Chapter 6

Black Hole Gap Emission from Galactic X-ray Binaries

§1 Observations of galactic XRBs

§2 Gap emission from stellar-mass BHs

§3 HE detectability of gap emission from XRBs

§1 Observations of galactic XRBs

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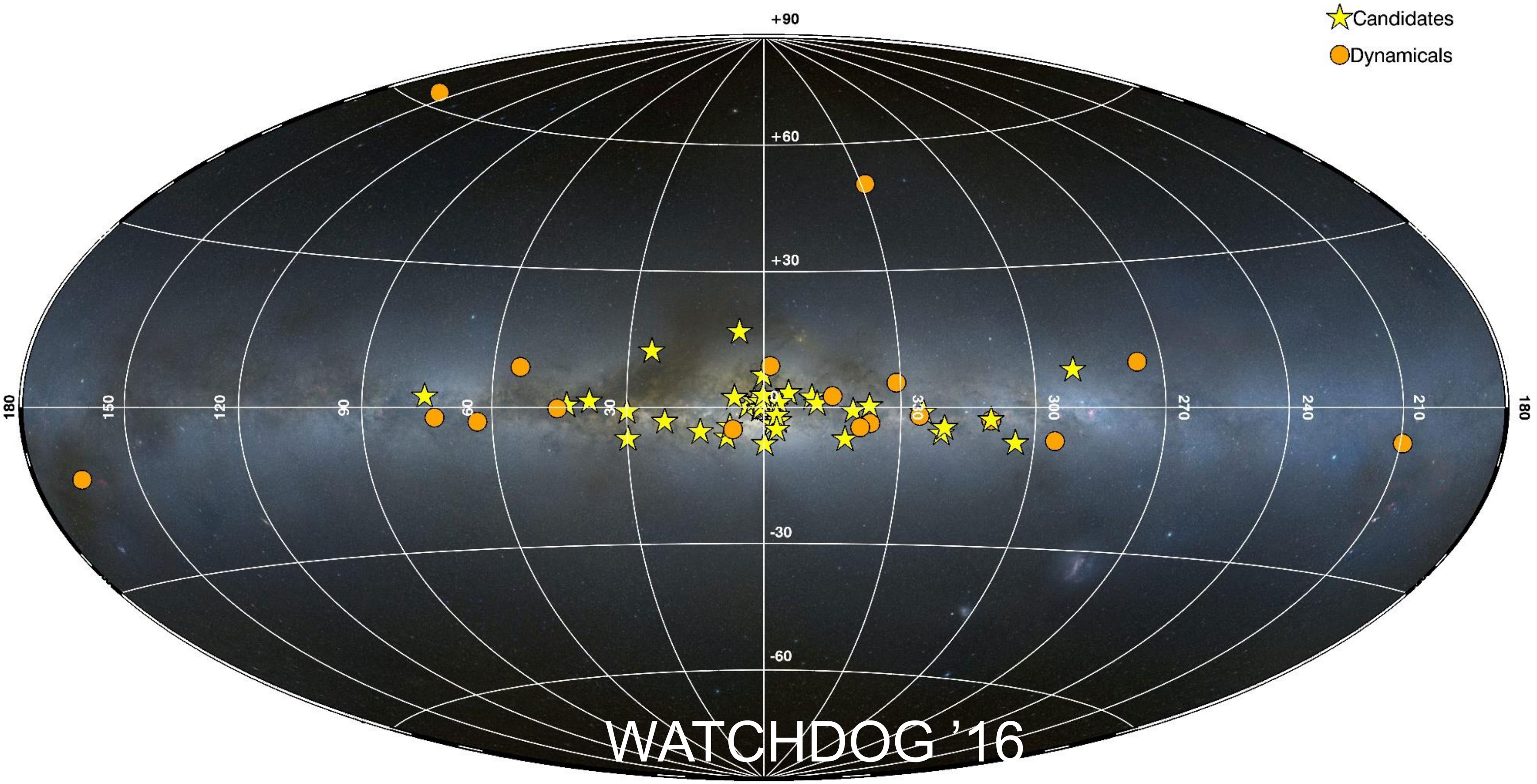
So far, 77 X-ray binary BHs and BHCs have found in MW & LMC.

BlackCAT (Corral-Santana + ’16, AA 587, A61)
WATCHDOG (Tetarenko + ’16, ApJS 222, 15)



§ 1 Observations of galactic XRBs

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In these BH X-ray binaries, material transfers from a companion star onto the BH primary.

HMXBs 6 are fed by wind, 1 by Roche-lobe overflow
Companion: O-B stars ($M>10M_\odot$)

LMXBs 45 are fed by Roche-lobe overflow.
Companion: K-M ($M<M_\odot$) or B-F ($M\sim M_\odot$)

(Companion nature of other 25 BHXBs are unknown.)

§ 1 Observations of galactic XRBs

The mass accretion rate $\dot{M}$ near the compact object determines their emission properties.

6 BH-HMXBs and 4 BH-LMXBs have $\dot{M} > 10^{-8}\ M_{\odot} yr^{-1}$, showing persistent X-ray emission with $L_X \sim L_{Edd}$.

Tanaka & Shibazaki 1996, ARA&A 34, 607

47 BH-LMXBs have much lower long-term accretion rate, $\dot{M} < 10^{-9}\ M_{\odot} yr^{-1}$, showing transient X-ray emission: Sporadic outbursts after long-time quiescence.

Tanaka & Lewin 1995, in *X-ray binaries*, p. 126

Outburst recurrence period ranges 10^{0-2} yrs.

WATCHDOT, BlackCAT

§ 1 Observations of galactic XRBs

For transient BH binaries, HE & VHE emissions are expected in the shock-in-jet model.

Marscher & Gear 1985, ApJ 298, 114

HE/VHE flux increases w/ increasing $\dot{M}$.

However, HE/VHE emissions can be alternatively emitted from BH gaps in transient BHBs.

KH & Pu 2016, ApJ 818, 50; KH + 2016, ApJ 833, 142

HE/VHE flux increases w/ decreasing $\dot{M}$.

