ZTF & SRG:
An emerging sub-class of Galactic black holes

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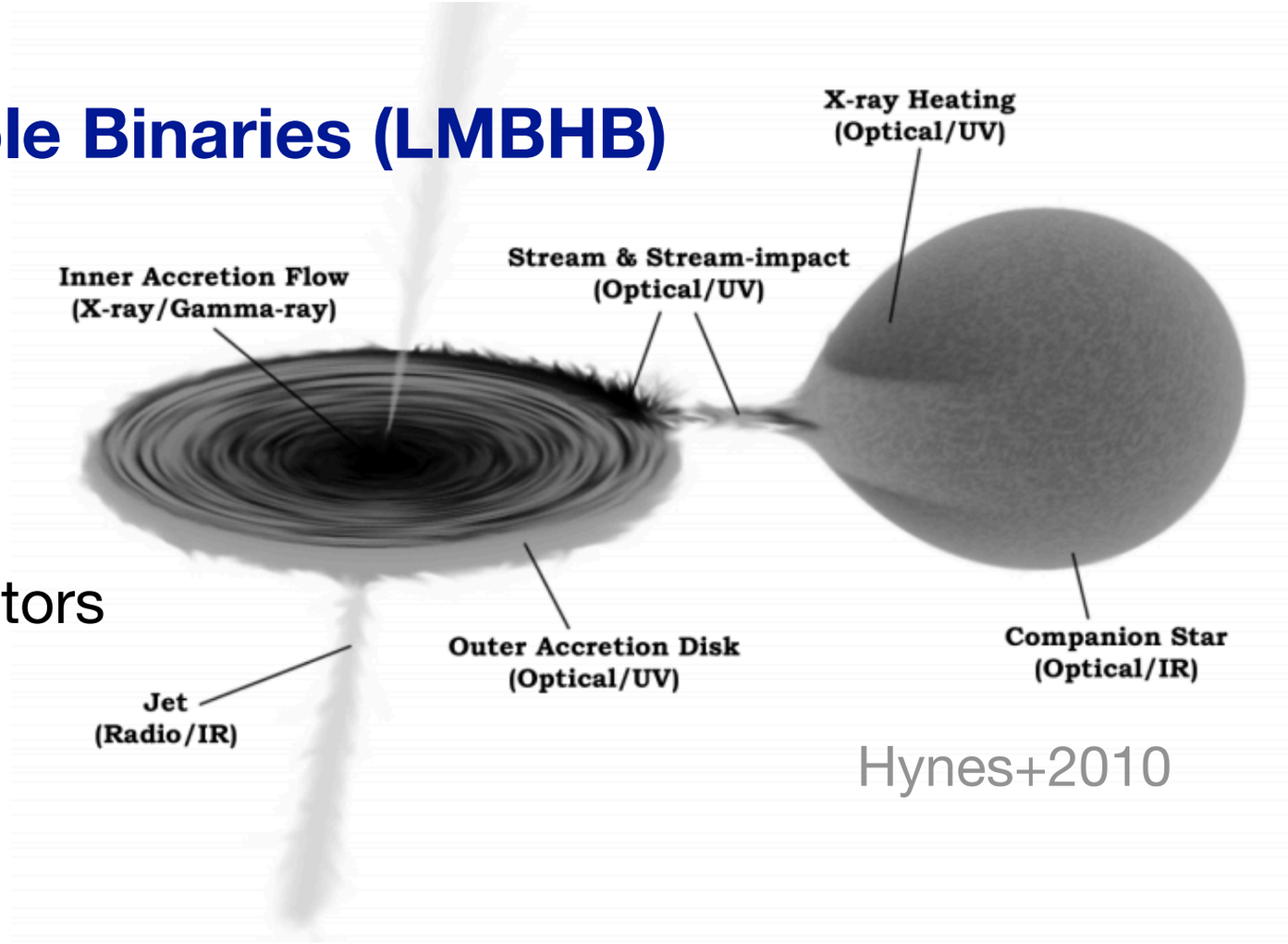
Caltech
Nov 19, 2020

Galactic Low-mass Black Hole Binaries (LMBHB)

- Low mass companion
- 66 known Galactic LMBHB
- All are transients
- Discovered by all sky X-ray monitors



Hynes+2010

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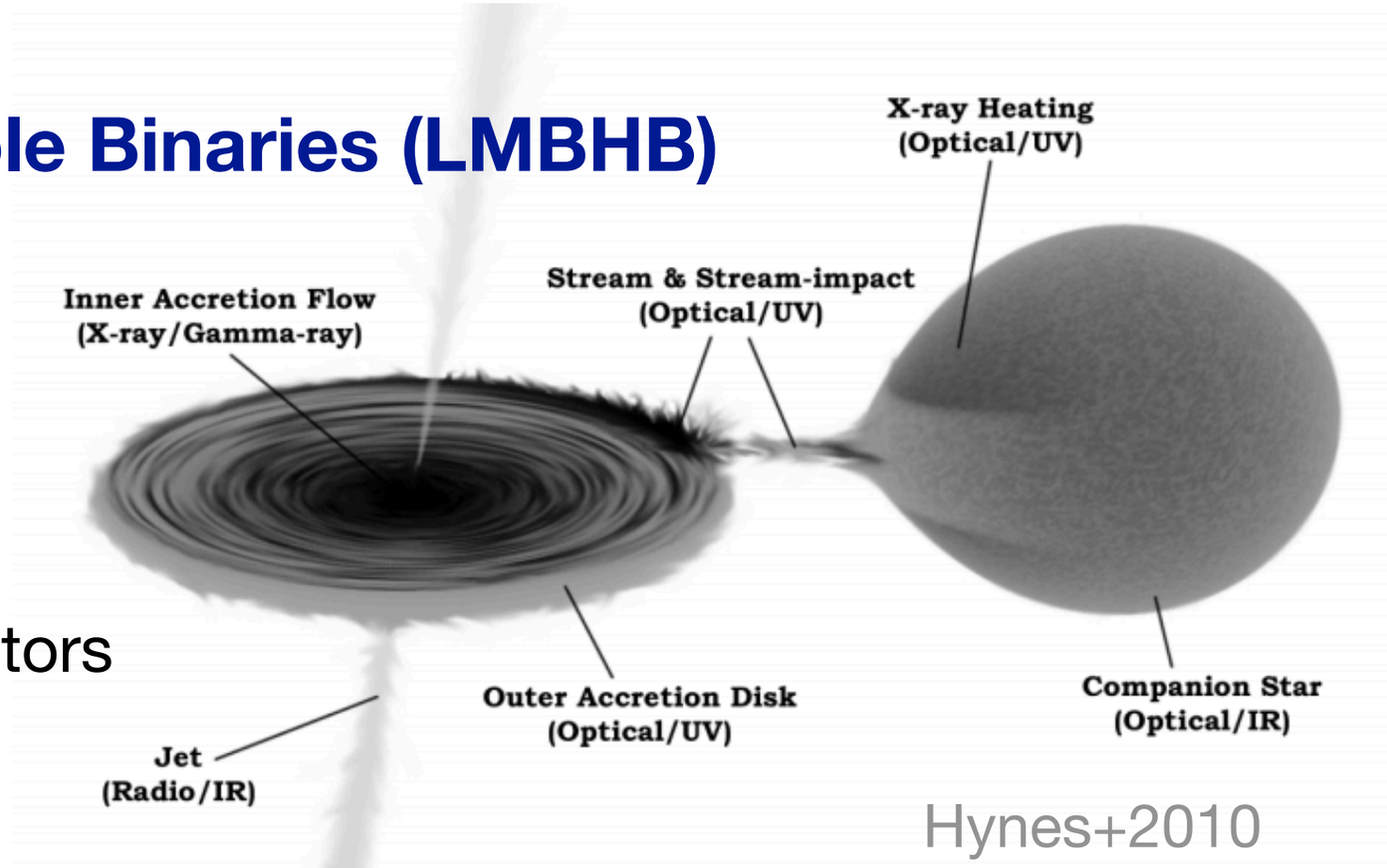
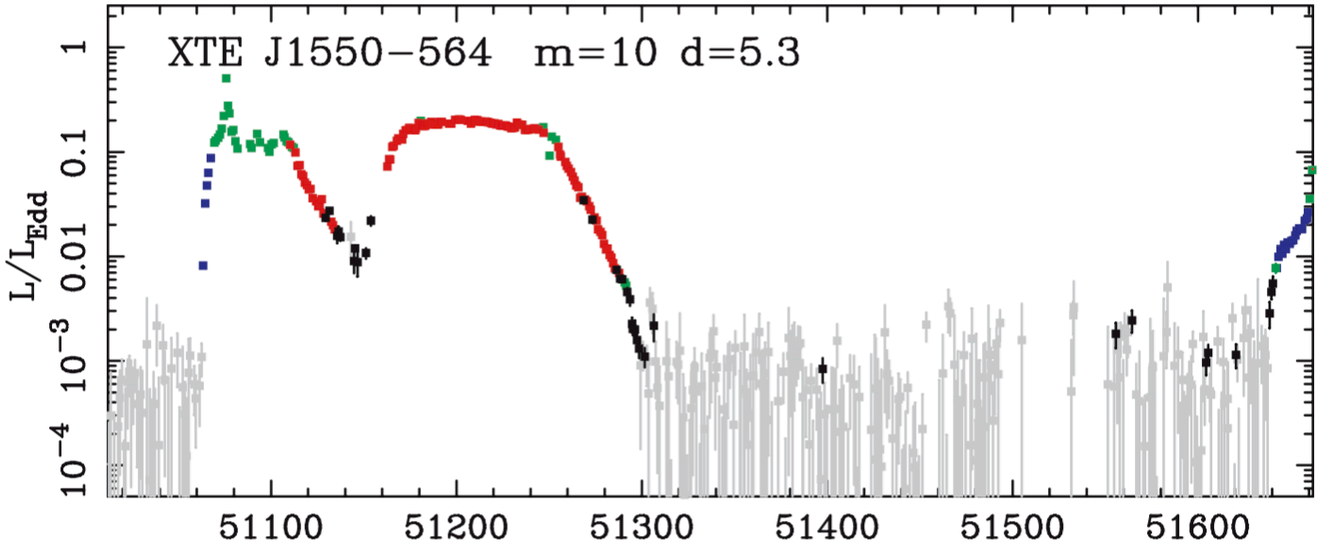
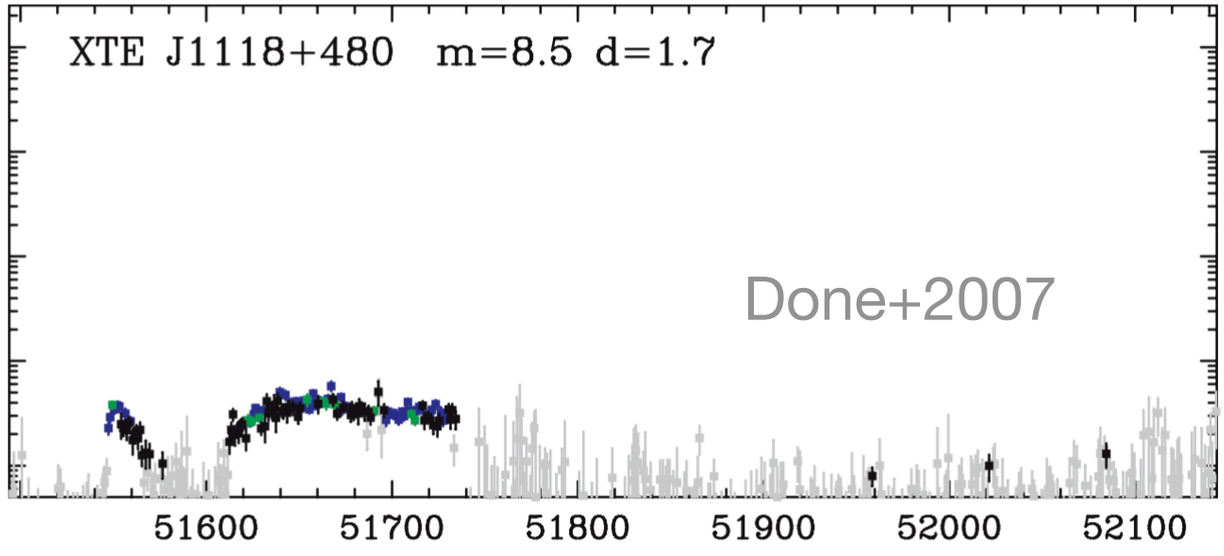


