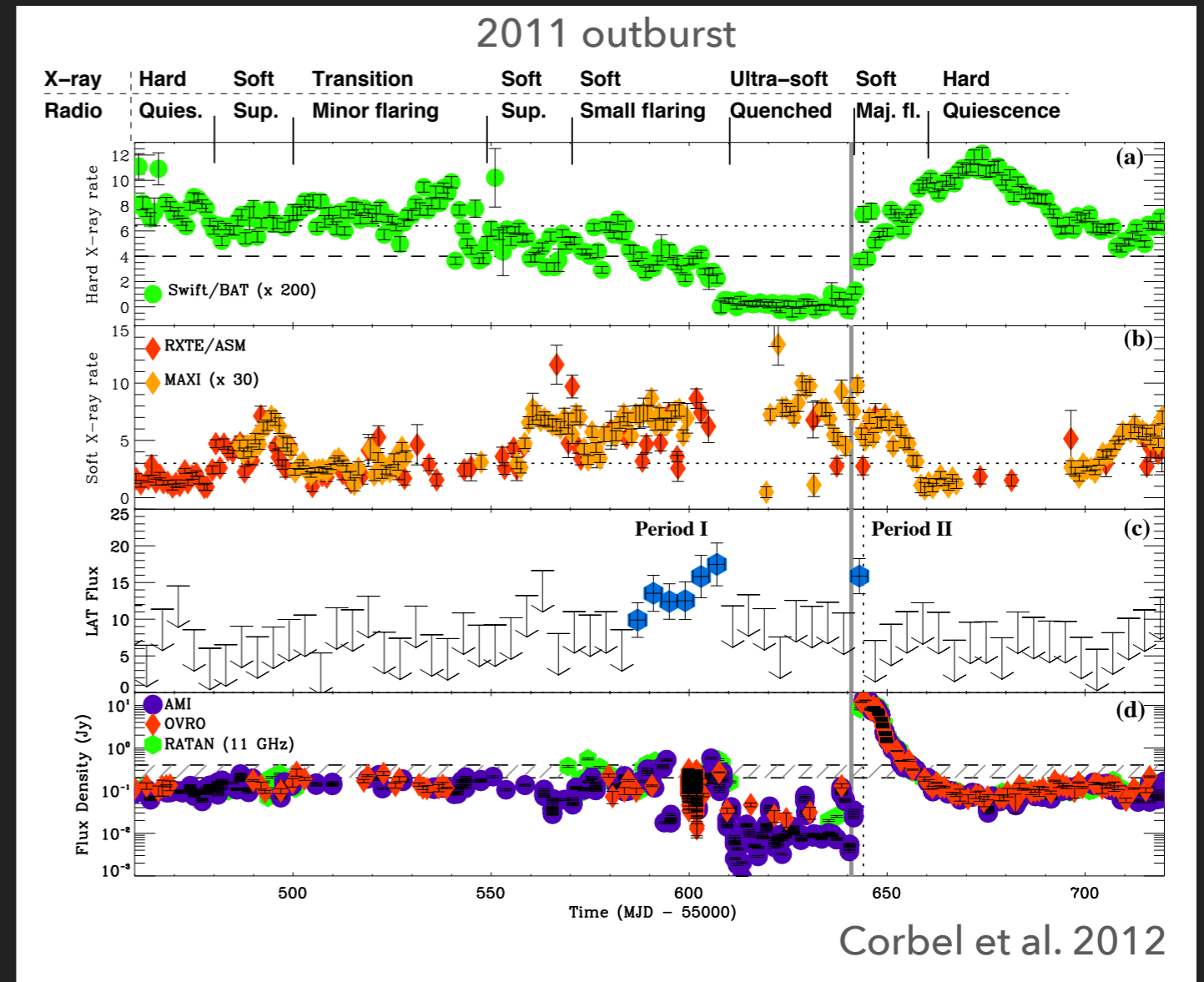
- ▶ HE gamma-ray emission theoretically predicted from BH XRB (e.g. Bosch-Ramon et al. 2006)
- ▶ HE emission linked to the presence of radio jet / accelerated particles
- ▶ If leptonic process, radio/gamma-rays: same electron population
  - ▶ Acceleration mechanism
  - ▶ Jet-environment interactions
  - ▶ Disk-jet coupling

# Cygnus X-3

Fermi-LAT Collaboration et al. 2009

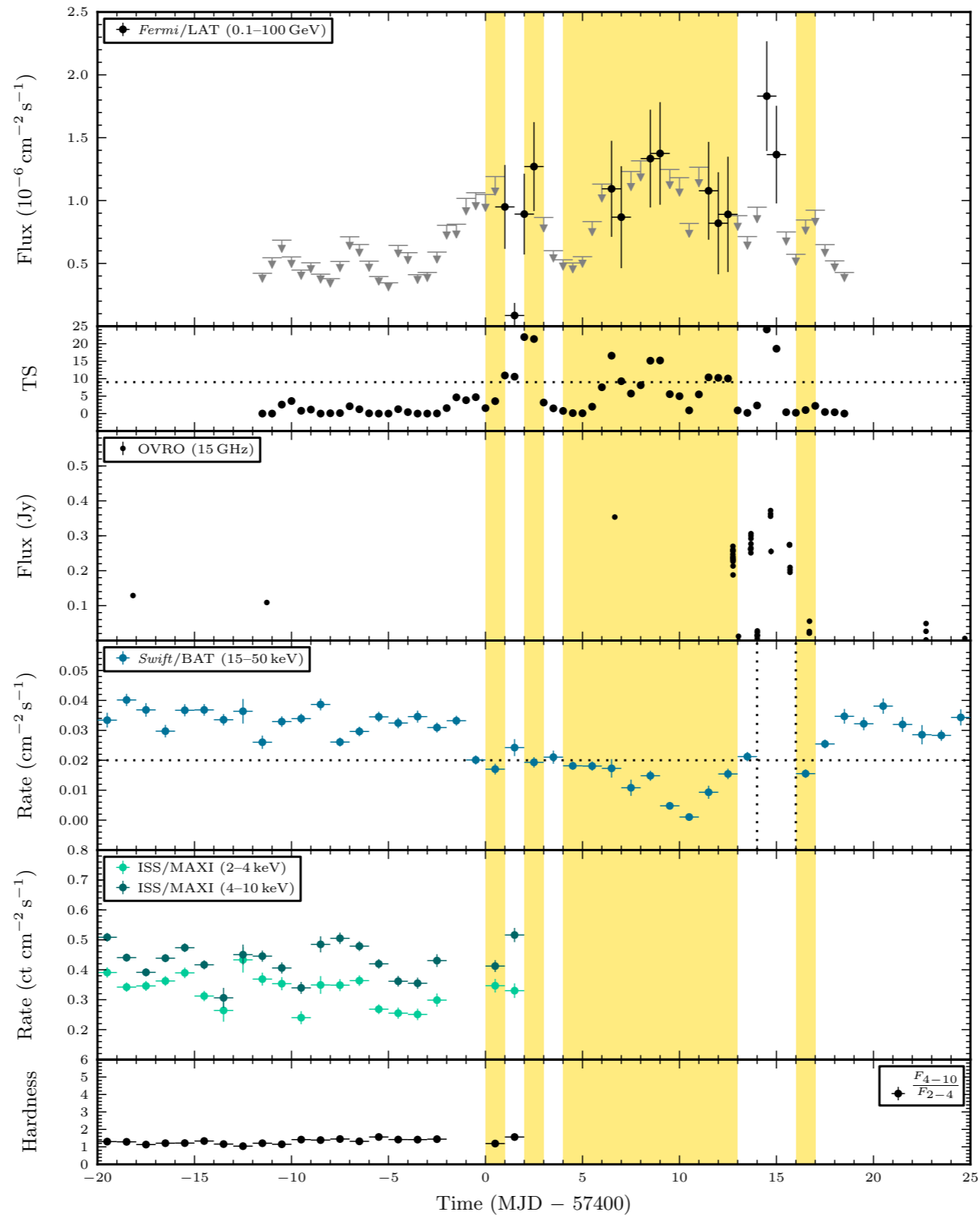


- ▶ Gamma-ray modulation (4.8h)
- ▶ Coincident with radio flares
- ▶ Soft X-ray state
- ▶ 'Sweet spot' of gamma-ray production (Cerutti et al. 2011): pair production vs seed photons



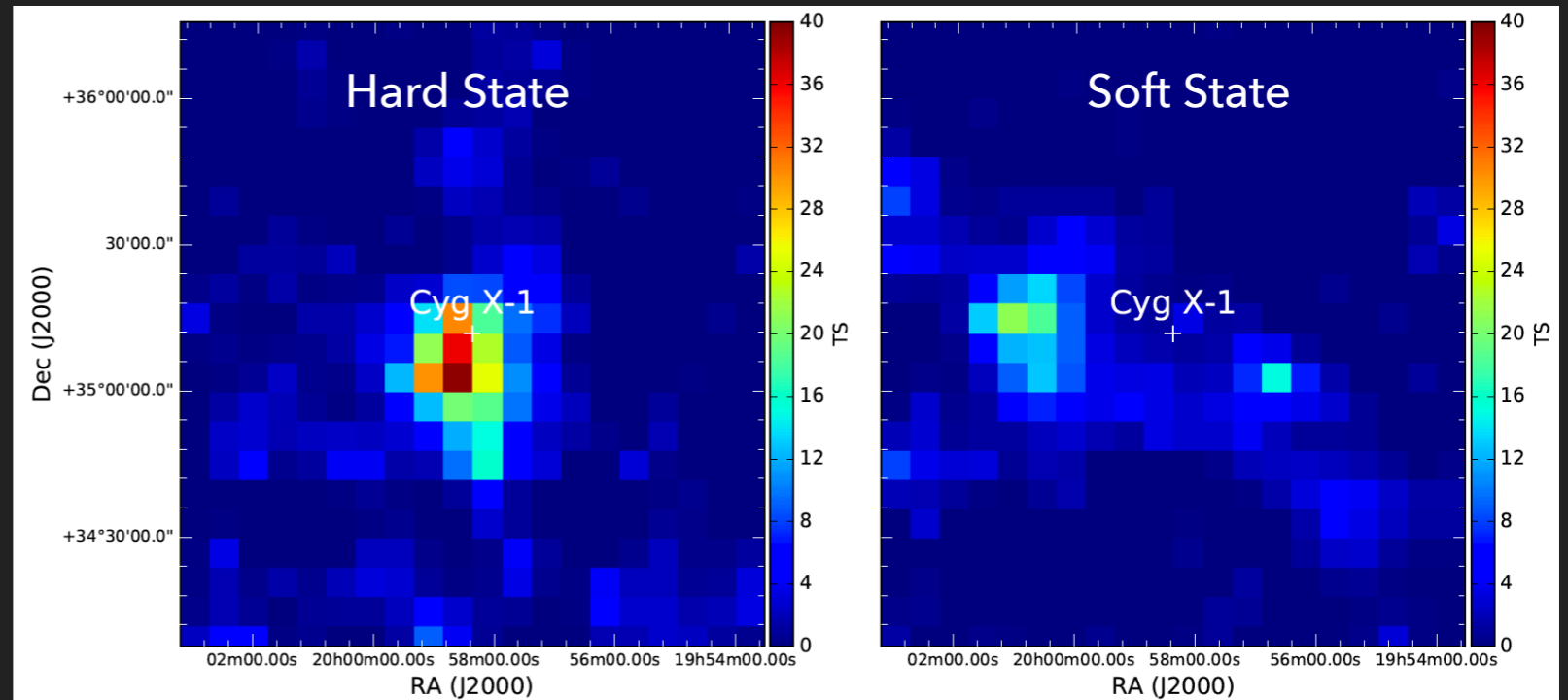
Fermi-LAT Collaboration et al. 2009; Tavani et al. 2009