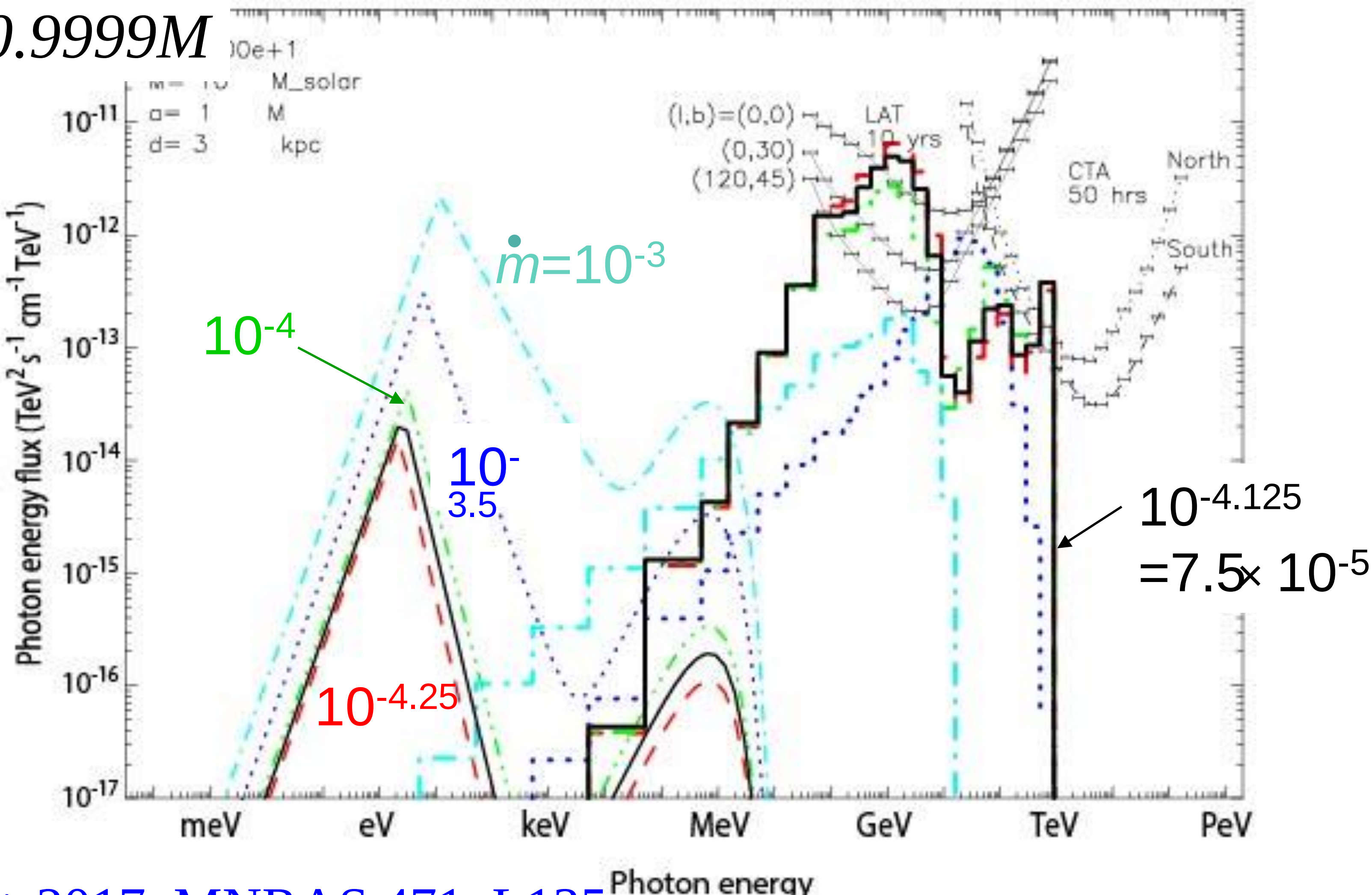
We will focus on the BH-gap model and discuss its theoretical predictions.

§ 2 Gap emission from stellar-mass BHs

§ 3 Enhanced gap emission when $a \to M$

M=10$M_\odot$, B=B_{eq}; SEDs @ six discrete $\dot{m}$ (along θ=0°)