Hynes+2010



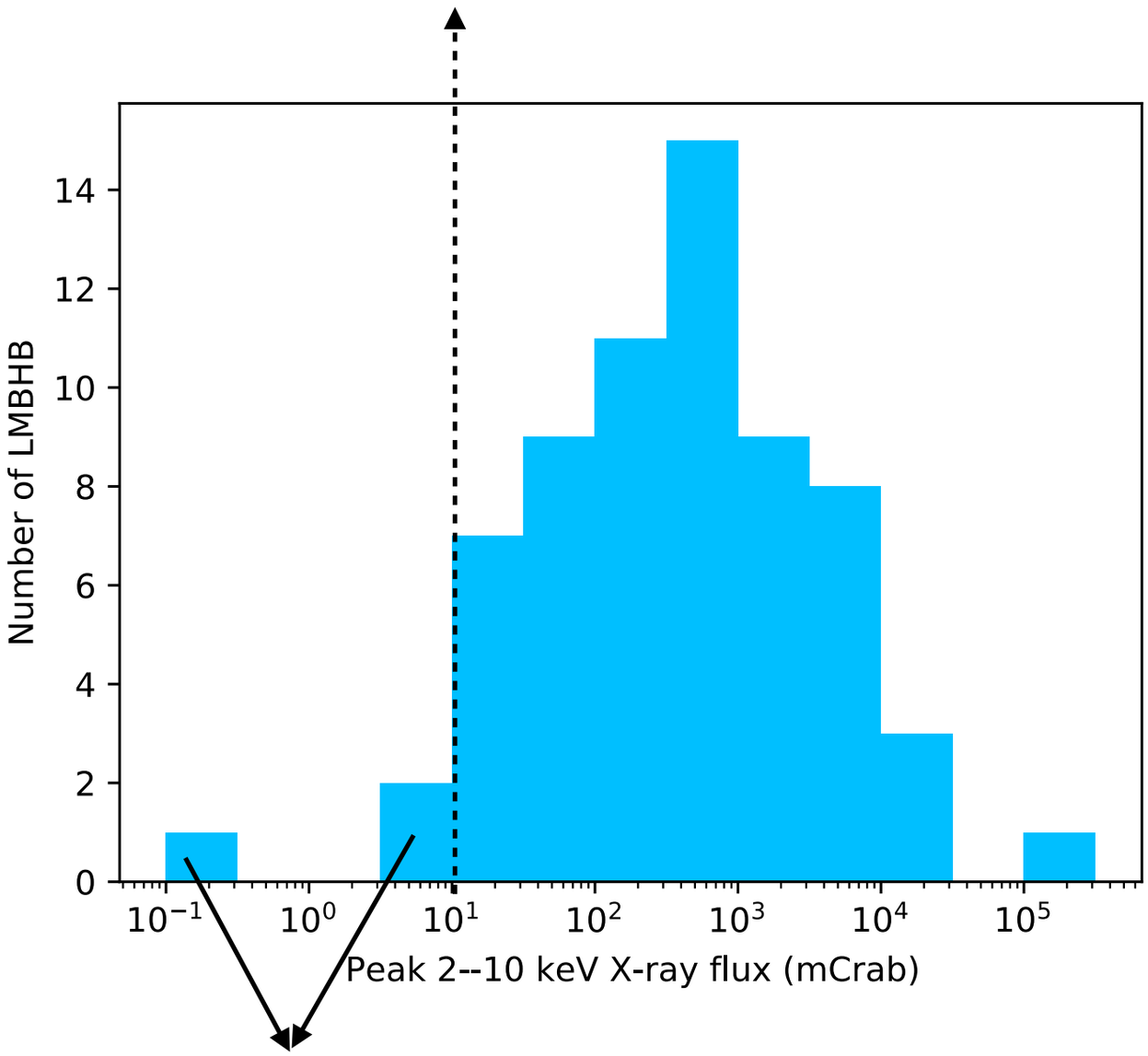
Peak X-ray flux = 6708 mCrab



Peak X-ray flux = 21 mCrab

LMBHB: X-ray Discovery

MAXI sensitivity threshold @ **~10mCrab**



Dedicated monitoring of the Galactic Center

Corral-Santana+2016

LMBHB: X-ray Discovery

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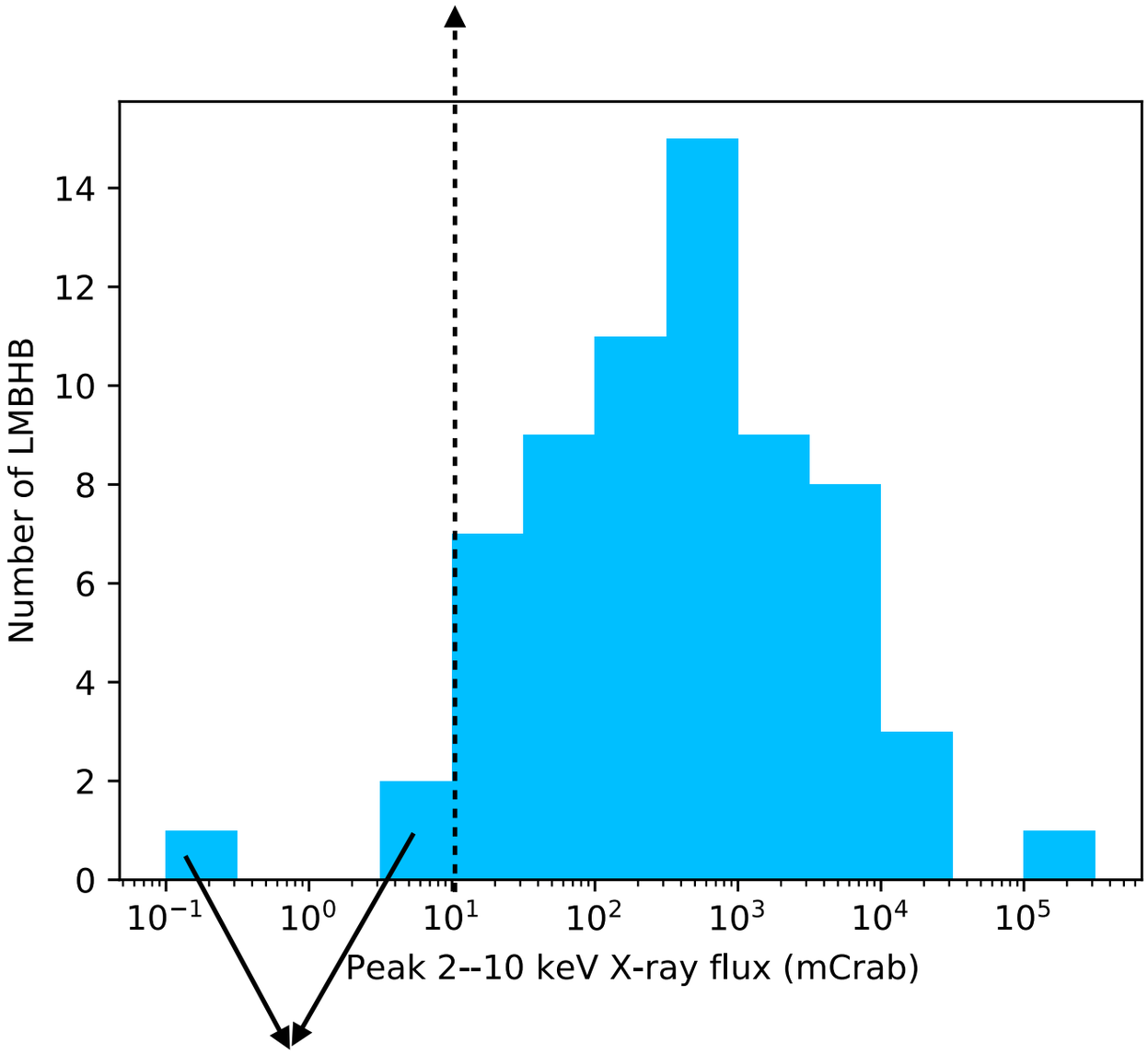
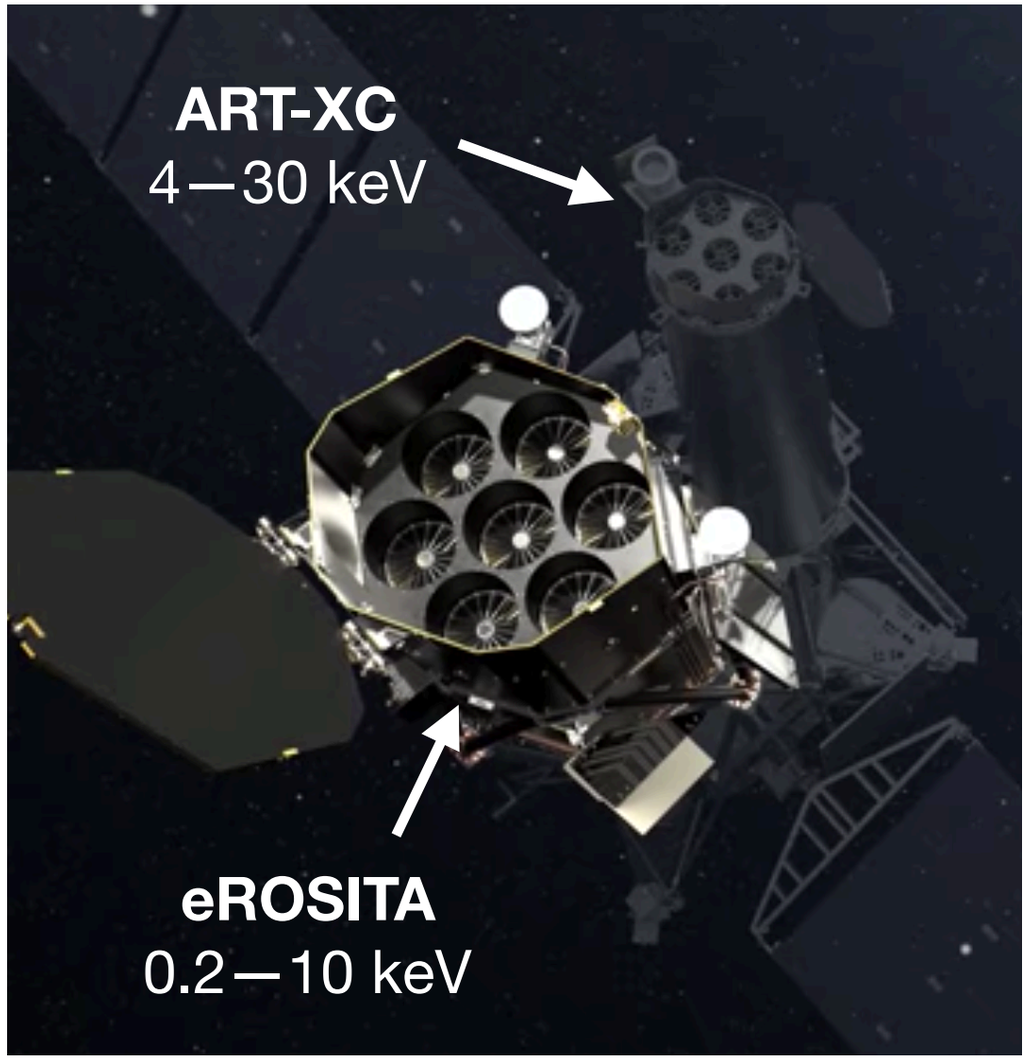


