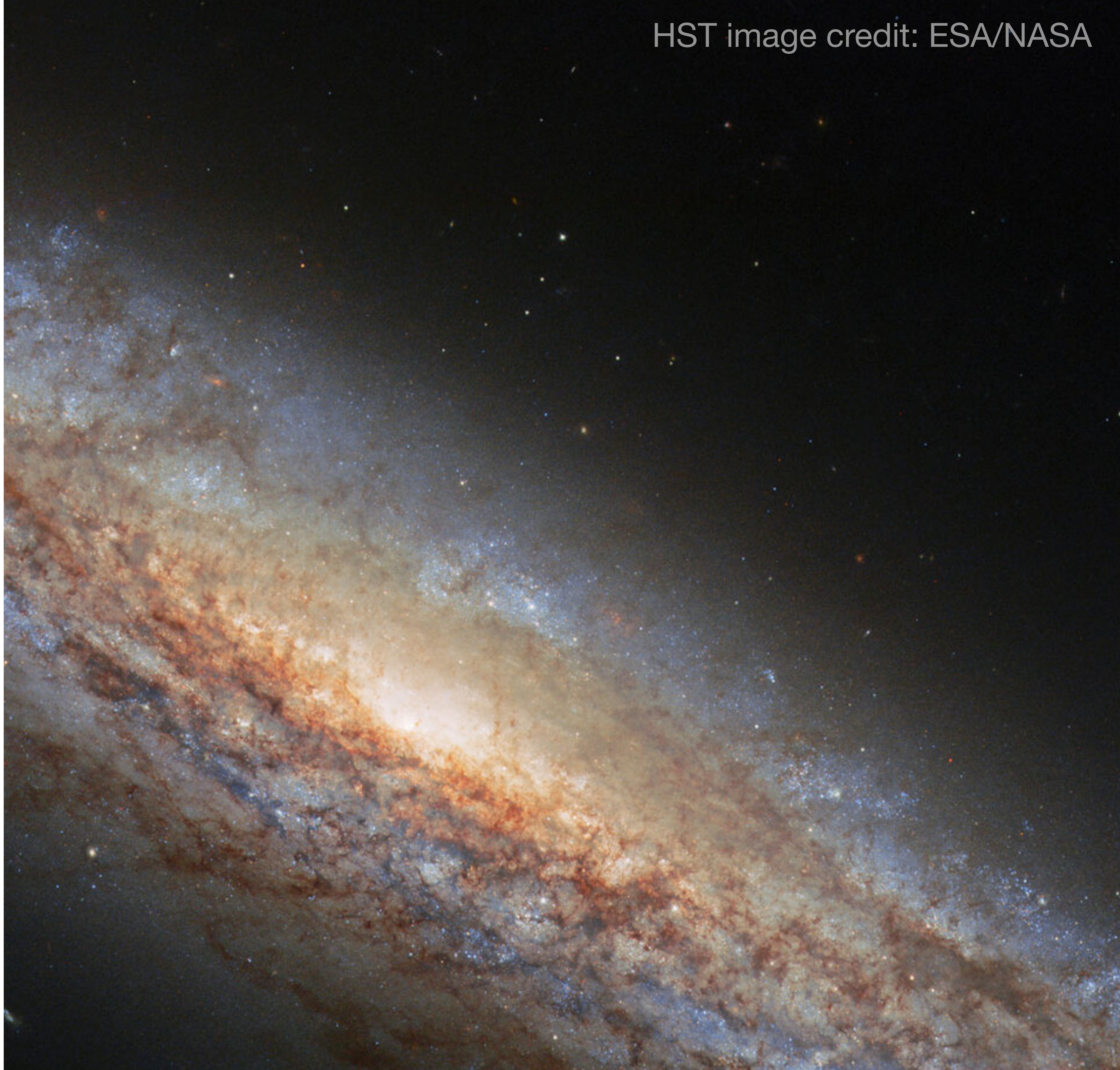
Nuclear Transients in ZTF and GW follow up

MMS Meeting
June 5, 2023

Simeon Reusch



I) ZTF 🔭

It has been an exciting few years for the study of nuclear transients!

First ZTF TDE

van Velzen+ 2019

The Astrophysical Journal, 872:198 (11pp), 2019 February 20 https://doi.org/10.3847/1538-4357/aafe0c

CrossMark

The First Tidal Disruption Flare in ZTF: From Photometric Selection to Multi-wavelength Characterization

Sjoert van Velzen[1,2], Suvi Gezari[1,3], S. Bradley Cenko[3,4], Erin Kara[1,3,5], James C. A. Miller-Jones[6], Tiara Hung[1], Joe Bright[7], Nathaniel Roth[1,3], Nadejda Blagorodnova[8], Daniela Huppenkothen[9], Lin Yan[10], Eran Ofek[11], Jesper Sollerman[12], Sara Frederick[1], Charlotte Ward[1], Matthew J. Graham[8], Rob Fender[7], Mansi M. Kasliwal[8], Chris Canella[8], Robert Stein[13], Matteo Giomi[14], Valery Brinnel[14], Jakob van Santen[13], Jakob Nordin[14], Eric C. Bellm[9], Richard Dekany[15], Christoffer Fremling[8], V. Zach Golkhou[9,16], Thomas Kupfer[8,17,18], Shrinivas R. Kulkarni[8], Russ R. Laher[19], Ashish Mahabal[8,20], Frank J. Masci[21], Adam A. Miller[22,23], James D. Neill[8], Reed Riddle[15], Mickael Rigault[24], Ben Rusholme[21], Maayane T. Soumagnac[25], and Yutaro Tachibana (優太朗橘)[26,27]

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29 more


THE ASTROPHYSICAL JOURNAL, 908:4 (26pp), 2021 February 10

https://doi.org/10.3847/1538-4357/abc258

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Seventeen Tidal Disruption Events from the First Half of ZTF Survey Observations: Entering a New Era of Population Studies

Sjoert van Velzen[1,2], Suvi Gezari[1,3], Erica Hammerstein[1], Nathaniel Roth[1,3], Sara Frederick[1], Charlotte Ward[1], Tiara Hung[4], S. Bradley Cenko[3,5], Robert Stein[6], Daniel A. Perley[7], Kirsty Taggart[7], Ryan J. Foley[4], Jesper Sollerman[8], Nadejda Blagorodnova[9], Igor Andreoni[10], Eric C. Bellm[11], Valery Brinnel[12], Kishalay De[10], Richard Dekany[13], Michael Feeney[13], Christoffer Fremling[10], Matteo Giomi[14], V. Zach Golkhou[11,15], Matthew J. Graham[10], Anna. Y. Q. Ho[10], Mansi M. Kasliwal[10], Charles D. Kilpatrick[4], Shrinivas R. Kulkarni[10], Thomas Kupfer[15], Russ R. Laher[16], Ashish Mahabal[10,17], Frank J. Masci[16], Adam A. Miller[18,19], Jakob Nordin[12], Reed Riddle[13], Ben Rusholme[16], Jakob van Santen[6], Yashvi Sharma[10], David L. Shupe[16], and Maayane T. Soumagnac[20,21]
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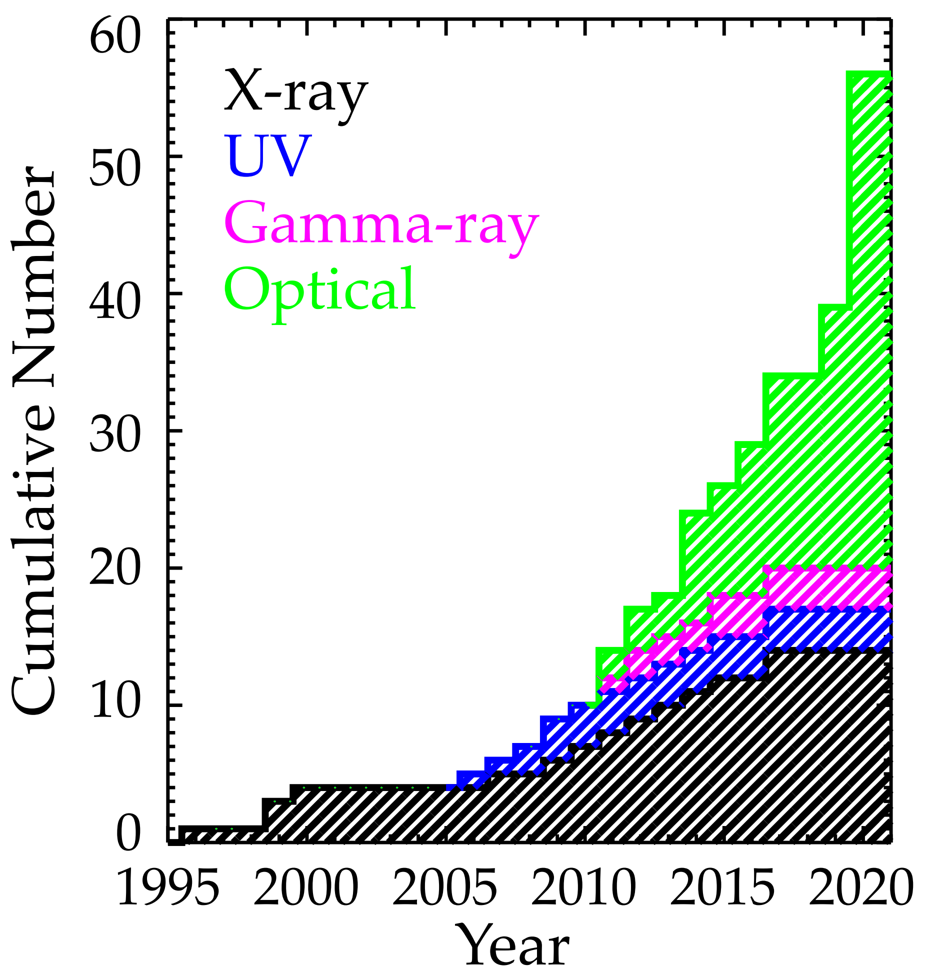
https://doi.org/10.3847/1538-4357/aafe0c

van Velzen+ 2019

van Velzen+ 2021



29 more


The Astrophysical Journal, 908:4 (26pp), 2021 February 10
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Seventeen Tidal Disruption Events ... Entering a N...

Sjoert van Velzen[1,2], Suvi Gezari[1,3], Erica Han..., Tiara Hung[4], S. Bradley Cenko[3,5], Robert Stein[6], Da..., Nadejda Blagorodnova[9], Igor Andreoni[10], Eric C..., Michael Feeney[13], Christoffer Fremling[10], Matt..., Anna. Y. Q. Ho[10], Mansi M. Kasliwal[10], Charles ..., Russ R. Laher[16], Ashish Mahabal[10,17], Frank J. Masc..., Ben Rusholme[16], Jakob van Santen[6], Yashvi Sharma...

The Astrophysical Journal, 942:9 (35pp), 2023 January 1
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The Final Season Reimagined: 30 Tidal Disruption Events from the ZTF-I Survey

Erica Hammerstein[1,2,3], Sjoert van Velzen[4], Suvi Gezari[5], S. Bradley Cenko[2,6], Yuhan Yao[7], Charlotte Ward[1,21], Sara Frederick[8], Natalia Villanueva[9], Jean J. Somalwar[7], Matthew J. Graham[7], Shrinivas R. Kulkarni[7], Daniel Stern[10], Igor Andreoni[1,2,6,22], Eric C. Bellm[11], Richard Dekany[12], Suhail Dhawan[13], Andrew J. Drake[7], Christoffer Fremling[7], Pradip Gatkine[7], Steven L. Groom[14], Anna Y. Q. Ho[15], Mansi M. Kasliwal[7], Viraj Karambelkar[7], Erik C. Kool[16], Frank J. Masci[14], Michael S. Medford[17,18], Daniel A. Perley[19], Josiah Purdum[12], Jan van Roestel[7], Yashvi Sharma[7], Jesper Sollerman[16], Kirsty Taggart[20], and Lin Yan[12]

Received 2022 February 25; revised 2022 October 13; accepted 2022 October 14; published 2022 December 28

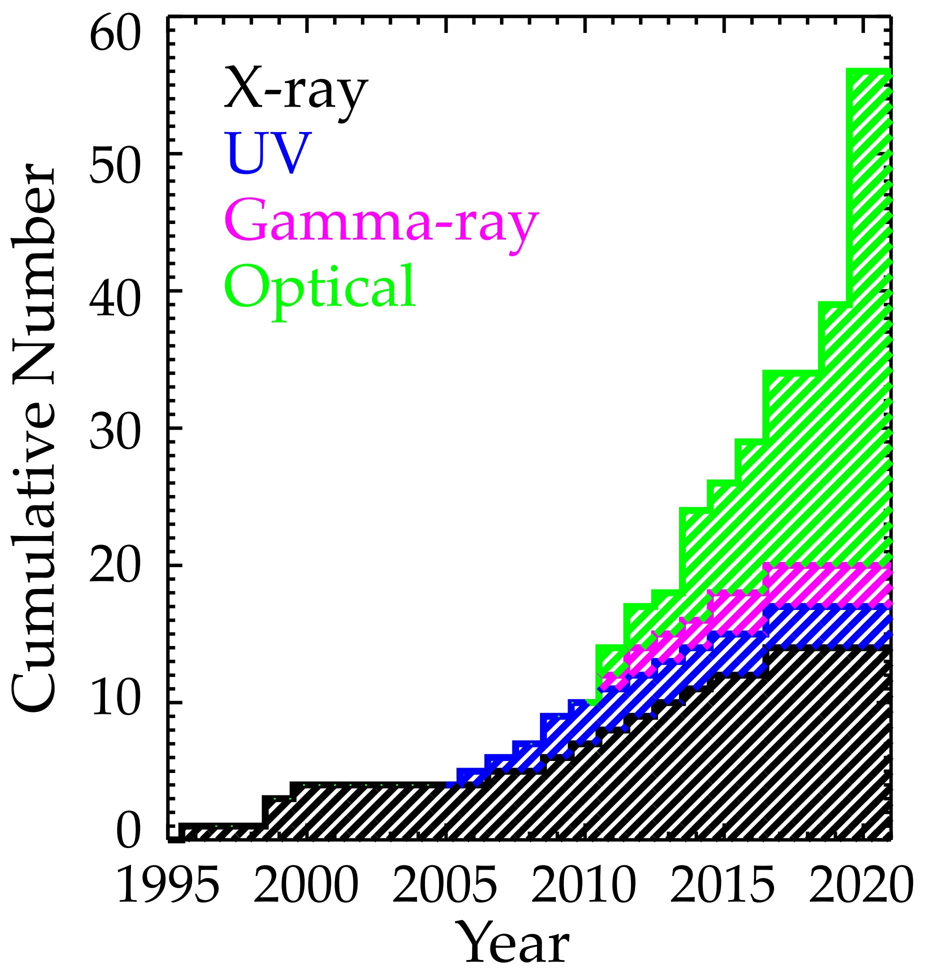
Abstract

Tidal disruption events (TDEs) offer a unique way to study dormant black holes. While the number of observed TDEs has grown thanks to the emergence of wide-field surveys in the past few decades, questions regarding the nature of the observed optical, UV, and X-ray emission remain. We present a uniformly selected sample of 30 spectroscopically classified TDEs from the Zwicky Transient Facility Phase I survey operations with follow-up