# Cygnus X-3: e.g., January 2016

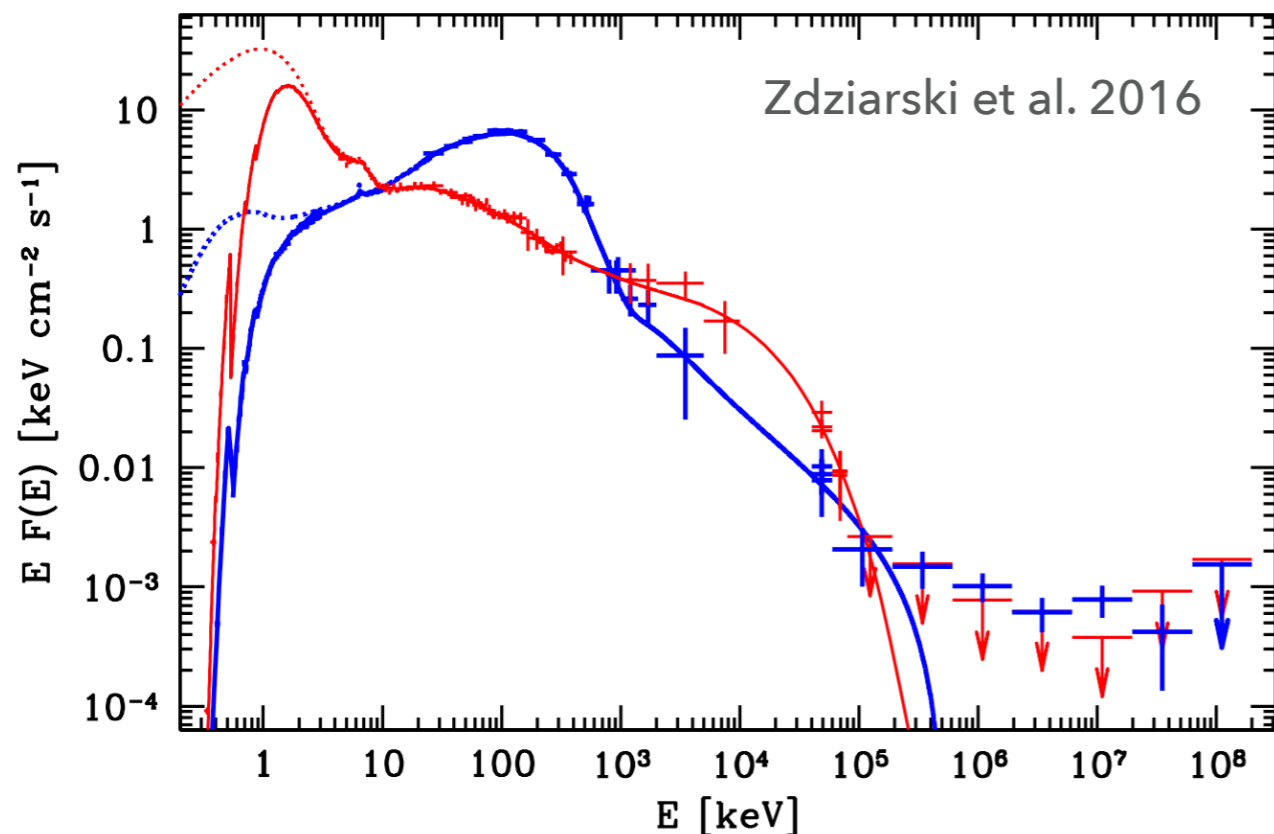


# Cygnus X-1

- ▶ Gamma-ray emission during the HS / IS
- ▶ Associated with steady jets



Zanin et al. 2016



- ▶ Hints of orbital flux variability

Malyshev et al. 2013; Bodaghee et al. 2013;  
Sabatini et al. 2010, 2013

# HMXBs vs LMXBs

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- ▶ Cyg X-3 & Cyg X-1 detected at HE:
  - ▶ HMXB sources ( $>10 M_{\odot}$  WR &  $20 M_{\odot}$  companion stars)
  - ▶ IC process: jet  $e^{-}$  on companion star's photon field
- ▶ What about LMXBs ?
  - ▶ Weaker photon field from the companion star
- ▶ **V404 Cygni's outburst: unique opportunity to search for gamma-ray emission from a LMXB!**

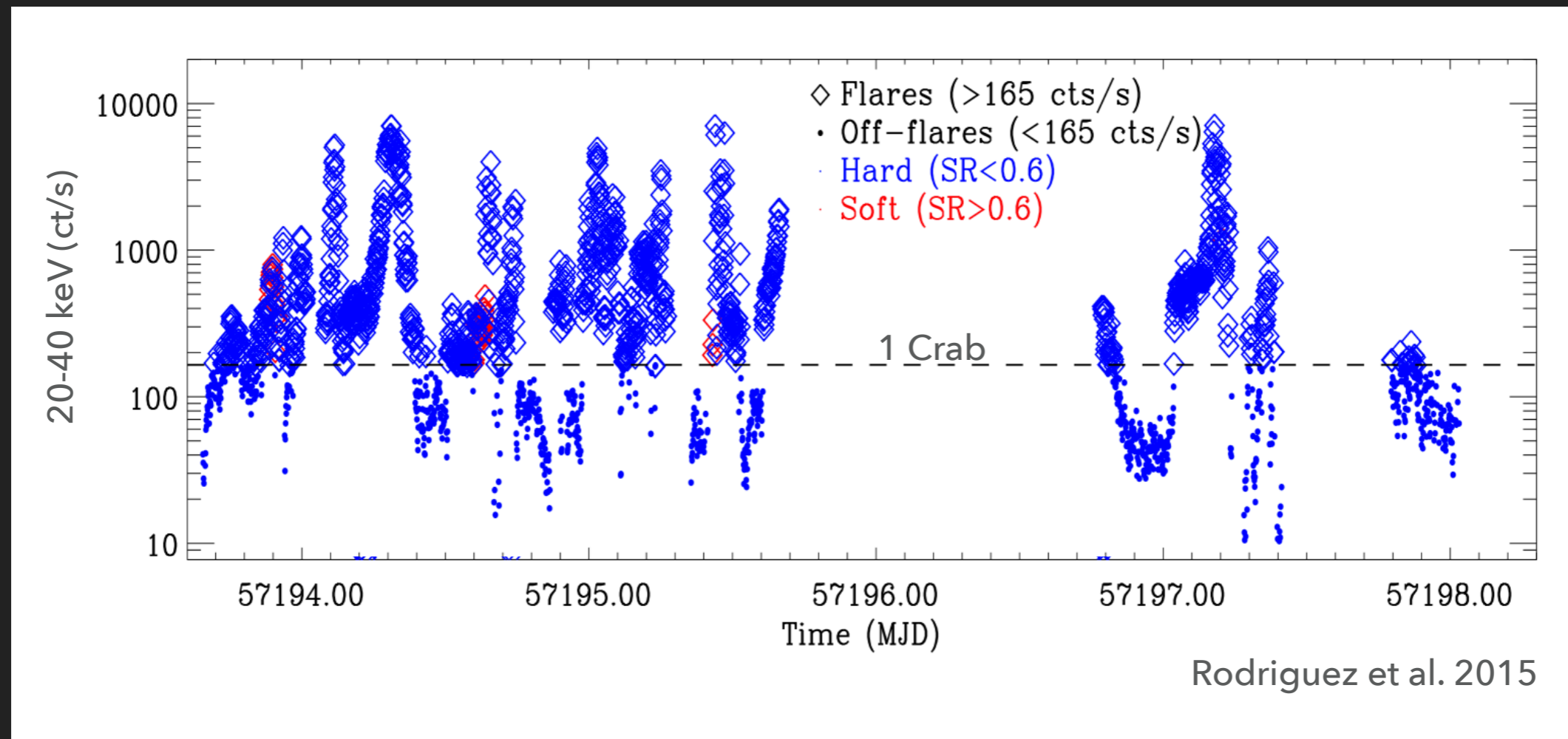
# Low-Mass X-ray Binary: V404 Cygni

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- ▶ ~9M<sub>o</sub> Black Hole
- ▶ ~1M<sub>o</sub> Companion star
- ▶ 6.5d Orbital period
- ▶ Parallax distance: 2.4 kpc
- ▶ Quiescence phase since 1989