Dedicated monitoring of the Galactic Center

Corral-Santana+2016

SRG X-ray all-sky survey
8 epochs in **4 years**
Reach **~1μCrab** in each epoch



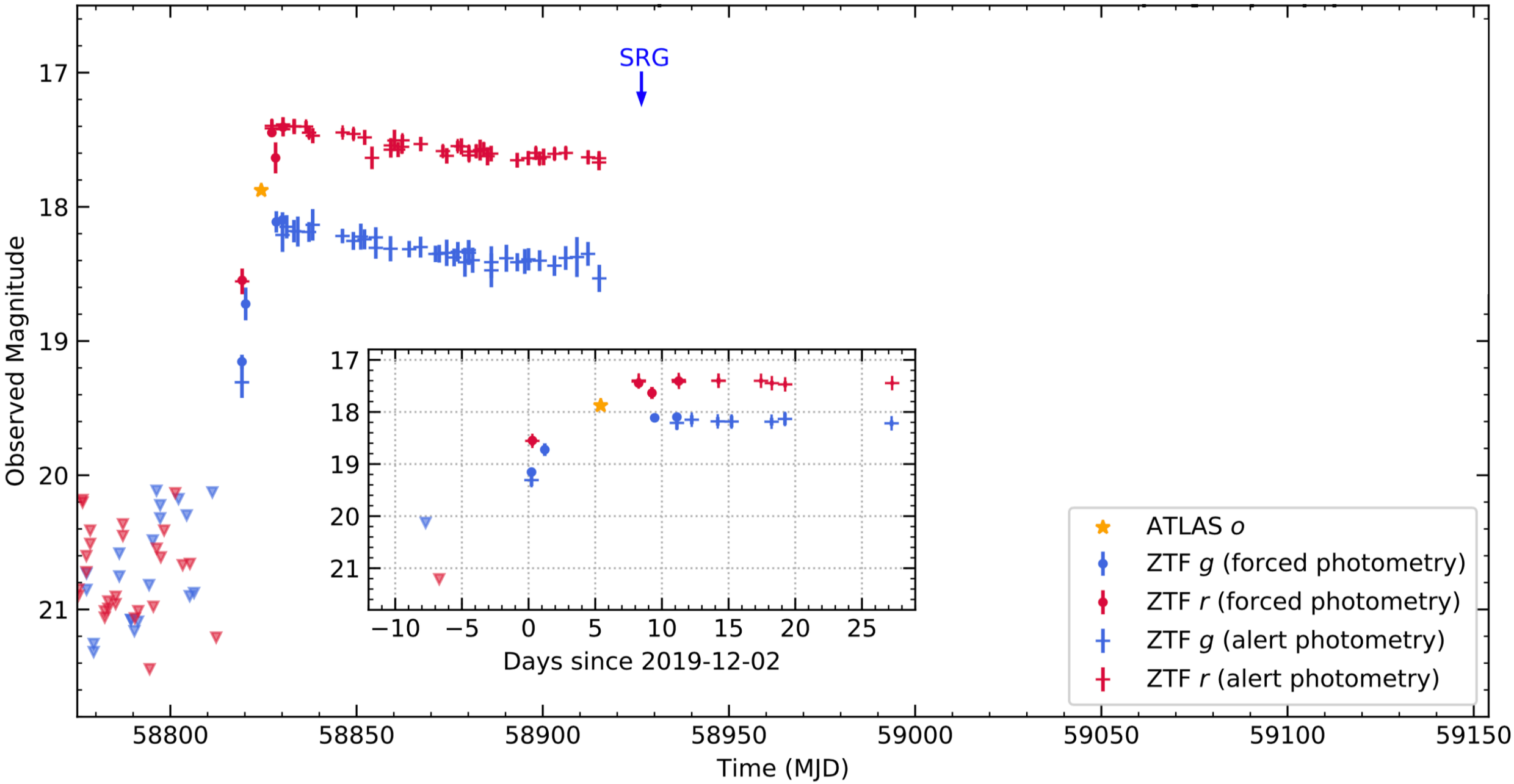
Localize sources to **~ 5”**

- Find faint X-ray bursts at large distance
- Easy to associate with optical counterpart

Discovery of an Optical and X-ray Transient

- ZTF 1st detection: Dec 2, 2019
- SRG discovery: Mar 18, 2020. ~1 mCrab.