van Velzen+ 2019

van Velzen+ 2021

Hammerstein+ 2021



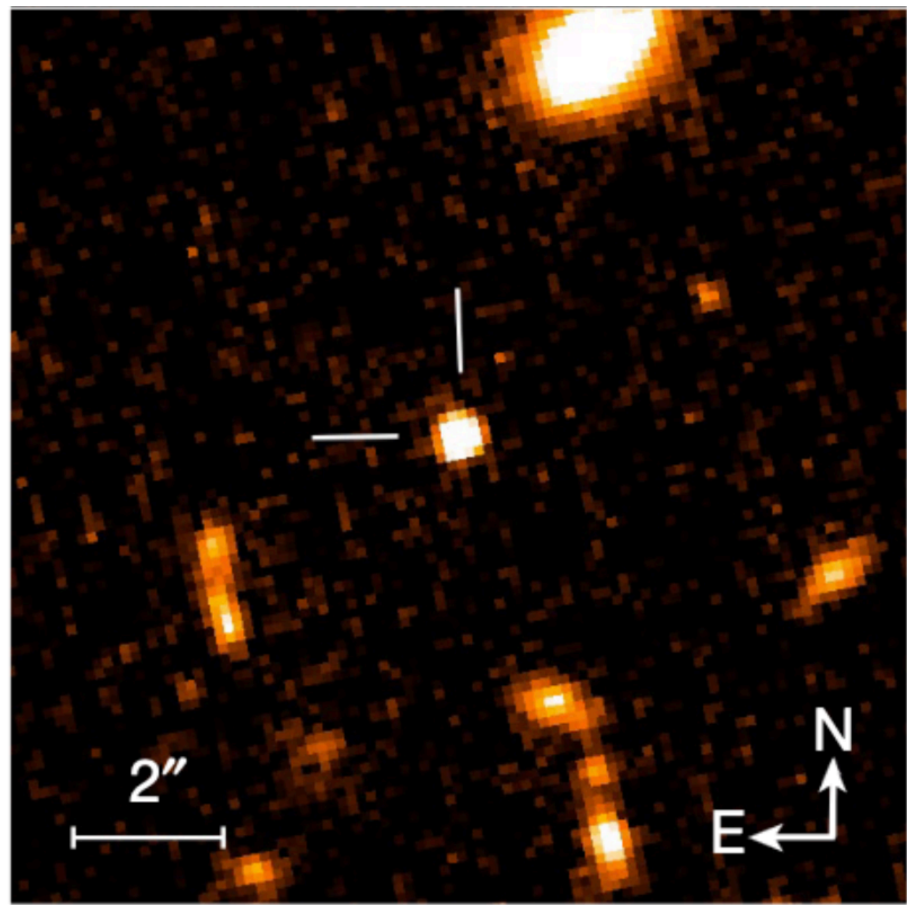
A jetted TDE

van Velzen+ 2019

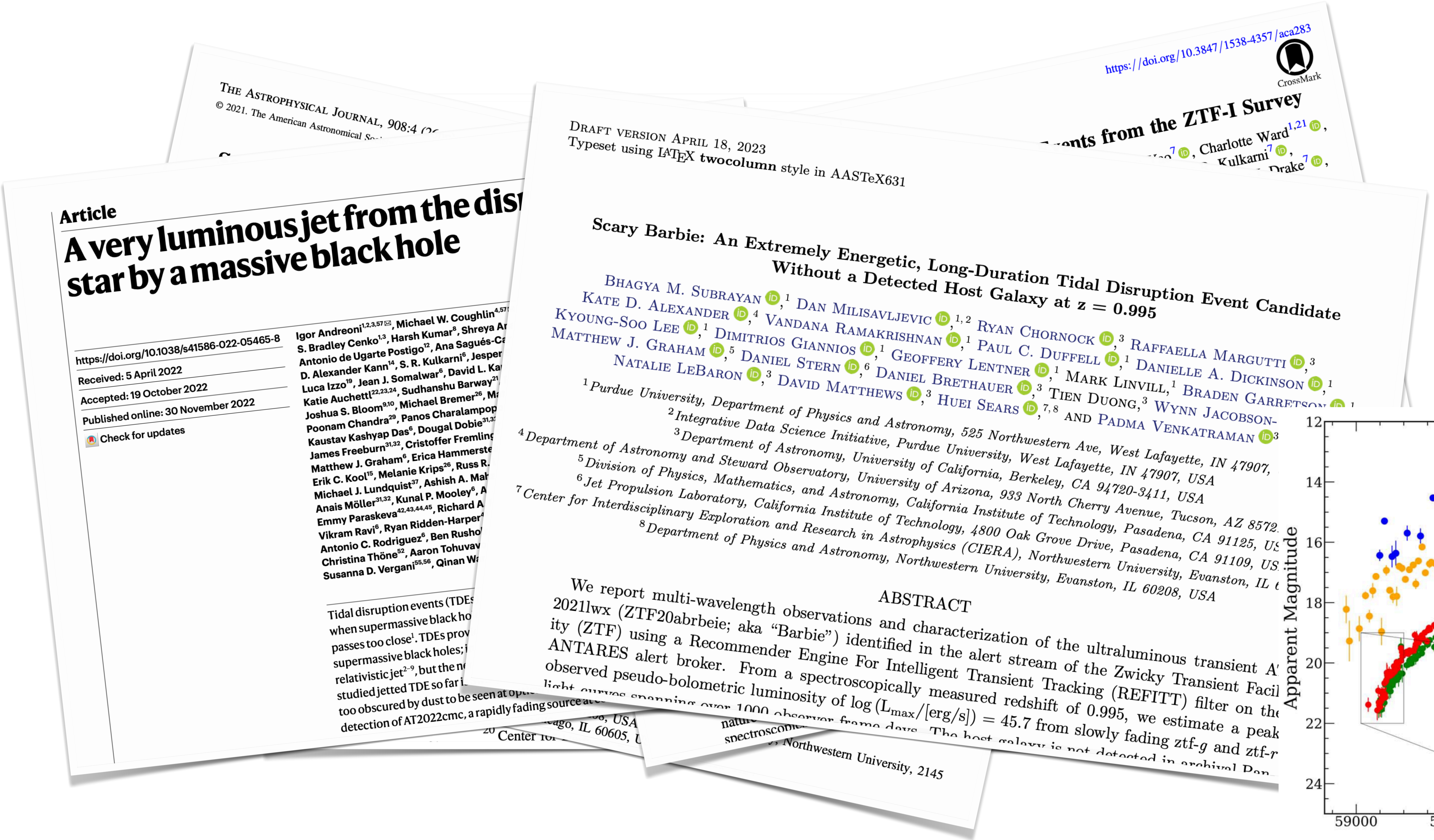
van Velzen+ 2021

Hammerstein+ 2021

Andreoni+ 2022



An extremely energetic TDE



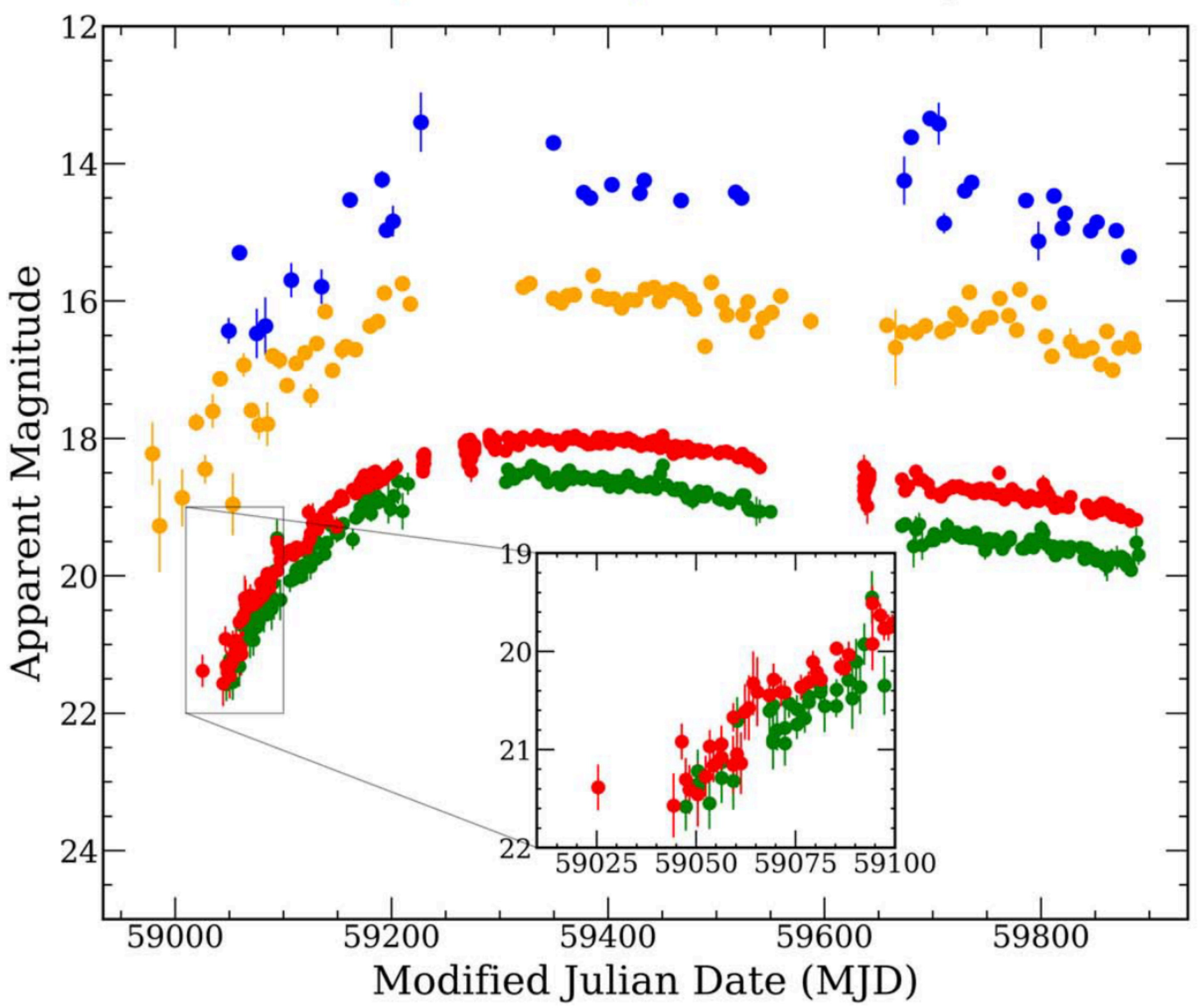
van Velzen+ 2019

van Velzen+ 2021

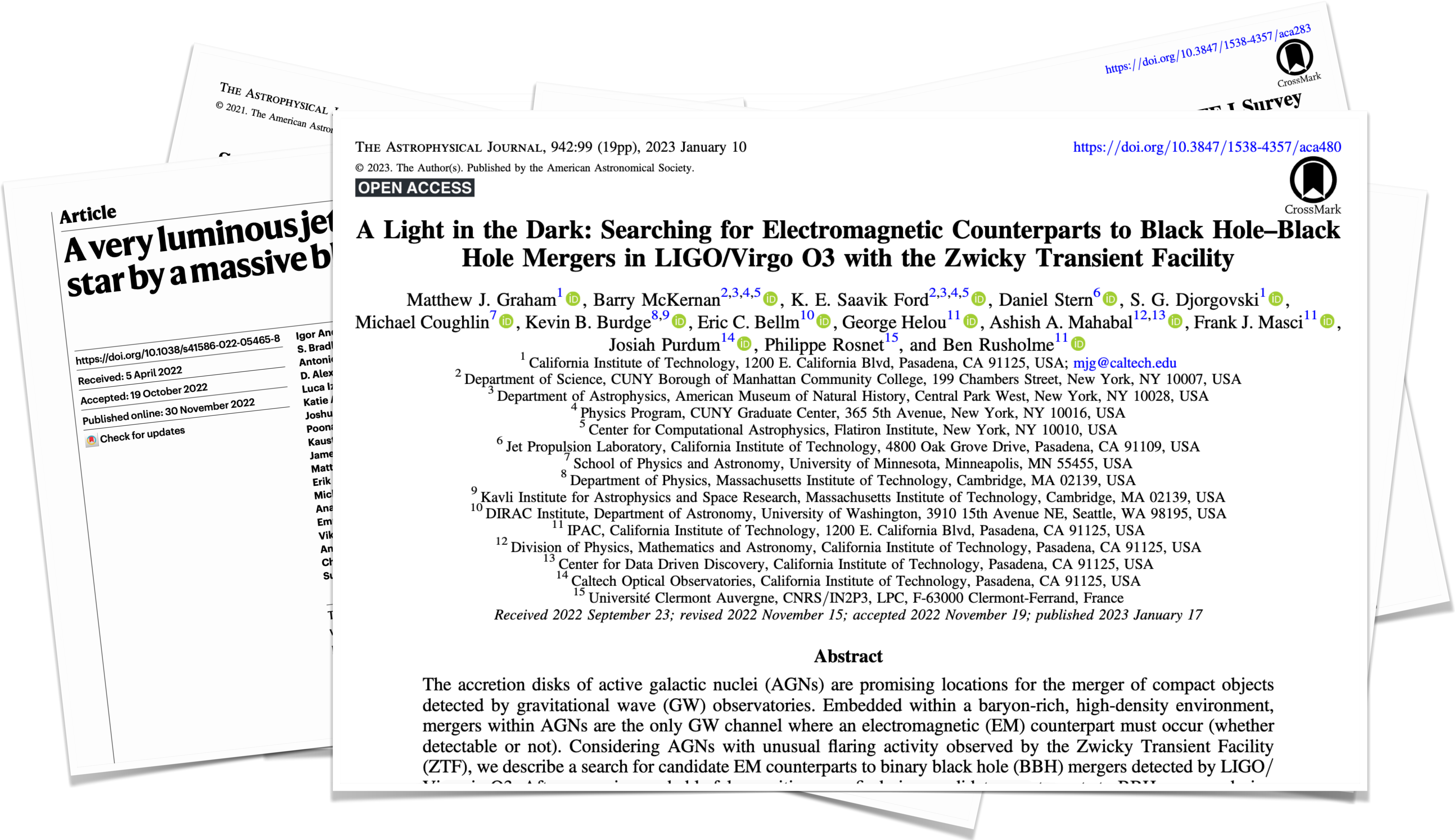
Hammerstein+ 2021

Andreoni+ 2022

Subrayan+ 2023



Possible EM counterparts to BH-BH mergers


The Astrophysical Journal, 942:99 (19pp), 2023 January 10 https://doi.org/10.3847/1538-4357/aca480

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A Light in the Dark: Searching for Electromagnetic Counterparts to Black Hole–Black Hole Mergers in LIGO/Virgo O3 with the Zwicky Transient Facility

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Received 2022 September 23; revised 2022 November 15; accepted 2022 November 19; published 2023 January 17

Abstract

The accretion disks of active galactic nuclei (AGNs) are promising locations for the merger of compact objects detected by gravitational wave (GW) observatories. Embedded within a baryon-rich, high-density environment, mergers within AGNs are the only GW channel where an electromagnetic (EM) counterpart must occur (whether detectable or not). Considering AGNs with unusual flaring activity observed by the Zwicky Transient Facility (ZTF), we describe a search for candidate EM counterparts to binary black hole (BBH) mergers detected by LIGO/