# Summer 2015 Outburst



- ▶ ...Monitored at all wavelengths, from radio to VHE gamma-rays

Barthelmy+2015; Younes+2015; Mooley+2015; Trushkin+2015; Sivakoff+2015; Kimura+2016; Bernardini+2016; Siegert+2016; Tanaka+2016; Gandhi+2016, Muñoz-Darias+2016; Heinz+2016; Jenke+2016; Radhika+2016; Beardmore+2016; Loh+2016; Shahbaz+2016; Huppenkothen+2017; Jourdain+2017; Rahoui+2017; Piano+2017; Walton+2017; Sanchez-Fernandez+2017; Motta+2017; Tetarenko+2017; Ahnen+2017; ... to cite just a few



# Fermi-LAT as High-Energy Transient Monitor

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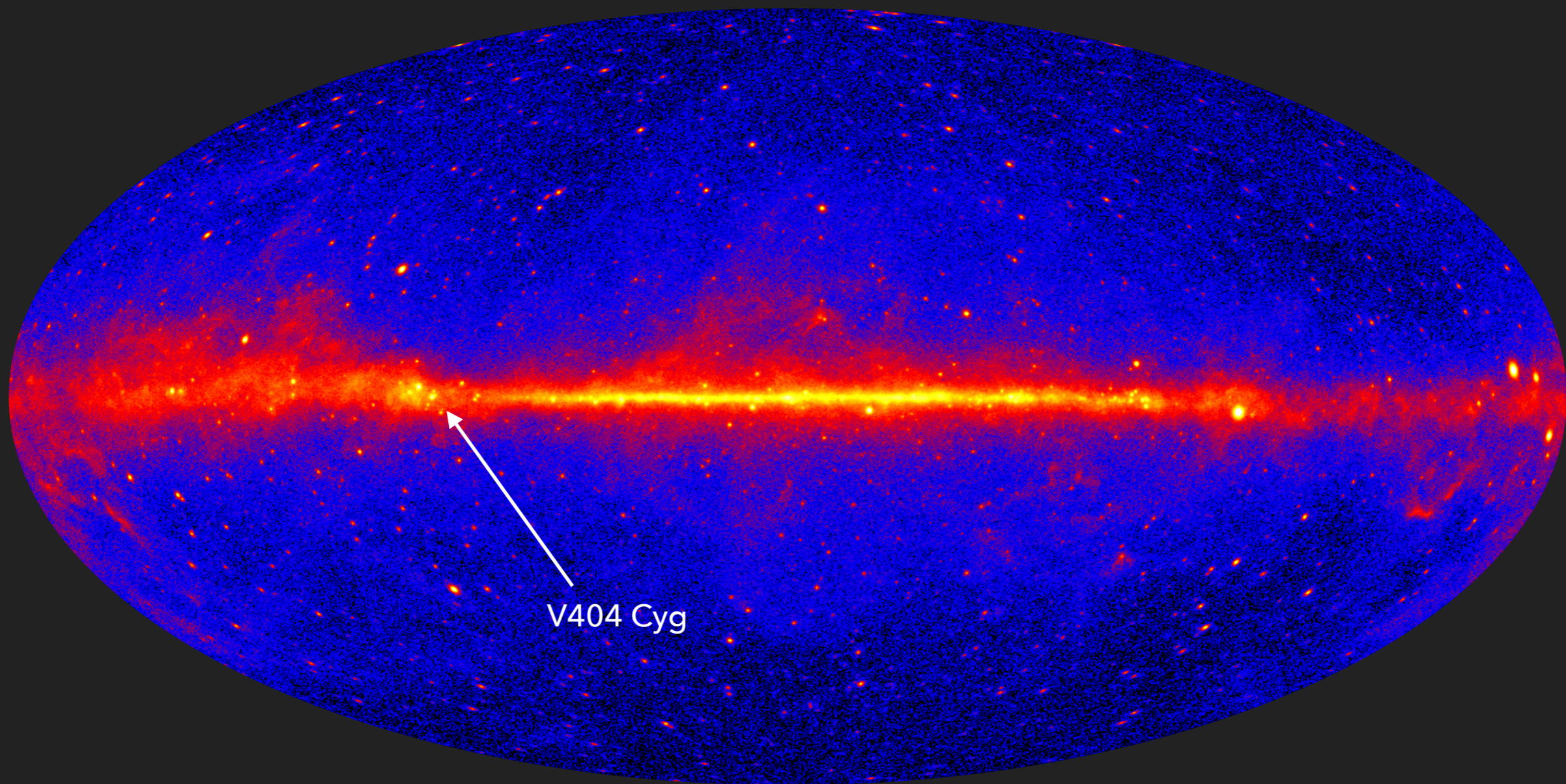
- ▶ Launched in 2008
- ▶ Two instruments:
  - ▶ Gamma-ray Burst Monitor (GBM, Meegan et al. 2009)
  - ▶ **Large Area Telescope (LAT, Atwood et al. 2009)**
    - ▶ 30 MeV–300 GeV → >100MeV
    - ▶ PSF: **5° @ 100 MeV;**  
0.8° @ 1 GeV



- ▶ Transient sources:
  - ▶ Large field of view: 2.4 sr / 20% of the sky
  - ▶ All-sky mapping every 3h

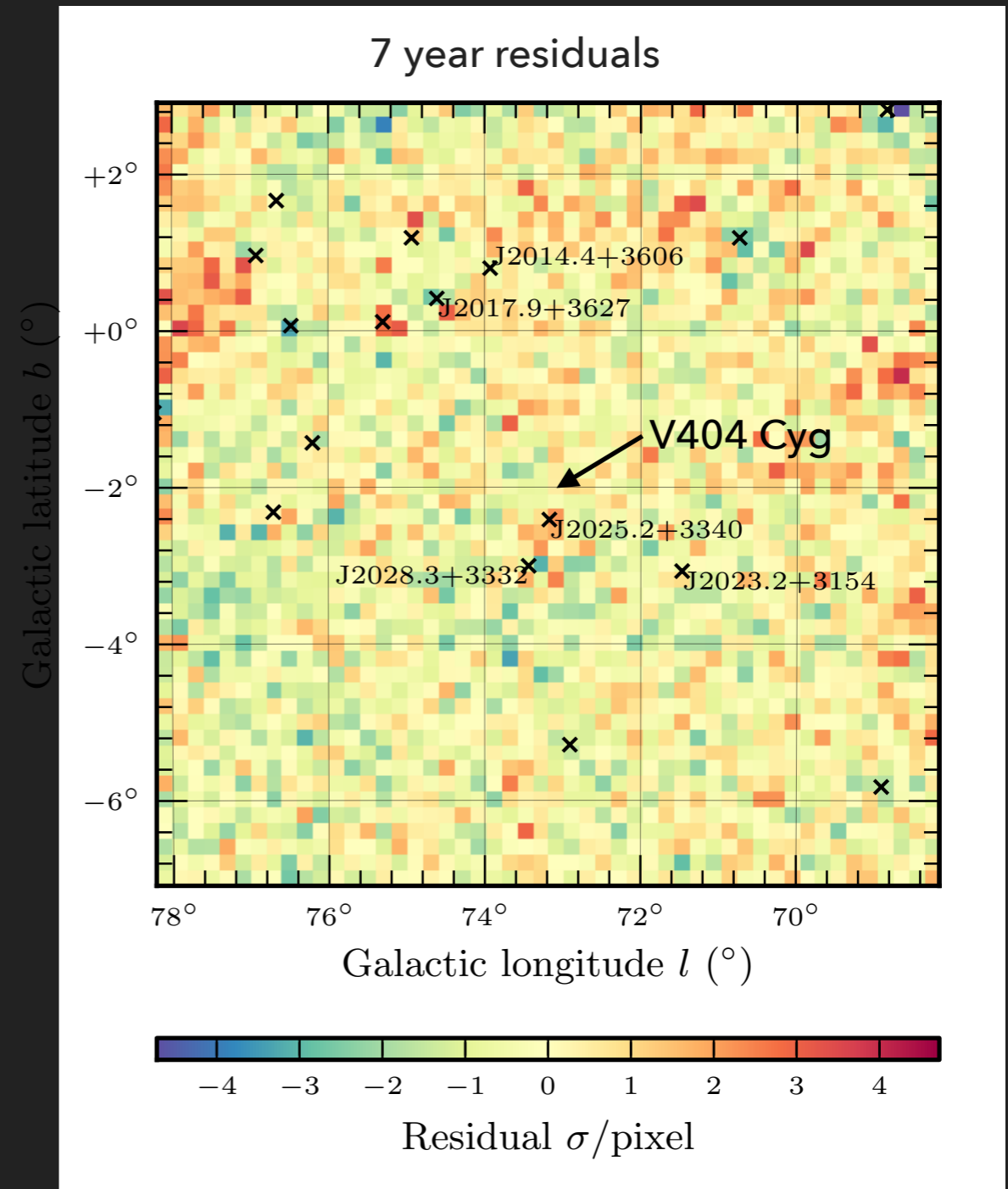
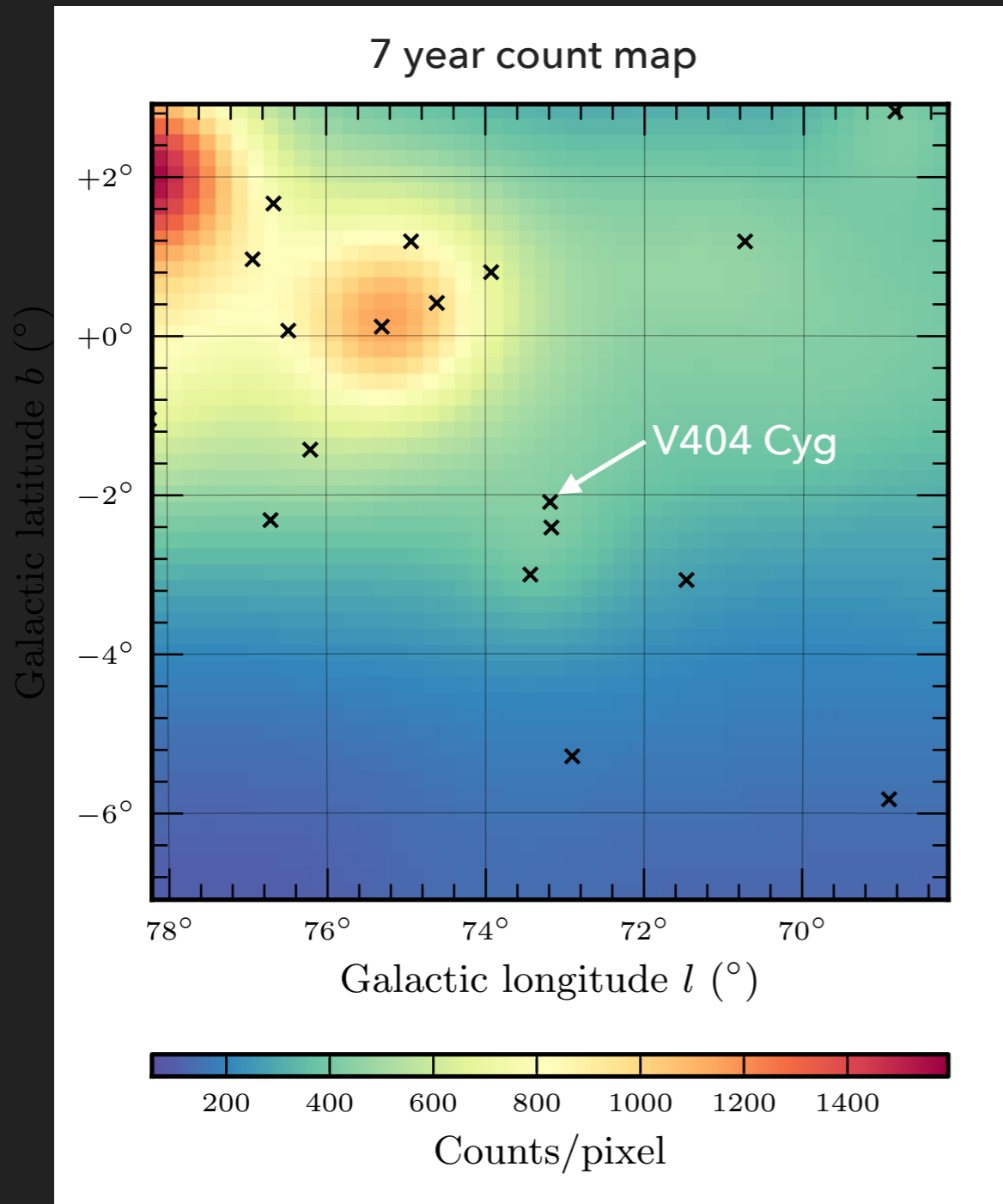
# Gamma-ray Sky seen by Fermi-LAT