AT2019wey

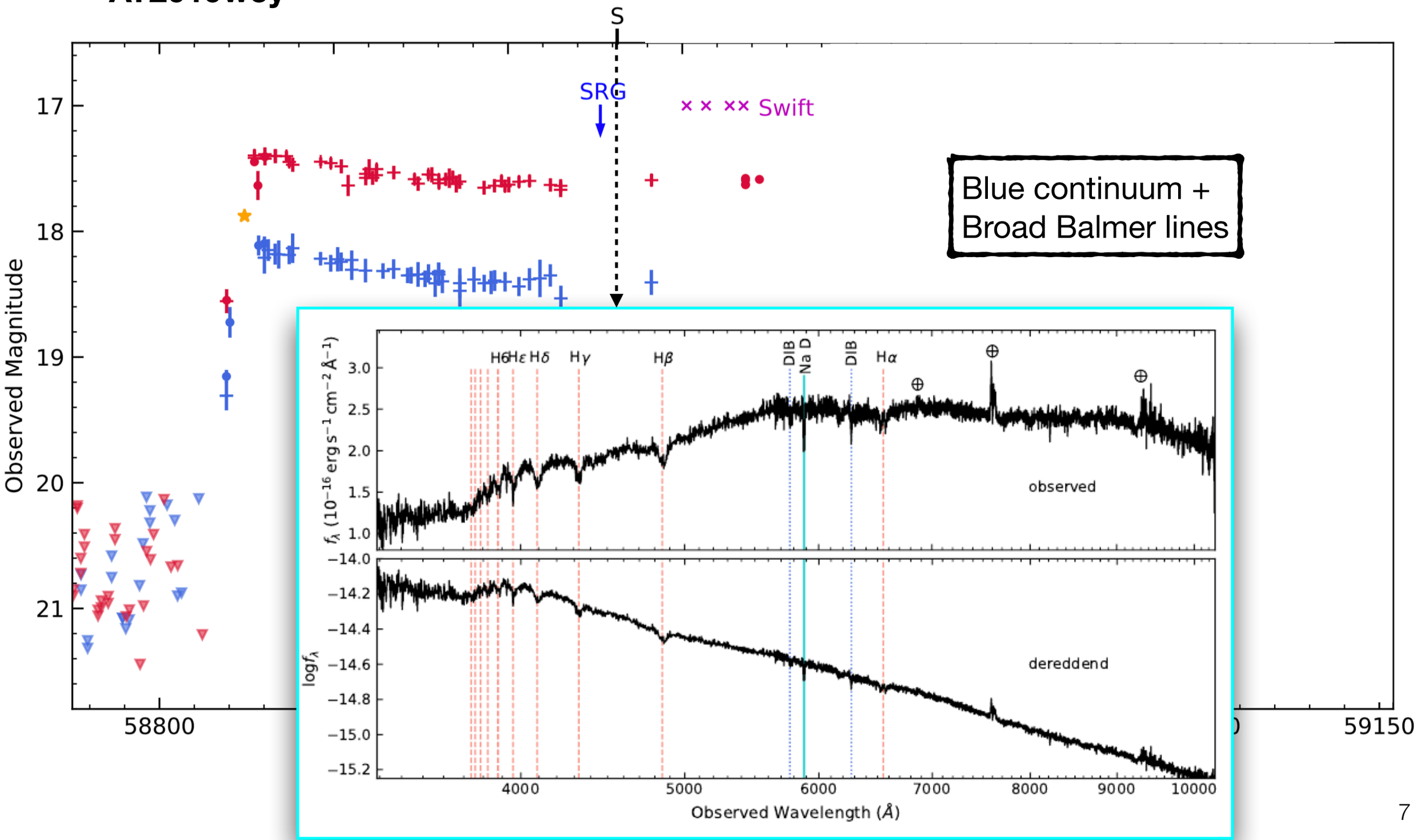


Discovery of an Optical and X-ray Transient

Galactic Origin
E(B-V) ~0.8—1.3 mag

- *Swift*/*NuSTAR* spectrum in Apr: power-law Γ~1.8

AT2019wey



Discovery of an Optical and X-ray Transient

Galactic Origin
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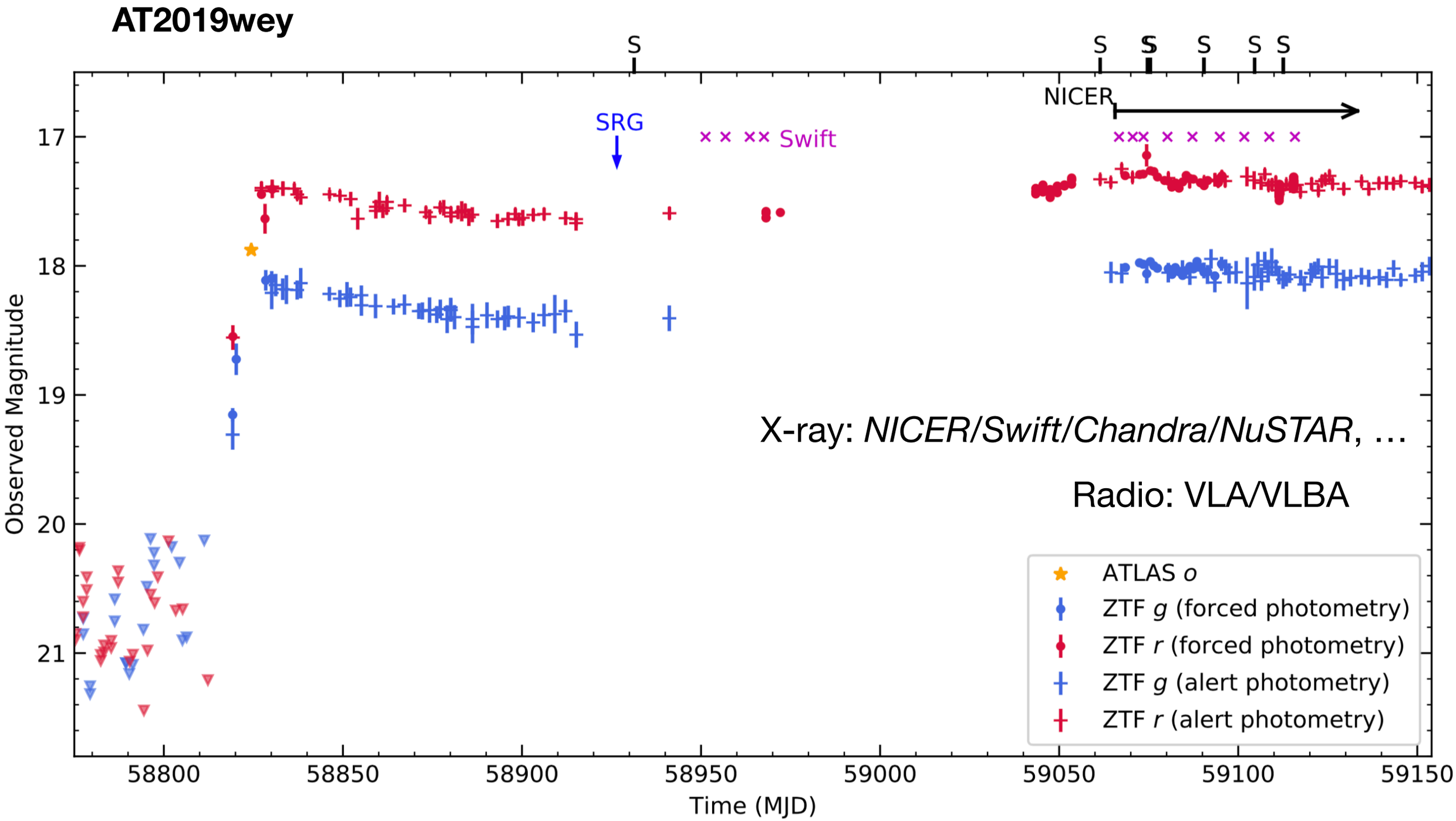
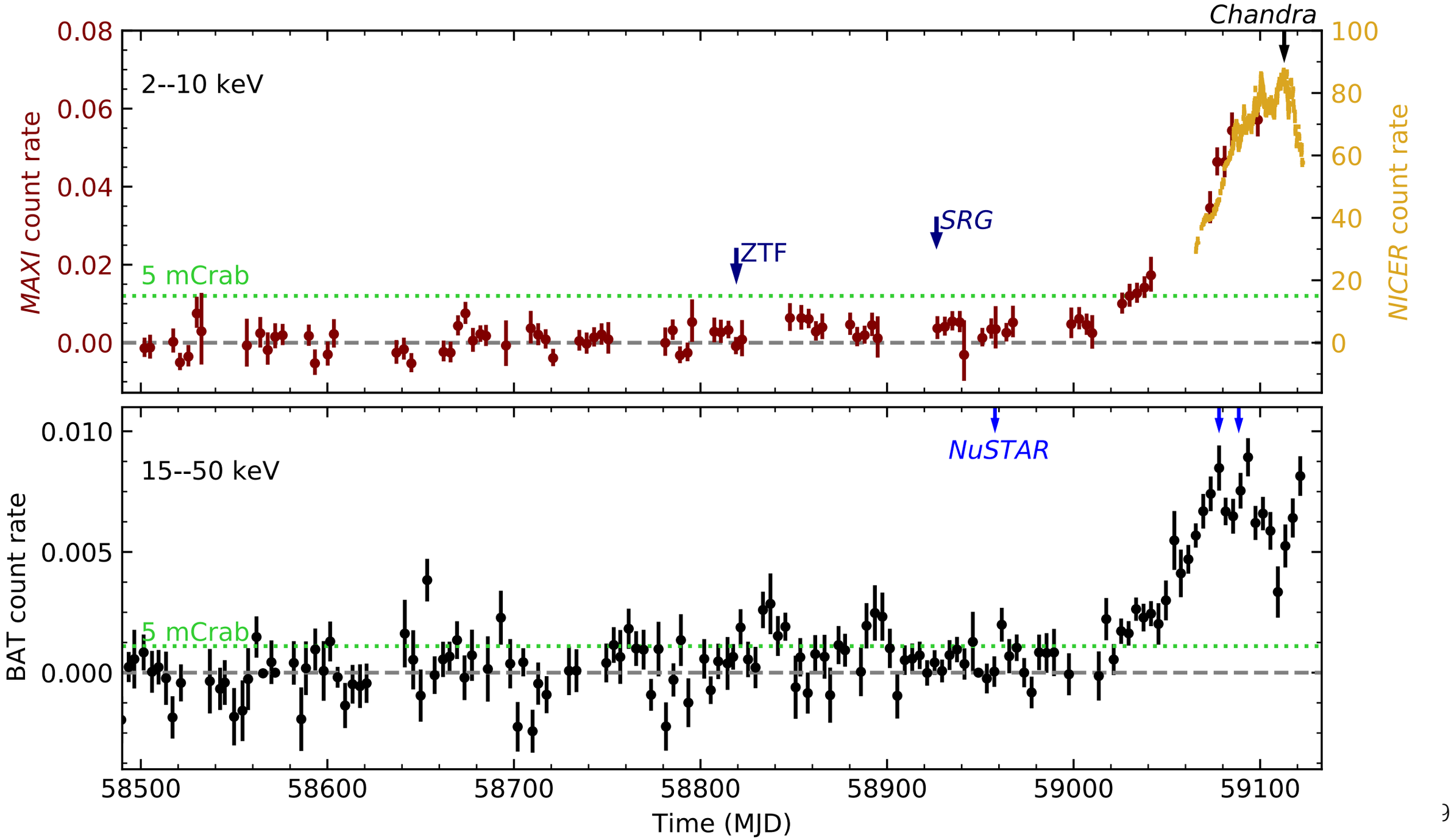
Comprehensive Multi-wavelength Follow-up