a=0.9999M

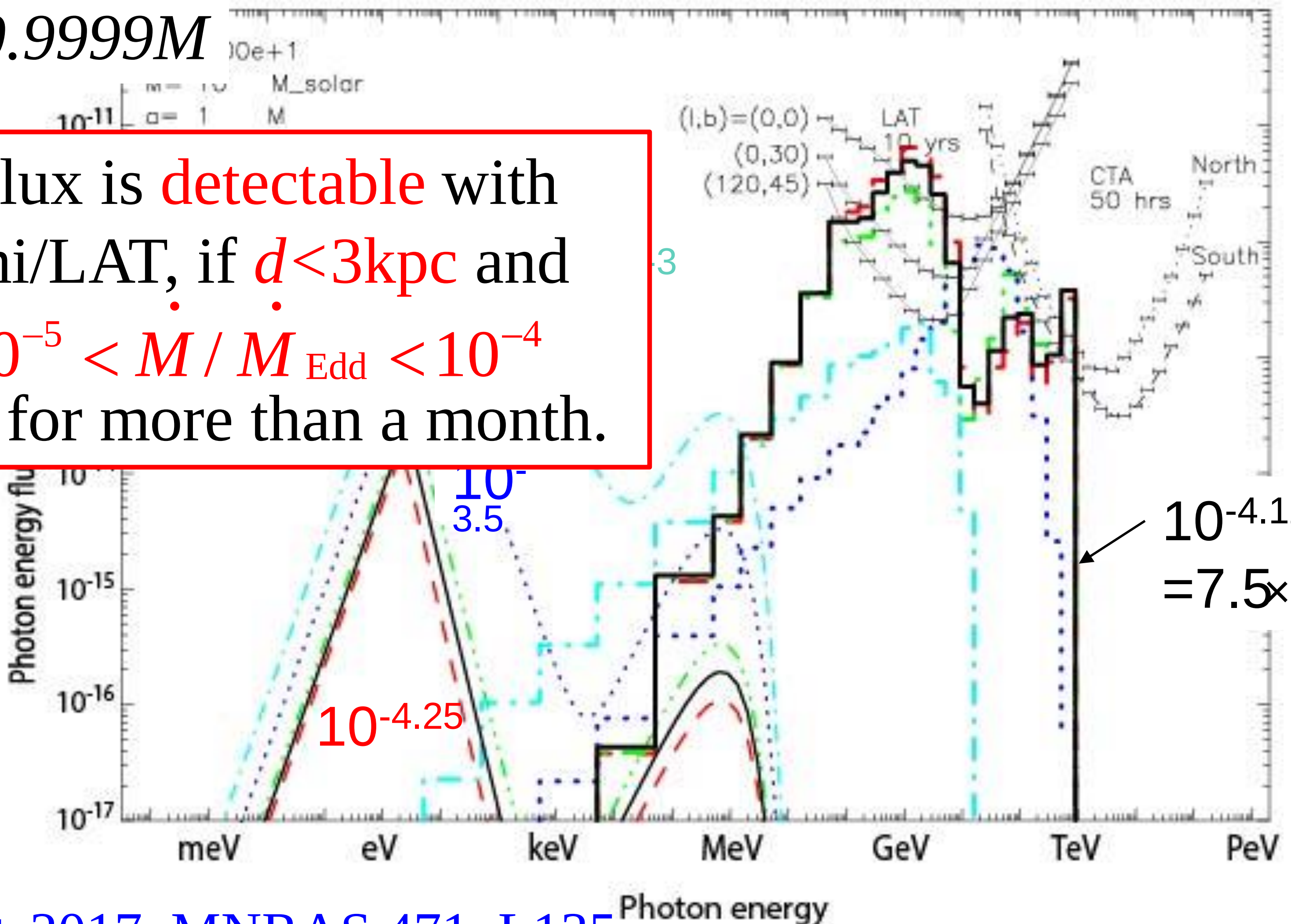


Y. Song+ 2017, MNRAS 471, L135

§ 3 Enhanced gap emission when $a \to M$

$M=10M_\odot$, $B=B_{eq}$; SEDs @ six discrete $\dot{m}$ (along $\theta=0^o$)

$a=0.9999M$



HE flux is detectable with Fermi/LAT, if d<3kpc and $6\times10^{-5} < \dot{M}\,/\,\dot{M}_{\rm Edd} < 10^{-4}$ lasts for more than a month.

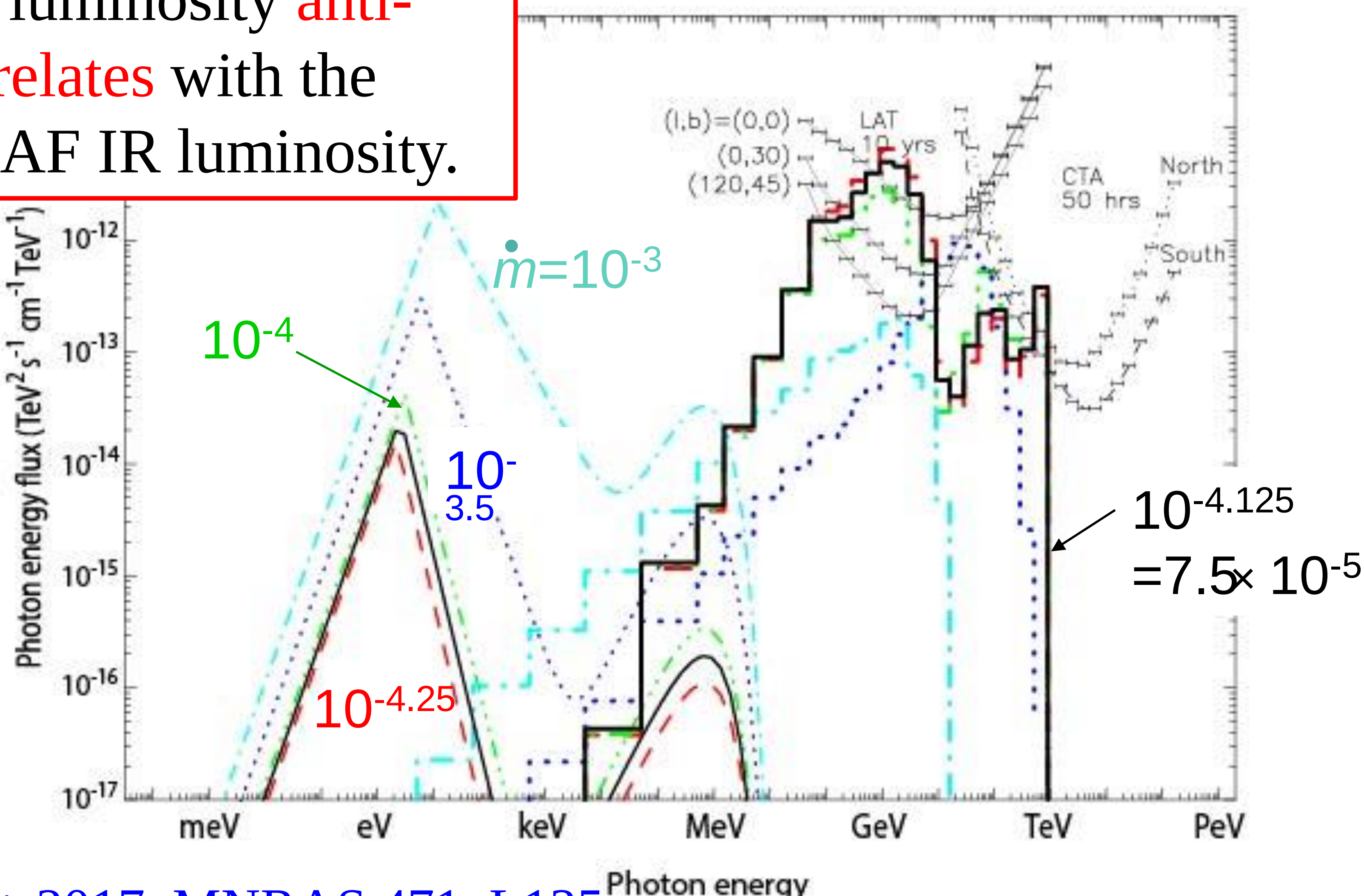
$10^{-4.125}$
$=7.5\times 10^{-5}$

Y. Song+ 2017, MNRAS 471, L135

§ 3 Enhanced gap emission when $a \to M$

What is more, the gap HE luminosity anti-correlates with the ADAF IR luminosity.

s @ six discrete $\dot{m}$ (along $\theta = 0^{\mathrm{o}}$)