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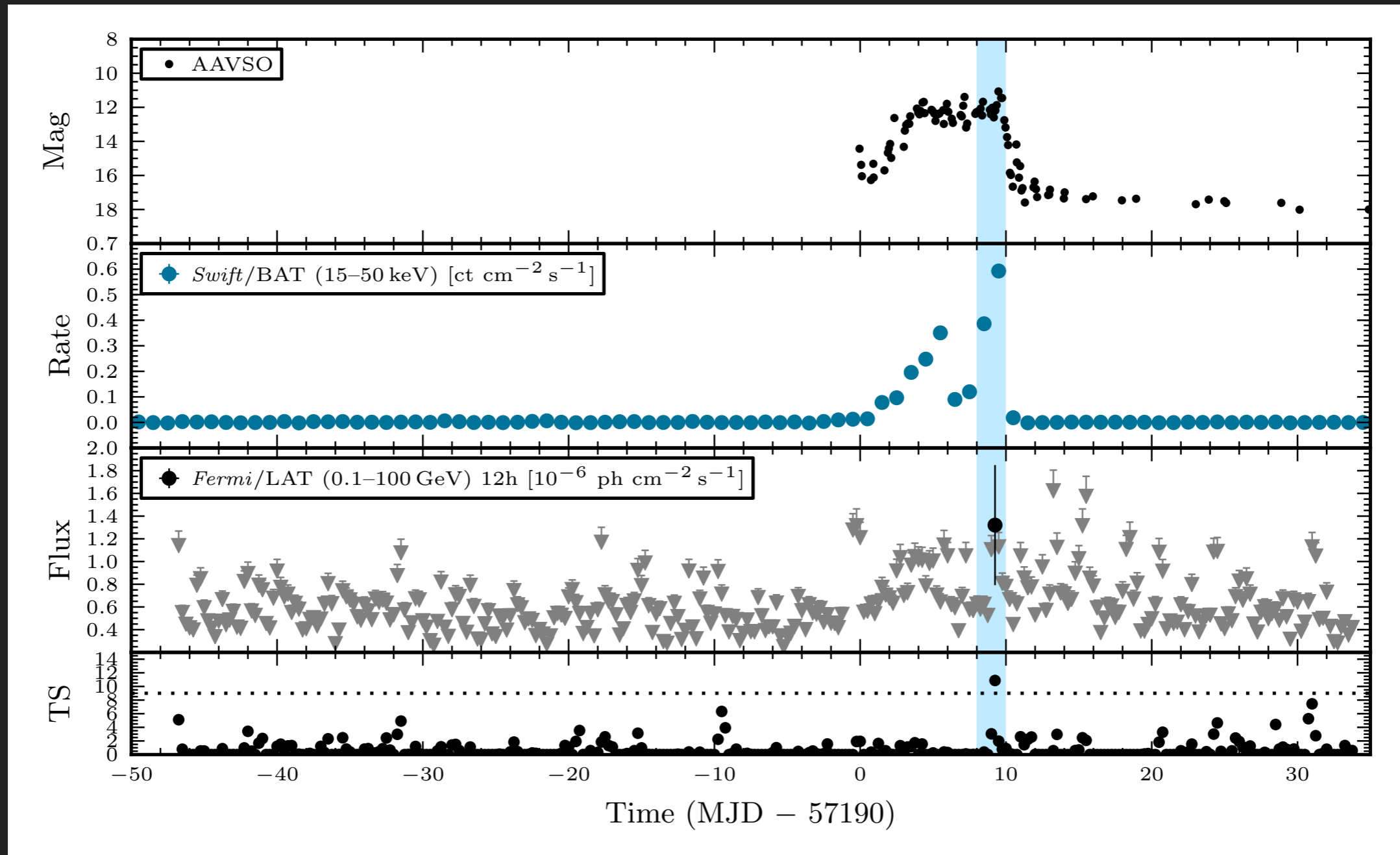
Fermi-LAT Collaboration, five-year map

# Source Model built on 7 years of LAT data



- ▶ Spatial/spectral fit of known gamma-ray sources (Acero et al. 2015)
- ▶ Add a source model at the position of V404 Cyg