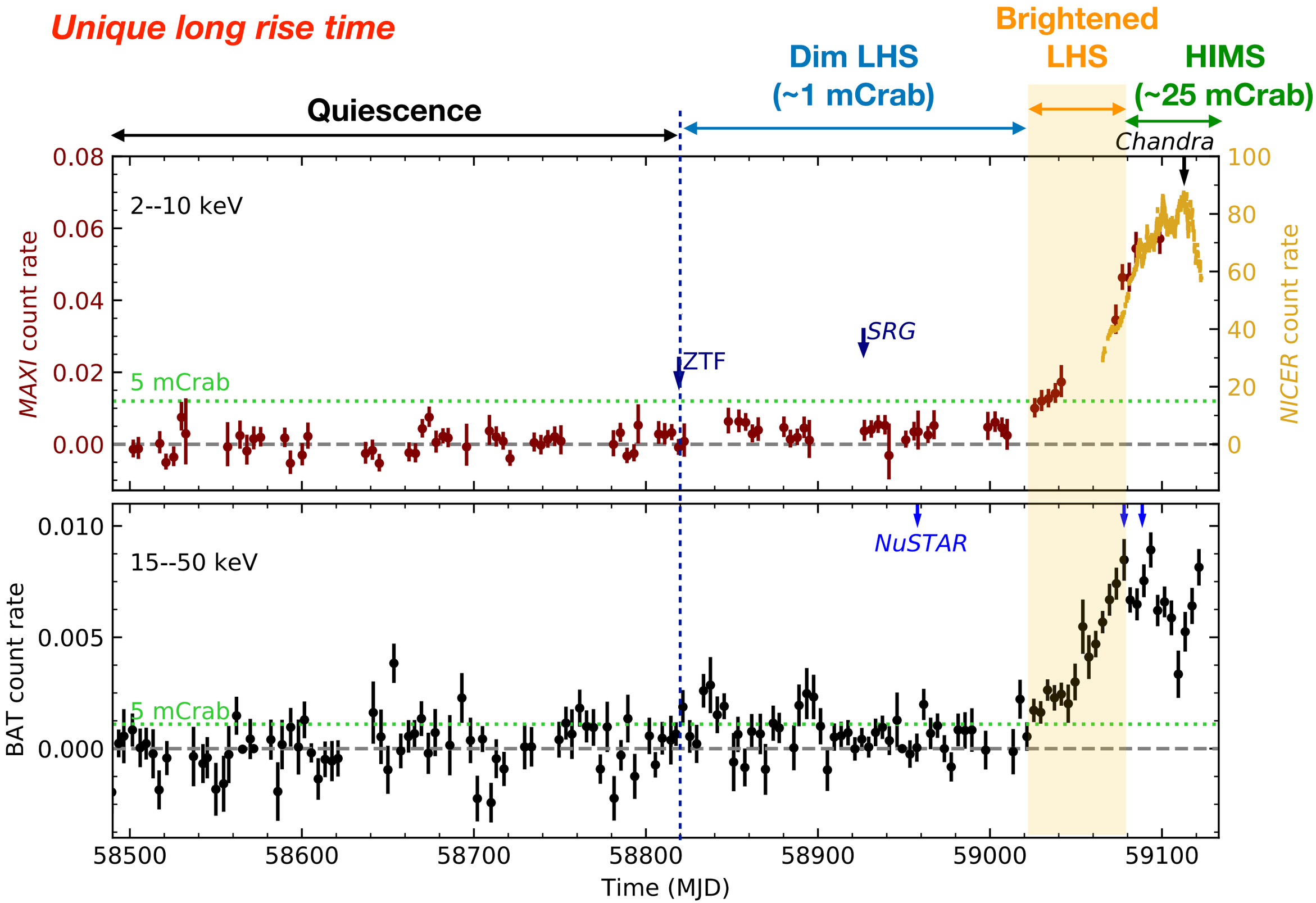


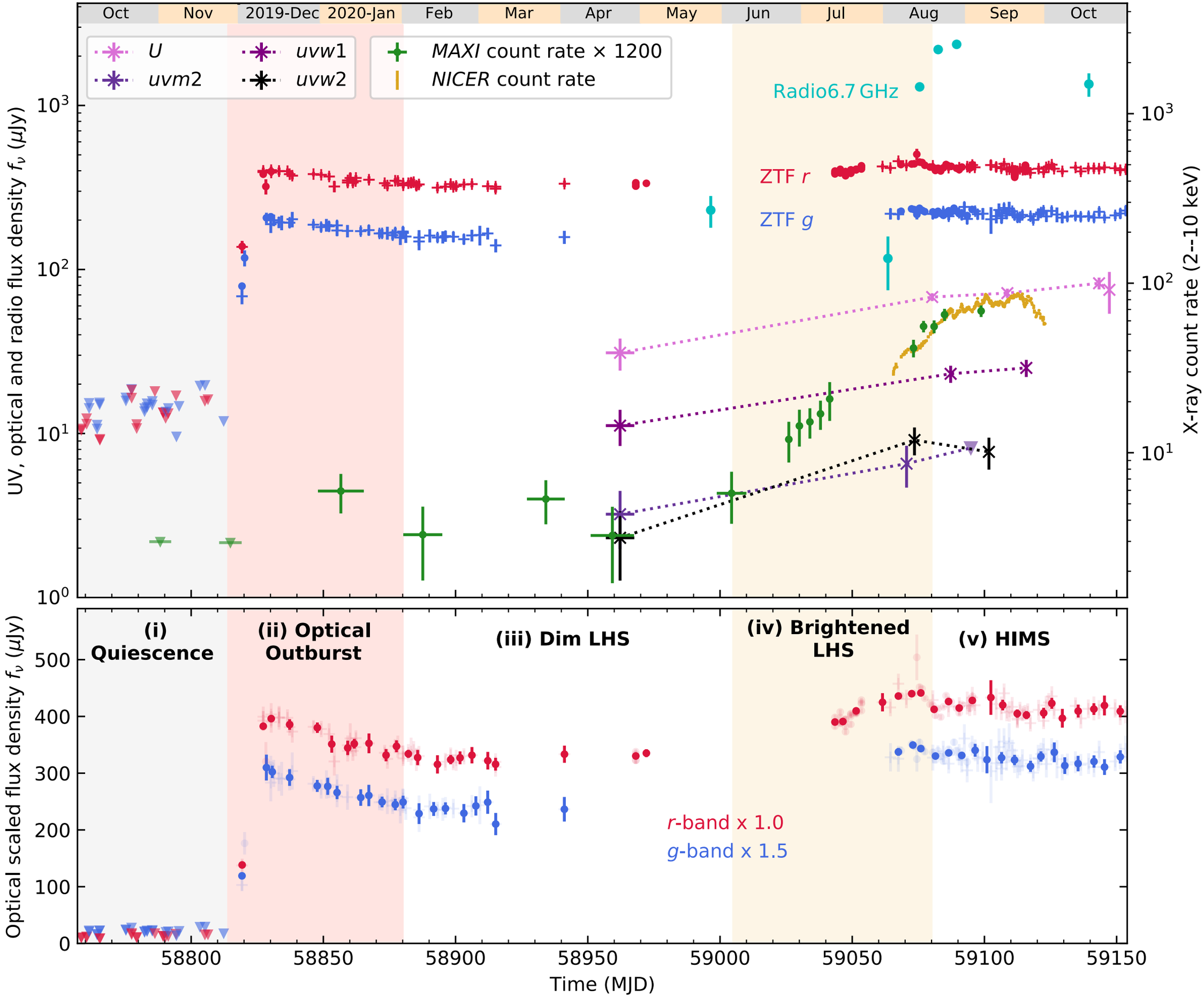
X-ray Light Curve



X-ray Light Curve

X-ray properties consistent with LMBHB in the low/hard-state (LHS) or hard-intermediate state (HIMS)