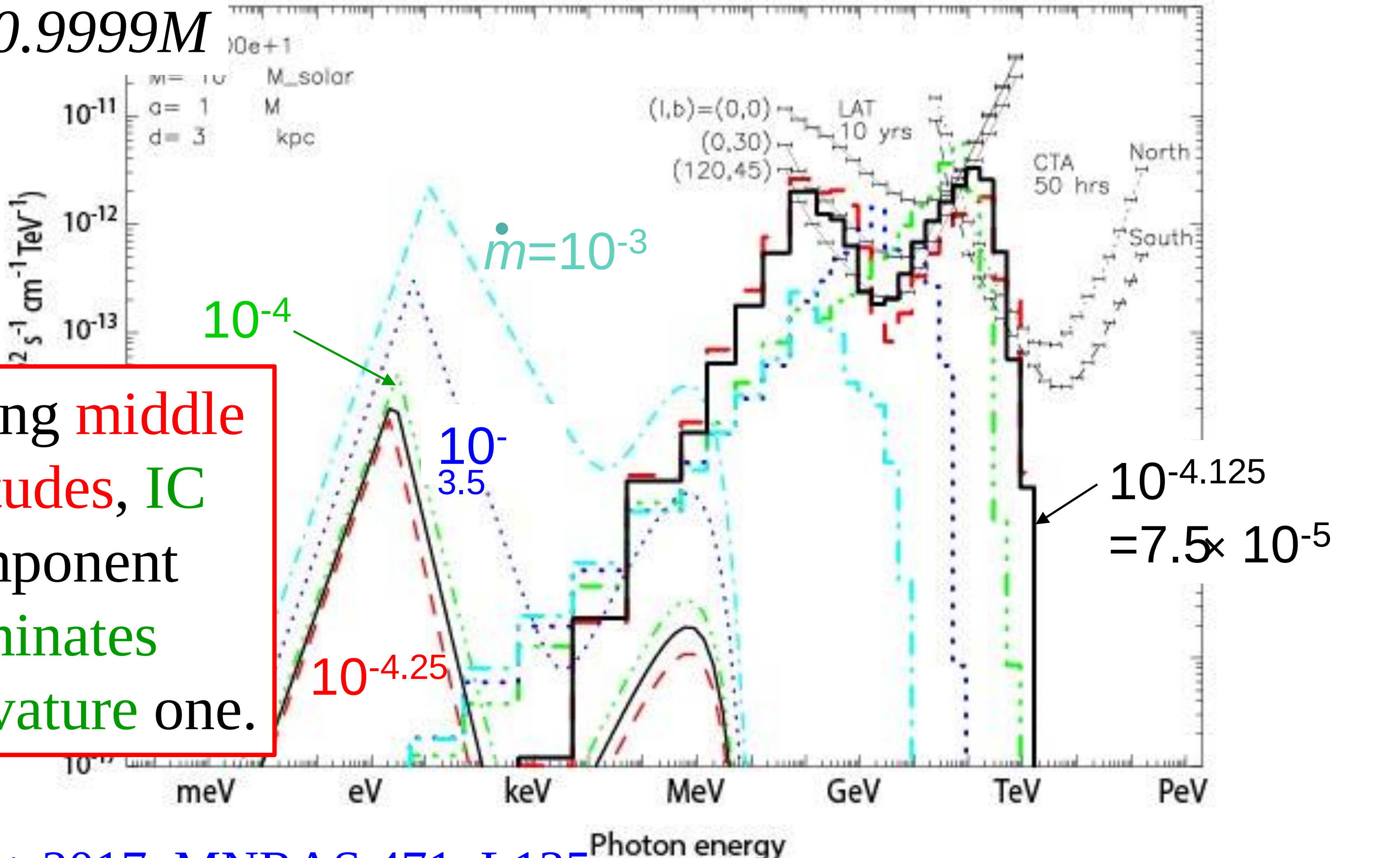


Y. Song+ 2017, MNRAS 471, L135

§ 3 Enhanced gap emission when $a \to M$

$M=10M_\odot$, $B=B_{eq}$; SEDs @ six discrete $\dot{m}$ (along $\theta=45^o$)

$a=0.9999M$



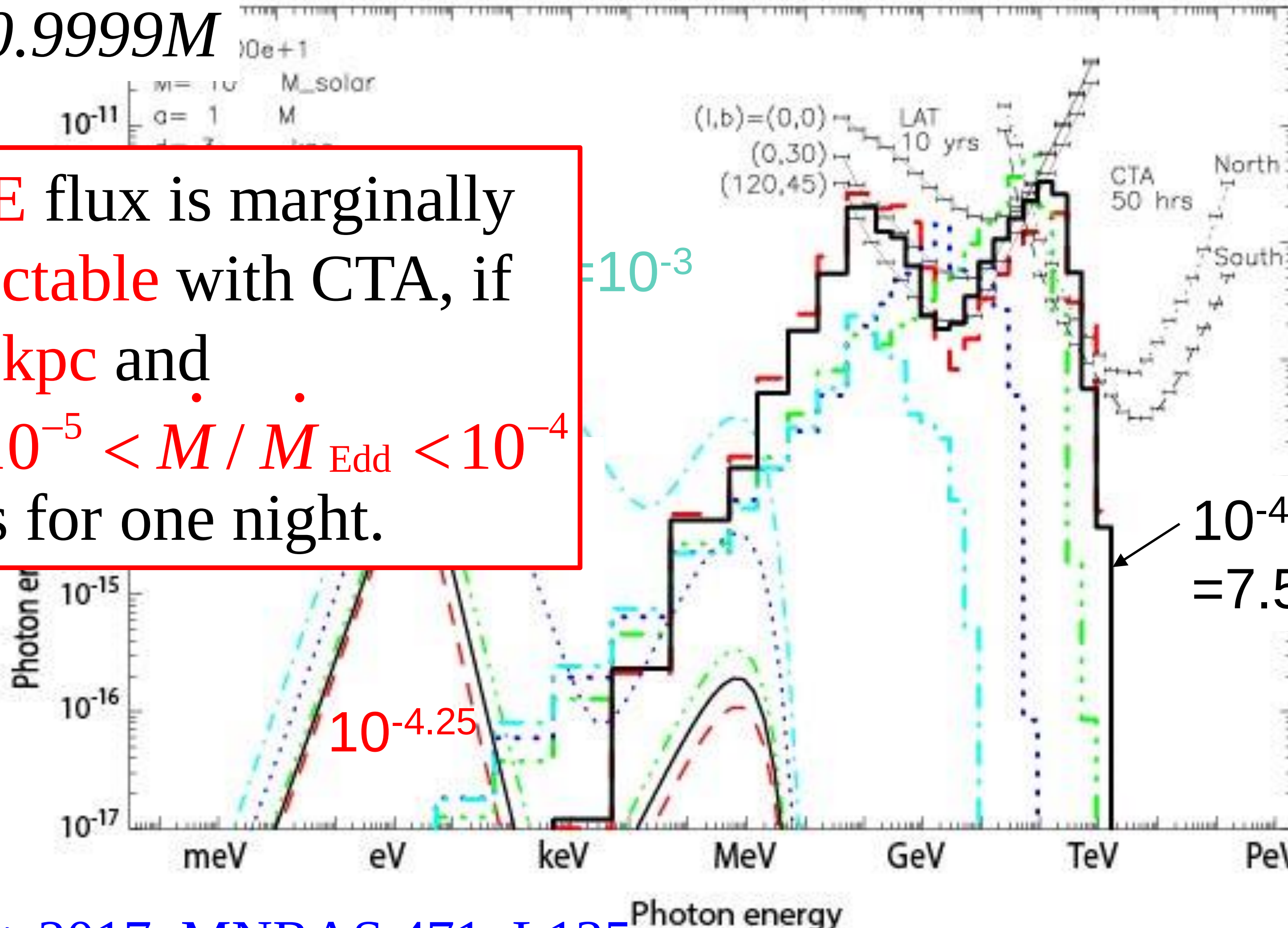
Along middle latitudes, IC component dominates curvature one.