# 'Long-term' Monitoring of the June 2015 Outburst

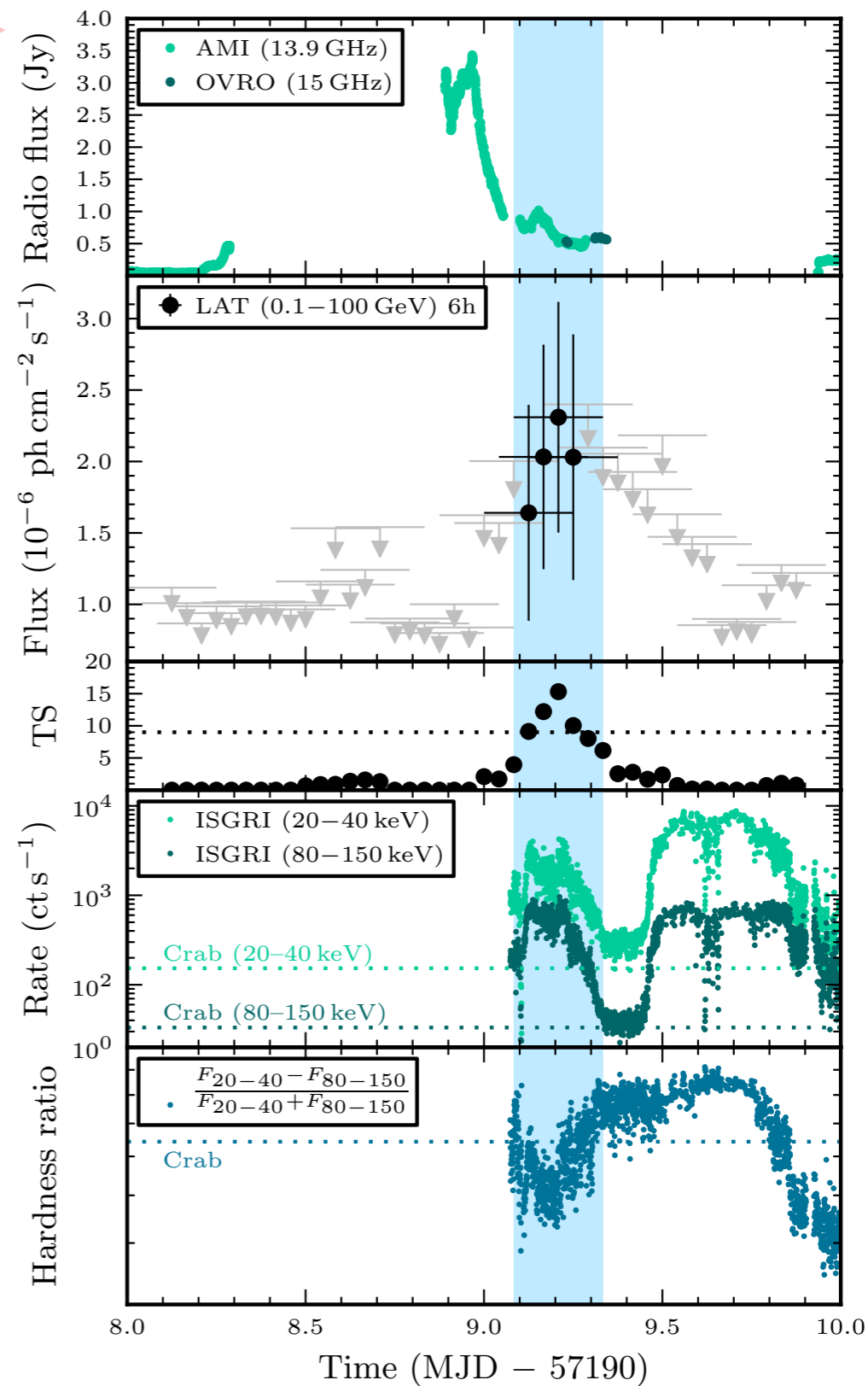
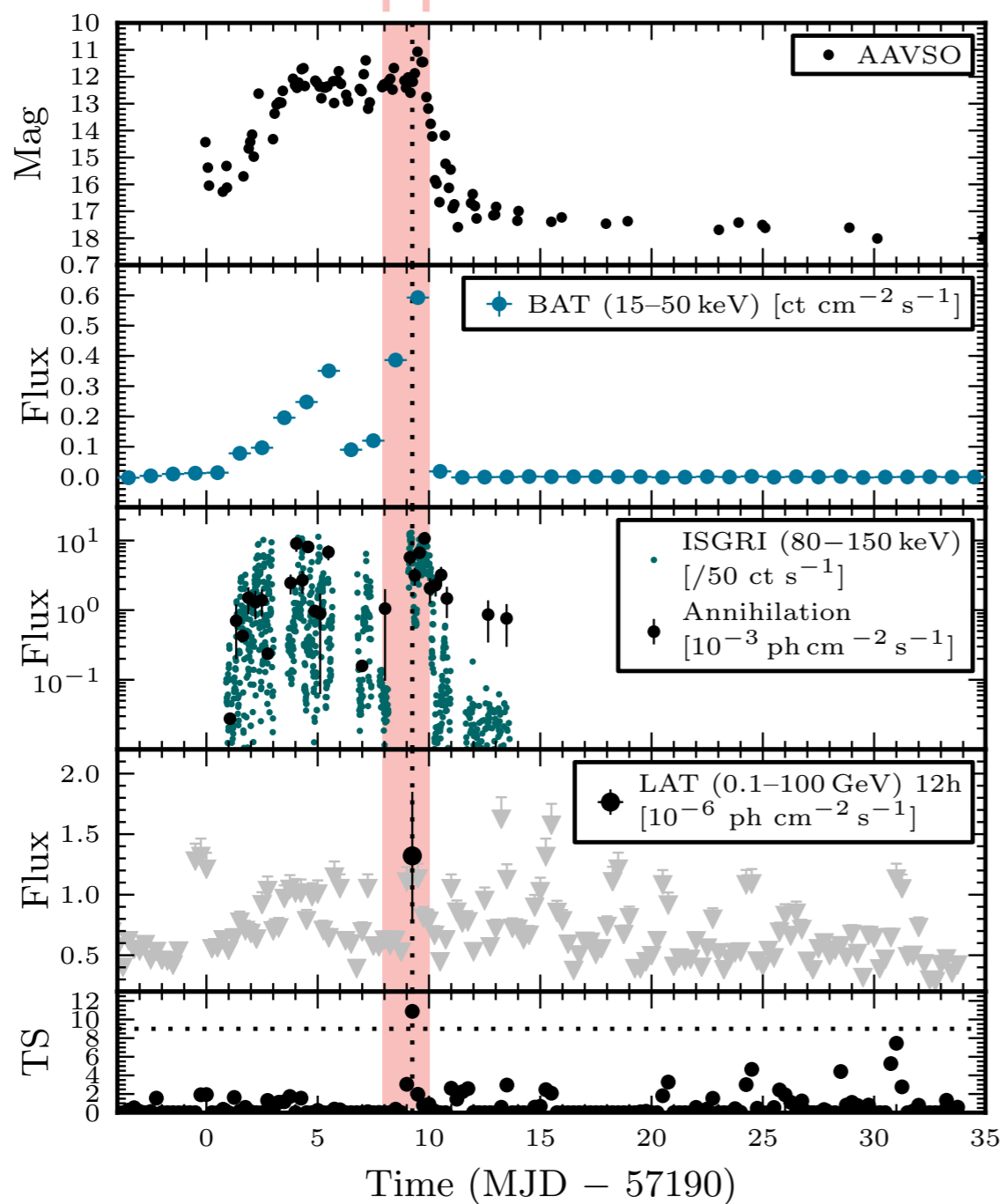


$$\text{TS} = 2 \ln ( L_1/L_0 ) \sim \sigma^2$$

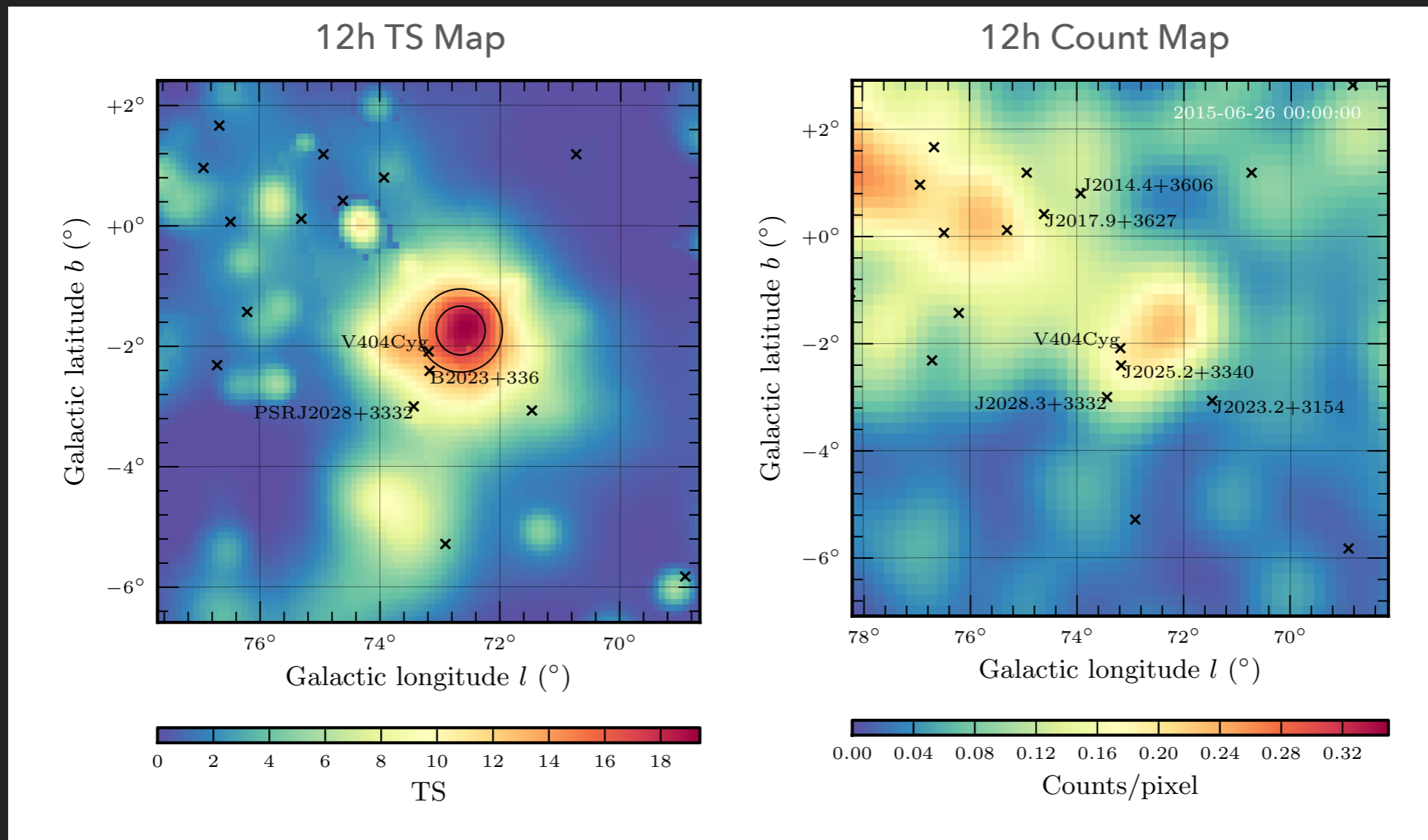
$L_1$ : Max likelihood **with** V404 Cyg