van Velzen+ 2019

van Velzen+ 2021

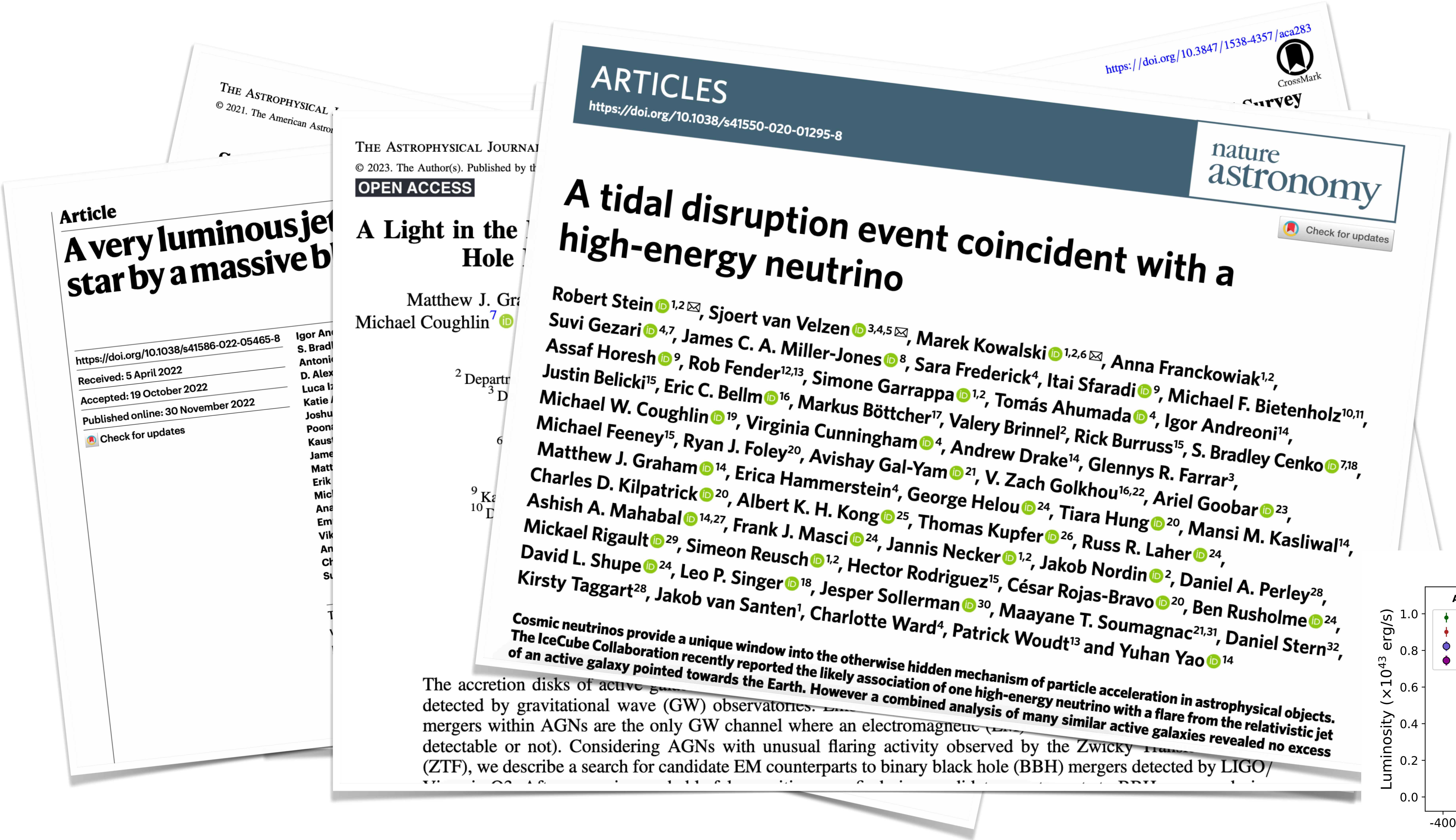
Hammerstein+ 2021

Andreoni+ 2022

Subrayan+ 2023

Graham+ 2023

Three neutrino-associated TDE candidates



van Velzen+ 2019

van Velzen+ 2021

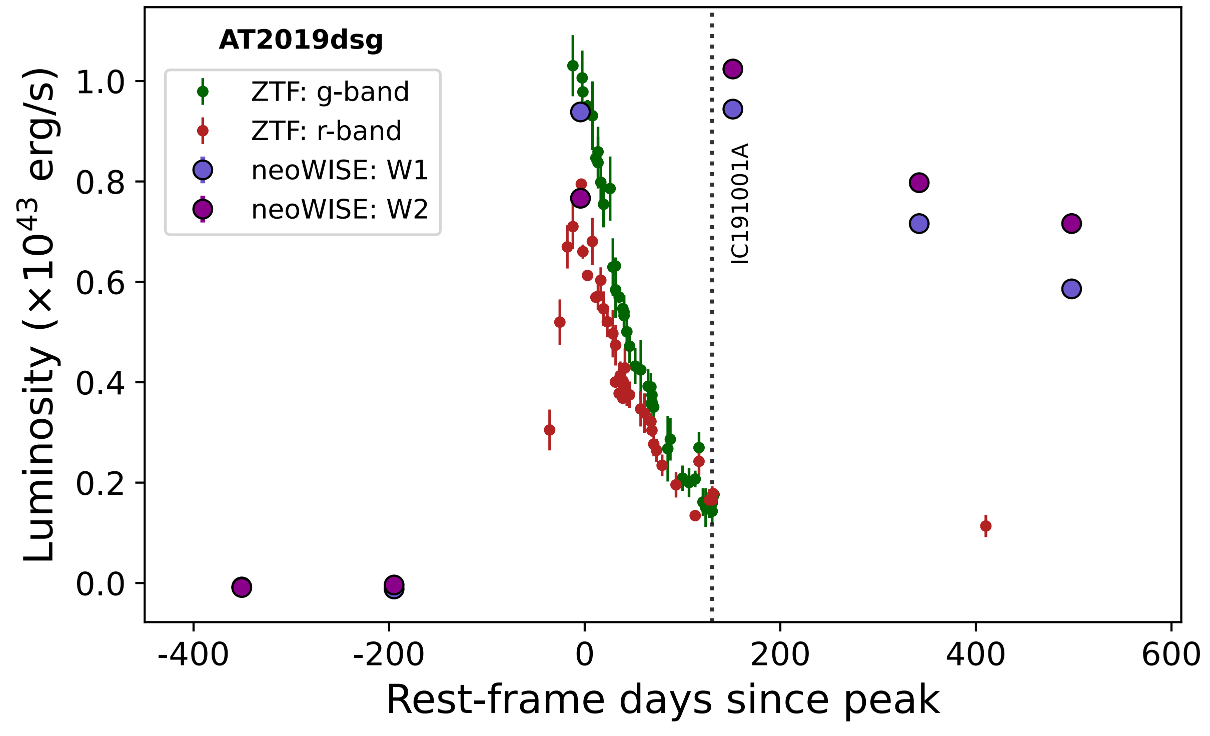
Hammerstein+ 2021

Andreoni+ 2022

Subrayan+ 2023

Graham+ 2023

Stein+ 2021



Three neutrino-associated TDE candidates

van Velzen+ 2019

van Velzen+ 2021

Hammerstein+ 2021

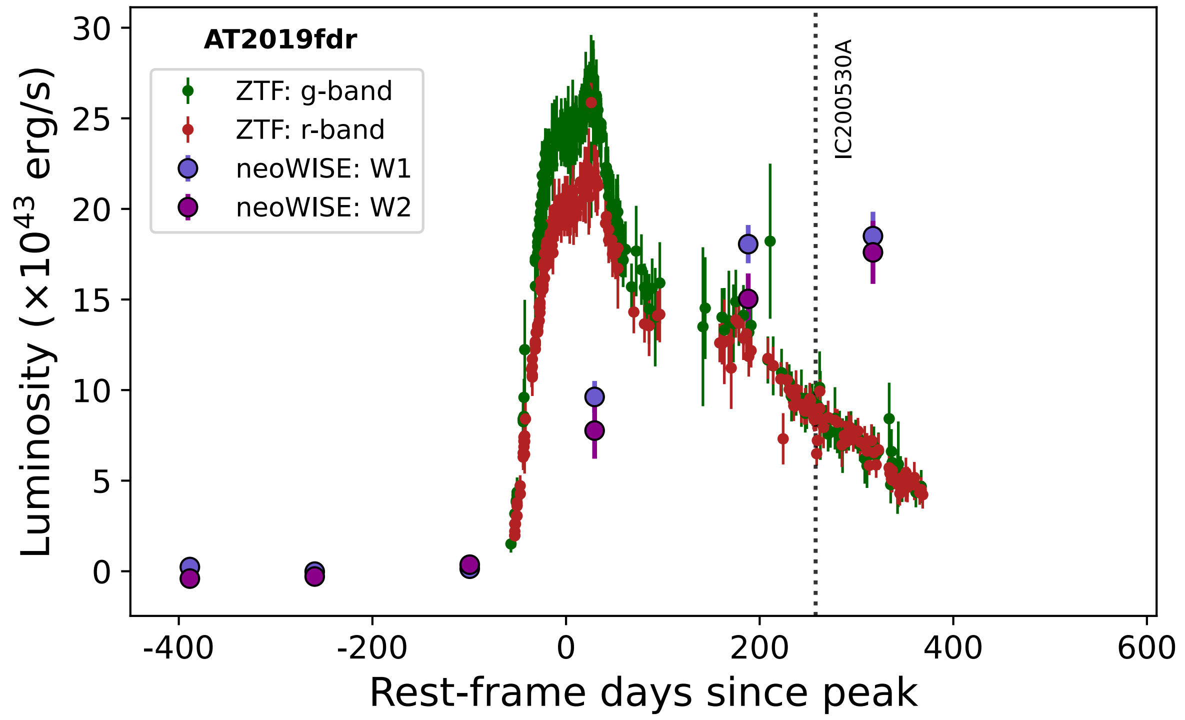
Andreoni+ 2022

Subrayan+ 2023

Graham+ 2023

Stein+ 2021

Reusch+ 2022



Three neutrino-associated TDE candidates

Image credit: DESY

Image credit: DESY

Three neutrino-associated TDE candidates

All had a very luminous dust echo

Image credit: DESY

Three neutrino-associated TDE candidates

All had a very luminous dust echo

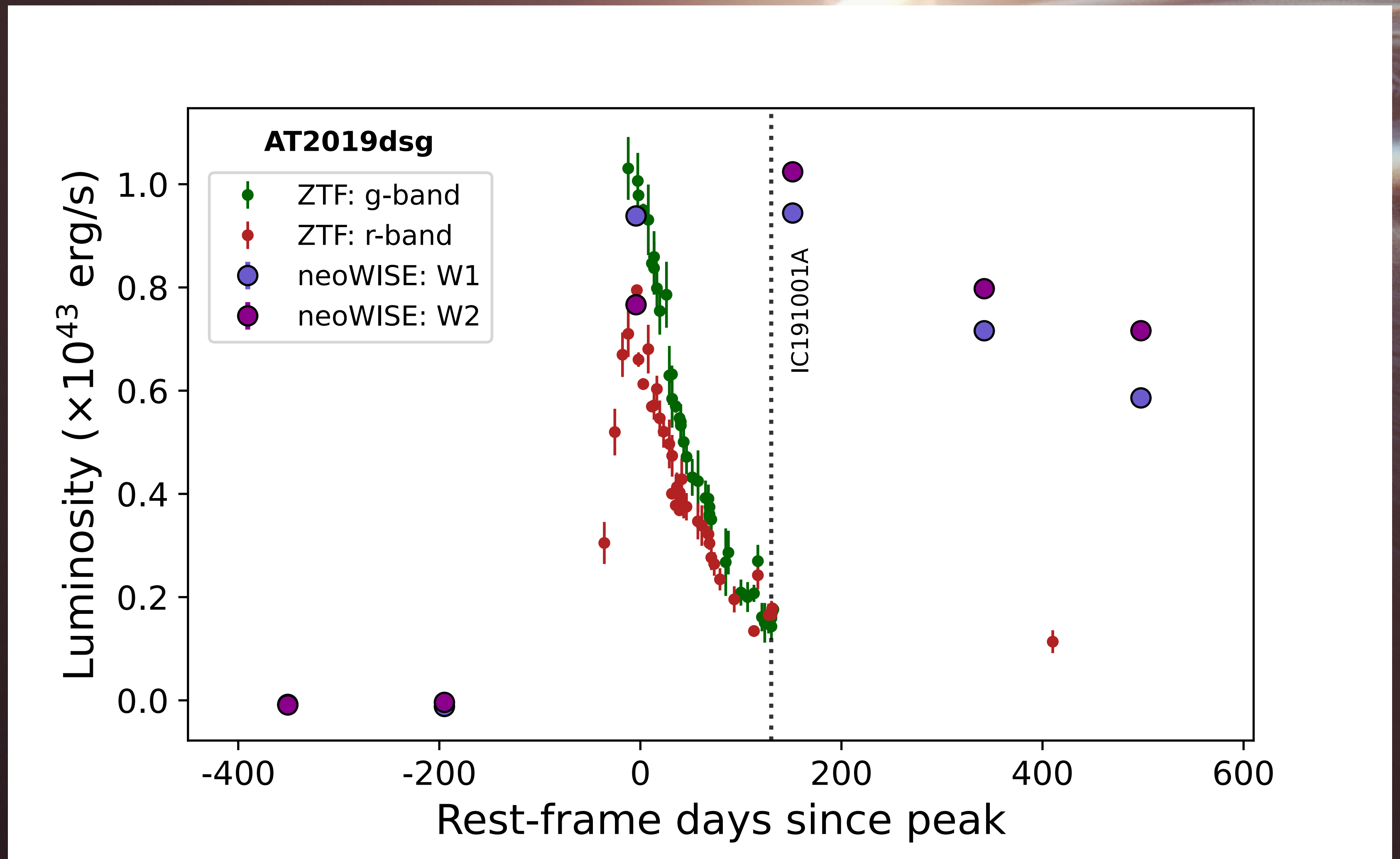
3.6σ correlation of 63 accretion flares with **strong dust echo** with high-energy alerts

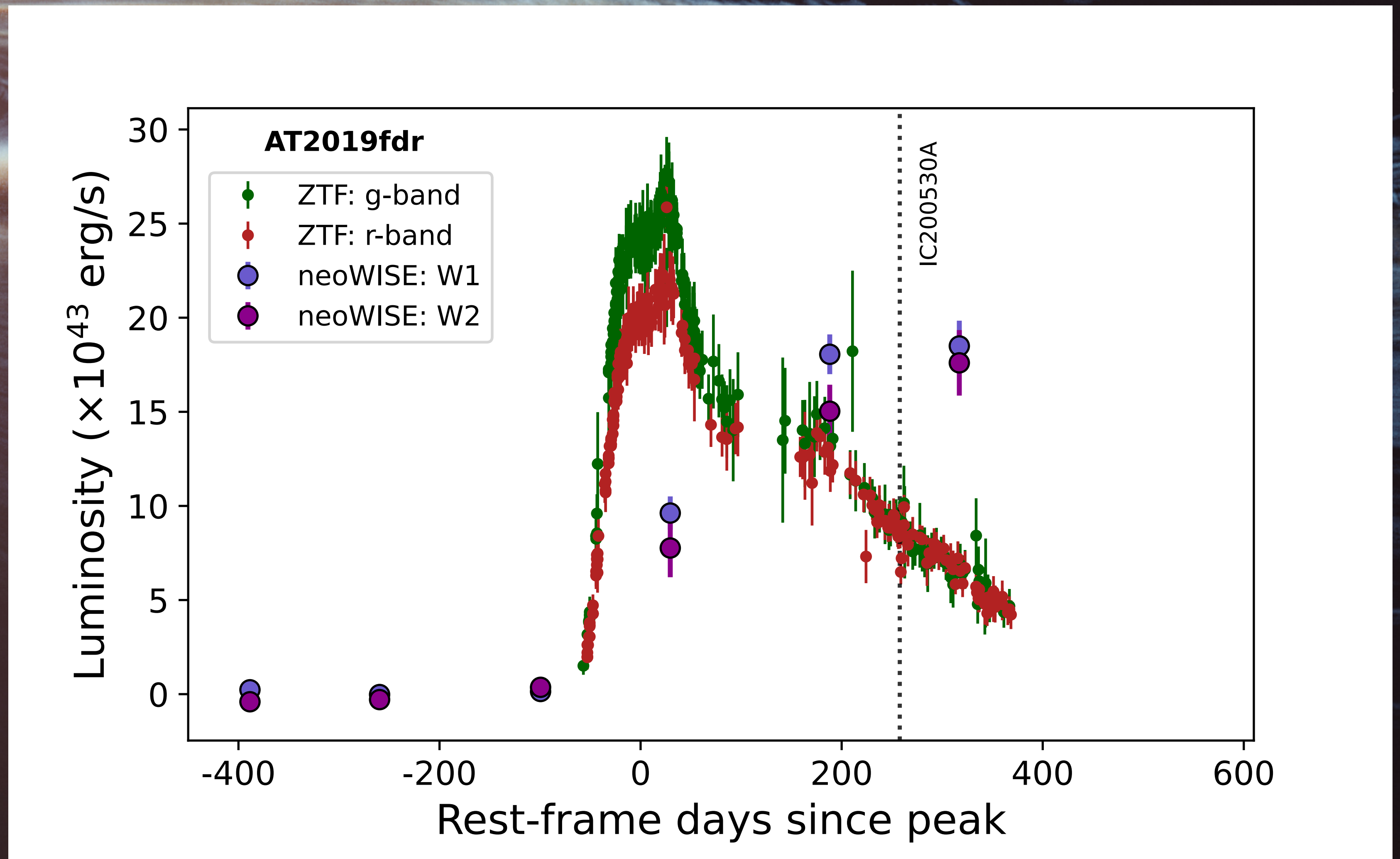
Image credit: DESY

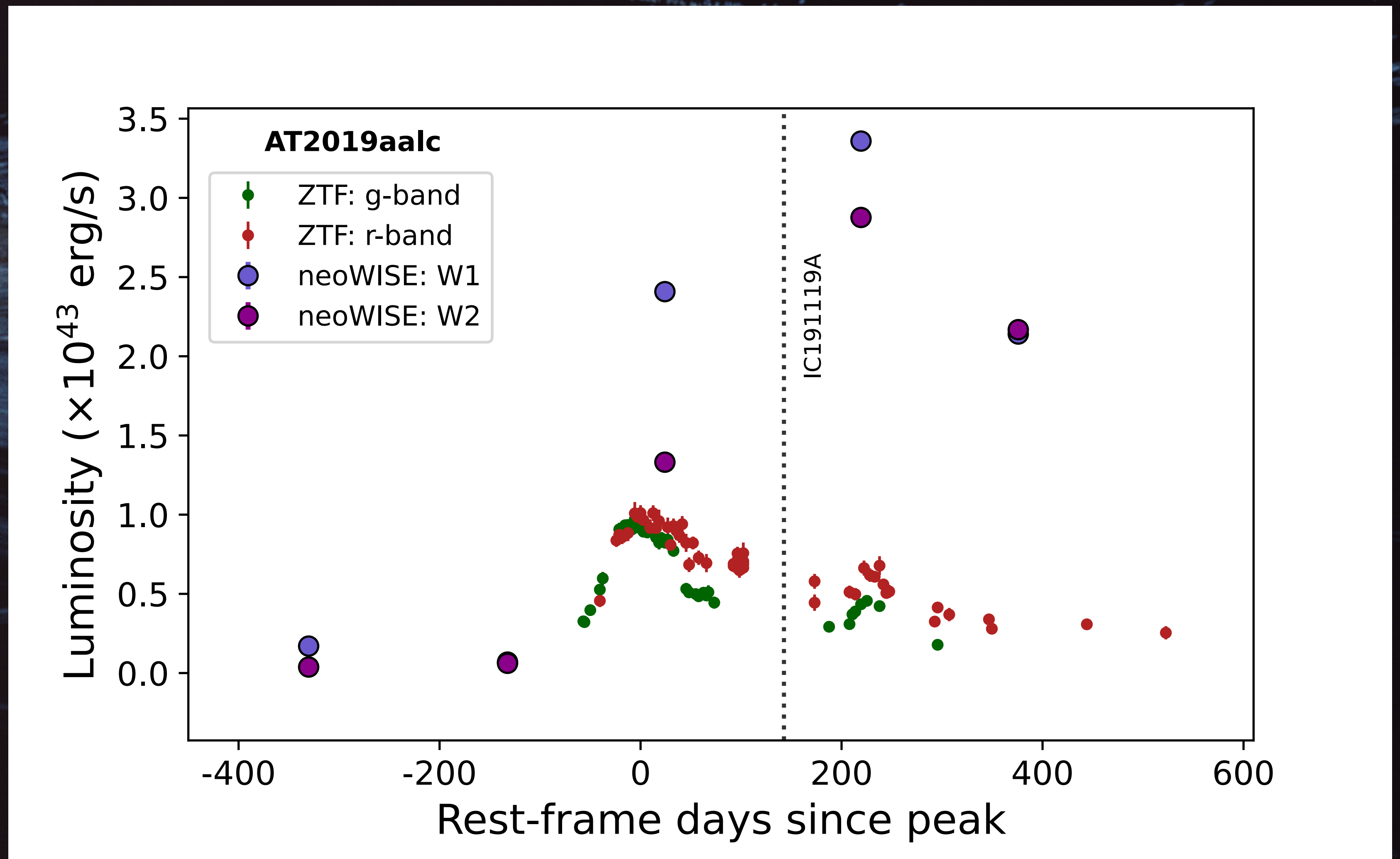
Three neutrino-associated TDE candidates

All had a very luminous dust echo

3.6σ correlation of 63 accretion flares with **strong dust echo** with high-energy alerts







Lots of interesting transients, but rather unstructured

Lots of interesting transients, but rather unstructured

What if we had a systematic sample of optical and IR lightcurves of the ZTF nuclear transients? 🤔

II) A nuclear sample 💥

Full Sample of all nuclear transients

Full Sample of all nuclear transients

[2018.5, 2021] → 3.5 years worth of data

(400 million alerts)

Full Sample of all nuclear transients

AMPEL nuclear filter

[2018.5, 2021] → 3.5 years worth of data

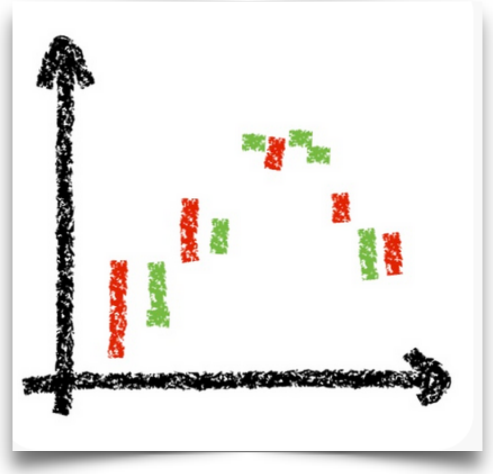
(400 million alerts)

Filtered by **host distance**, **PS1 star-galaxy score**, max. **brightness** and number of **detections**

11687 transients in final selection

Full Sample of all nuclear transients

AMPEL nuclear filter



fpbot

[2018.5, 2021] → 3.5 years worth of data

(400 million alerts)

Filtered by **host distance**, **PS1 star-galaxy score**, max. **brightness** and number of **detections**