Y. Song+ 2017, MNRAS 471, L135

§ 3 Enhanced gap emission when $a \rightarrow M$

M=$10M_{\odot}$, B=B_{eq}; SEDs @ six discrete $\dot{m}$ (along θ=45°)

a=$0.9999M$



VHE flux is marginally detectable with CTA, if d<3kpc and $6\times10^{-5} < \dot{M}/\dot{M}_{\rm Edd} < 10^{-4}$ lasts for one night.

=10^{-3}

$10^{-4.25}$

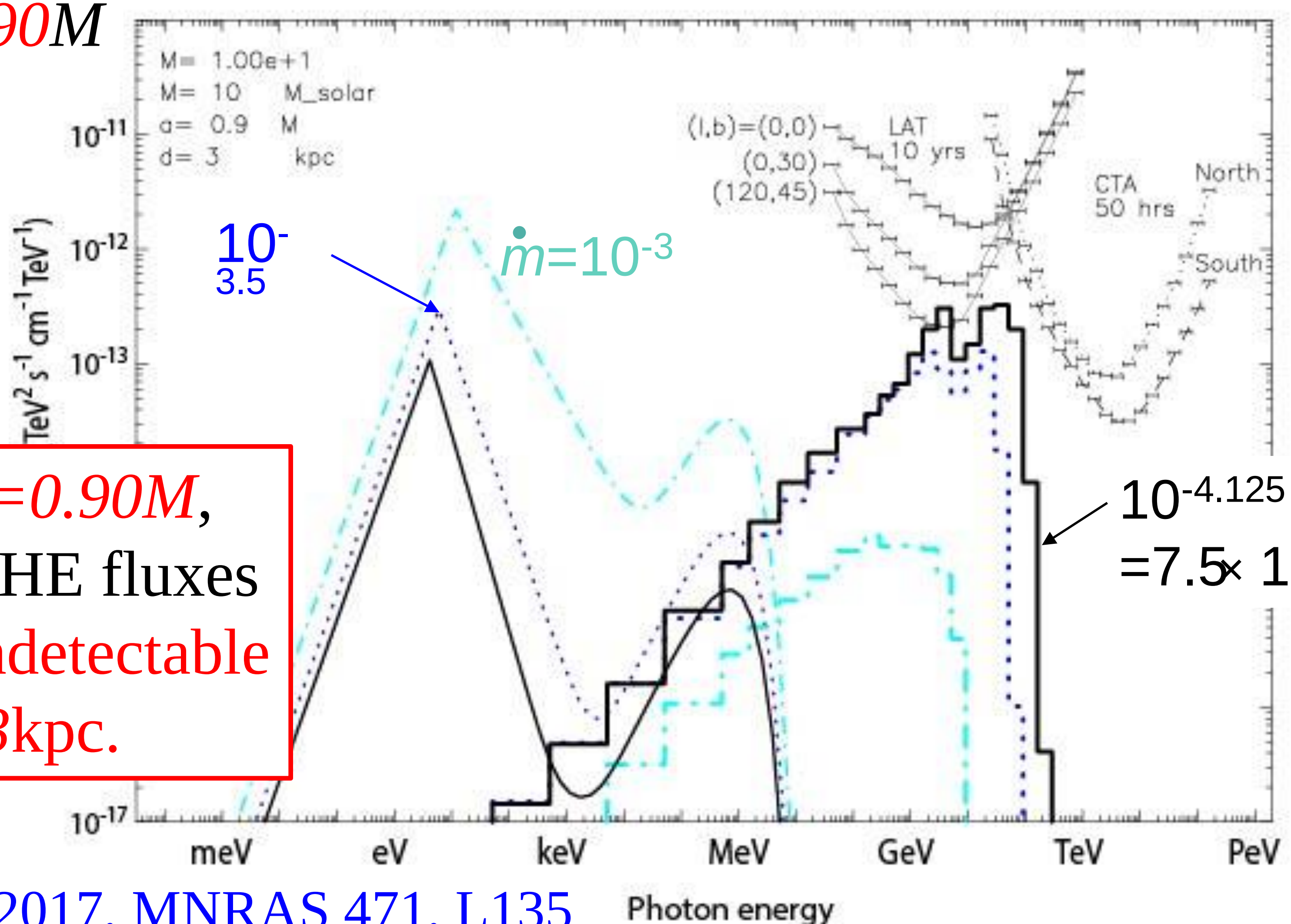
$10^{-4.125}$ =7.5×10^{-5}

Y. Song+ 2017, MNRAS 471, L135

§ 3 Enhanced gap emission when $a \to M$

$M=10M_\odot$, $B=B_{eq}$; SEDs @ 3 discrete $\dot{m}$ (along $\theta=0^o$)

$a=0.90M$



For $a=0.90M$, HE/VHE fluxes are undetectable if $d>3$kpc.