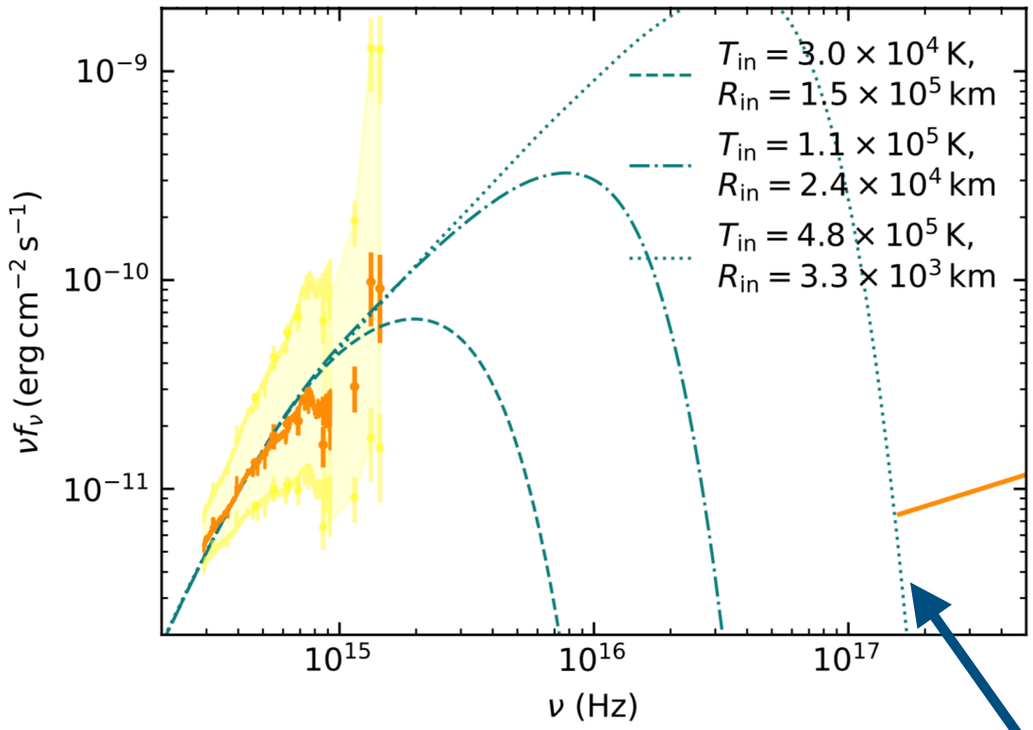


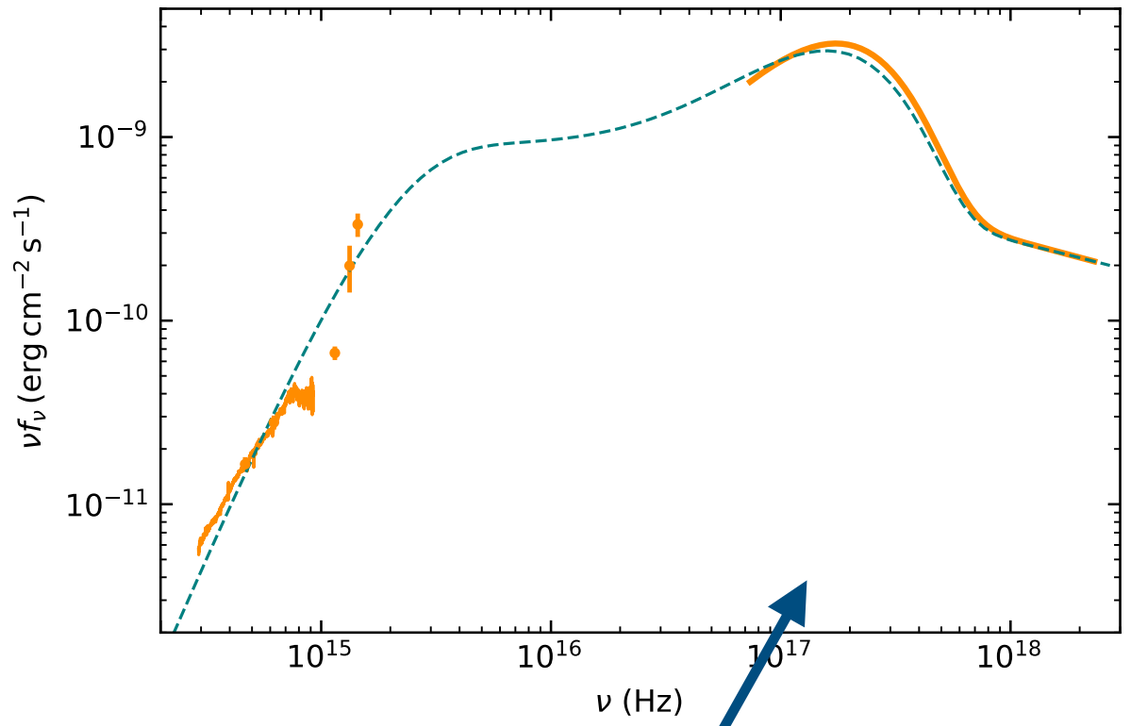

Oct
Nov
2019-Dec
2020-Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
U
uvm2
uvw1
uvw2
MAXI count rate × 1200
NICER count rate
Radio6.7 GHz
ZTF r
ZTF g
UV, optical and radio flux density f_ν (μJy)
X-ray count rate (2--10 keV)
(i) Quiescence
(ii) Optical Outburst
(iii) Dim LHS
(iv) Brightened LHS
(v) HIMS
r-band x 1.0
g-band x 1.5
Optical scaled flux density f_ν (μJy)
Time (MJD)

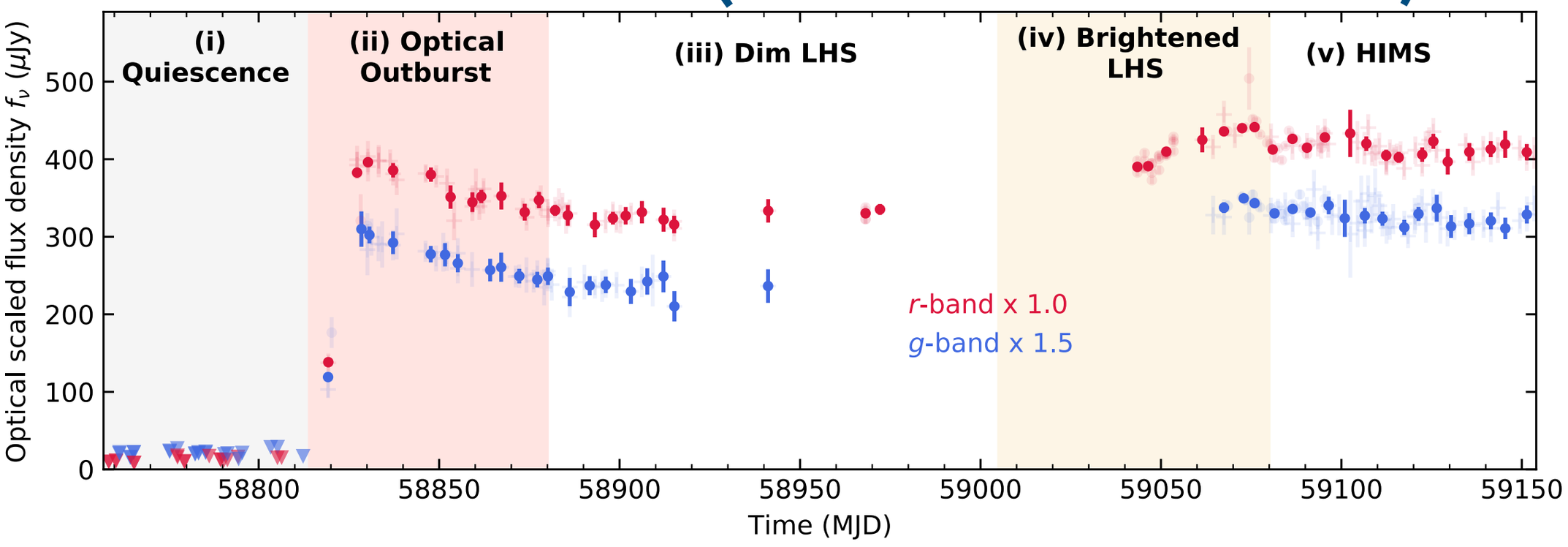
Origin of UV/optical emission in LHS & HIMS

$$L_{\rm opt} = A L_{\rm X}^{\beta}$$

- Most other LMBHBs: β ~ 0.6 (irradiation/jet)
- AT2019wey: β ~ 0.1 (???)