11687 transients in final selection

Obtained forced photometry with **fpbot**, applied baseline correction

Crossmatch with WISE IR

Crossmatch with WISE IR

Vast majority has a WISE counterpart

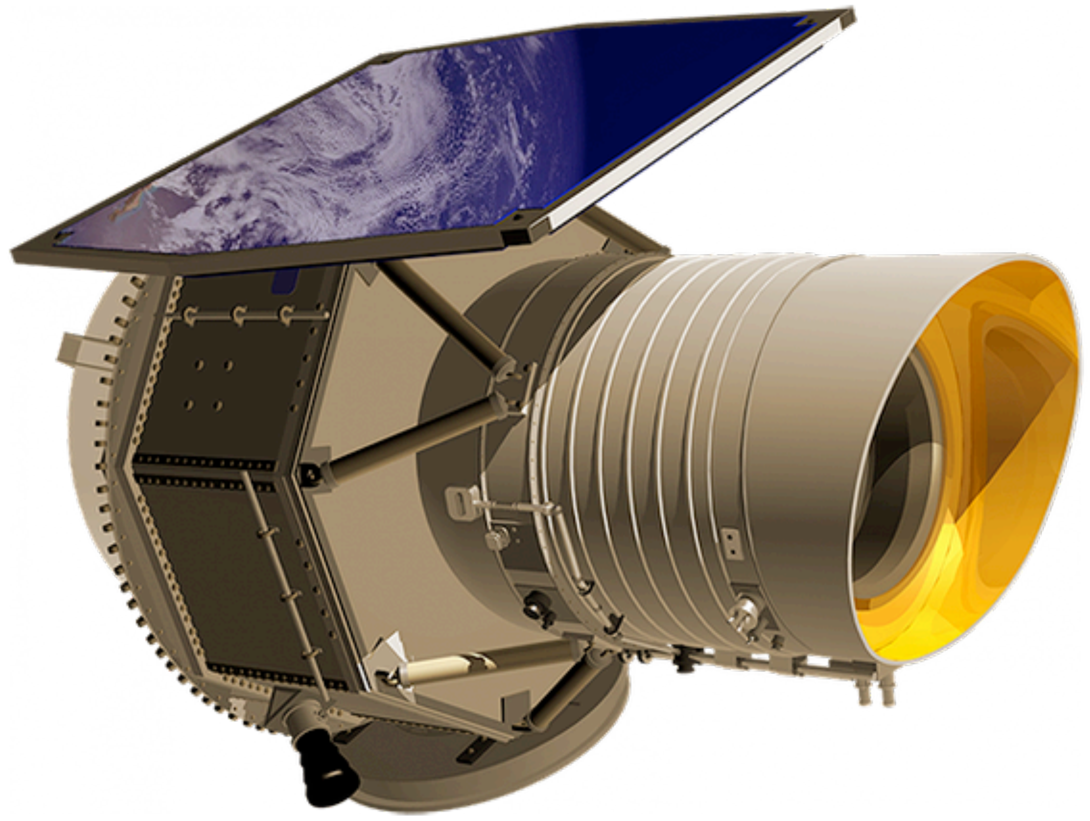


Image credit: NASA

Crossmatch with WISE IR

Vast majority has a WISE counterpart

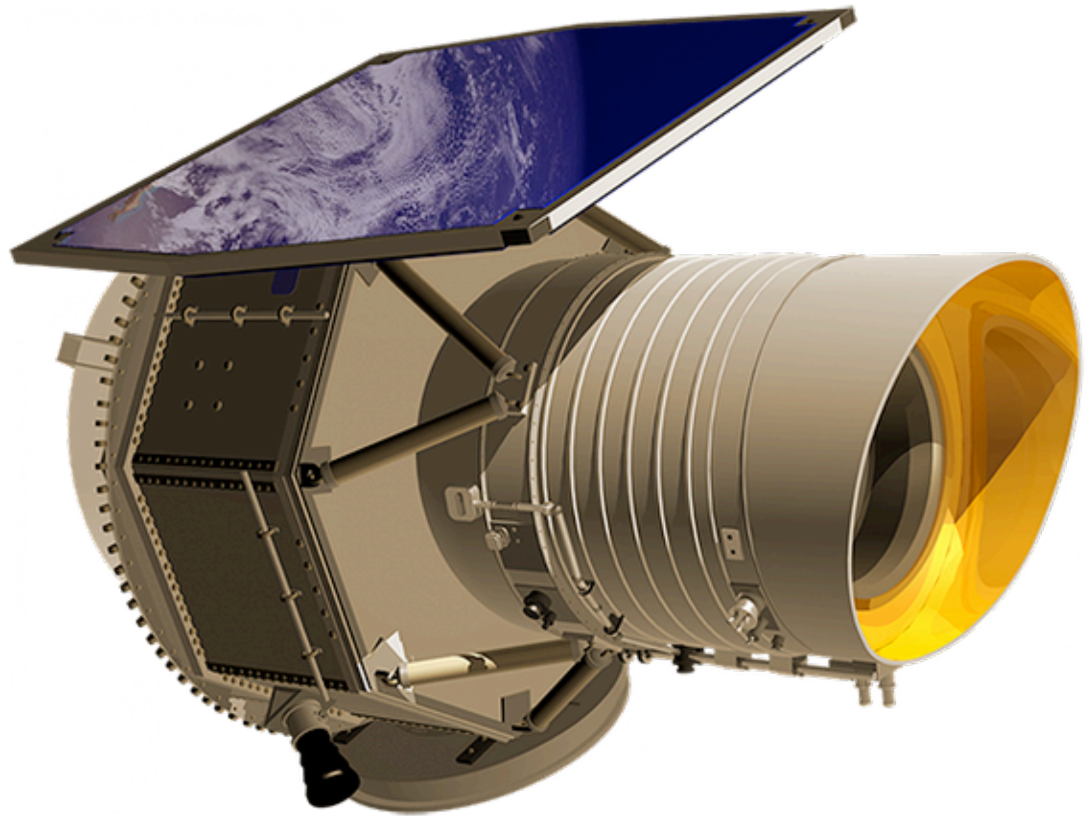
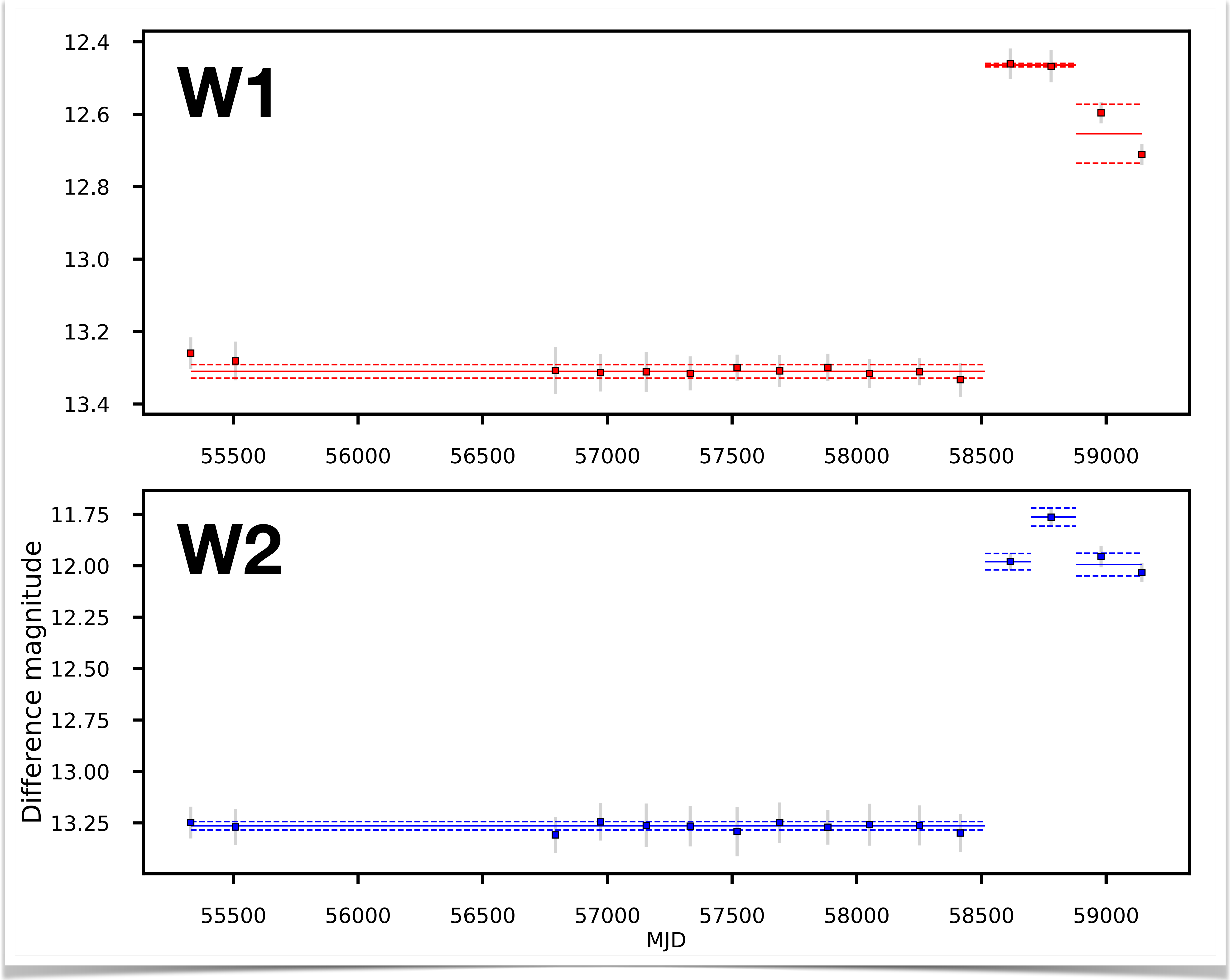


Image credit: NASA

Analyzed with a Bayesian block framework to find flares



Crossmatch with WISE IR

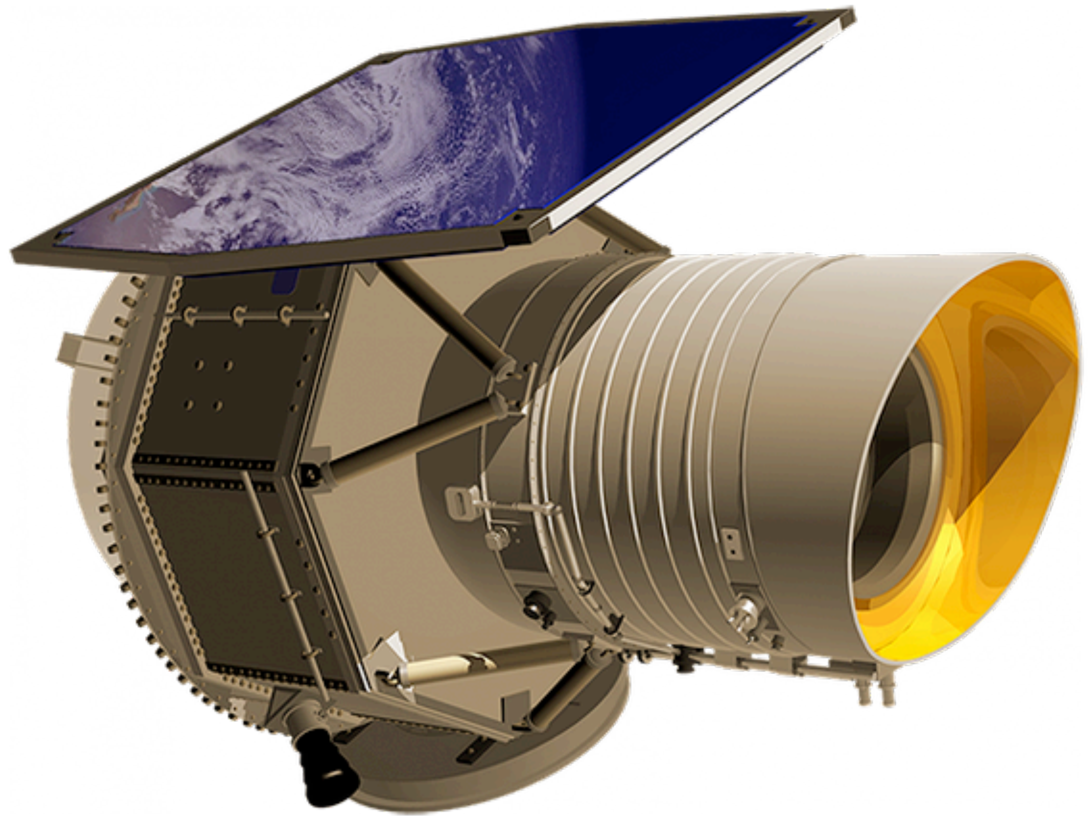


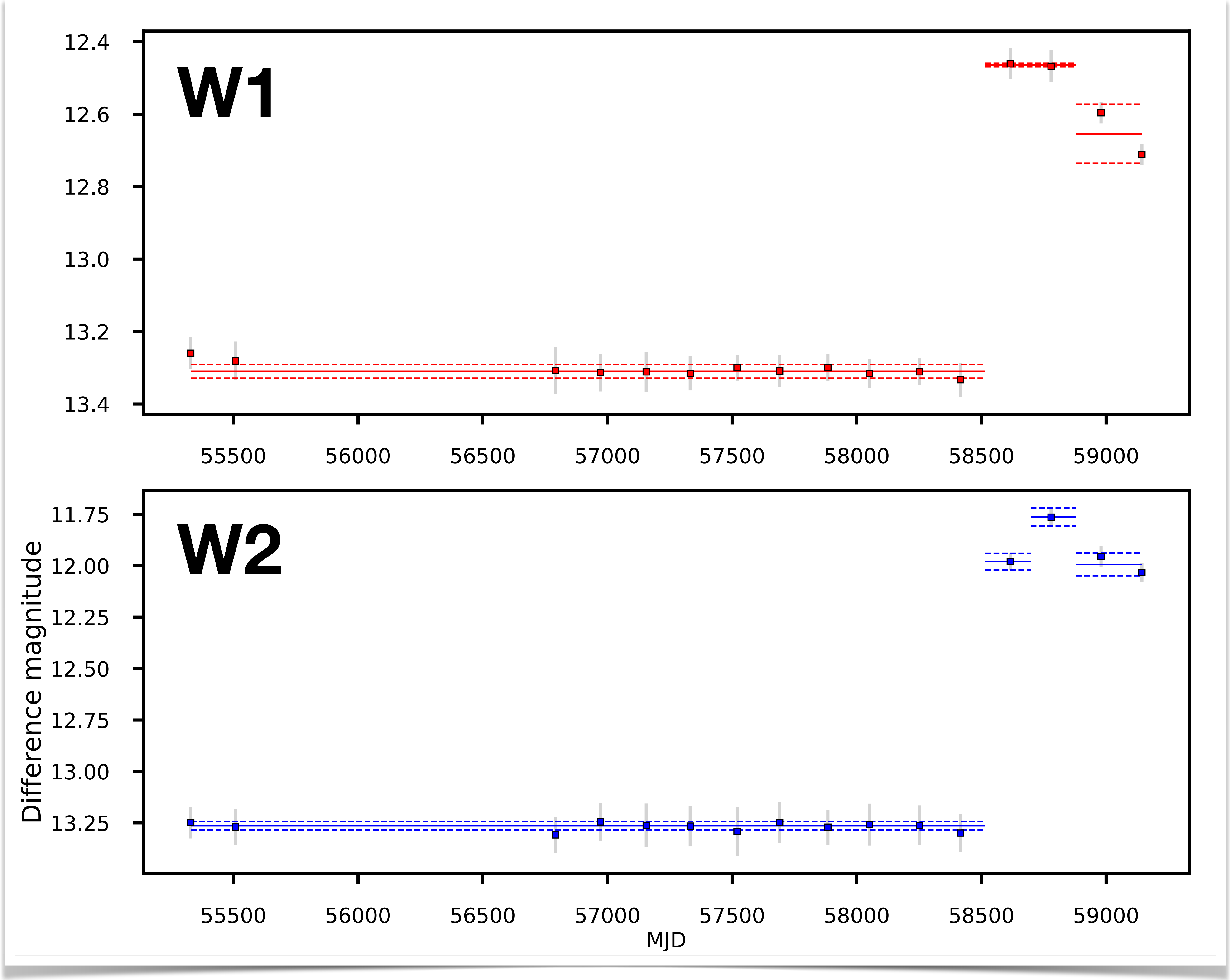
Image credit: NASA

Vast majority has a WISE counterpart

Analyzed with a Bayesian block framework to find flares

15% have a prominent IR flare

2% flare **after** the optical peak



Trained BDT classifier with noisified lightcurves from the Bright Transient Survey

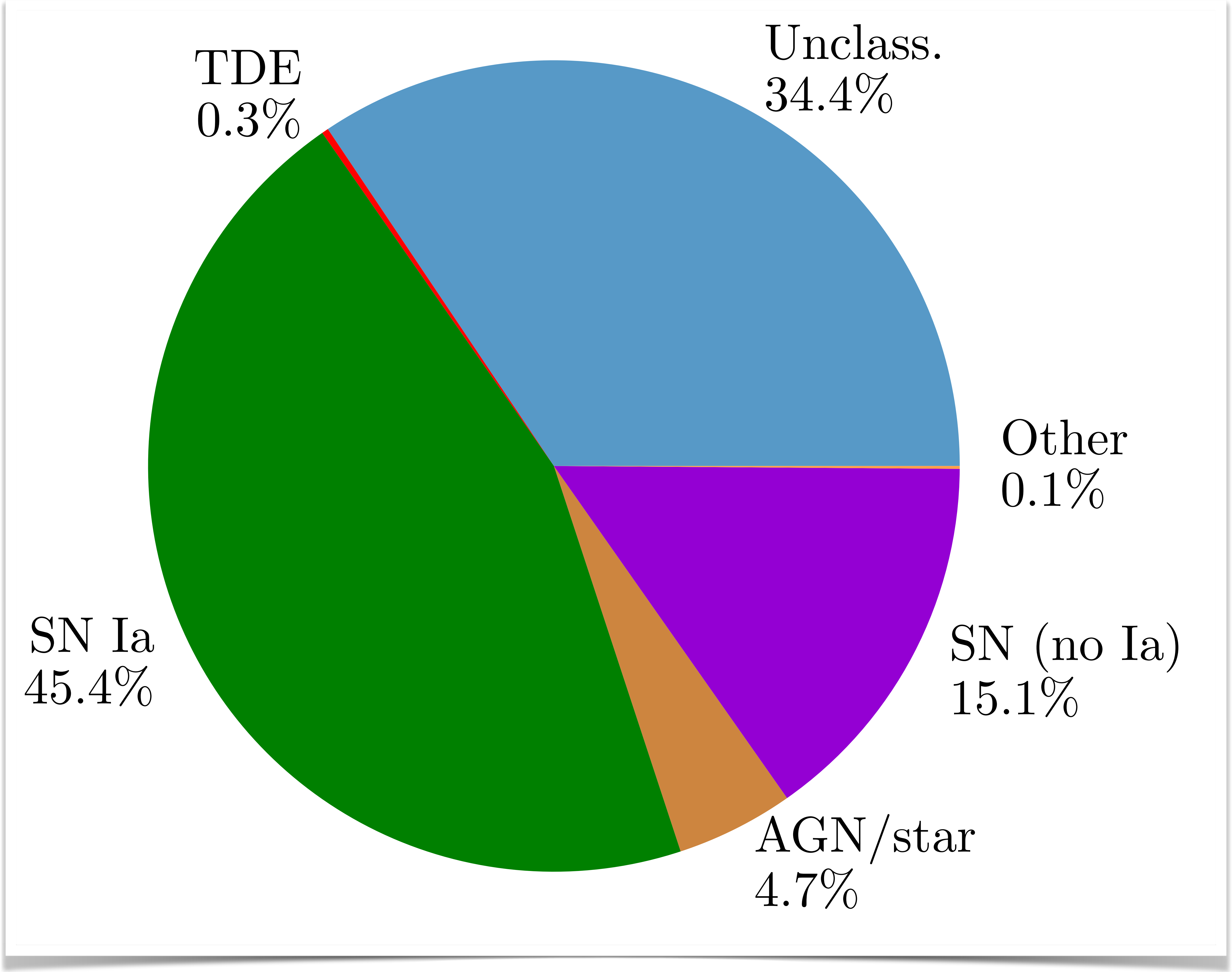
Trained BDT classifier with noisified lightcurves from the Bright Transient Survey