Y. Song+ 2017, MNRAS 471, L135

§ 3 Detectability of the gap emission from individual XRBs in HE γ-rays

§ 3 Detectability of BH transients

Next, examine BH transients. The Blandford-Znajek flux, $F_{BZ}=L_{BZ}/4\pi d^2$, gives the maximum possible flux @ Earth.

Four greatest F_{BZ} BHTs (descending order):

Name	mass $M_\odot$	distance kpc	obs. $\dot{M}$ / $\dot{M}_{Edd}$	Comments*
1A 0620-00	6.60	1.06	2.08×10^{-3}	L, T, V616 Mon
4U 1956+350	14.81	1.86		H, P, Cyg X-1
XTE J1118+480	7.30	1.72	4.96×10^{-4}	L, T, KV UMa
GS 2023+338	7.15	2.39	.017-.224	L, T, V404 Cyg

* Low-mass/High-mass companion, Transient/Persistent

We exclude Cyg X-1, because $\dot{M} \gg 10^{-4}\,\dot{M}_{Edd}$.

§ 3 Detectability of BH transients

Although the observed $\dot{m}$ exceeds 10^{-4} for all the 3 BHTs, there may be a certain fraction of time in which

$5.7 \times 10^{-5} < \dot{m} \equiv \dot{M} / \dot{M}_{\rm Edd} < 10^{-4}$ is satisfied.

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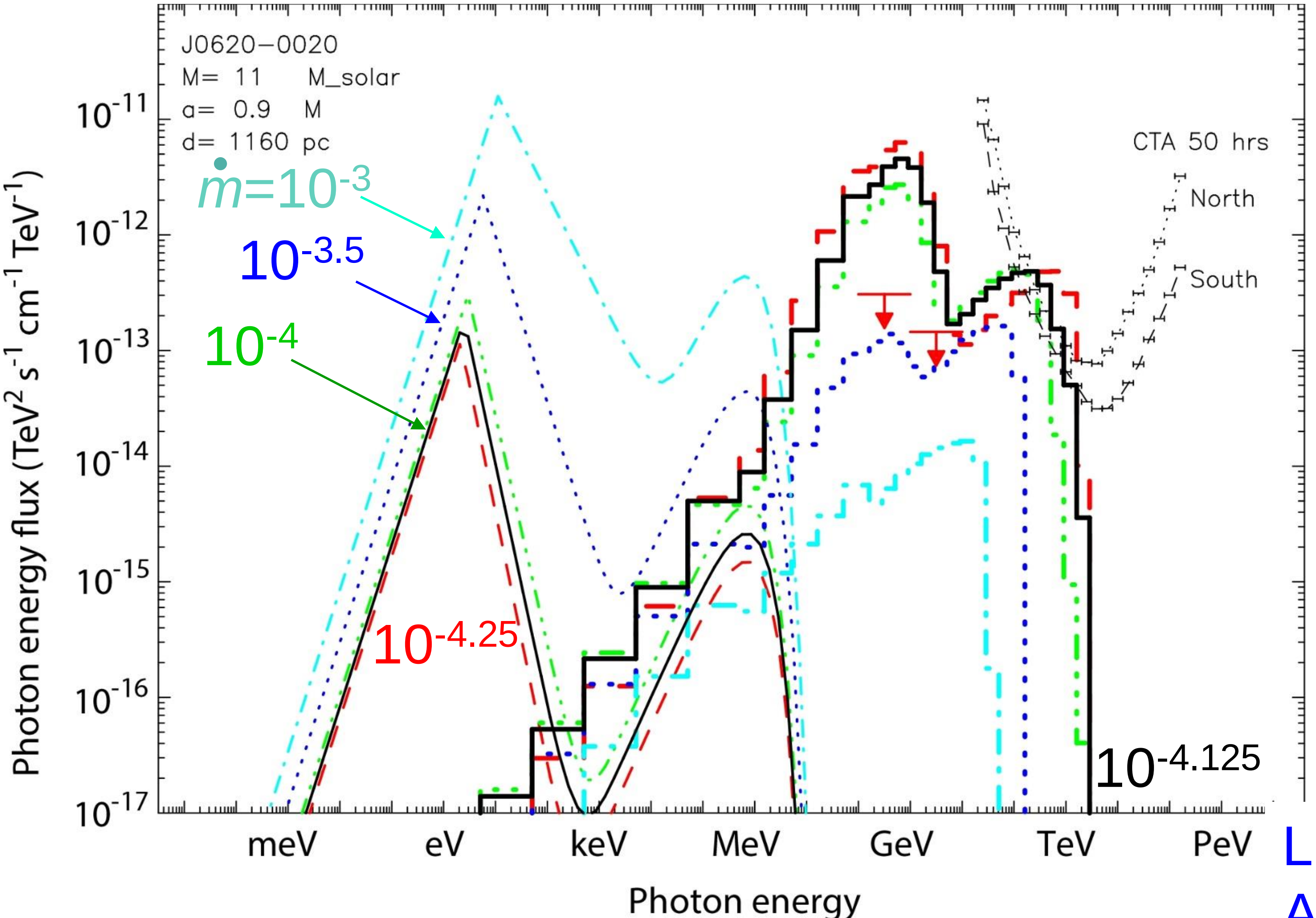
We thus examine these three BH LMXBs w/ greatest $F_{\rm BZ}$.

§ 3 Detectability of BH transients

J0620-0020: LAT 7-yr averaged flux appears below the theoretical prediction.



Obs. acc. rate (1917-75): $\dot{m}\sim 0.002$.

