

GAMMA-RAY OBSERVATIONS OF THE MICROQUASARS  
CYGNUS X-1, CYGNUS X-3, GRS 1915+105, AND GX 339-4 WITH FERMI-LAT

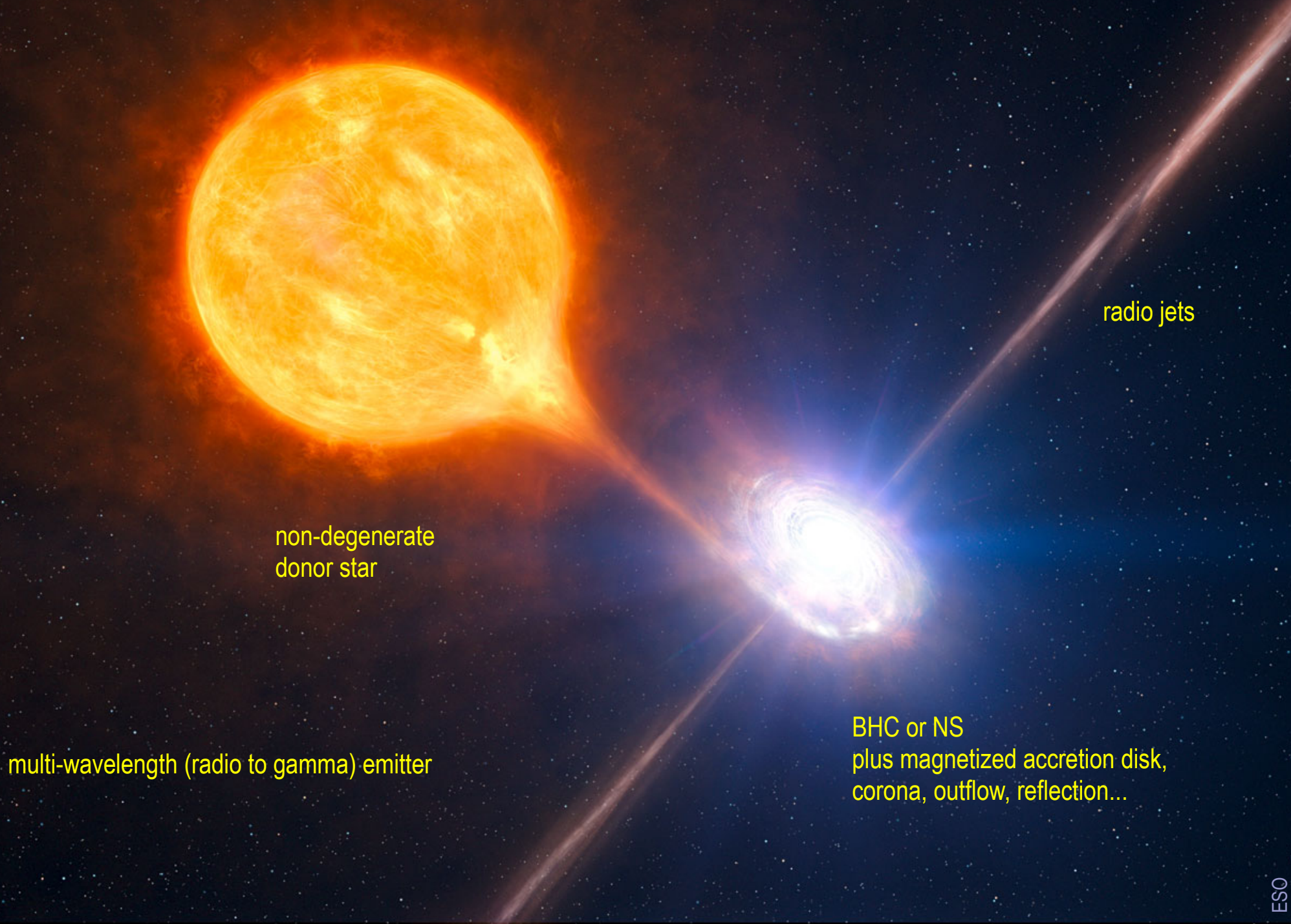
A BODAGHEE<sup>1</sup>  
JA TOMSICK<sup>1</sup>  
J RODRIGUEZ<sup>2</sup>  
K POTTSCHMIDT<sup>3</sup>  
J WILMS<sup>4</sup>  
GG POOLEY<sup>5</sup>

<sup>1</sup> UC BERKELEY  
<sup>2</sup> CEA SACLAY  
<sup>3</sup> UMBC/GSFC  
<sup>4</sup> ECAP BAMBERG  
<sup>5</sup> CAMBRIDGE





# MICROQUASARS: QUASARS FOR THE IMPATIENT (R. BLANDFORD)



non-degenerate  
donor star

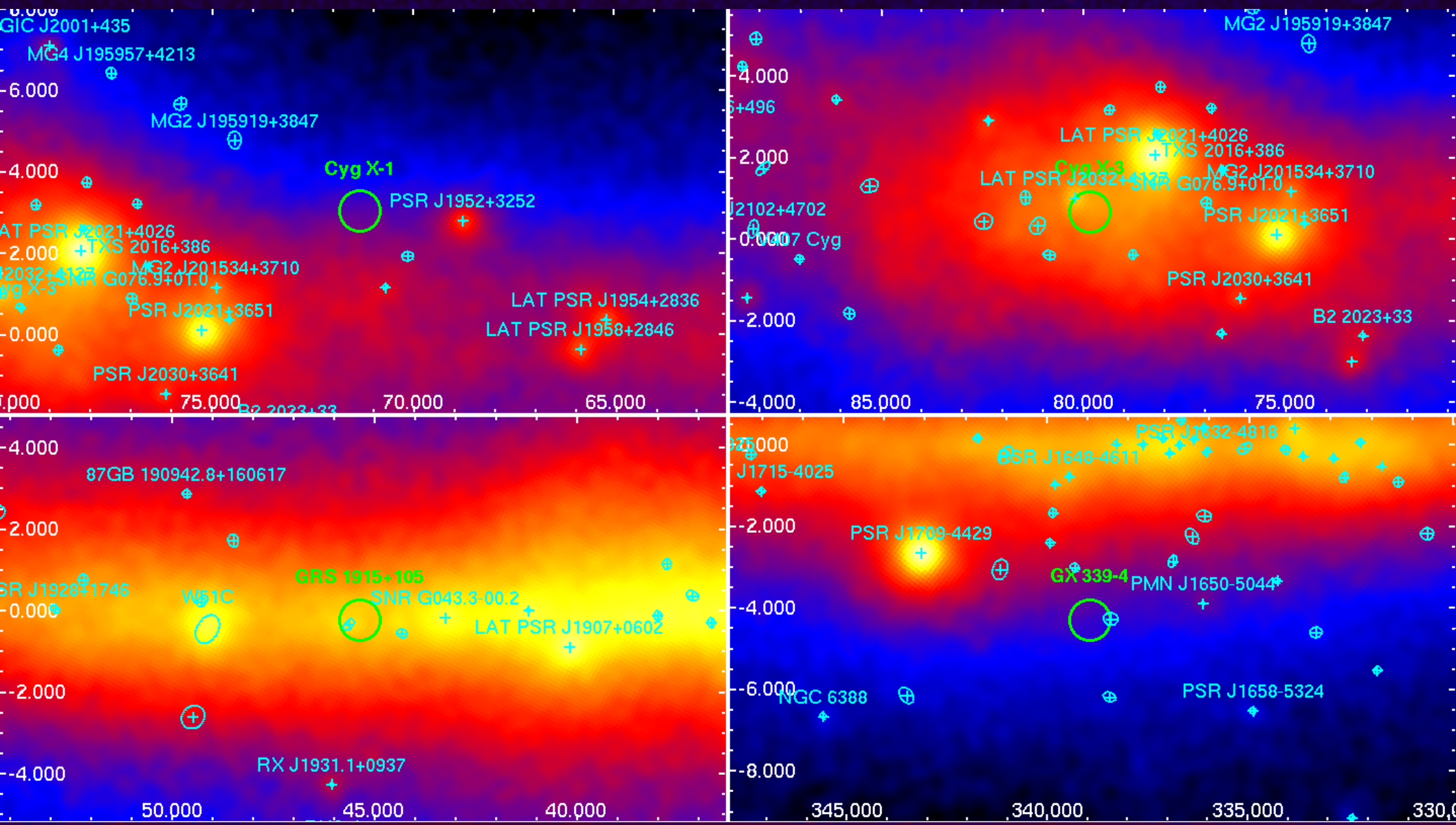
multi-wavelength (radio to gamma) emitter

radio jets

BHC or NS  
plus magnetized accretion disk,  
corona, outflow, reflection...