7284 ZTF transients

Trained BDT classifier with noisified lightcurves from the Bright Transient Survey

7284 ZTF transients

5315 of them classified (brighter than 18.5 mag)

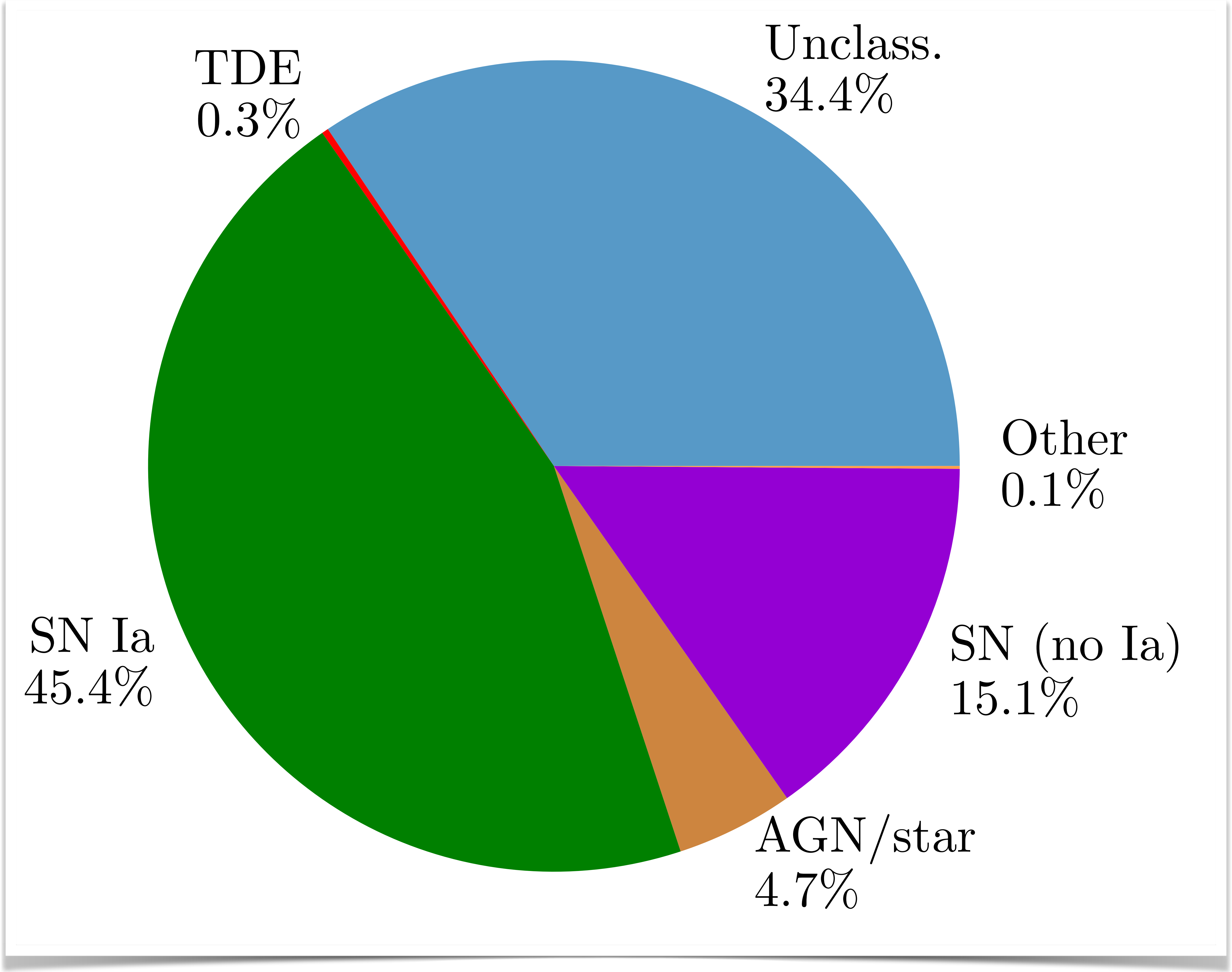


Trained BDT classifier with noisified lightcurves from the Bright Transient Survey

7284 ZTF transients

5315 of them classified (brighter than 18.5 mag)

Problem: Brighter than nuclear selection, high class imbalance



Trained BDT classifier with noisified lightcurves from the Bright Transient Survey

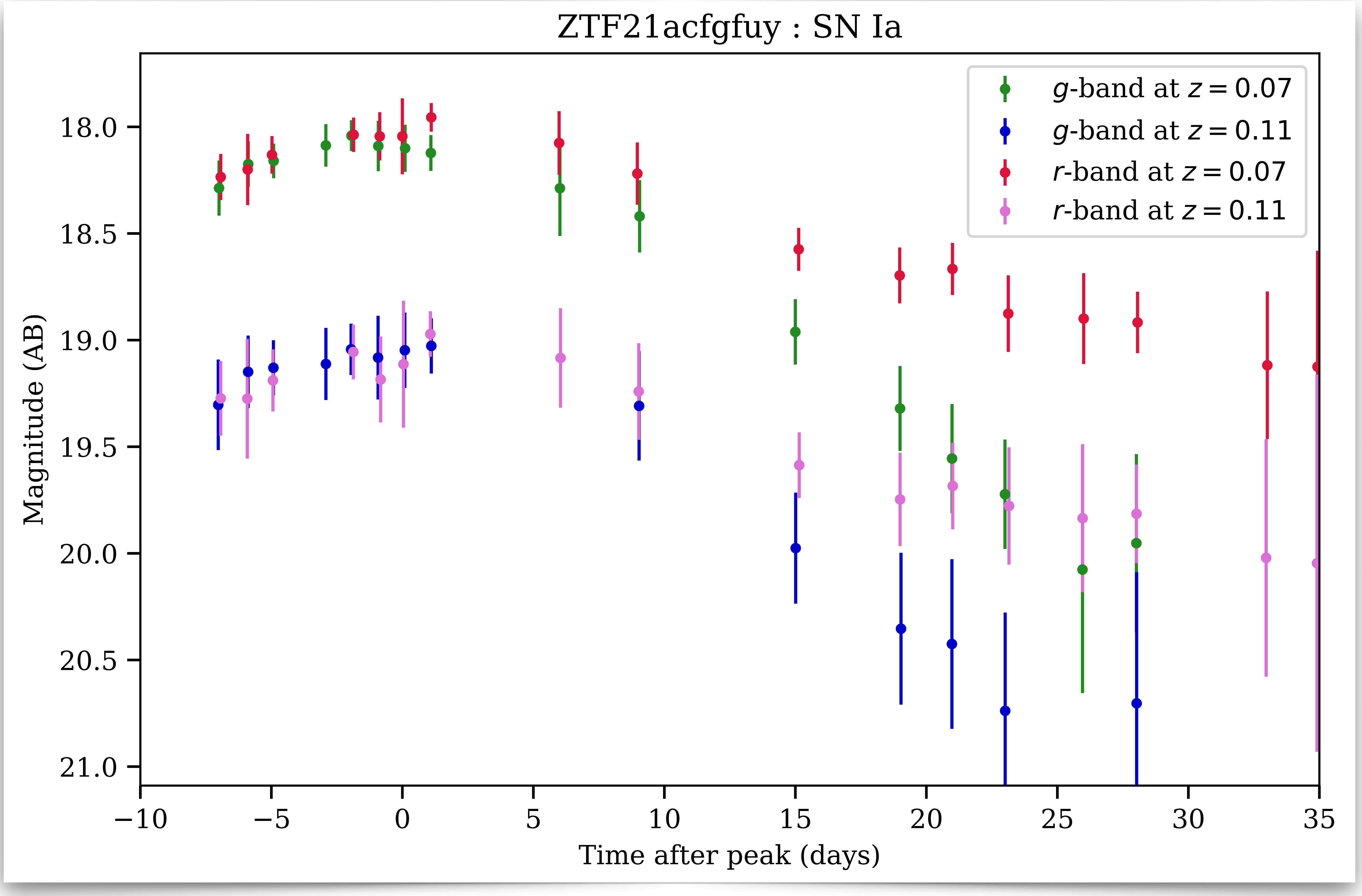
Trained BDT classifier with noisified lightcurves from the Bright Transient Survey

Noisification: Physically motivated remedy

Trained BDT classifier with noisified lightcurves from the Bright Transient Survey

Noisification: Physically motivated remedy

→ redshift
→ noisify
→ K-correct

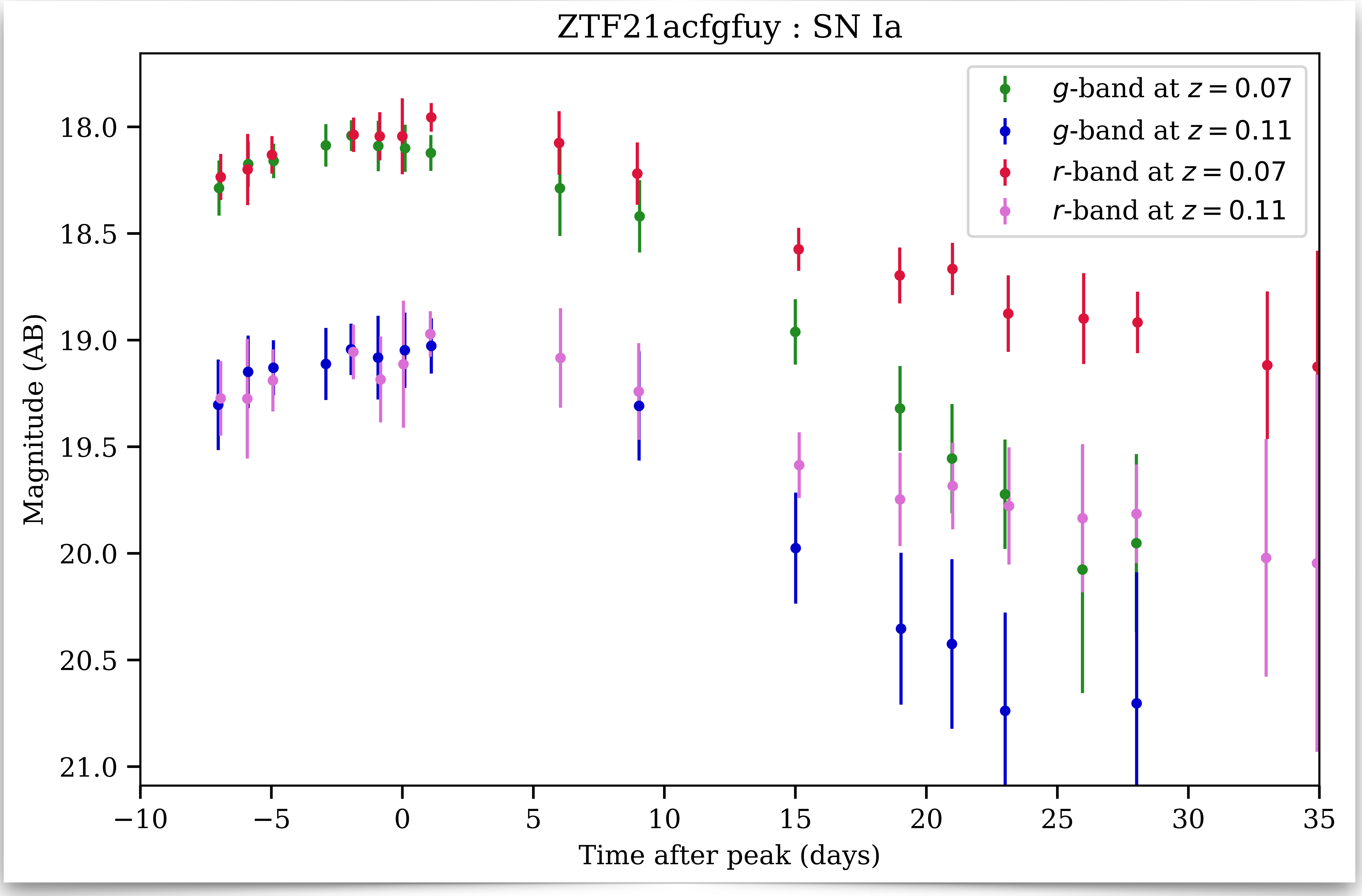


Trained BDT classifier with noisified lightcurves from the Bright Transient Survey

Noisification: Physically motivated remedy

→ redshift
→ noisify
→ K-correct

See Alice's talk!