Lin + (2017) ApJ 845, 40

§ 3 Detectability of BH transients

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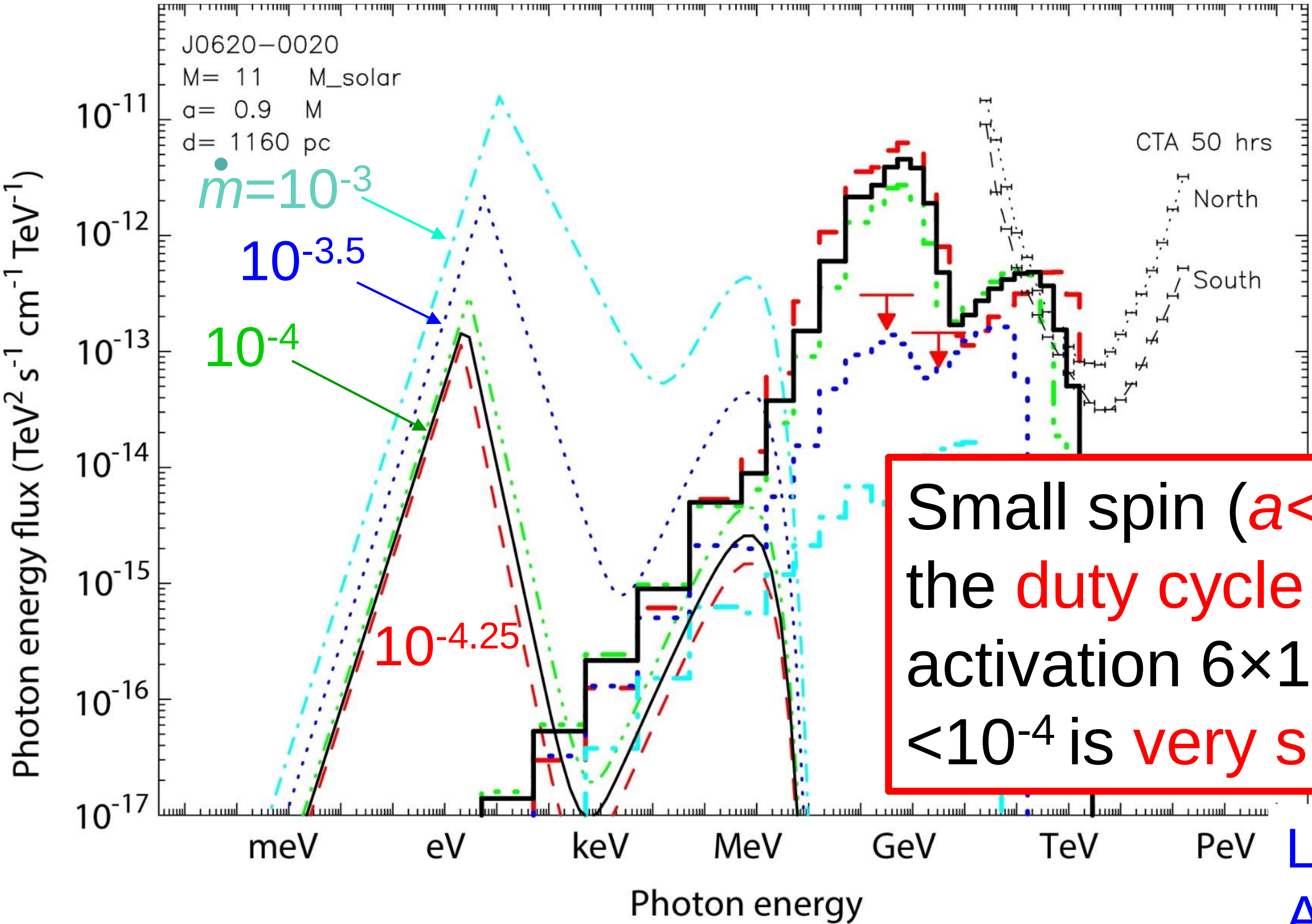


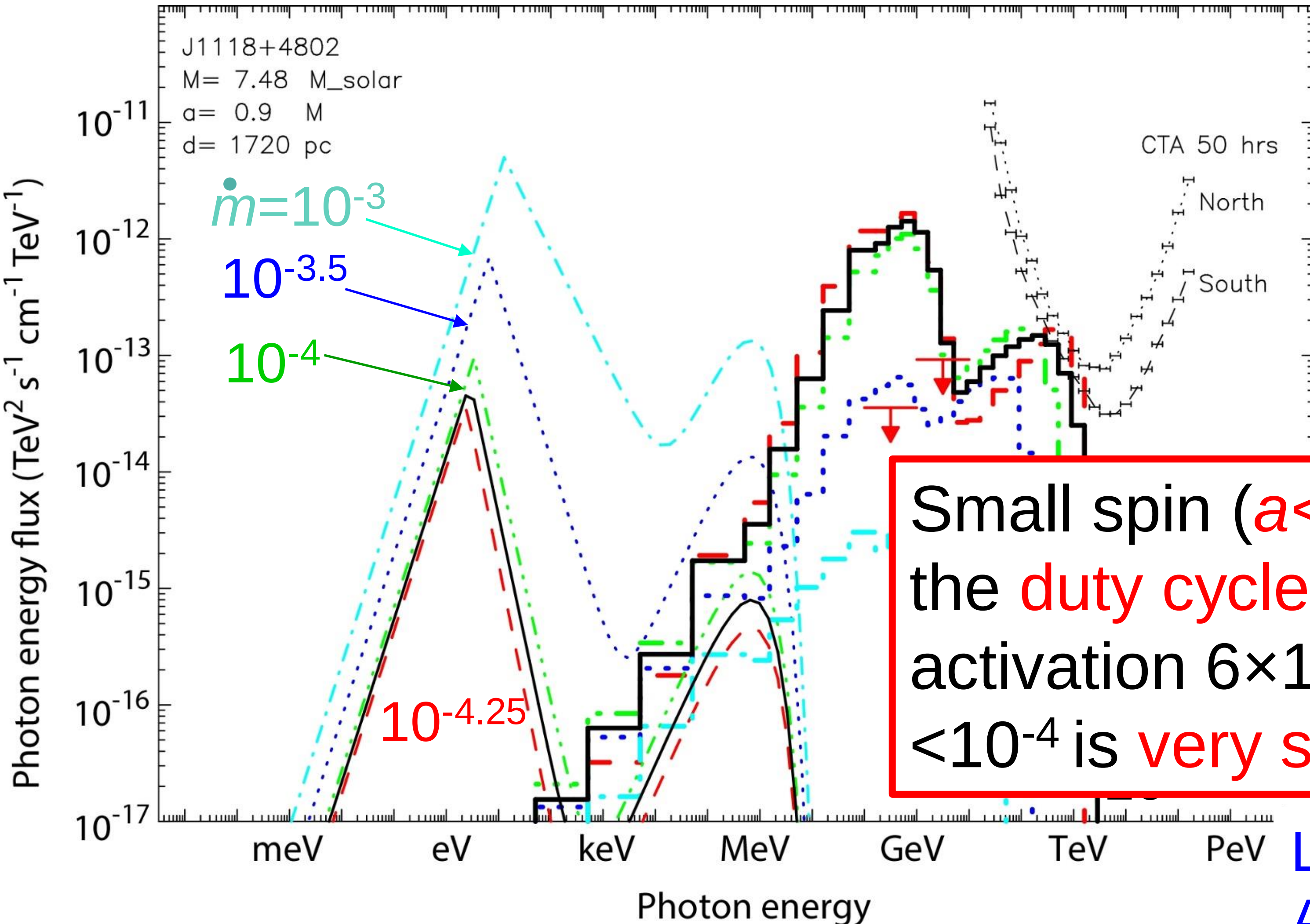
Obs. acc. rate (1917-75): $\dot{m}\sim 0.002$.