# MICROQUASARS: QUASARS FOR THE IMPATIENT (R. BLANDFORD) AND MASOCHISTIC (A. BODAGHEE)



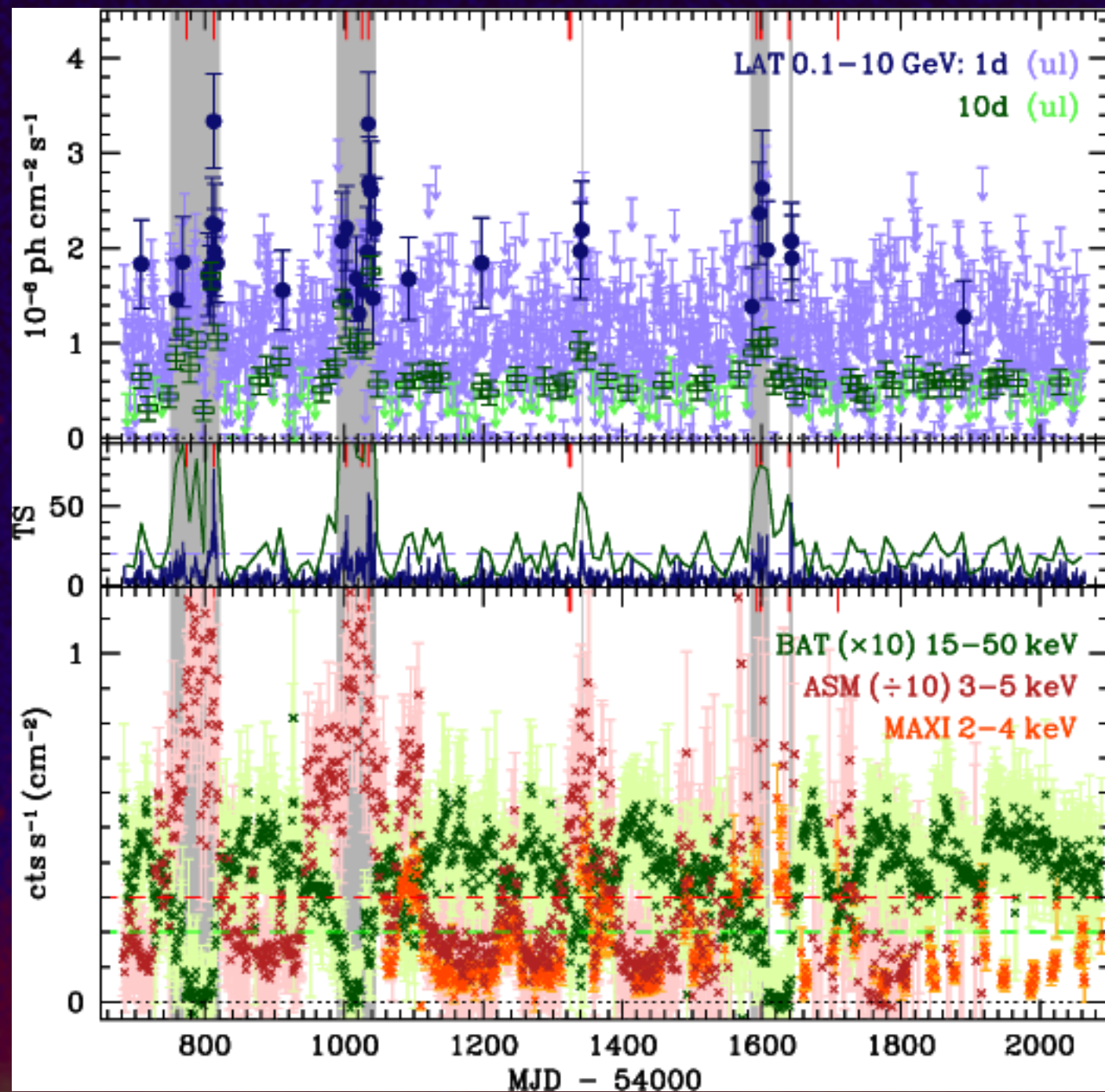
extremely low source counts  
 extremely high diffuse background  
 emission < 10 GeV where Fermi PSF ~ 2 degs  $\Rightarrow$  source confusion



# CYG X-3: GAMMA-RAY LIGHT CURVE

blue points:  $TS \geq 20$  in 1d bin  
green points:  $TS \geq 20$  in 10d bin

gray bands: known LAT detections  
red marks: known AGILE detections





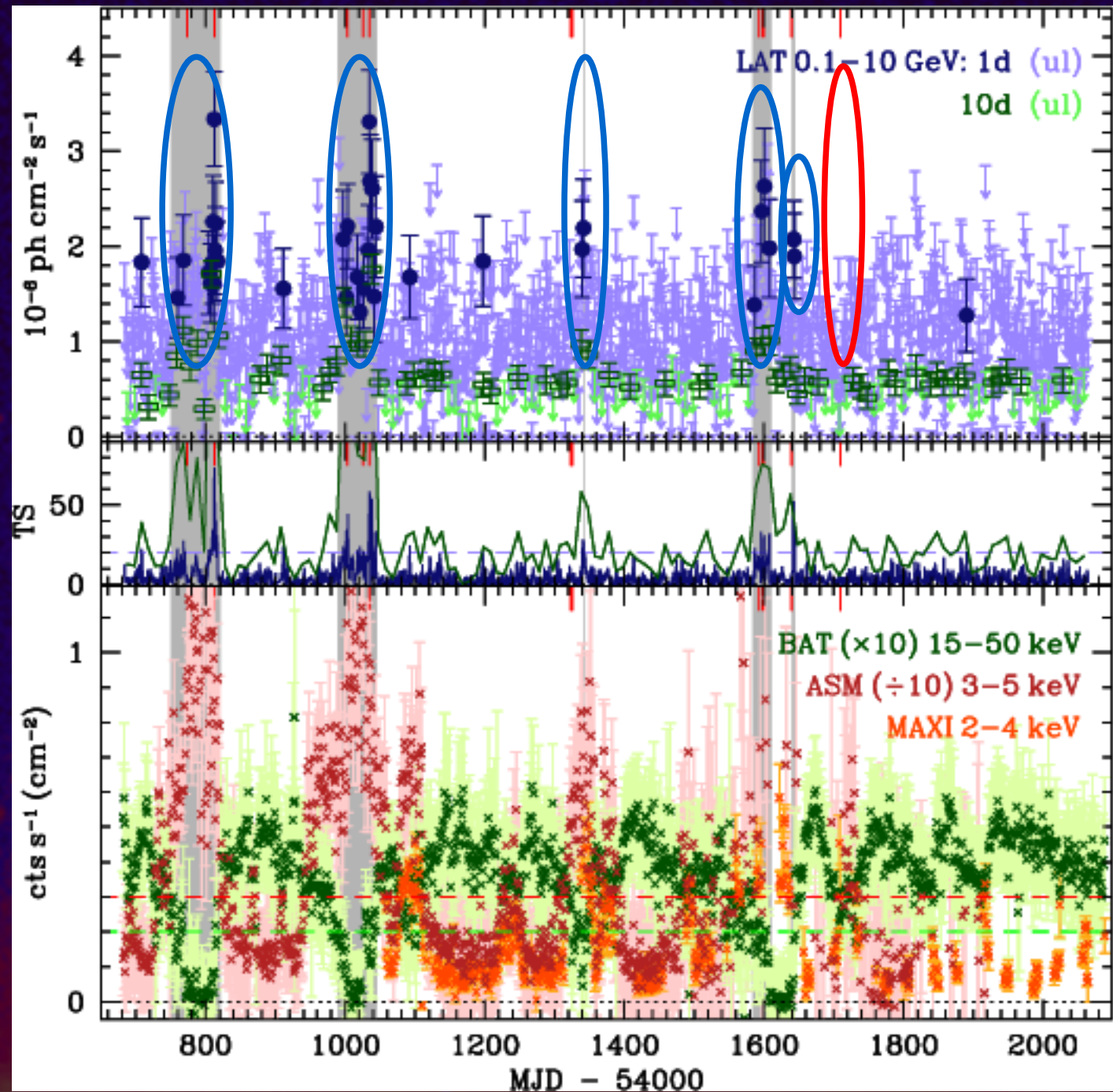
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previous gamma-ray detections  
by LAT or AGILE are reproduced  
(except the last one)

c.f. Abdo et al. (2009)  
Bulgarelli et al. (2010)  
Bulgarelli et al. (2011a)  
Bulgarelli et al. (2011b)  
Corbel & Hays (2010)  
Corbel et al. (2011)  
Corbel et al. (2012)  
Piano et al. (2012)  
Tavani et al. (2009)  
Williams et al. (2011)