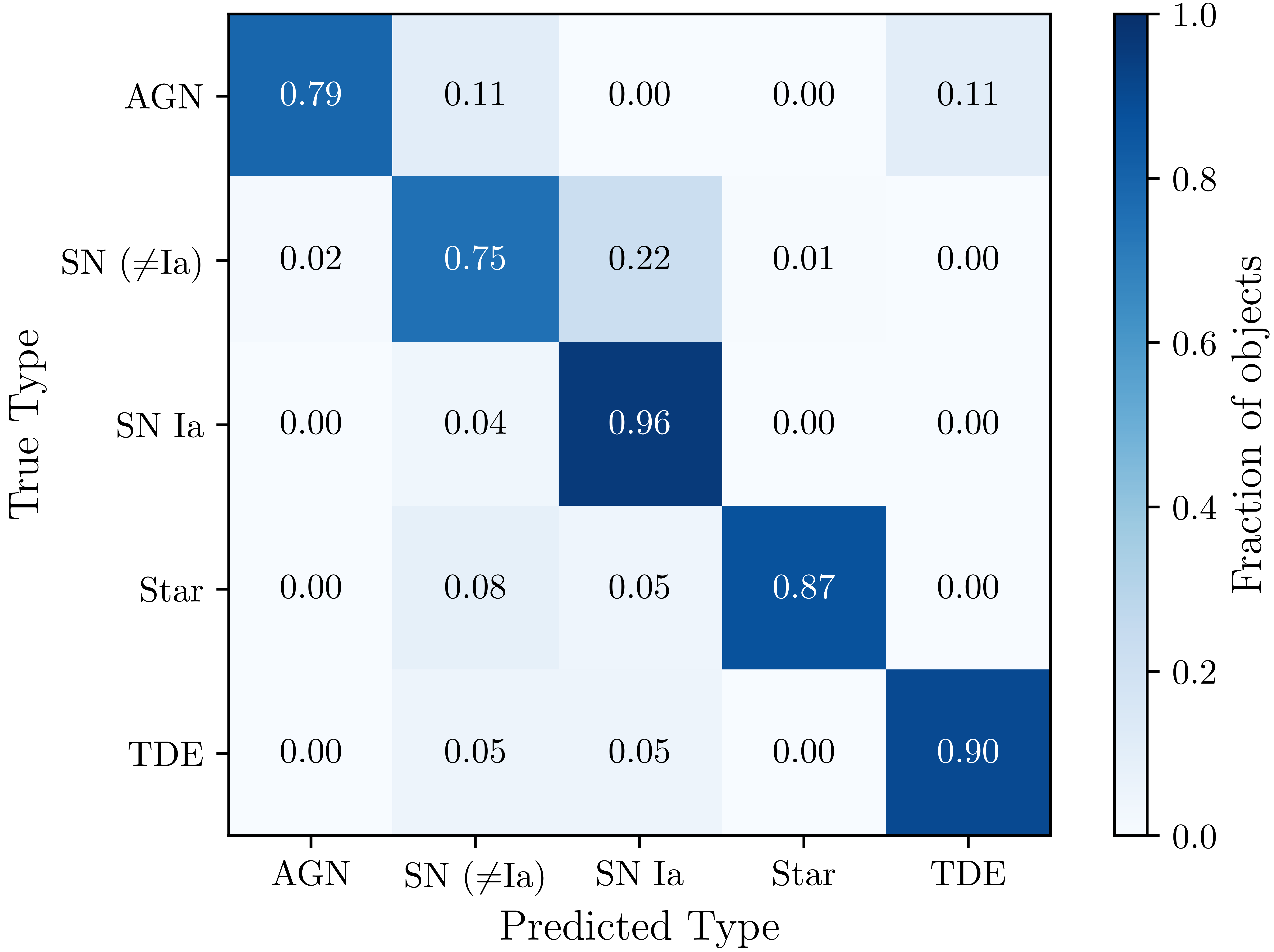


Feature extraction, currently only based on optical data

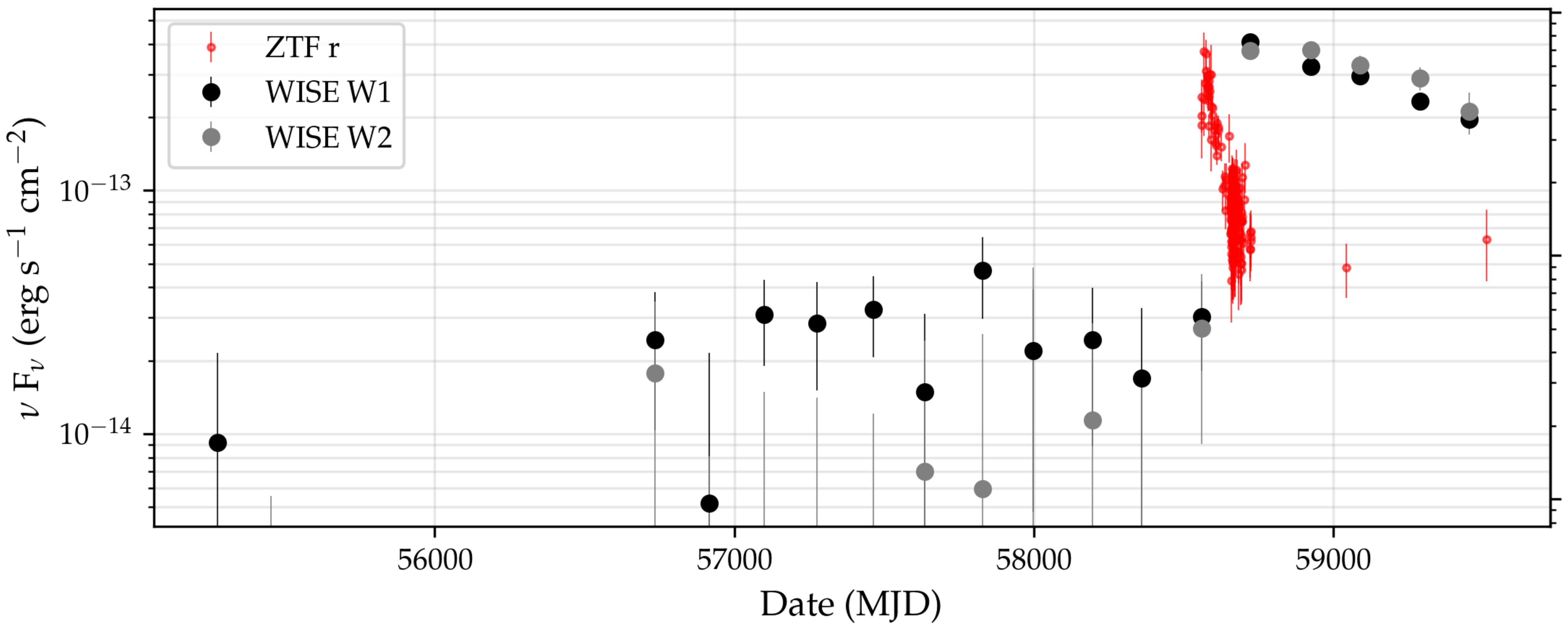
Evaluation with test sample

preliminary

Not including noisified lightcurves in the test sample



Identified some strong TDE candidates previously missed



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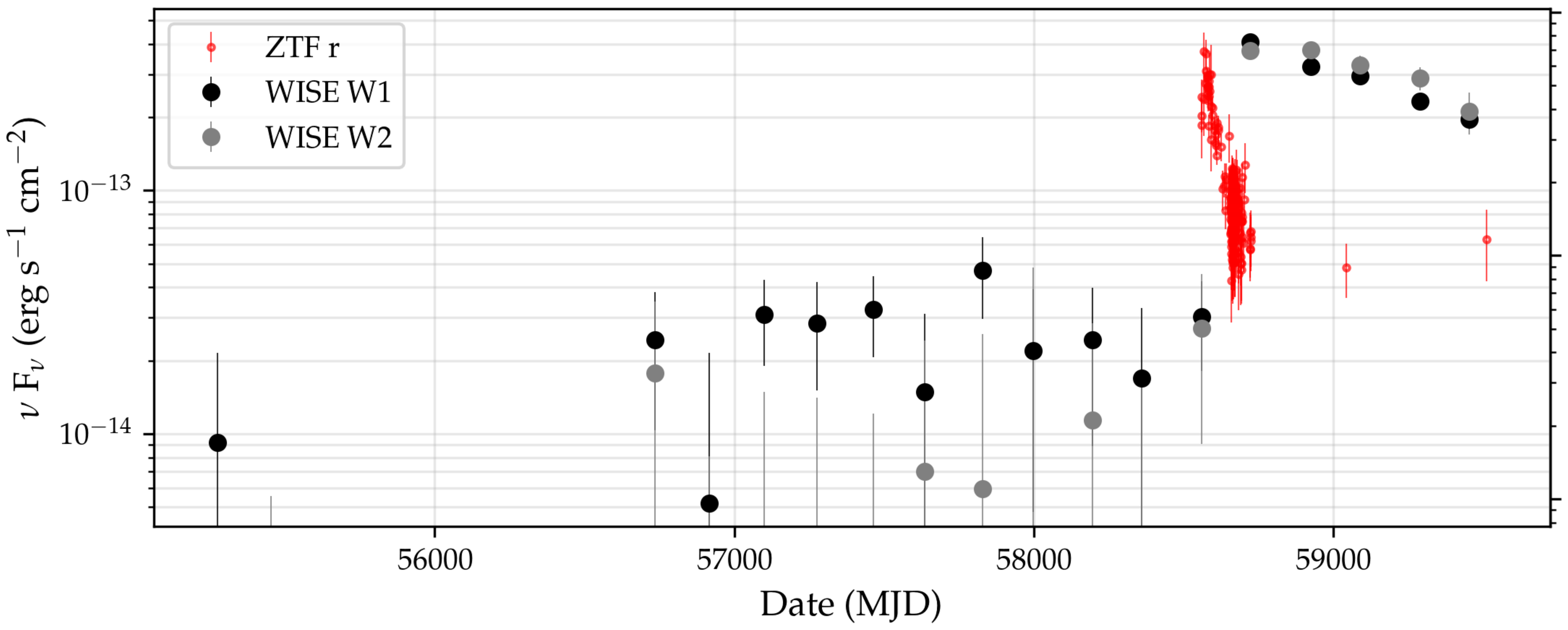

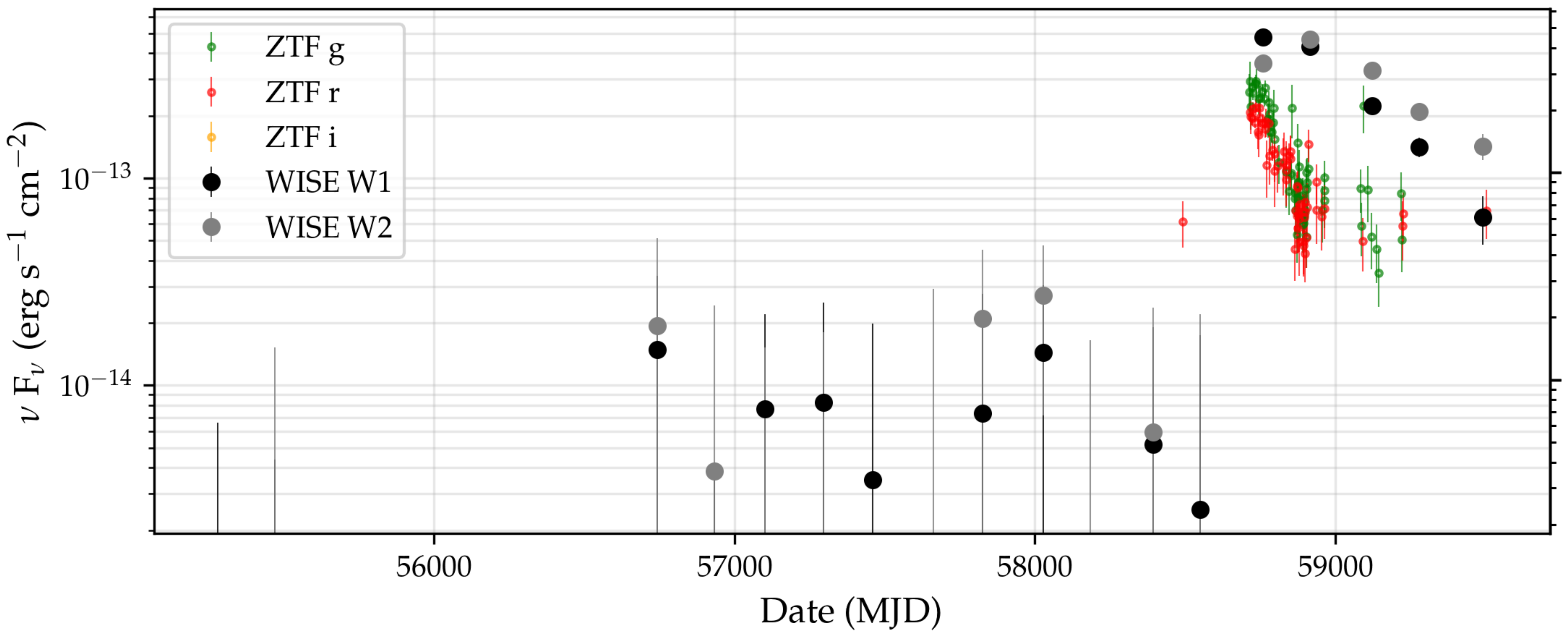

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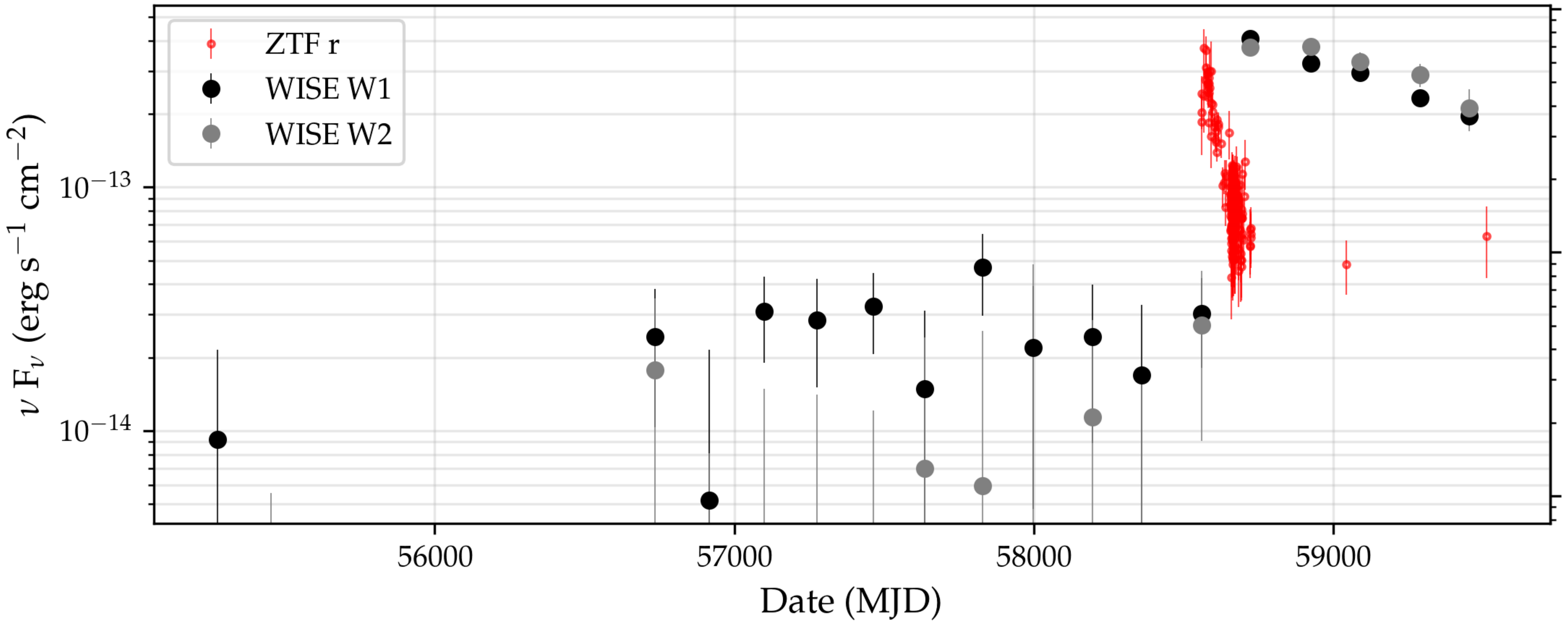