$L_0$ : Max likelihood **without** V404 Cyg

# Zoom on the Gamma-ray Excess



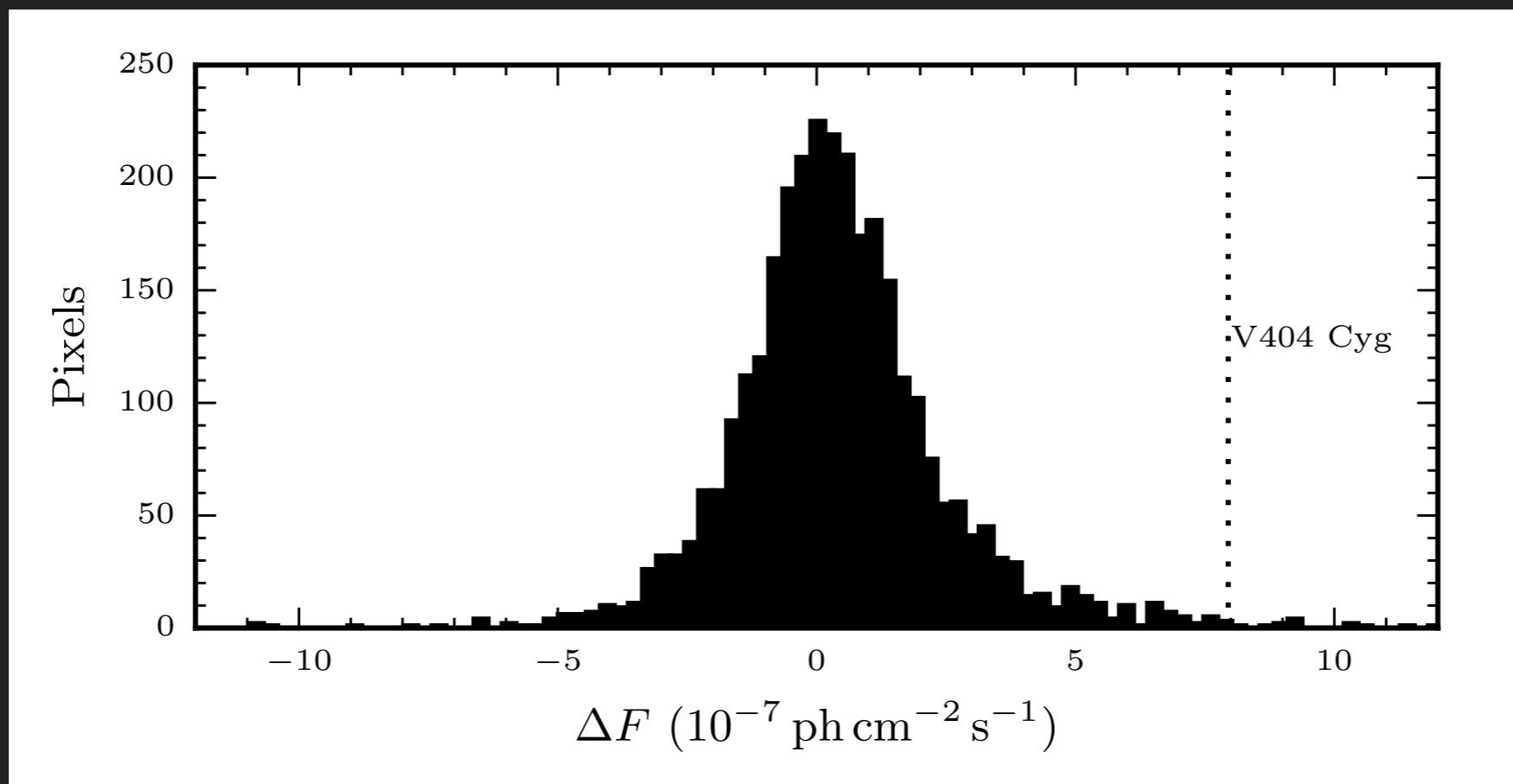
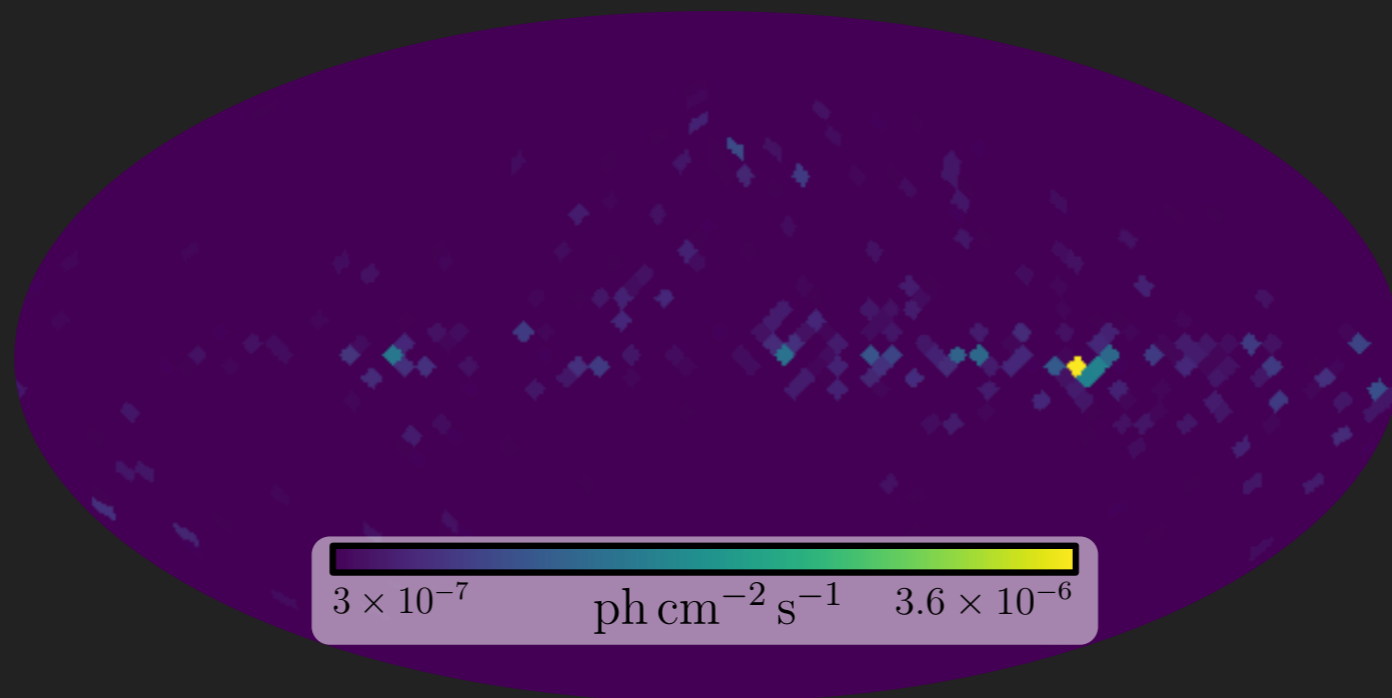
# Gamma-ray excess properties



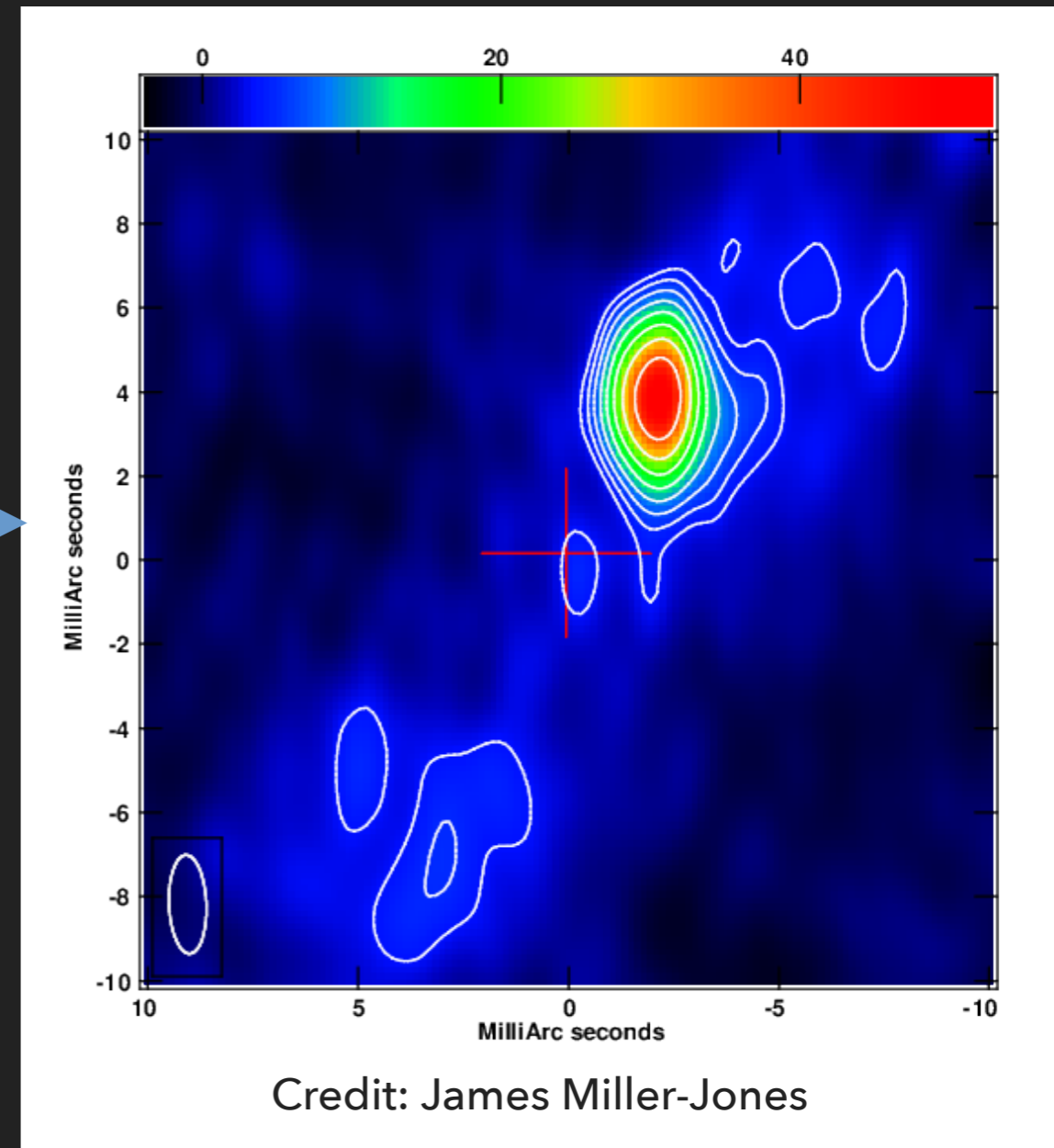
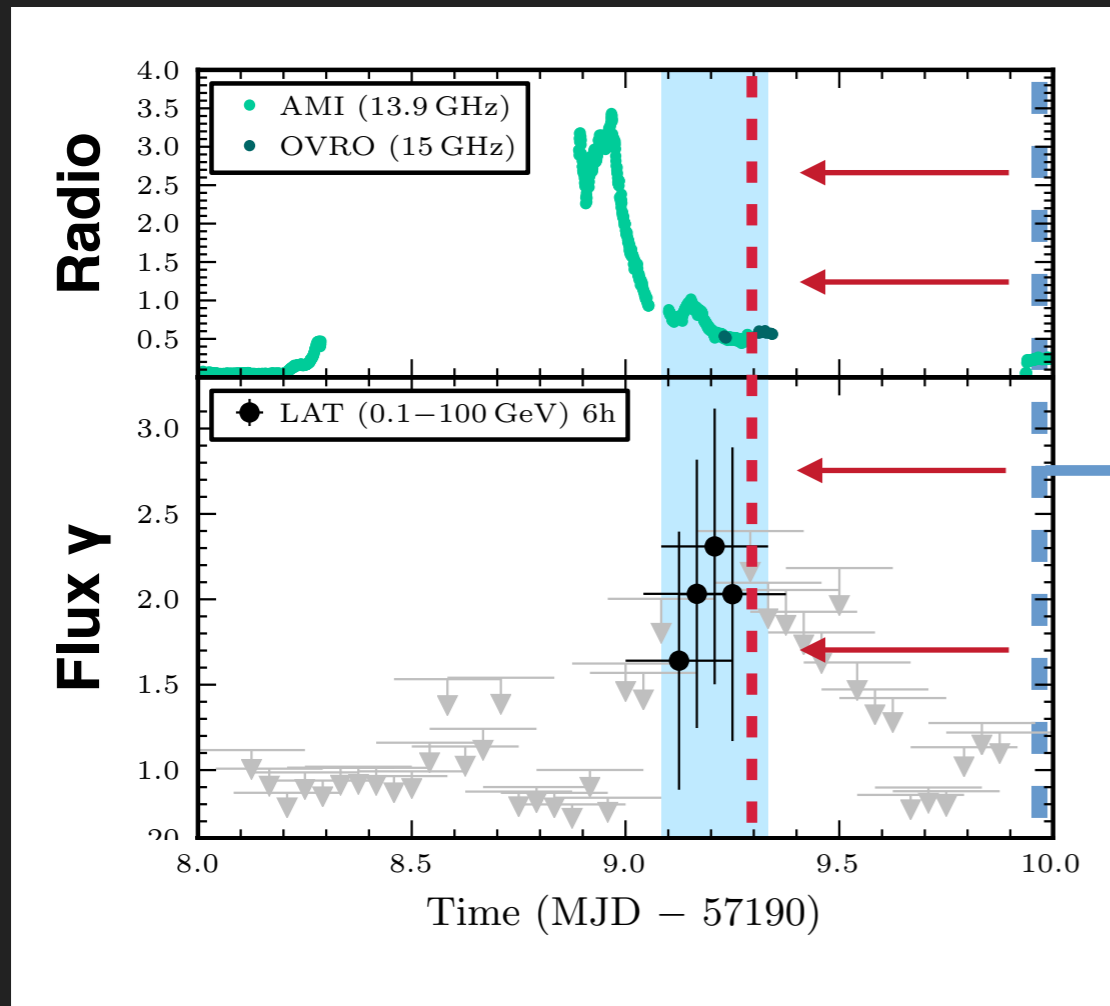
- ▶ MJD 57199.2 +/- 0.1 (June 26th)
- ▶ Soft spectrum (photon index  $\sim -3.5 \pm 0.8$ ),  $L_{\text{gamma}} \sim 2 \times 10^{35}$  erg/s
- ▶ V404 position within the 95% confidence region
- ▶ Peak significance  $\sim 4.5\sigma$  ( $\sim 4\sigma$  @ V404 Cyg position)