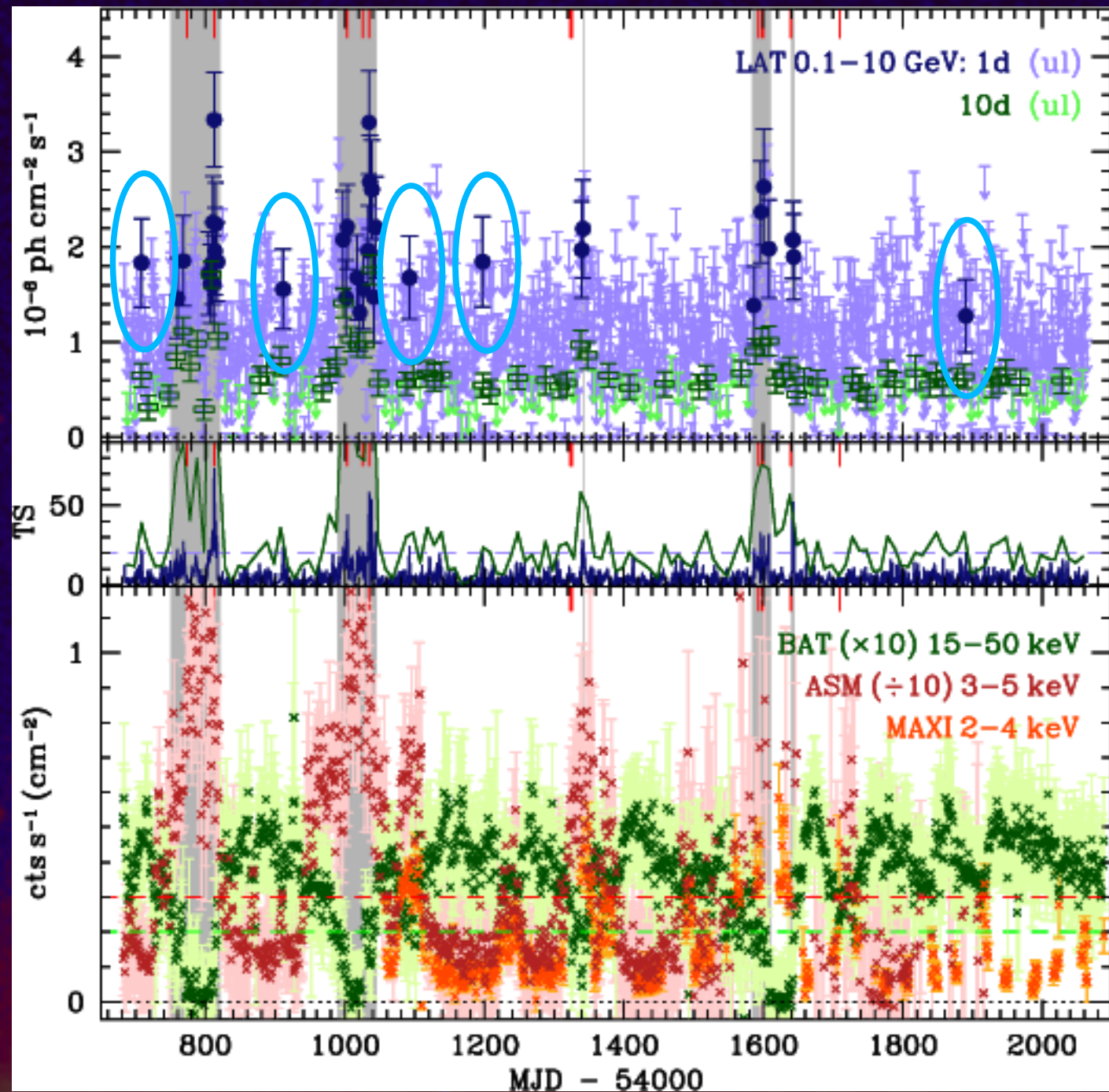
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there are 5 new daily detections  
( $TS \sim 20$ — $25$ ; backed up by 10d)





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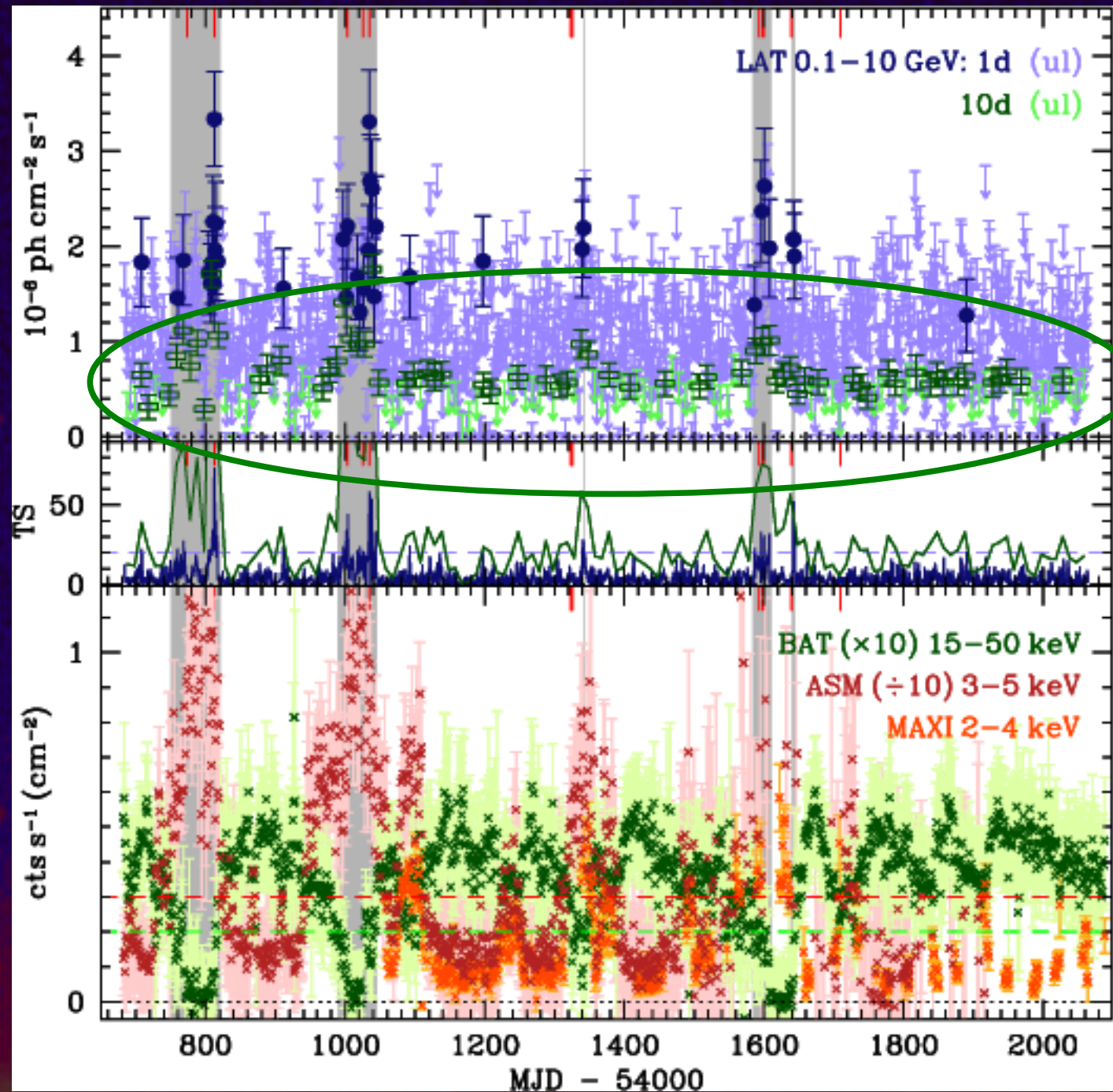
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there are 5 new daily detections  
( $TS \sim 20$ — $25$ ; backed up by 10d)

numerous 10d detections  
in and out of flaring epochs:  
persistent gamma-ray emission