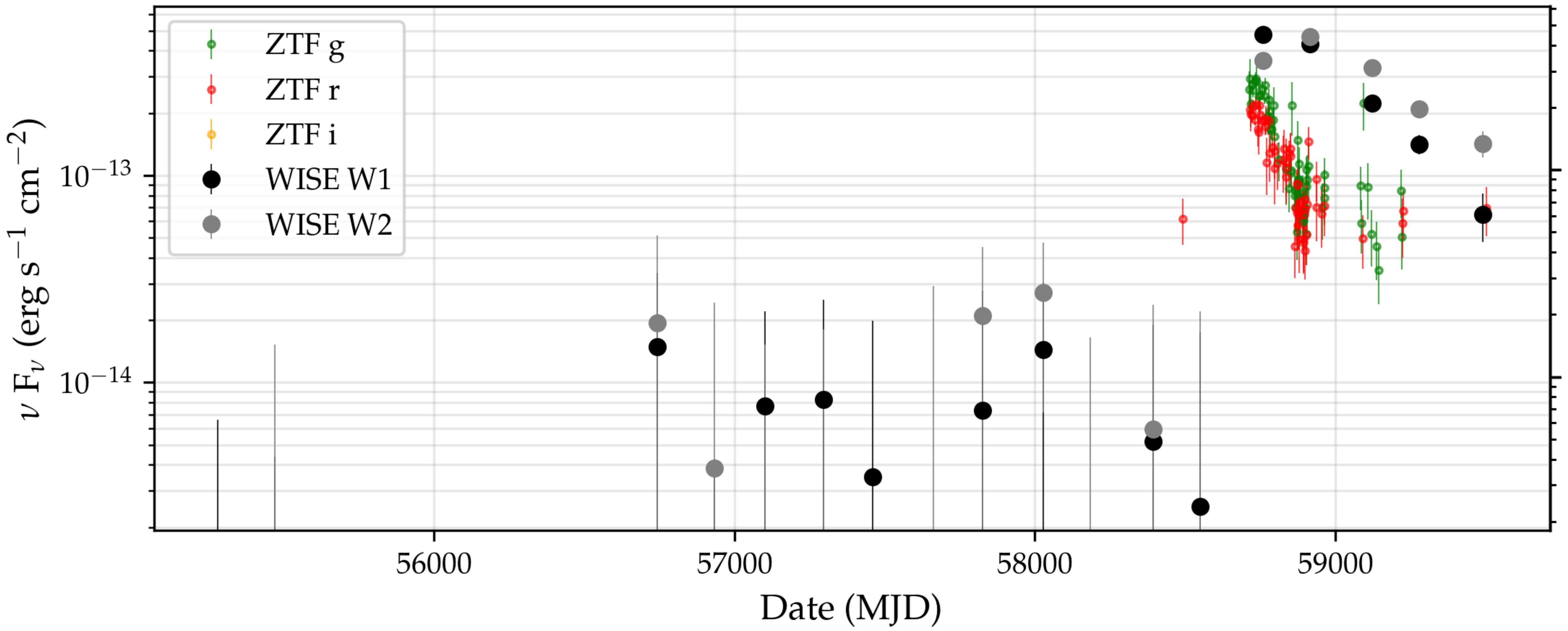

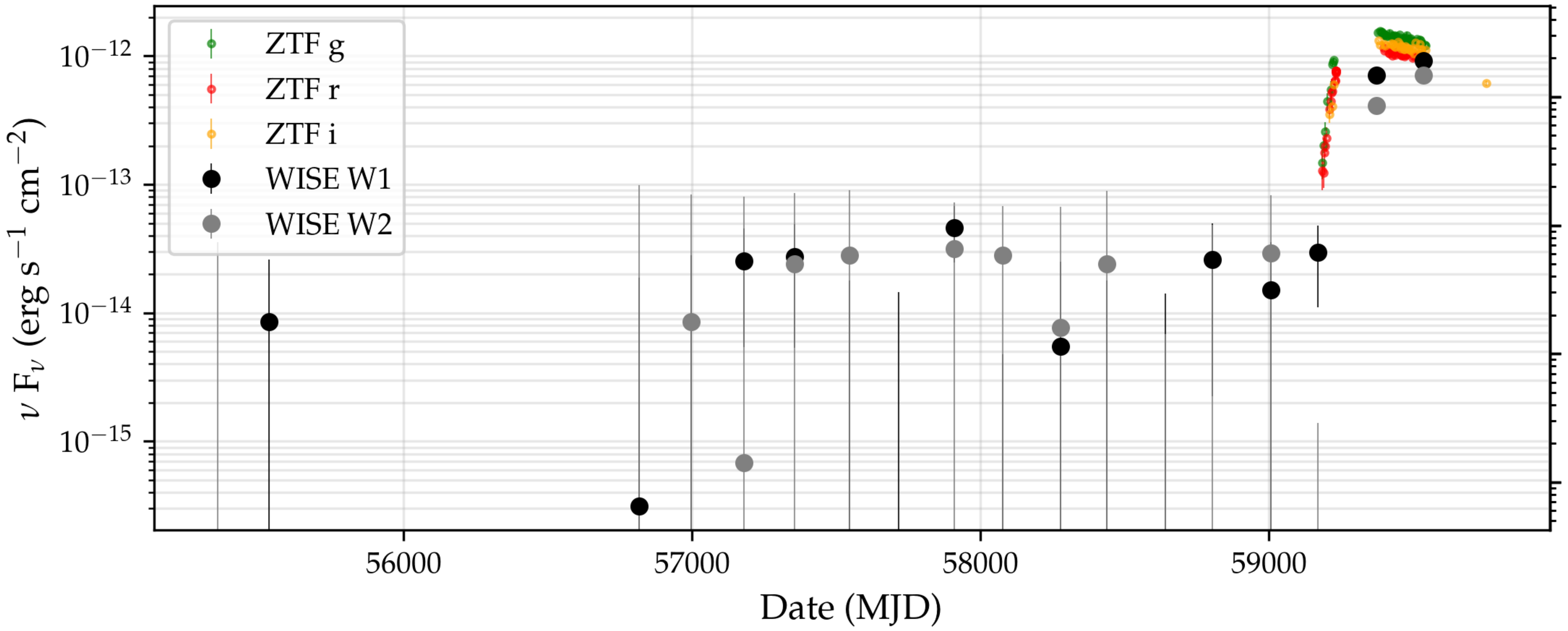

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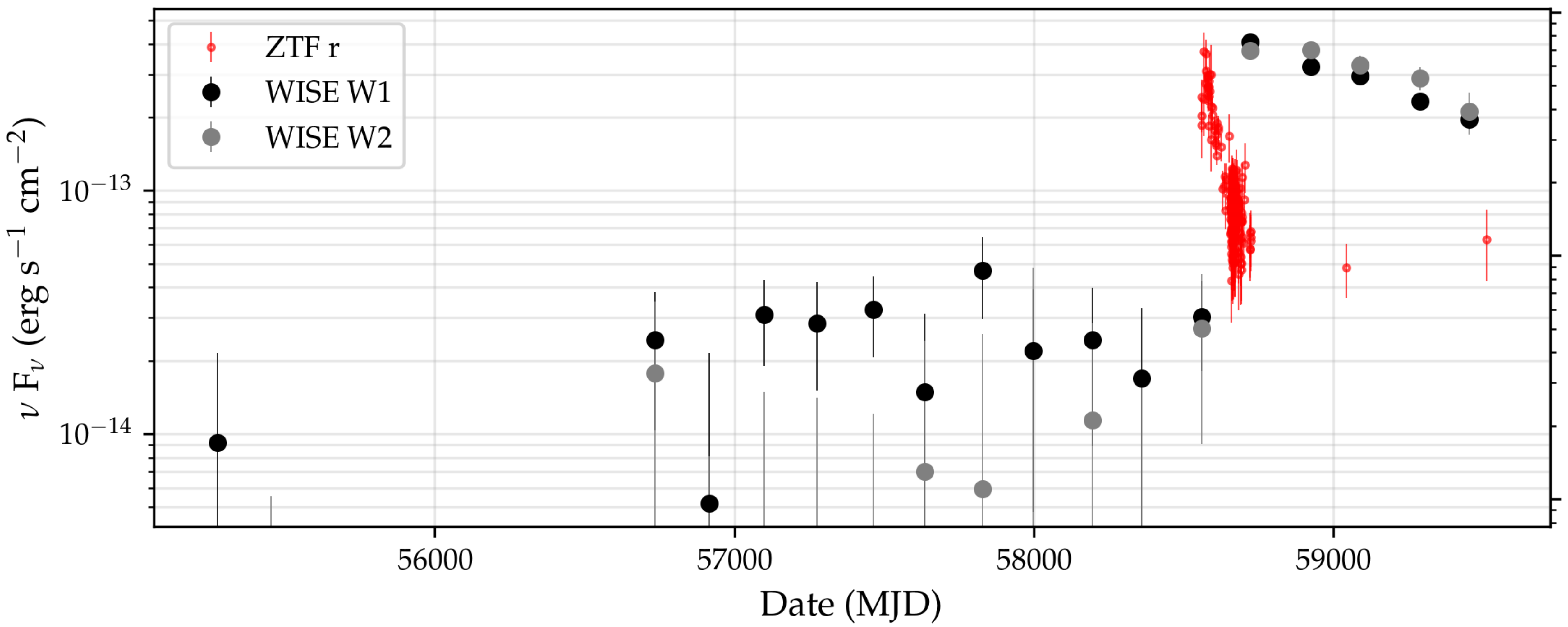
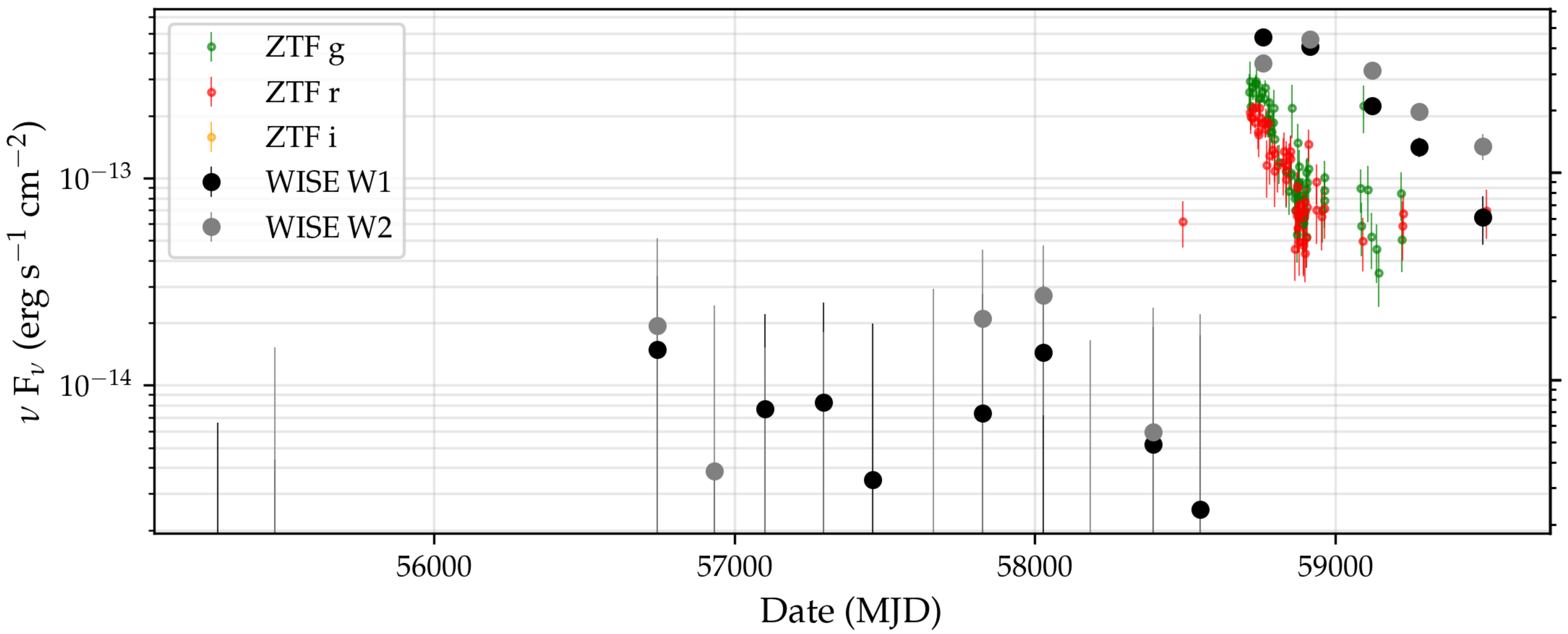
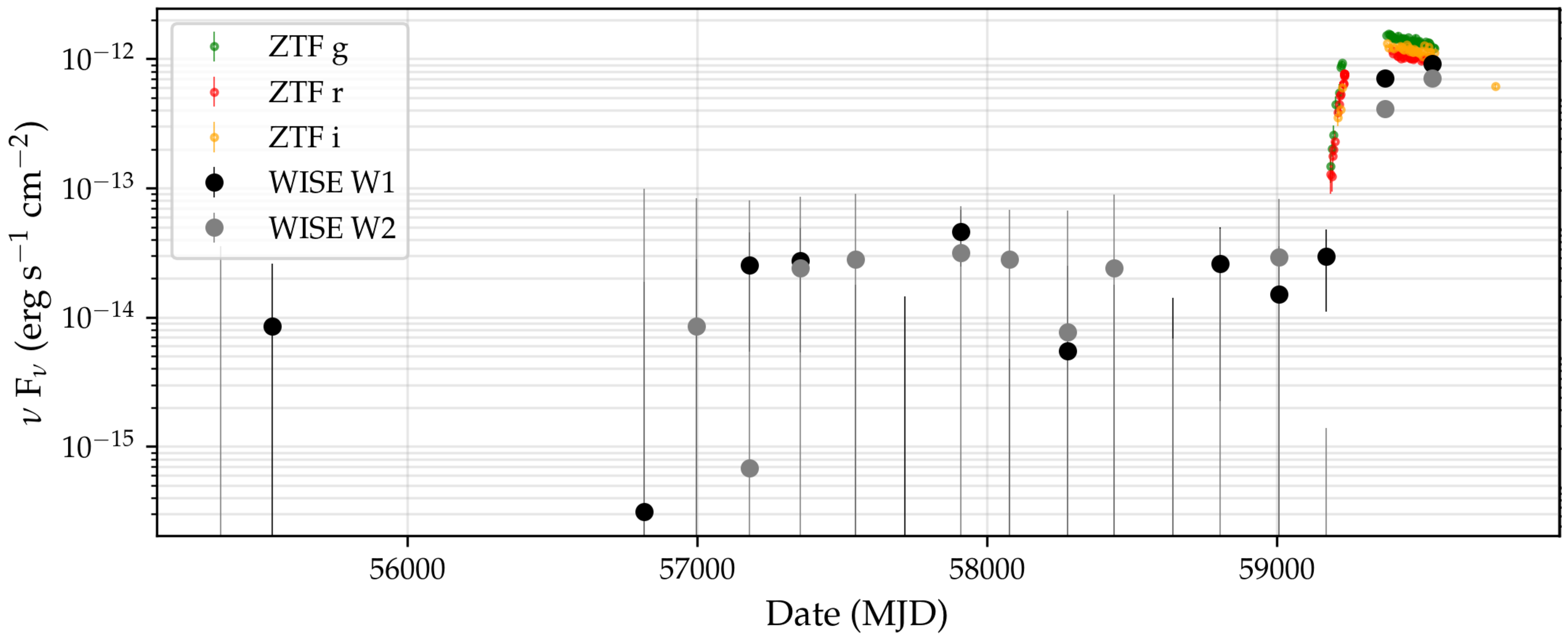
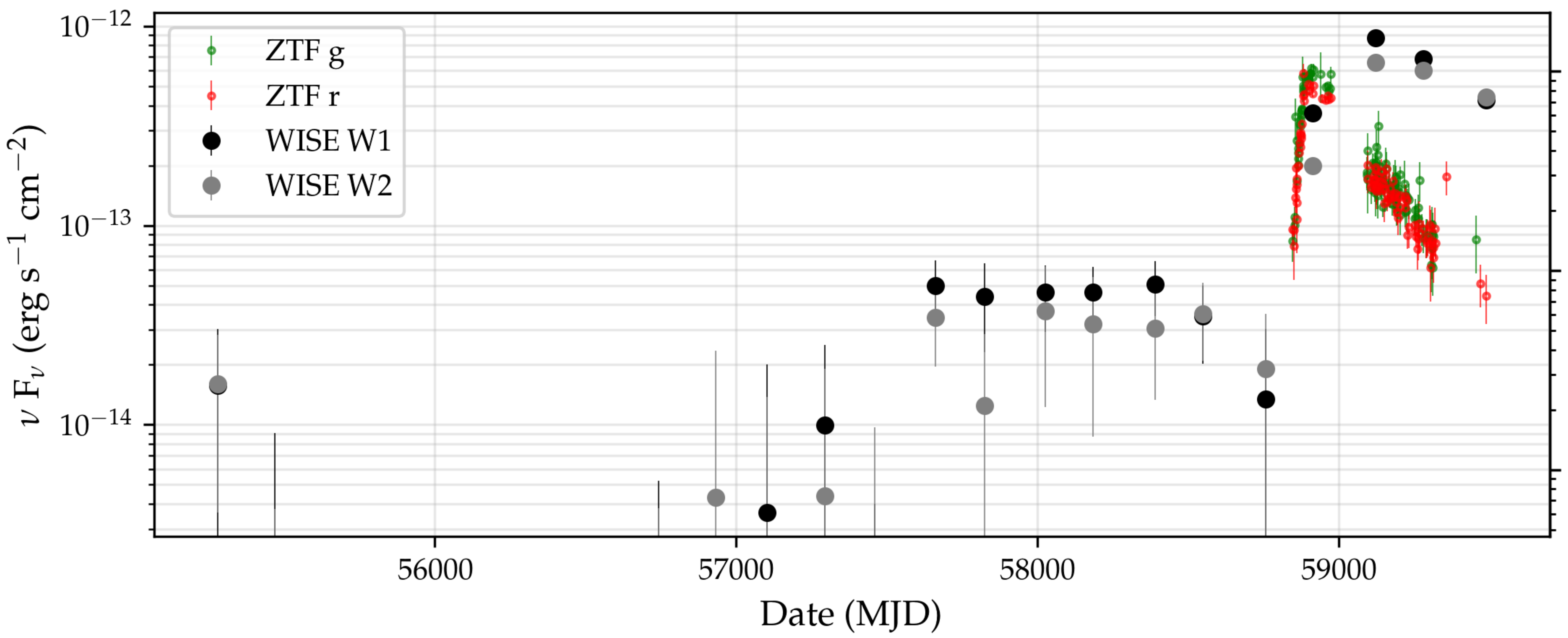
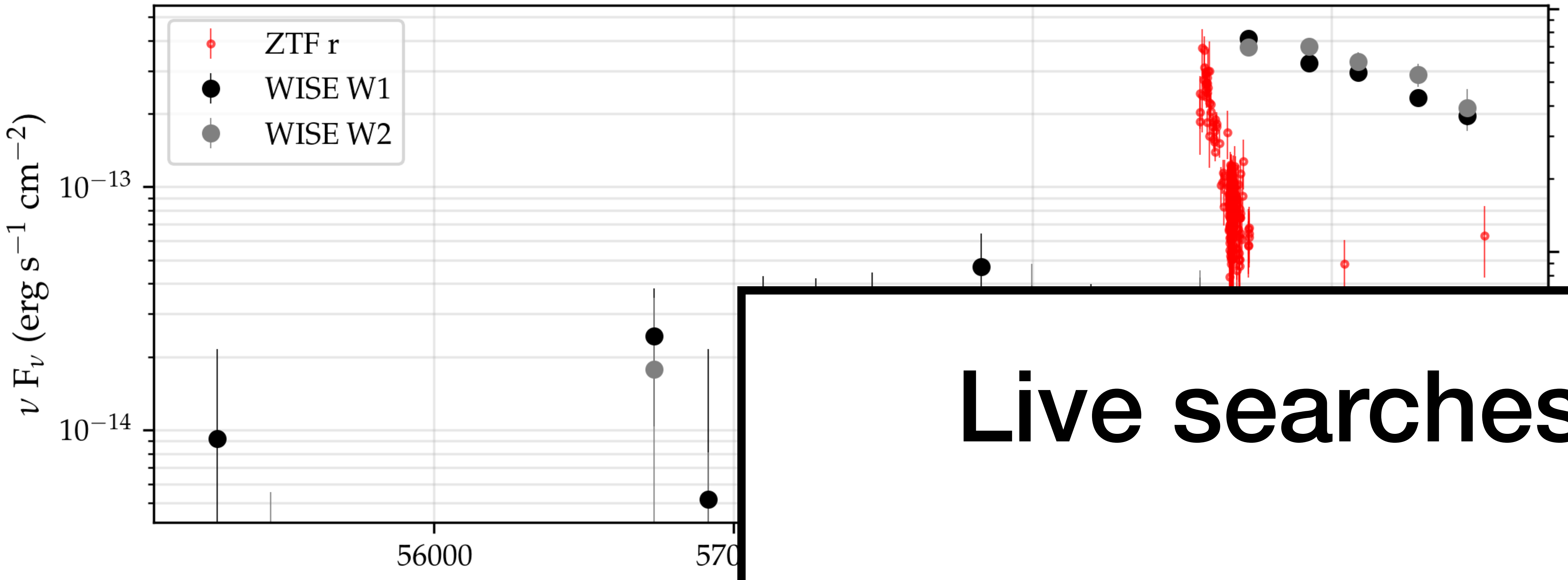