Small spin ($a<0.3M$), or the duty cycle of gap activation $6\times10^{-5}<\dot{m}<10^{-4}$ is very small («1).

Lin + (2017) ApJ 845, 40

§ 3 Detectability of BH transients

J1118+4802: LAT 7-yr averaged flux also appears below prediction.



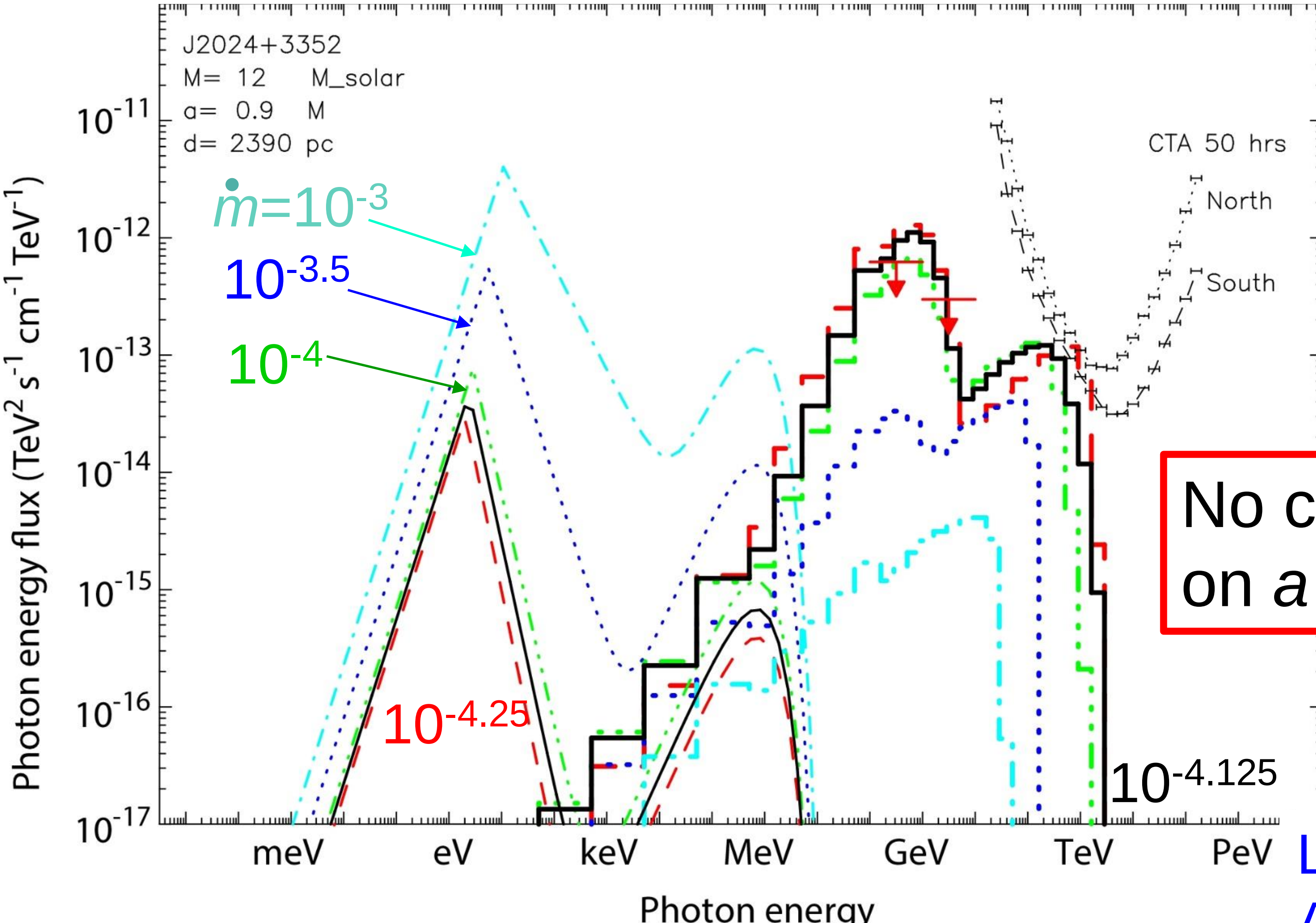
Obs. acc. rate (1998-2015): $\dot{m} \sim 5\times10^{-4}$.

Small spin ($a<0.3M$), or the duty cycle of gap activation $6\times10^{-5}< \dot{m} <10^{-4}$ is very small («1).

Lin + (2017) ApJ 845, 40

§ 3 Detectability of BH transients

V404 Cyg: LAT 7-yr averaged flux appear slightly below prediction.



Obs. acc. rate (1995-2005): $\dot{m} > 0.02$.

No constraints on a or $\dot{m}$.

Lin + (2017) ApJ 845, 40

Summary on BH gap model

- If an X-ray binary located within 2 kpc, if the BH is extremely rotating, and if we view it pole-on, its gap emission will be detectable with Fermi/LAT, provided that the accretion rate is regulated in the range $6\times10^{-6} < \dot{M}/\dot{M}_{\rm Edd} < 2\times10^{-5}$ for more than a month

(Lin + 2017, ApJ 845, 40).

- In fact, we can discriminate gap vs. jet emissions by anti-correlation vs. correlations at near-IR & VHE for stellar-mass BH (KH+, 2016, ApJ 818, 50).

END OF CHAPTER 6