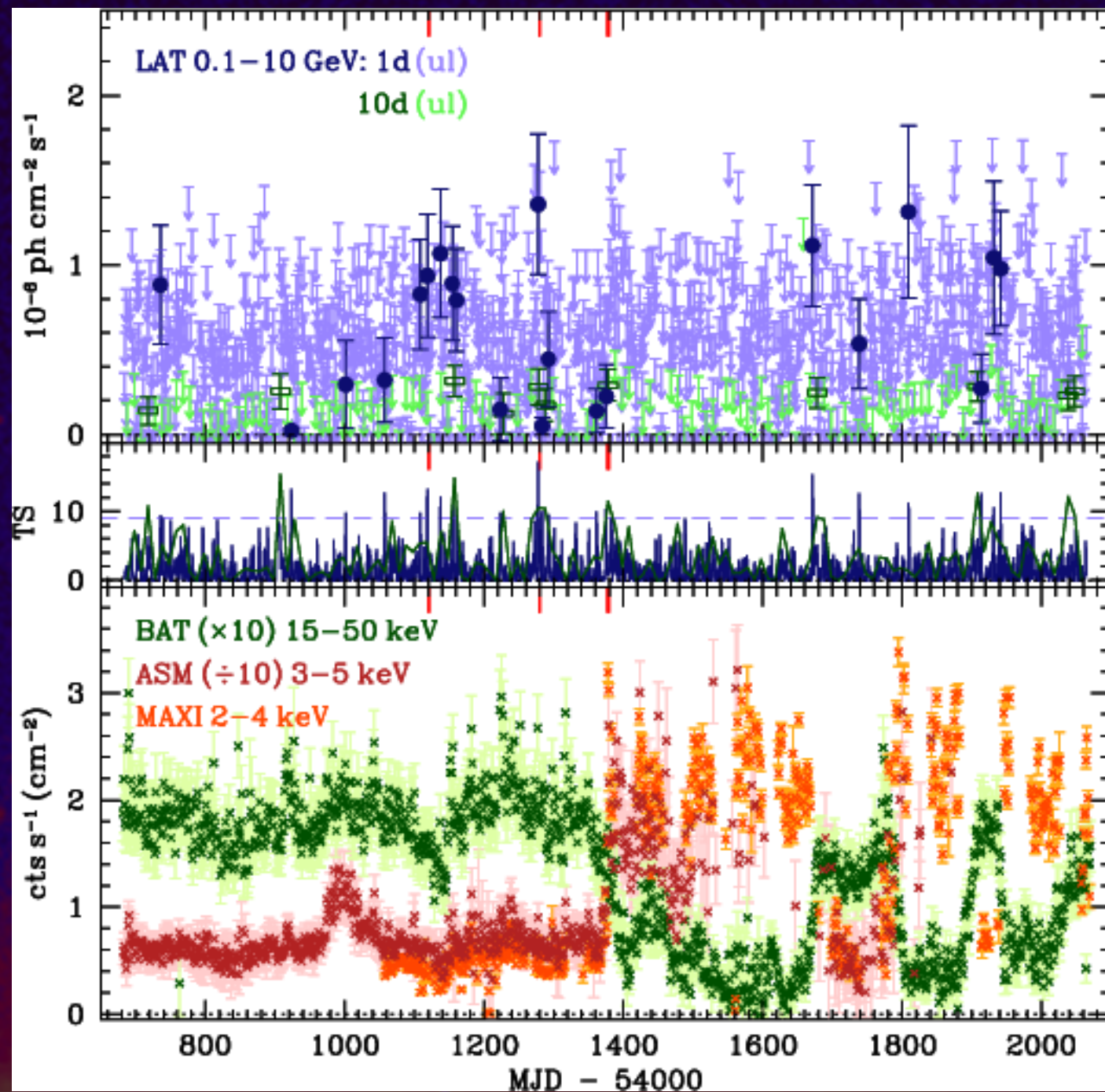
# CYG X-1: GAMMA-RAY LIGHT CURVE

blue points:  $TS \geq 9$  in 1d bin  
green points:  $TS \geq 9$  in 10d bin

red marks: known AGILE detections

3 previous gamma-ray detections  
by AGILE are reproduced for  
the first time with LAT

c.f. Bulgarelli et al. (2010a)  
Sabatini et al. (2010a)  
Sabatini et al. (2010b)





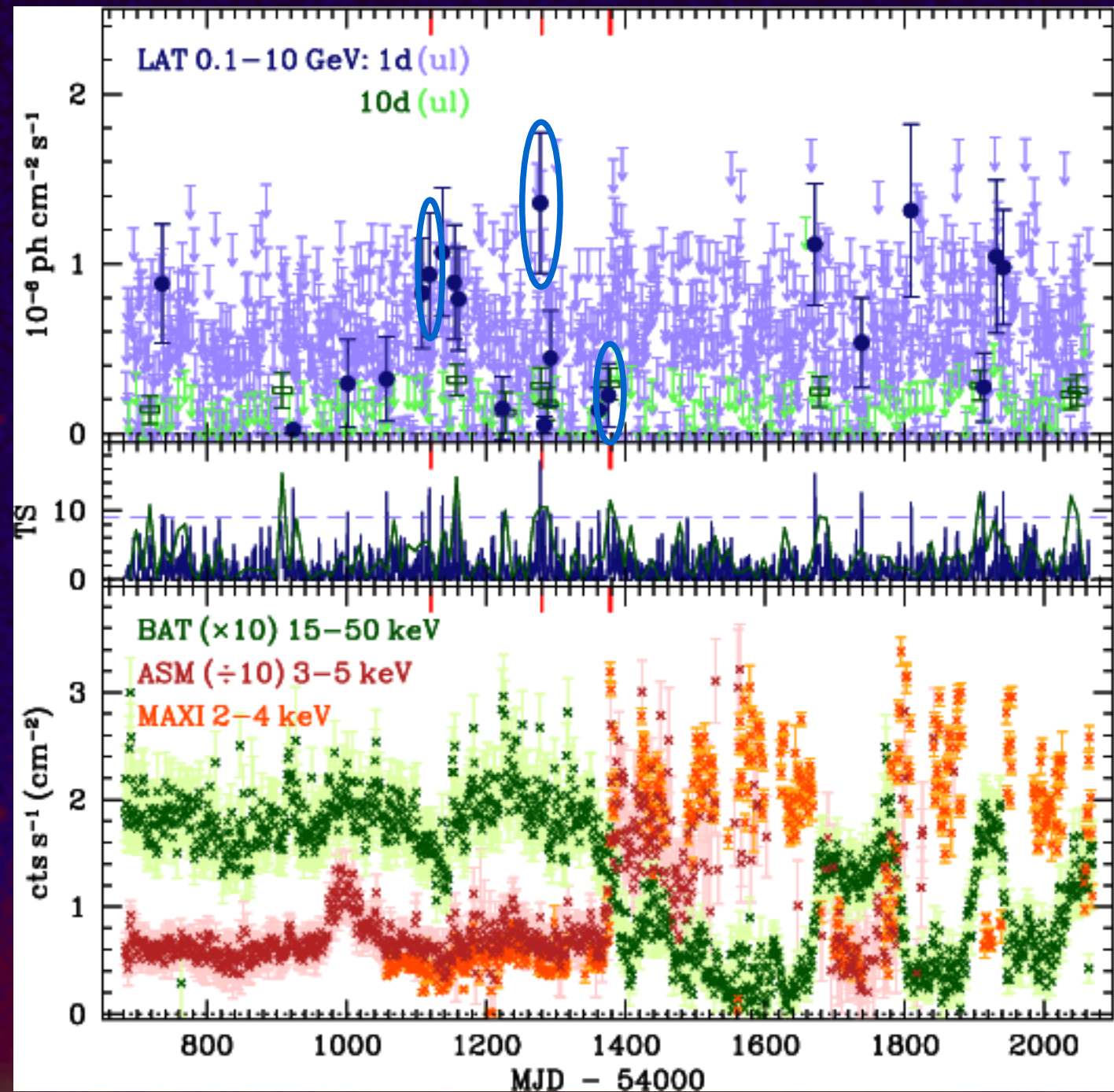
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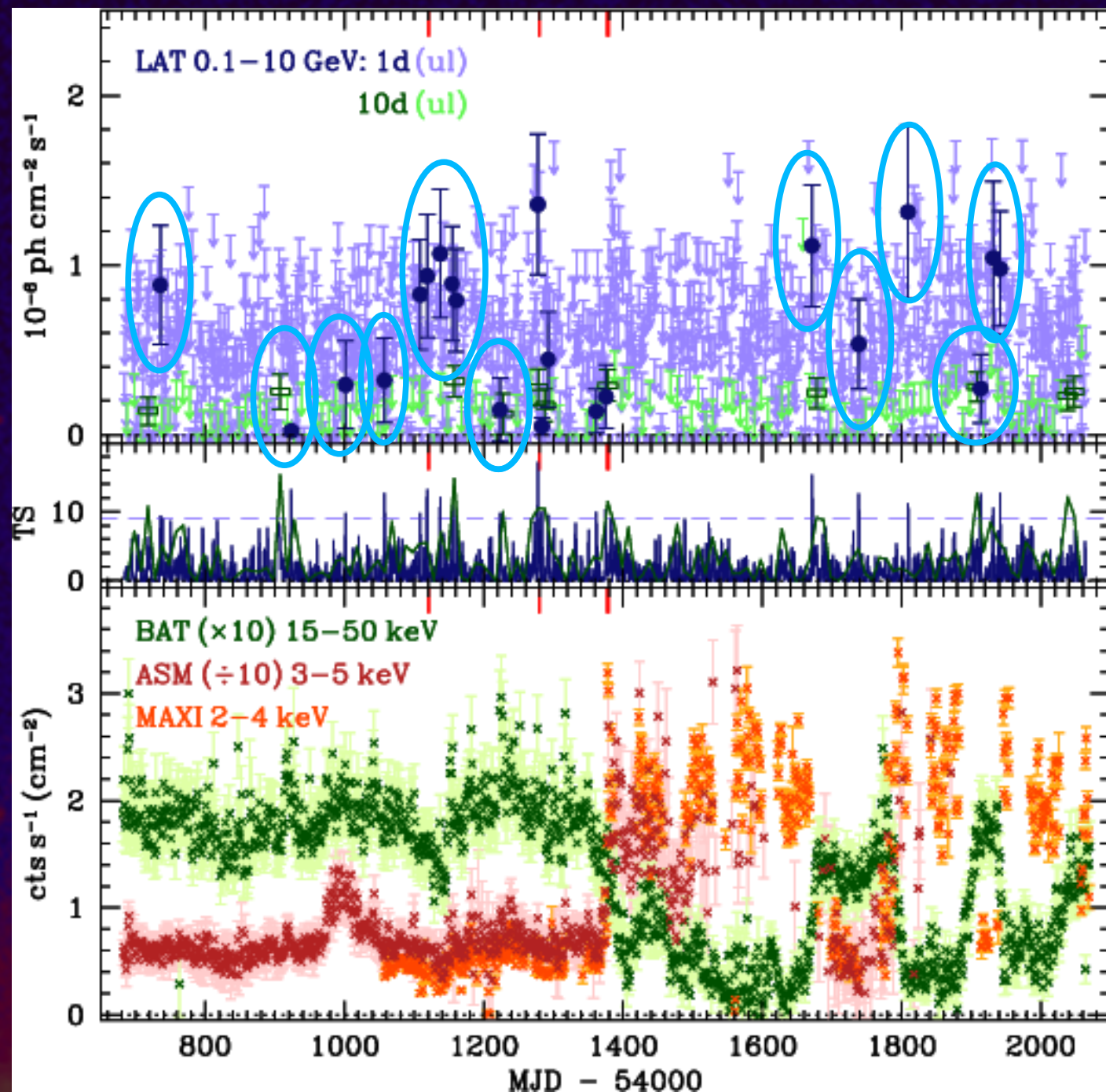
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21 days with  $TS \sim 9$ —16  
some are backed by 10d