# Statistical fluctuation?

- ▶ Detection bin flux - Mean flux



# Gamma-ray emission coincident with Jet Launching Event

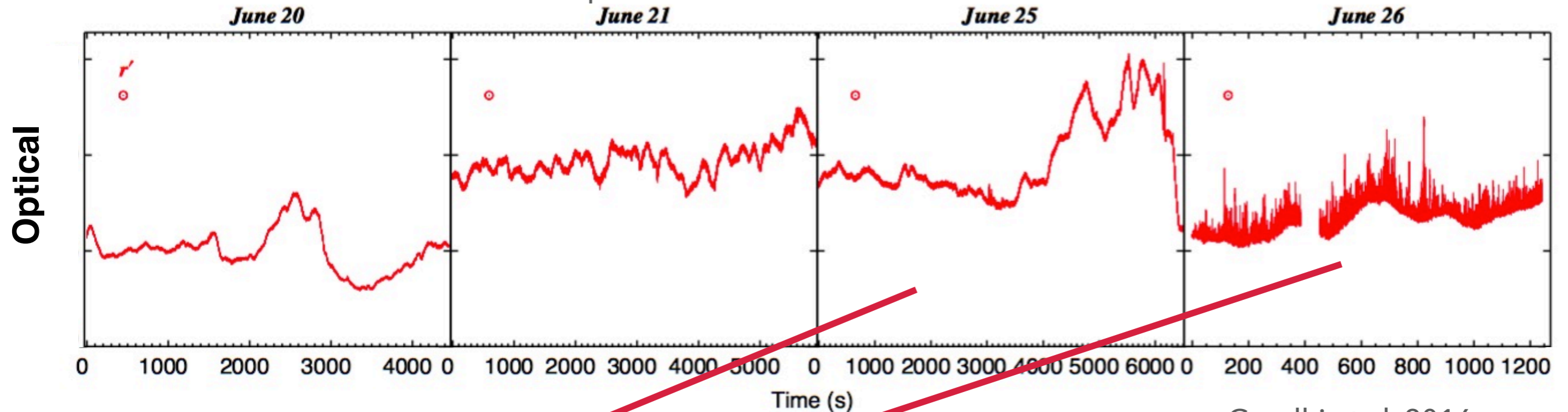


- ▶ VLBA: many resolved ejecta between June 17th-27th
- ▶ Slowest ejecta ( $\sim 0.05c$ ) + core switched off
- ▶ Constant ballistic ejecta motion fit  $\rightarrow$  launched around **MJD 57199.3** (g-rays: **MJD 57199.2 $\pm$ 0.1**)