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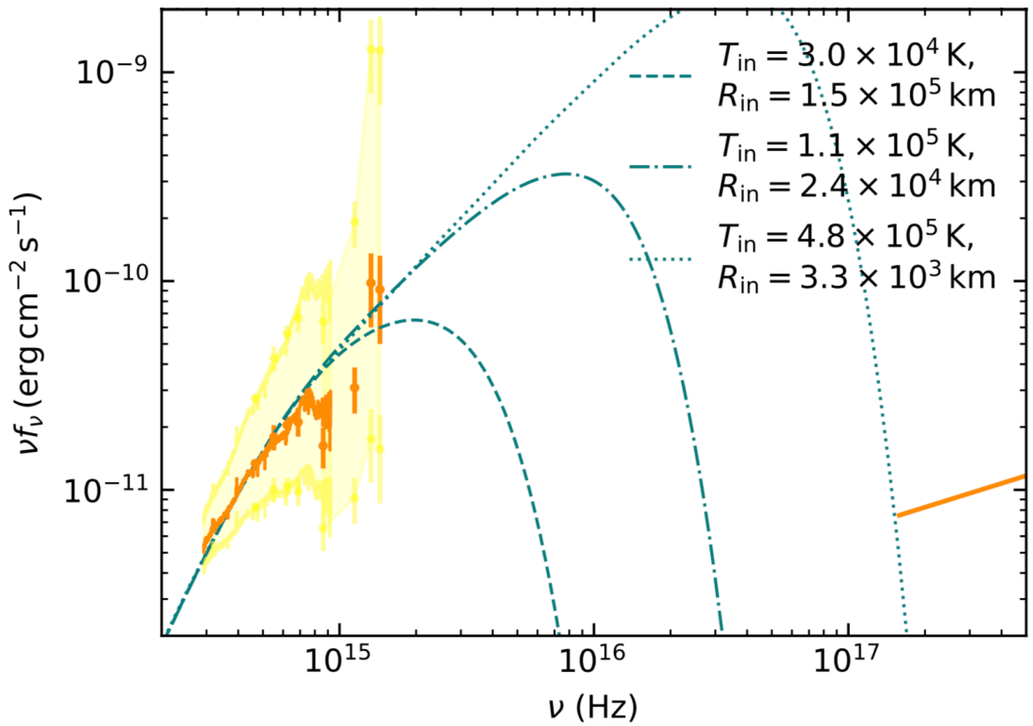
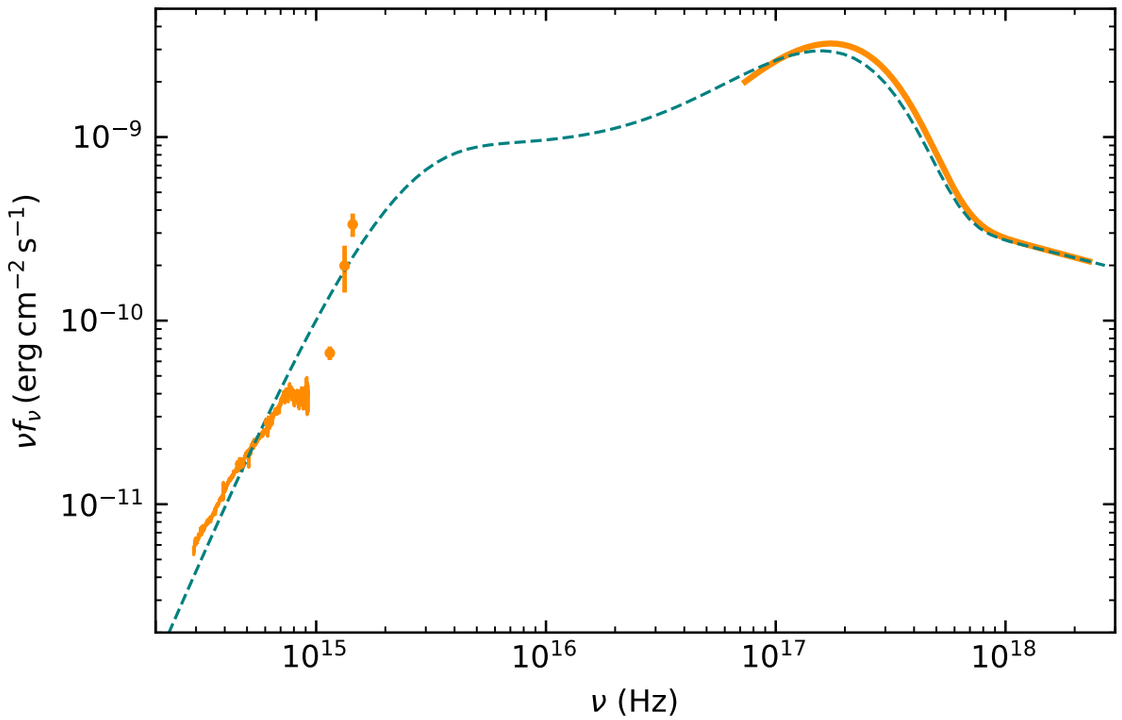
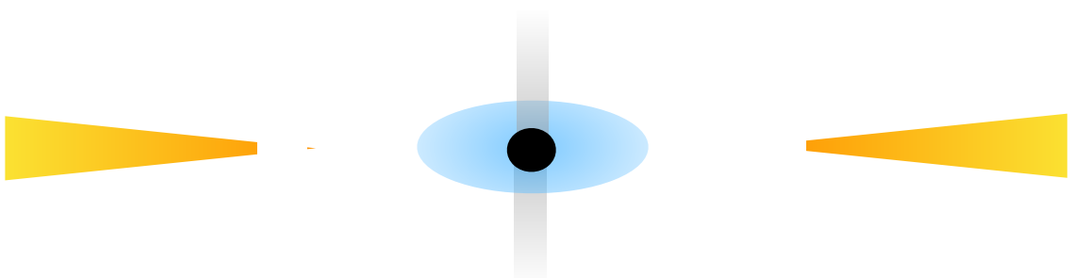
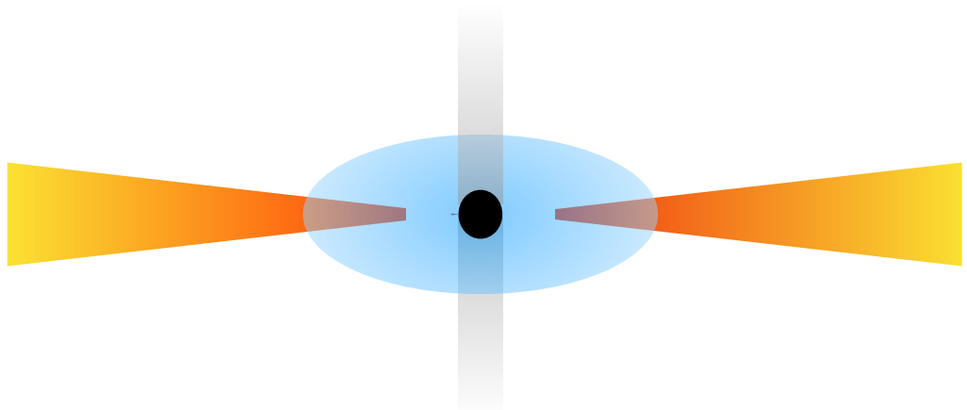