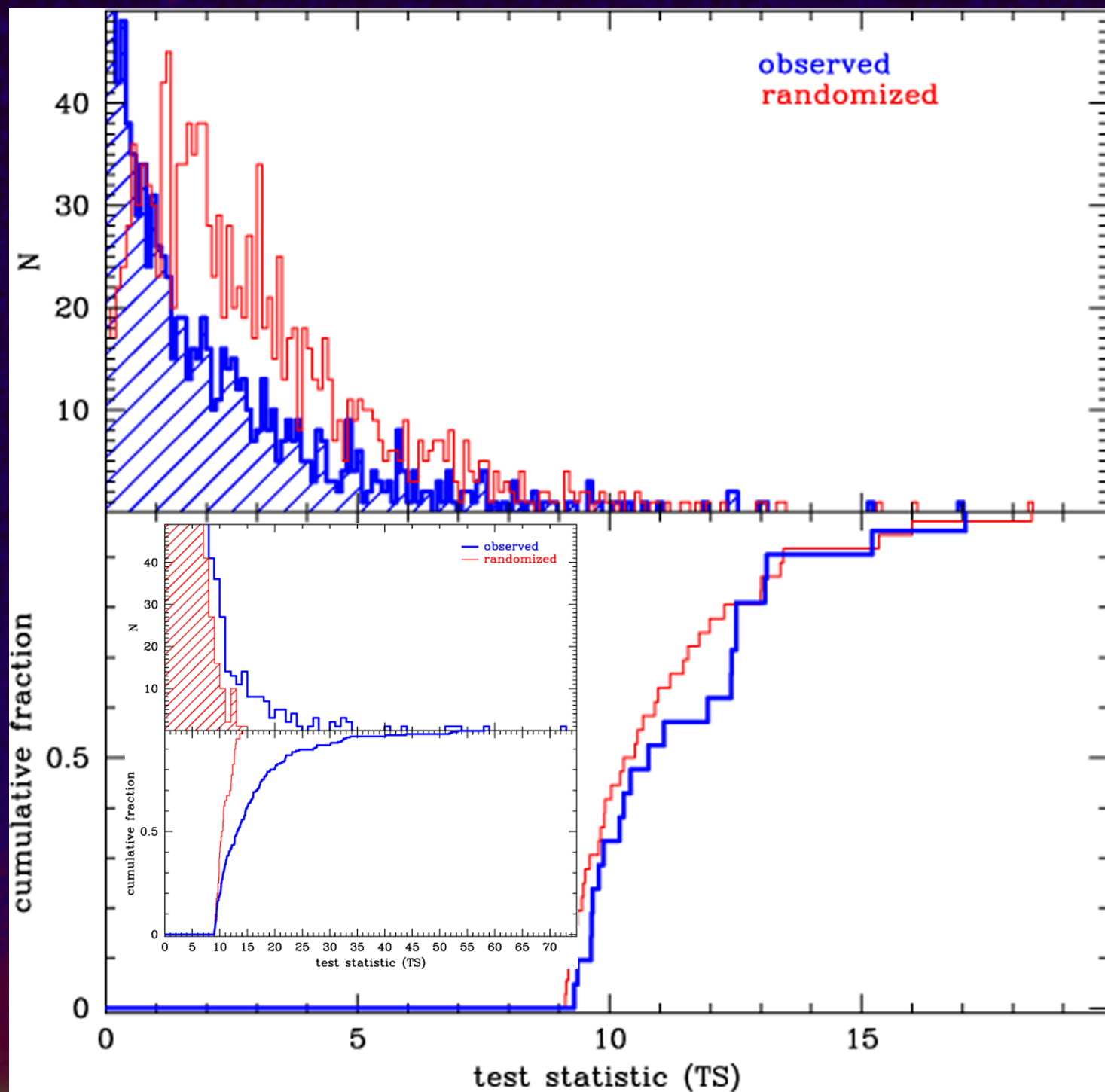




# CYG X-1: GAMMA-RAY LIGHT CURVE

comparison with TS distribution of  
spurious source yields 55%  
KS-test prob. of match

candidate LAT detections not  
contemporaneous with AGILE  
are probably spurious