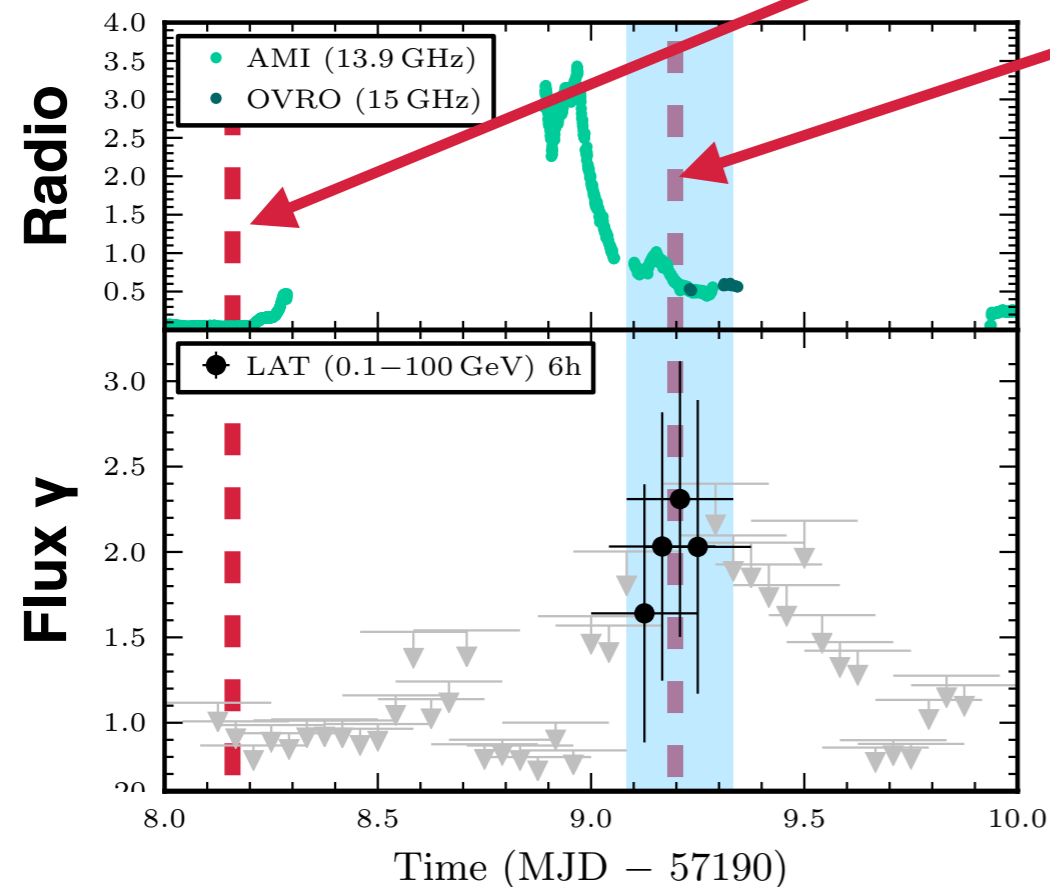


# Gamma-ray emission coincident with Jet Launching Event

ULTRACAM / William Herschel Telescope

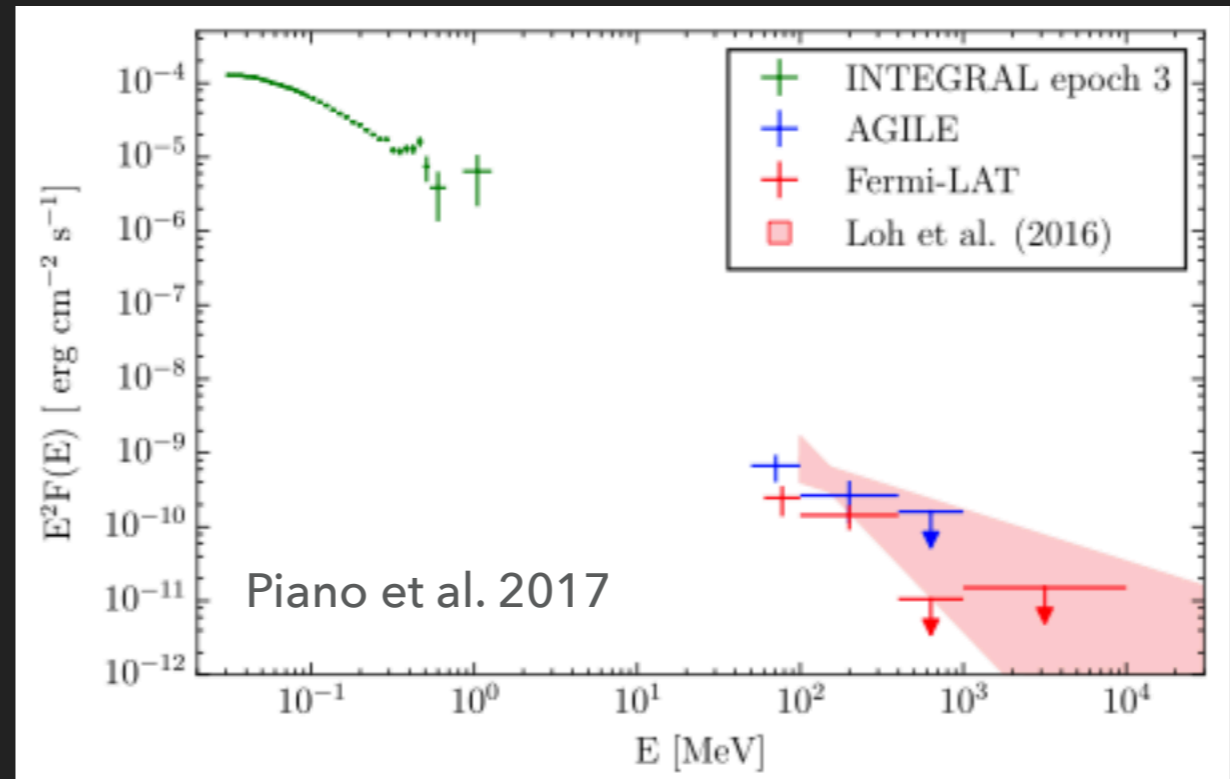
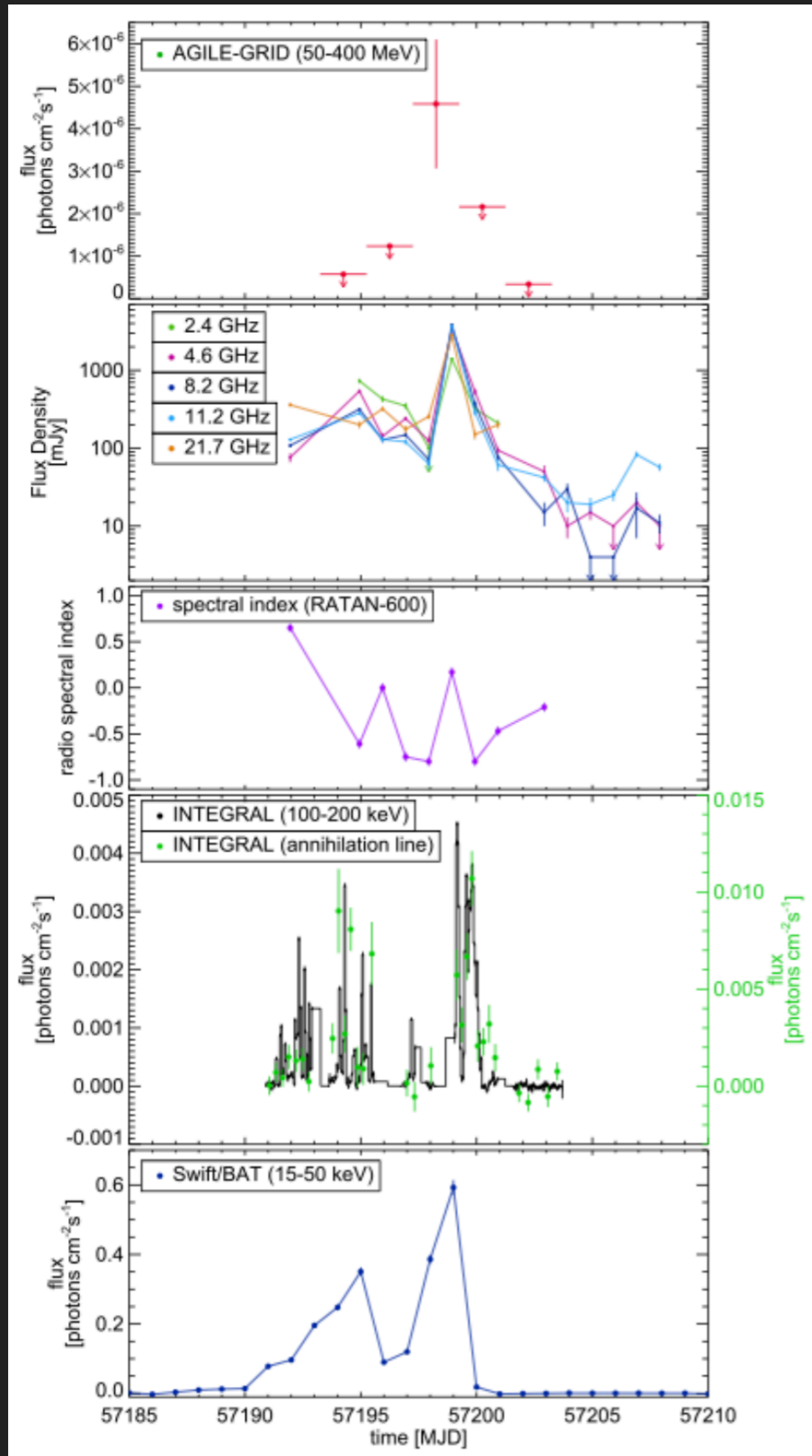


Gandhi et al. 2016

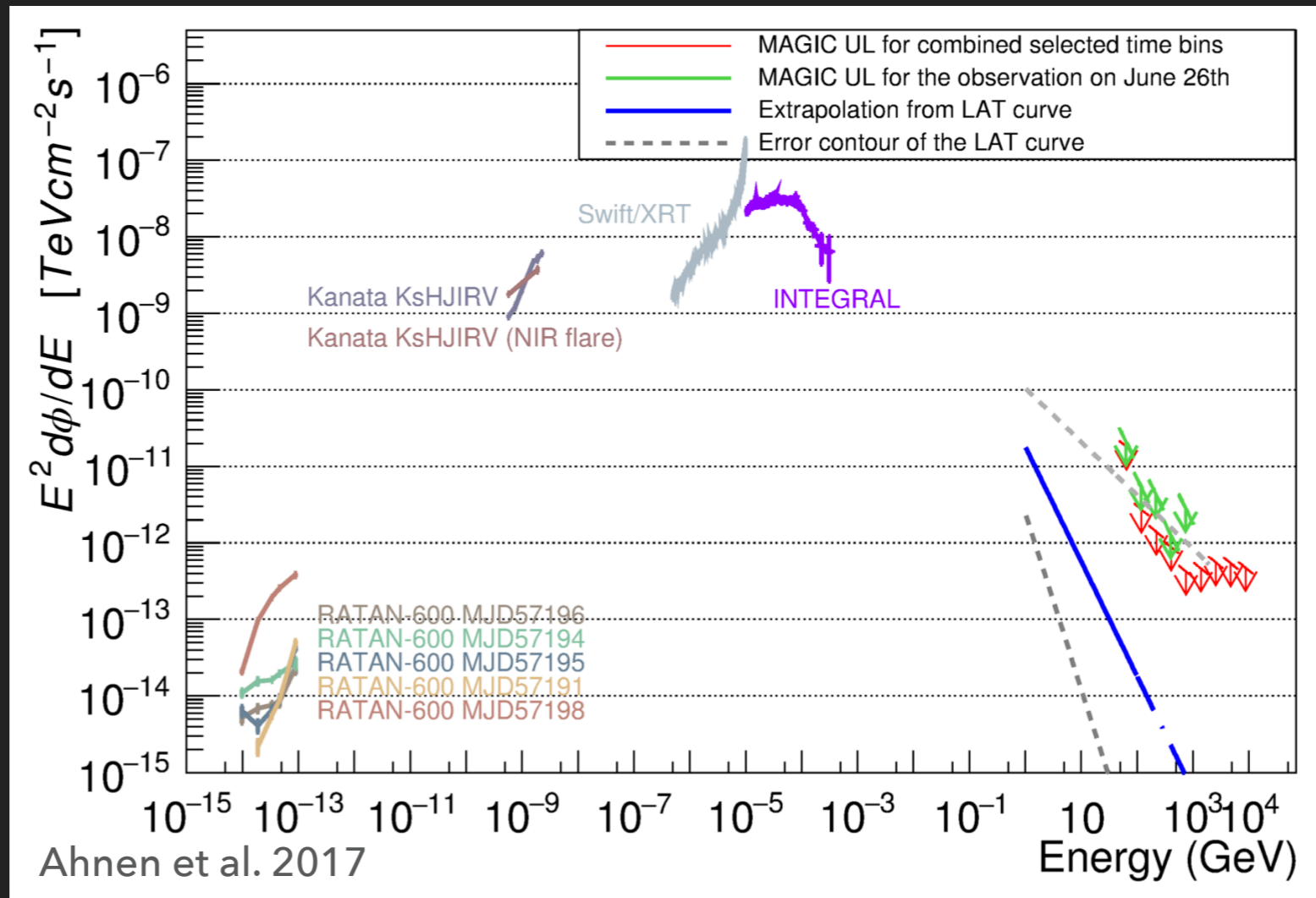


- ▶ Fast sub-second flaring
- ▶ Optically-thin synchrotron from a compact jet arising on size scales  $< 500 R_g$
- ▶ Absorption/changing line of sight?

# Confirmation by AGILE



# VHE non-detection by MAGIC



- ▶ ~10h on-source (18–27 June 2015)
- ▶ 1h of simultaneous observation with LAT excess

# Summary

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- ▶ HE gamma-ray excess:
  - ▶  $4\sigma$  significance level
  - ▶ Compatible with V404 Cyg position
  - ▶ Contemporaneous with brightest radio / hard X-ray emissions
  - ▶ Coincident with optical fast flaring / jet launching event
  - ▶ Confirmation by AGILE
  - ▶ → Detection of a LMXB at HE gamma-rays? (Loh et al. 2016, MNRAS)
- ▶ Detecting HE gamma-ray emission from microquasars:
  - ▶ Soft spectra, same process to produce hard X-rays and gamma-rays?  
→ Need to observe  $< 100$  MeV!
  - ▶ No HE gamma-ray facilities after Fermi and AGILE :-(
  - ▶ No detection with MAGIC → VHE with CTA?

Thanks