Intrinsic thermal emission from accretion disk at $R_{\rm in}$ > 100 $R_{\rm s}$



X-ray reprocessing at the outer accretion disk

The Population of LMBHBs with Faint X-ray Outbursts

Short-period (<10 h) binaries ⟷ Small disks ⟷ Low accretion rates

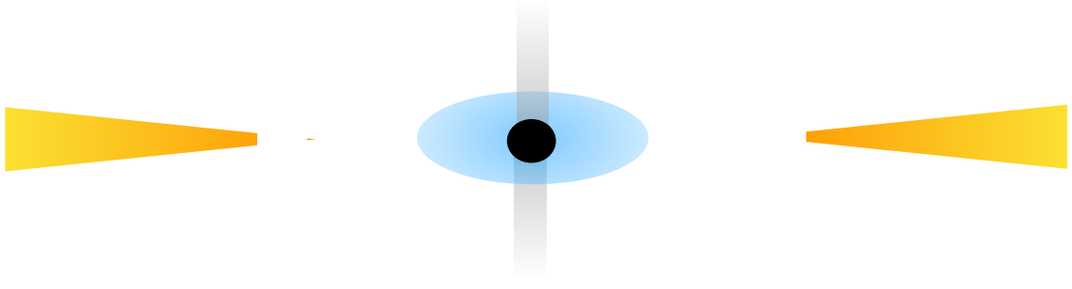
↓

Hot Accretion Flows

↙ ↘

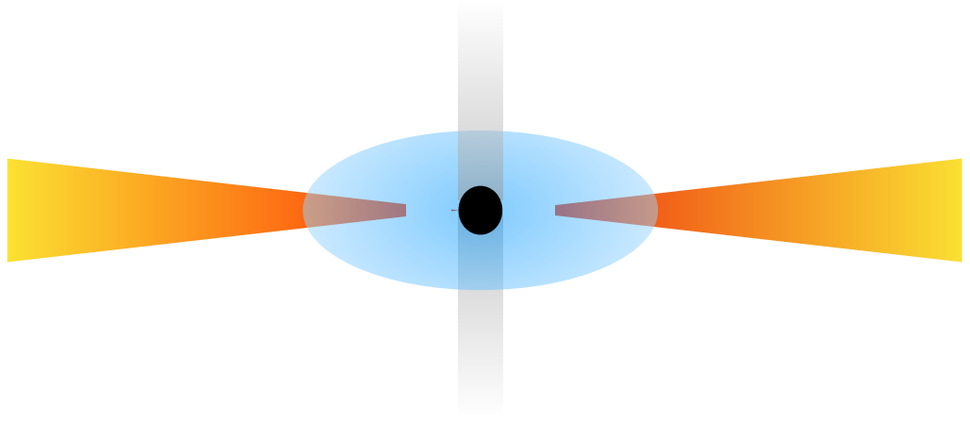
Bright Optical Outbursts

Wide-field optical Survey:
ZTF, ATLAS, …



Faint prolonged X-ray Outbursts

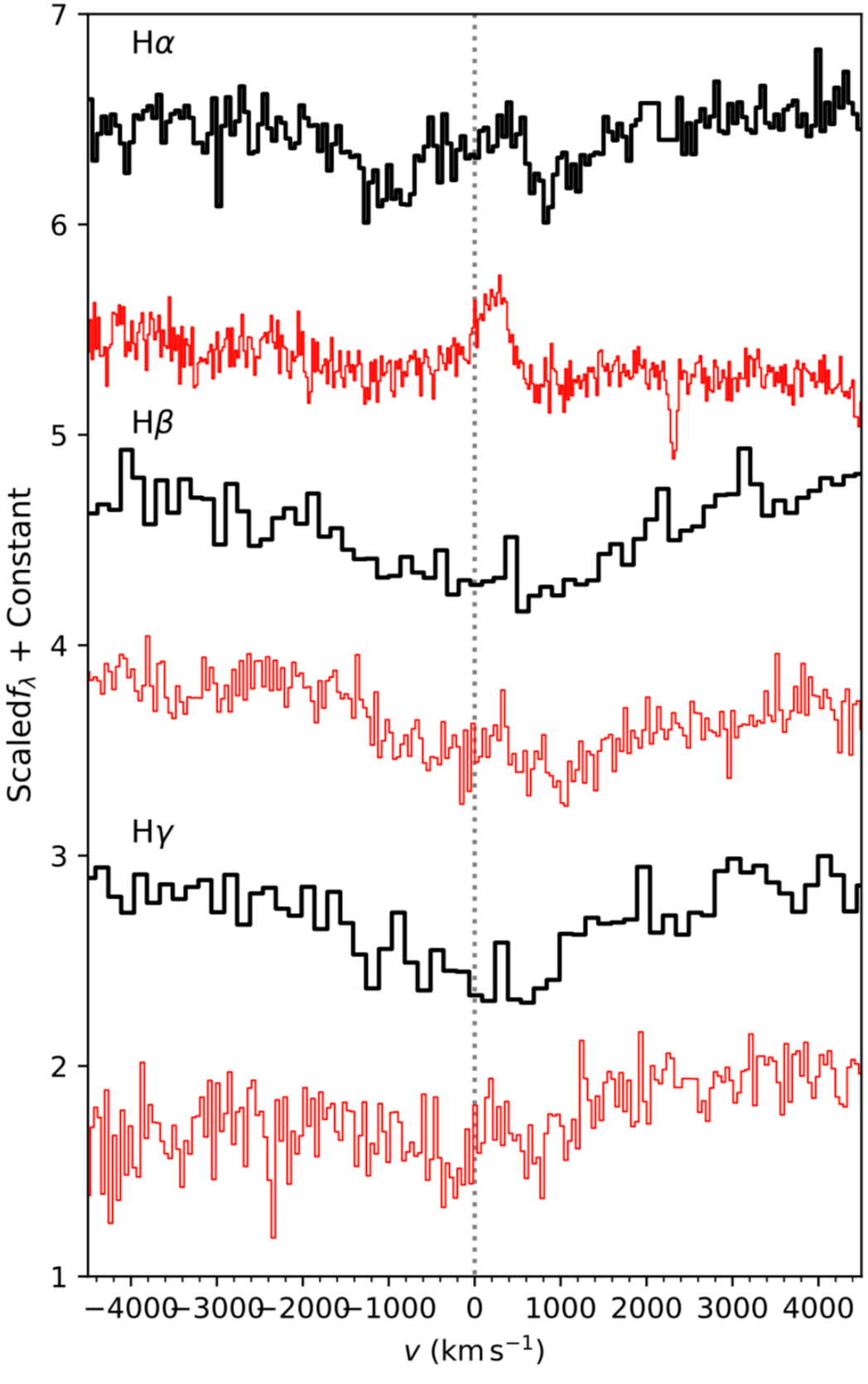
SRG for discovery
Follow-up: *Swift*, *Chandra*, *XMM*, *NICER*, *NuSTAR*, …



Thank you!

Back-up

Optical: Variable Balmer

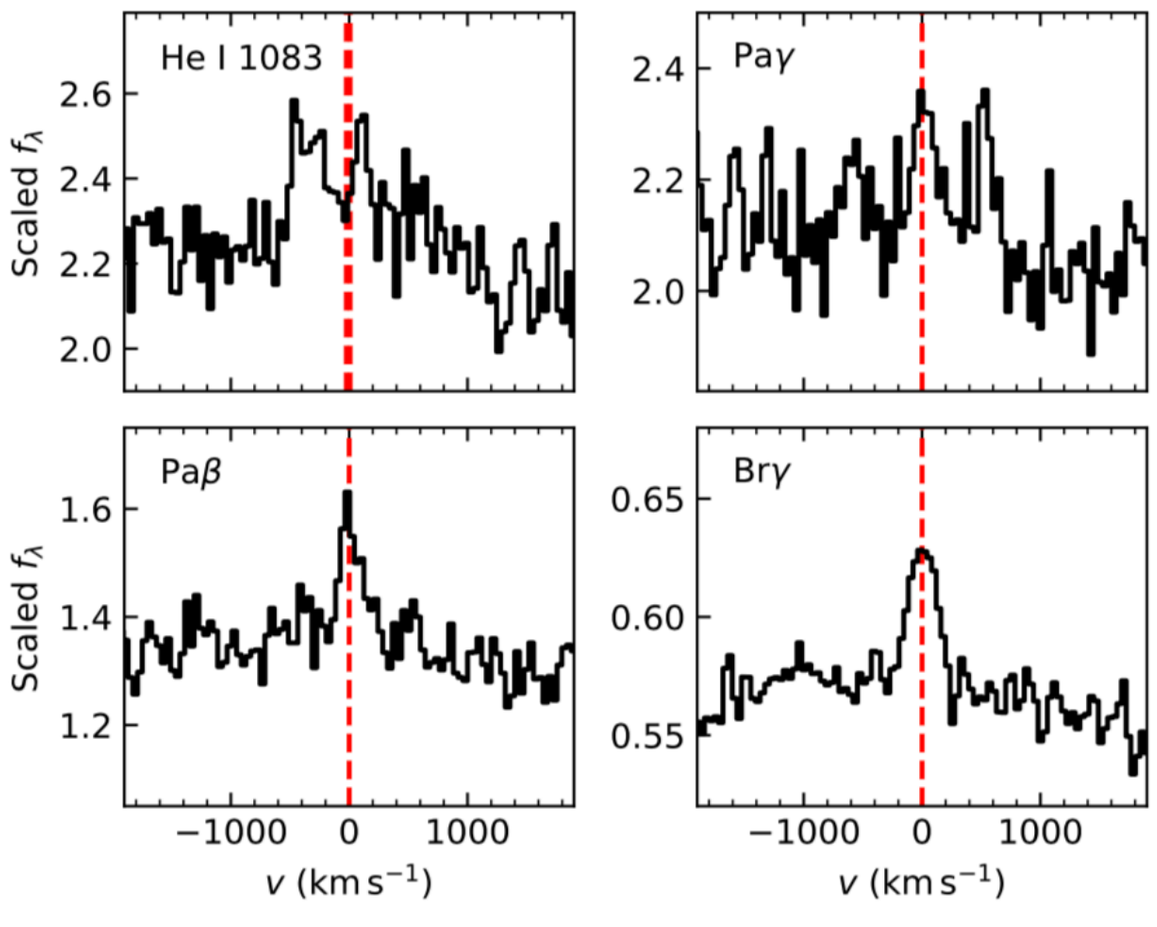


2020-03-23
KeckI-LRIS

2020-09-12
KeckII-ESI

- Broad emission and absorption lines
- Observed in LMXB BHB & DN

NIR: Helium and Hydrogen



Orbital Modulation at 1.3 hr? Not conclusive…

ZTF deep drill observation