# GRS 1915+105

# GX 339-4

no prior gamma-ray detections  
by AGILE or LAT

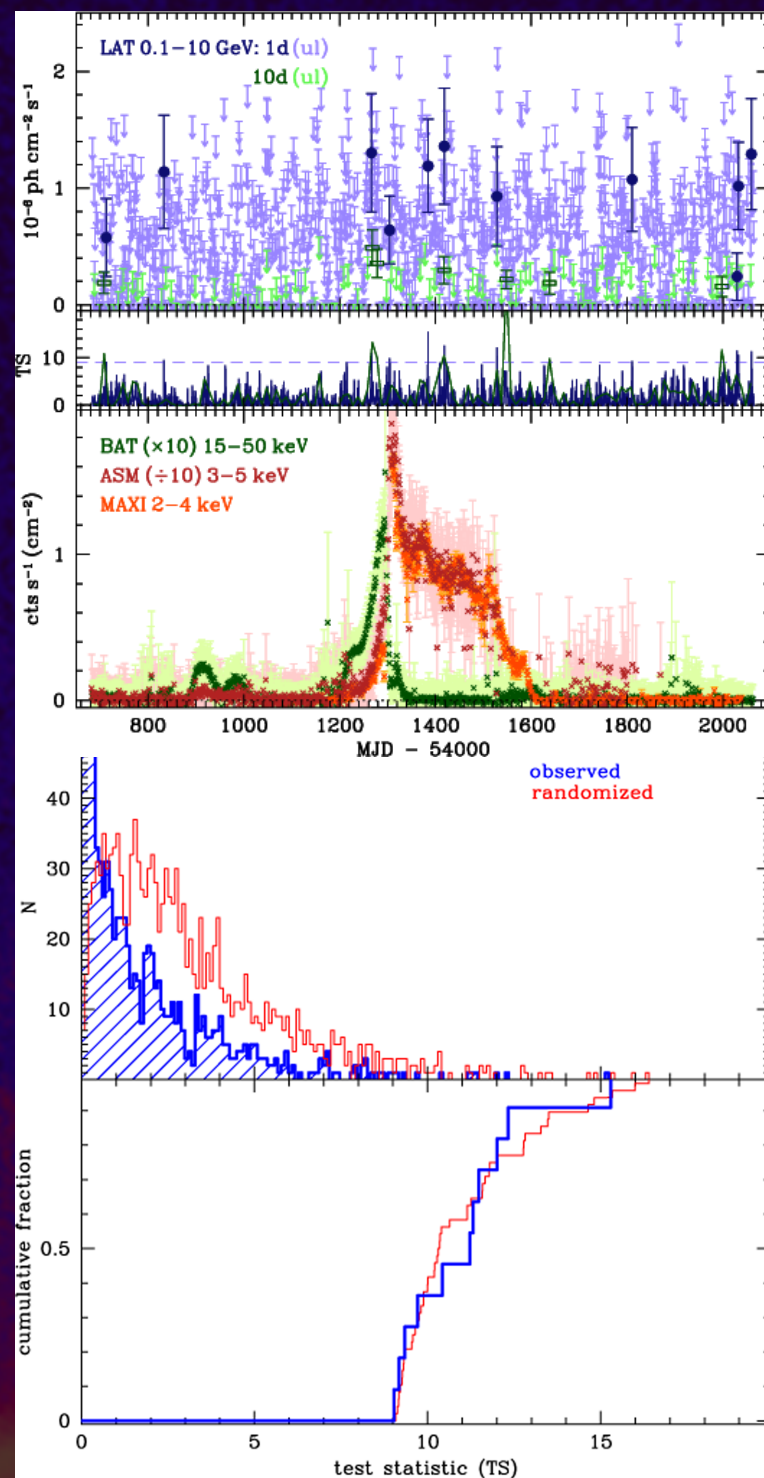
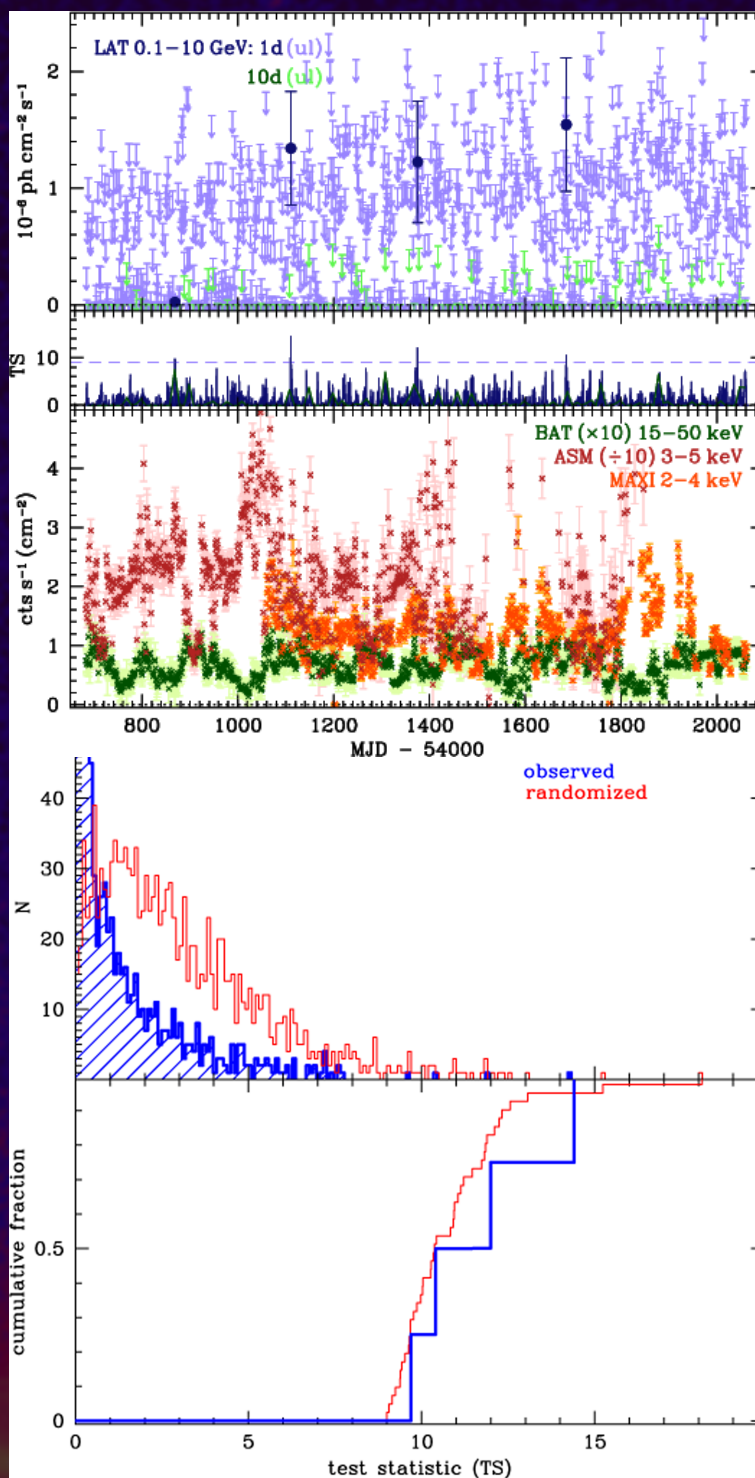
comparison with TS distribution  
of spurious source yields  
>70% KS-test prob. of match

the few candidate detections  
we have are likely spurious

$3\sigma$  upper limits on persistent  
flux in 0.1—10 GeV:

GRS1915+105:  $2.3 \times 10^{-8}$  ph/cm<sup>2</sup>/s

GX 339-4:  $1.6 \times 10^{-8}$  ph/cm<sup>2</sup>/s

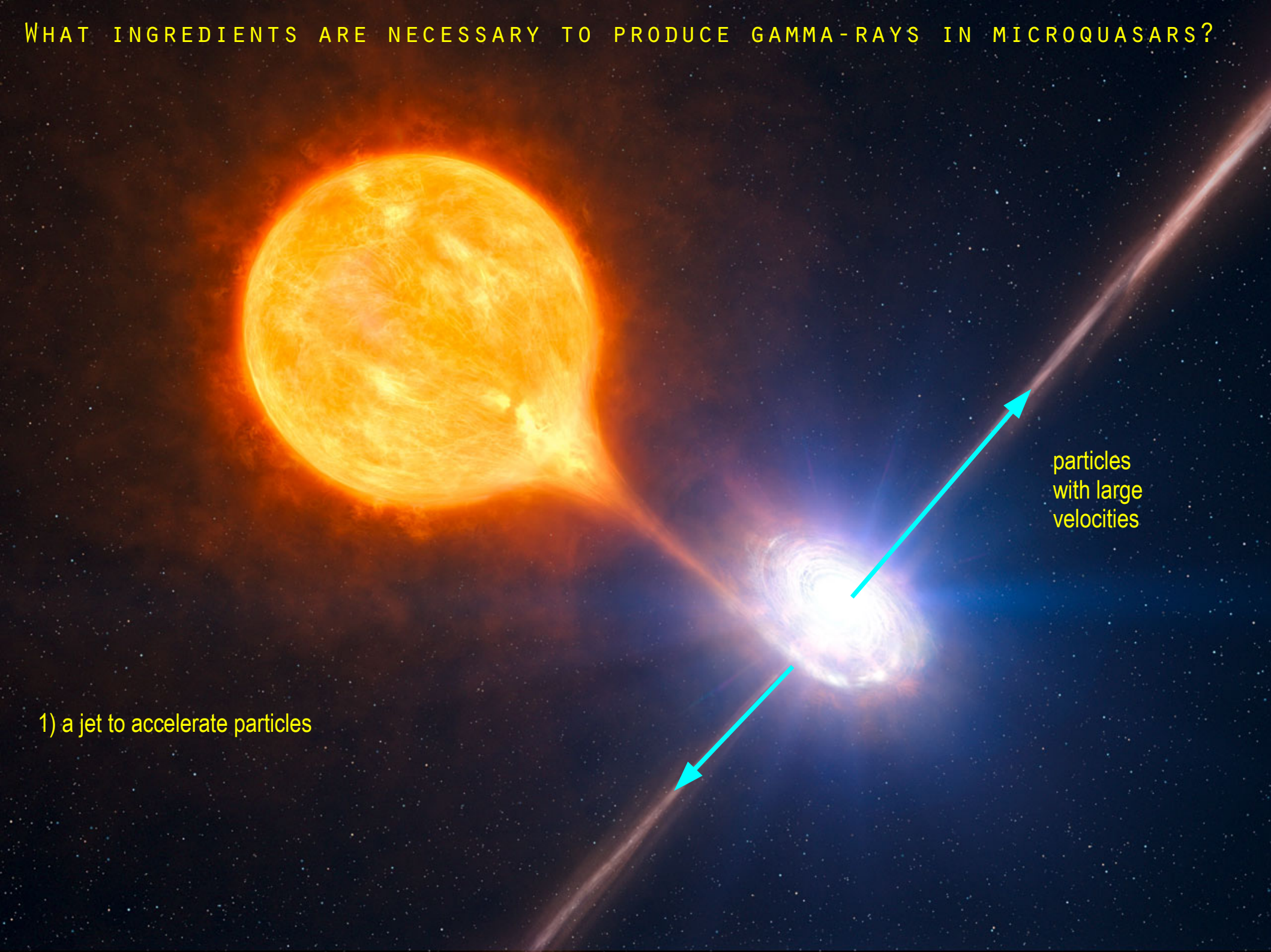




# WHAT INGREDIENTS ARE NECESSARY TO PRODUCE GAMMA-RAYS IN MICROQUASARS?

1) a jet to accelerate particles

particles  
with large  
velocities



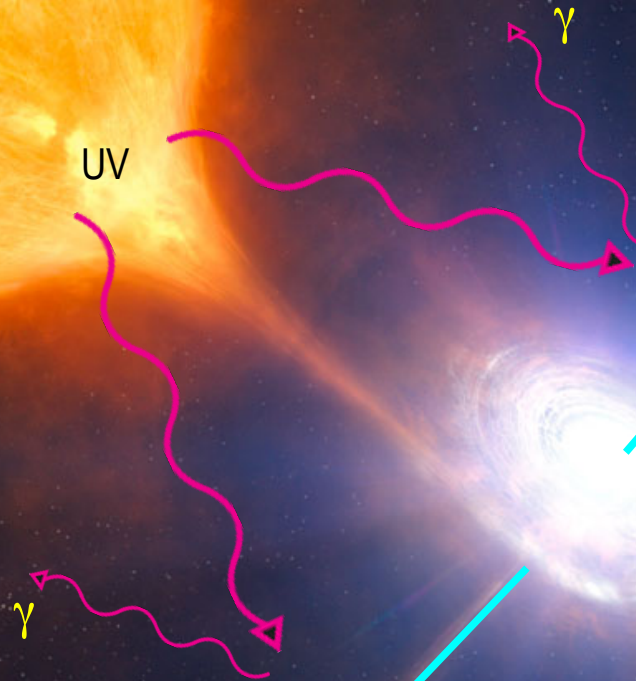
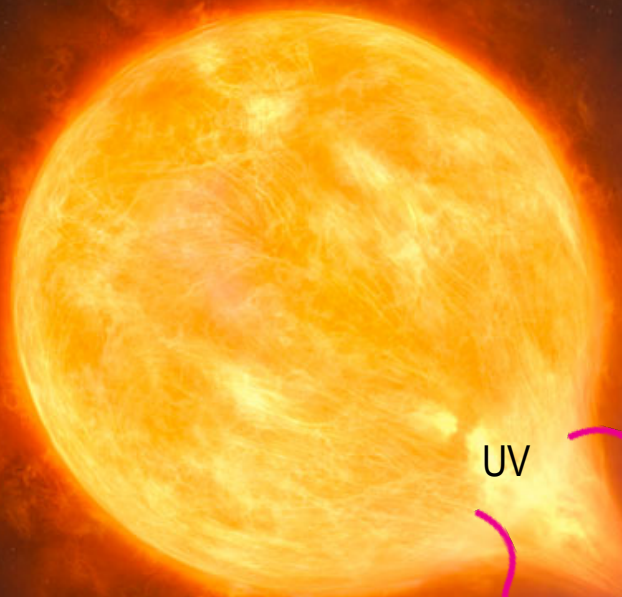
The diagram illustrates a microquasar system. On the left is a large, bright orange-yellow sphere representing a star. To its right is a smaller, bright blue-white accretion disk with a central point source. Two narrow, glowing jets of light extend from the central source in opposite directions. Two red arrows originate from the central source: one points towards the upper right jet, and the other points towards the lower left jet. The background is a dark blue space filled with numerous small white stars.



# WHAT INGREDIENTS ARE NECESSARY TO PRODUCE GAMMA-RAYS IN MICROQUASARS?

1) a jet

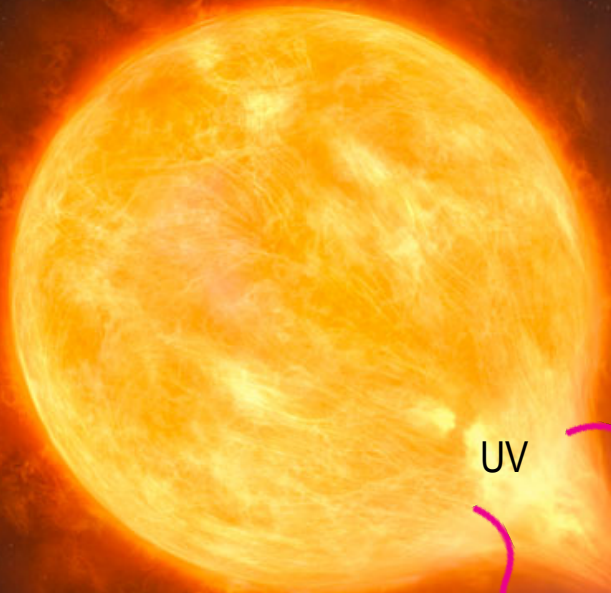
2) a high-mass donor to provide a soft radiation field:  
c.f. Cyg X-3, Cyg X-1, LS 5039, LS I+61°303,  
1FGL J1018.6–5856, PSR B1259–63,  
and probably HESS J0632+057



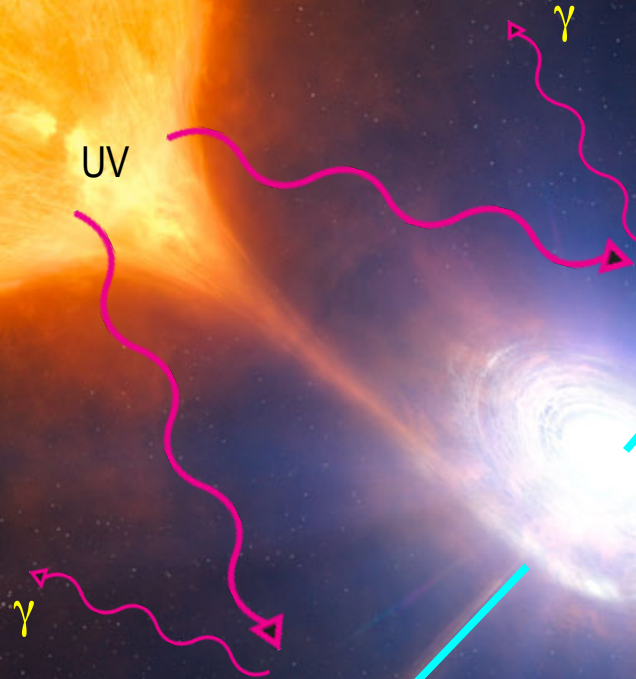
particles  
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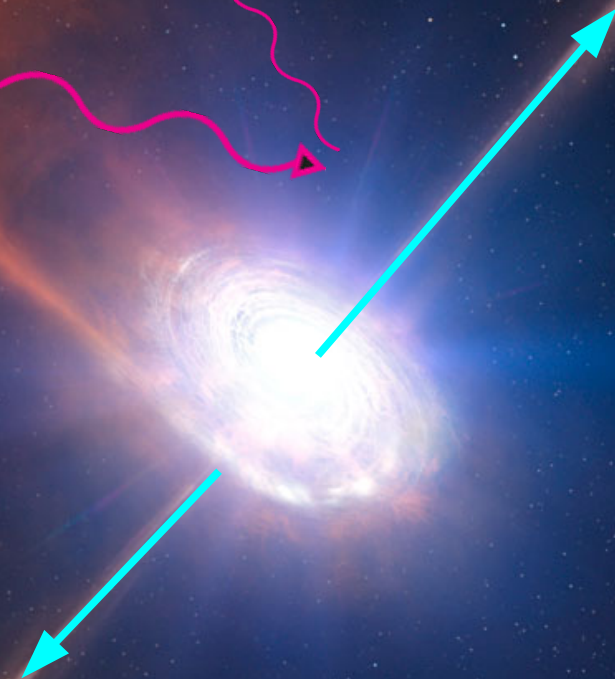
# WHAT INGREDIENTS ARE NECESSARY TO PRODUCE GAMMA-RAYS IN MICROQUASARS?



UV



particles  
with large  
velocities



1) a jet

2) a high-mass donor

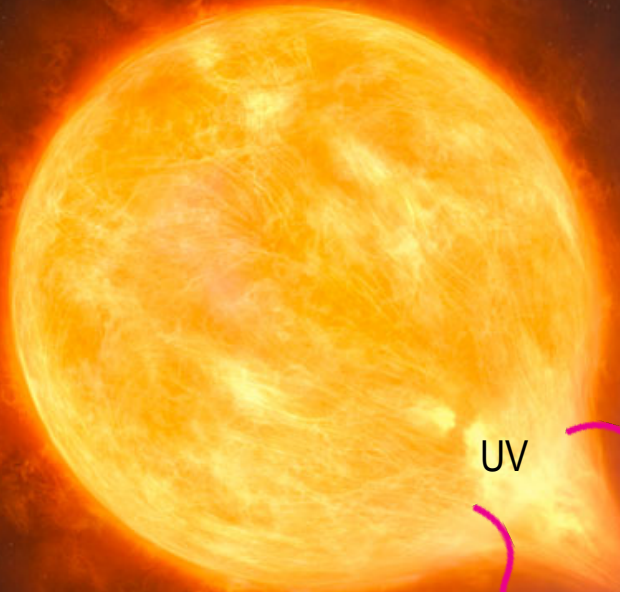
3) superior conjunction to maximize area of soft photon target (?)

Cyg X-3: orbital period shows peaks at SC

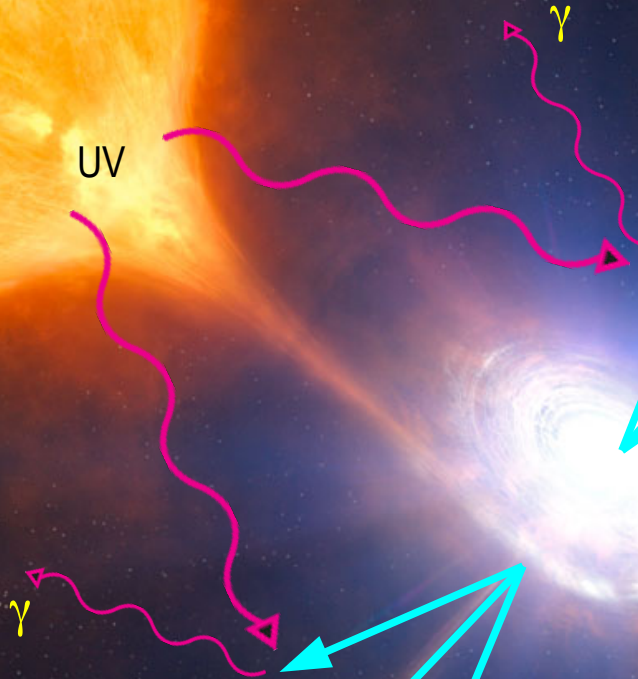
Cyg X-1: MAGIC detection and 2 of 3 LAT-AGILE detections at SC



# WHAT INGREDIENTS ARE NECESSARY TO PRODUCE GAMMA-RAYS IN MICROQUASARS?



UV



particles  
with large  
velocities

- 1) a jet
- 2) a high-mass donor
- 3) superior conjunction (?)
- 4) others: jet angle, magnetic field, etc. (?)



## SUMMARY & CONCLUSIONS

### Cyg X-3:

- confirmed all but one previously-reported gamma-ray detections
- found five additional unreported gamma-ray flares
- uncovered evidence of persistent emission

### Cyg X-1:

- LAT confirmed all previous gamma-ray detections by AGILE
- other candidate gamma-ray detections likely spurious

### GRS 1915+105 and GX 339-4:

- candidate gamma-ray detections likely spurious

### recipe for producing gamma-rays from microquasars:

- jet
- high-mass donor star
- superior conjunction (?)
- other factors (?)

*Fermi observations of microquasars can shed light on the role of relativistic jets in producing gamma-ray emission around accreting compact objects.*

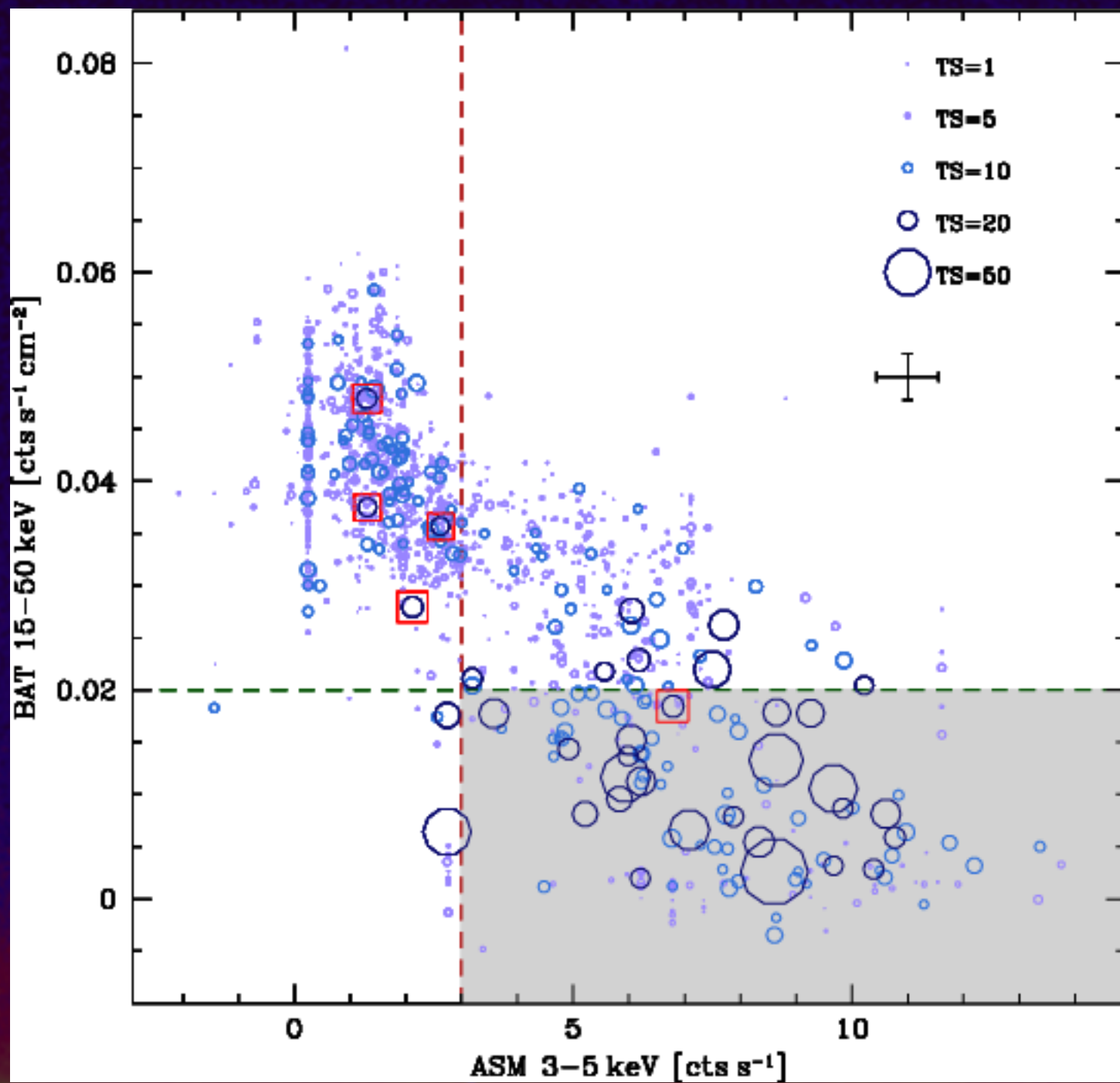
Bodaghee et al. 2013 submitted to ApJ

thank you



## CYG X-3: PREDICTING THE NEXT GAMMA-RAY FLARE

criteria of Corbel et al. (2012) are good predictors of gamma flaring





## CYG X-1: PREDICTING THE NEXT GAMMA-RAY FLARE

use X-ray state definitions of  
Grinberg et al. (2013)