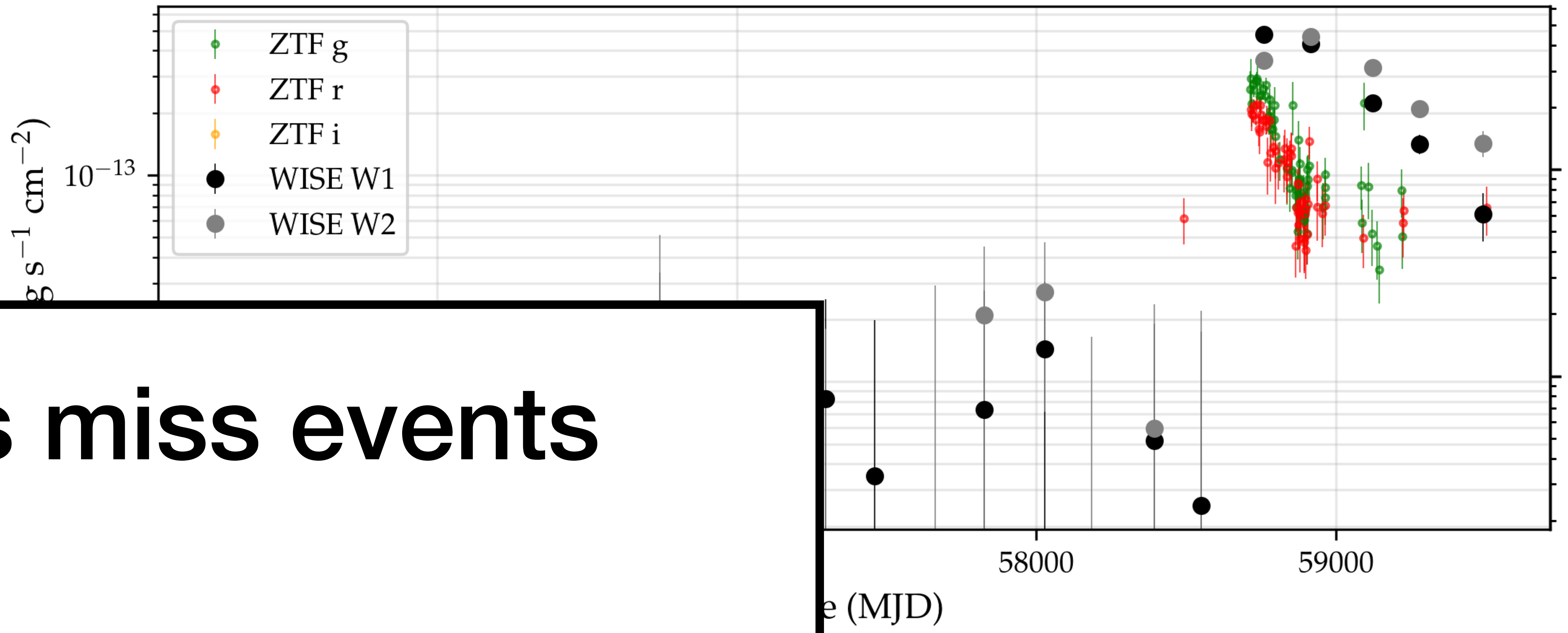






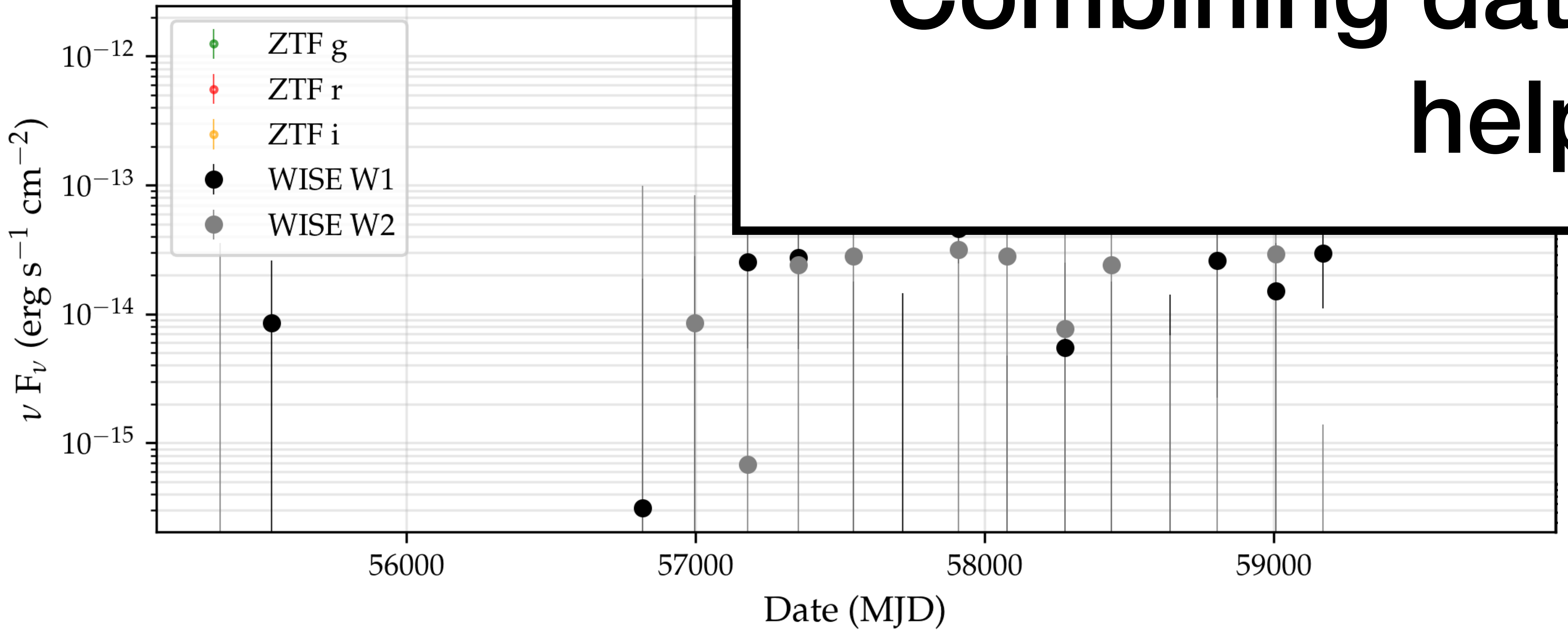
Identified some strong TDE candidates previously missed

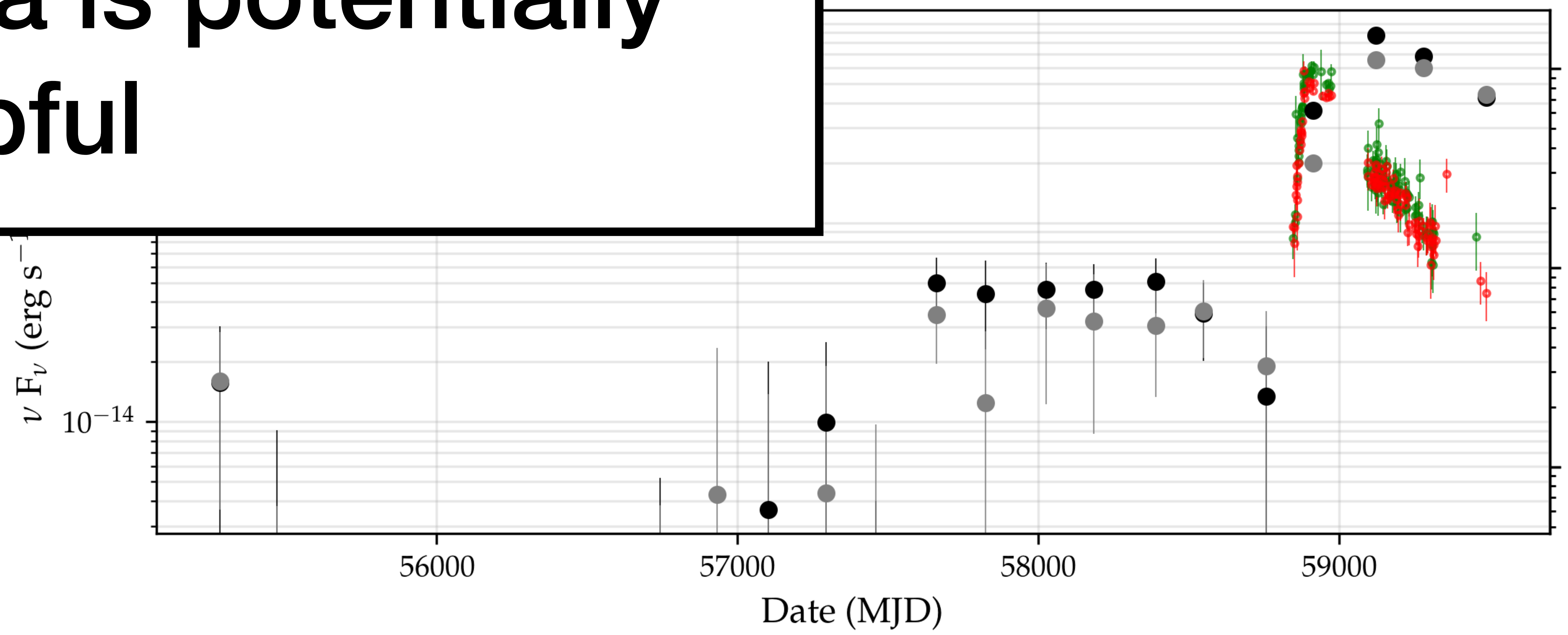




Live searches miss events

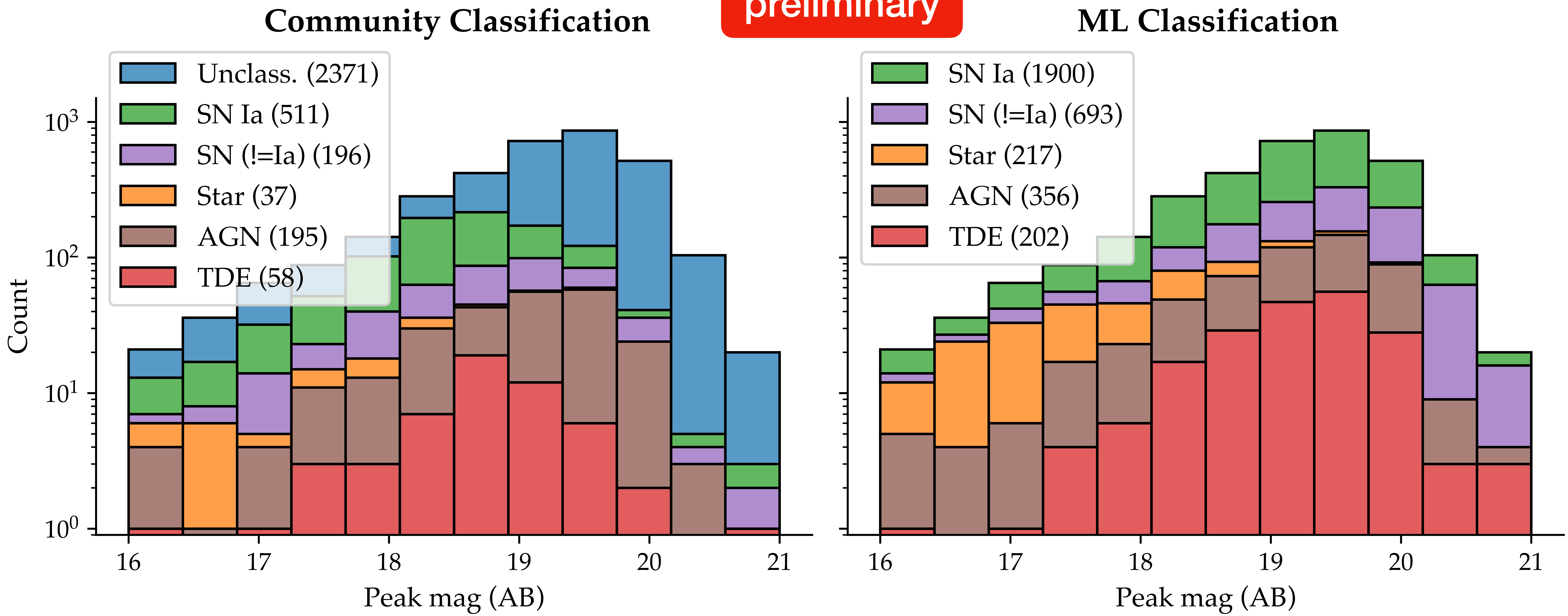
Combining data is potentially helpful





Classification results

preliminary



III) What does this tell us about GW follow up?

What can we learn from such a sample?

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Photometric identification is still a challenge!

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We know about SNe, stochastic AGN variability, AGN flares, CVs and TDEs. But what else?

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Exclusively looking for KN signatures poses the danger of missing something

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There might be types of events in the sample we missed so far

We know about SNe, stochastic AGN variability, AGN flares, CVs and TDEs. But what else?

Exclusively looking for KN signatures poses the danger of missing something

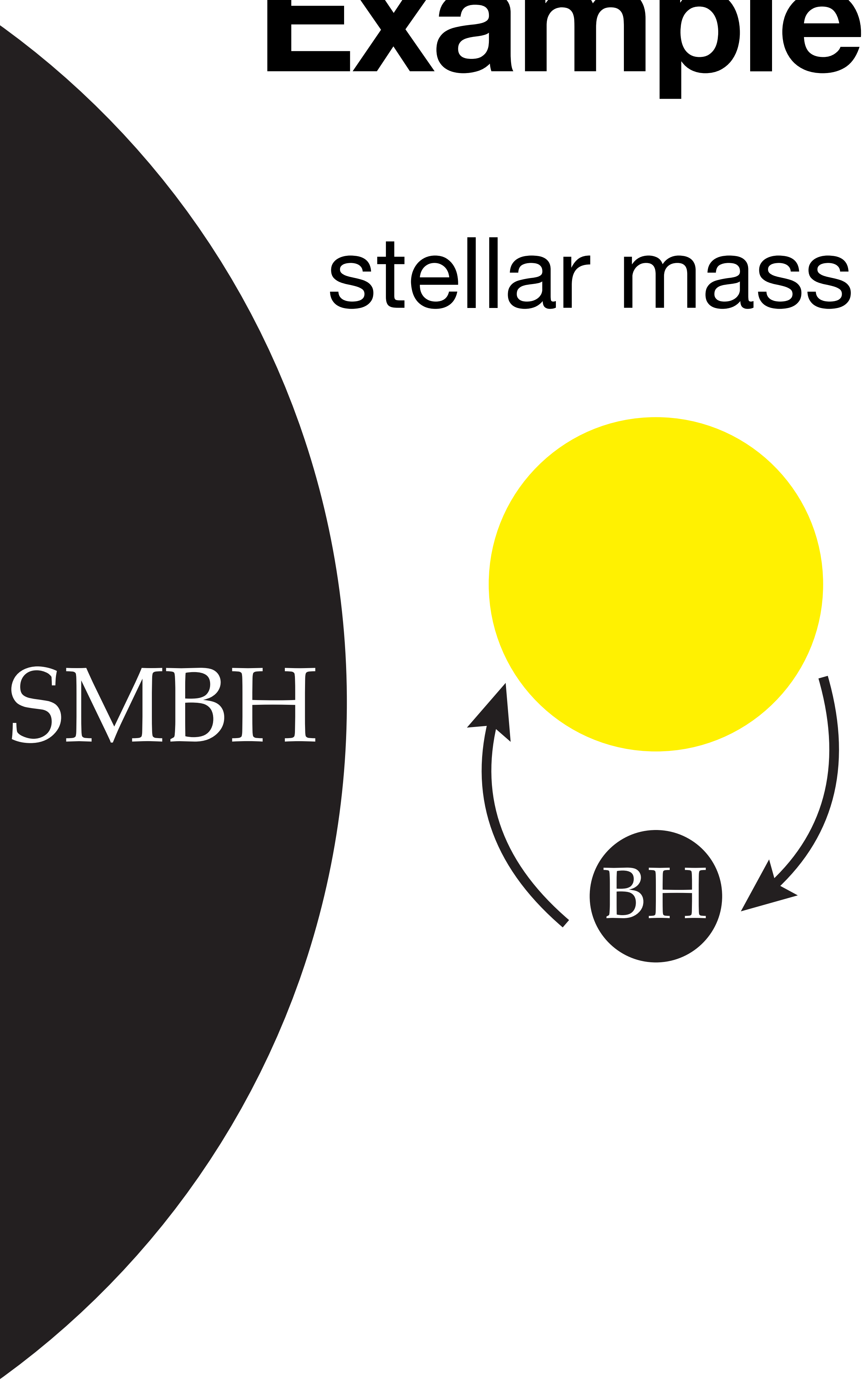
BBH counterparts (slowly evolving!)

Example: What about micro-TDEs?

Y. Yang+ 2022

Example: What about micro-TDEs?

stellar mass BH tidally disrupting a star



Y. Yang+ 2022

Example: What about micro-TDEs?

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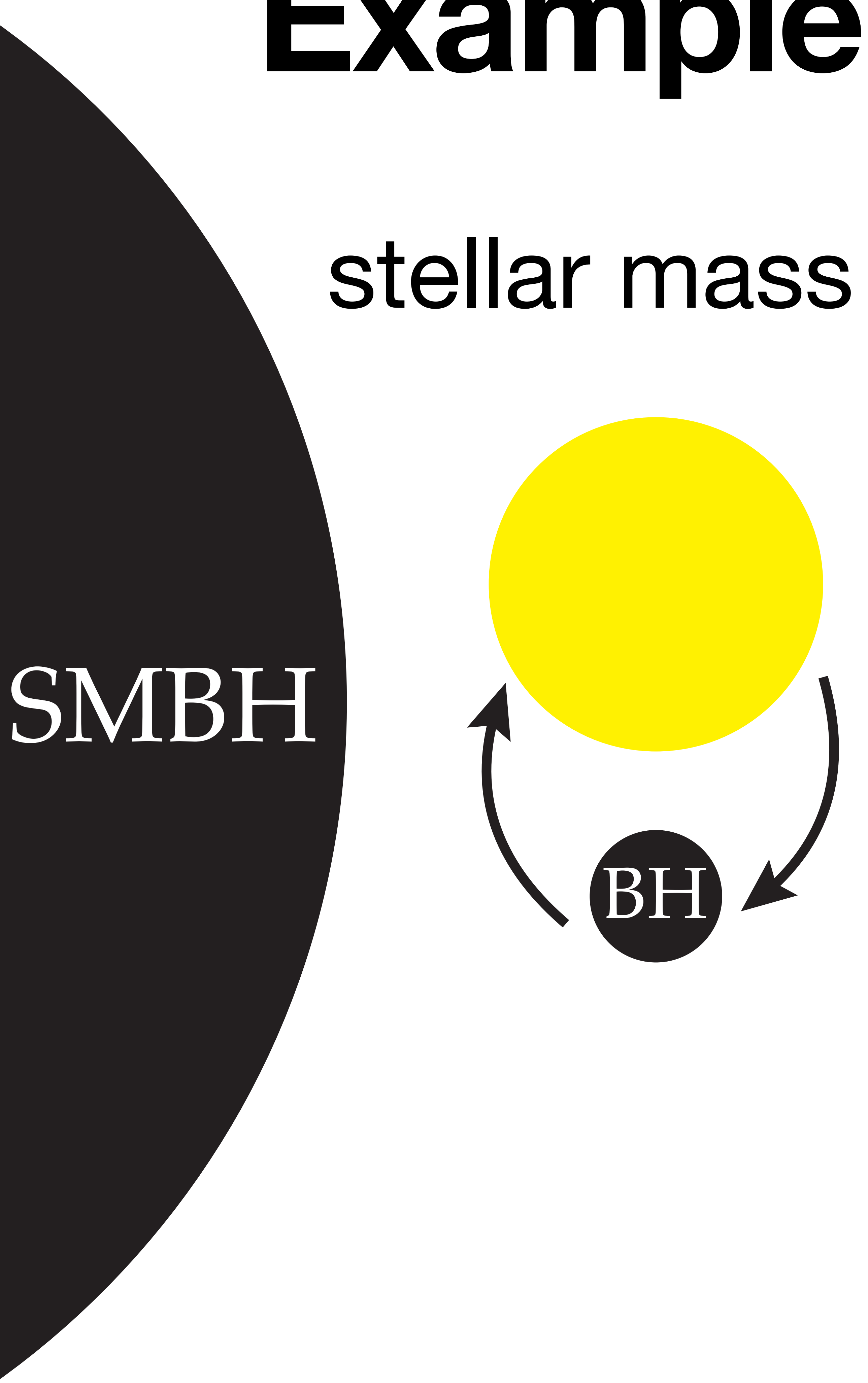

Maybe enhanced rate close to the SMBH due to pre-existing accretion disk

Y. Yang+ 2022

Example: What about micro-TDEs?

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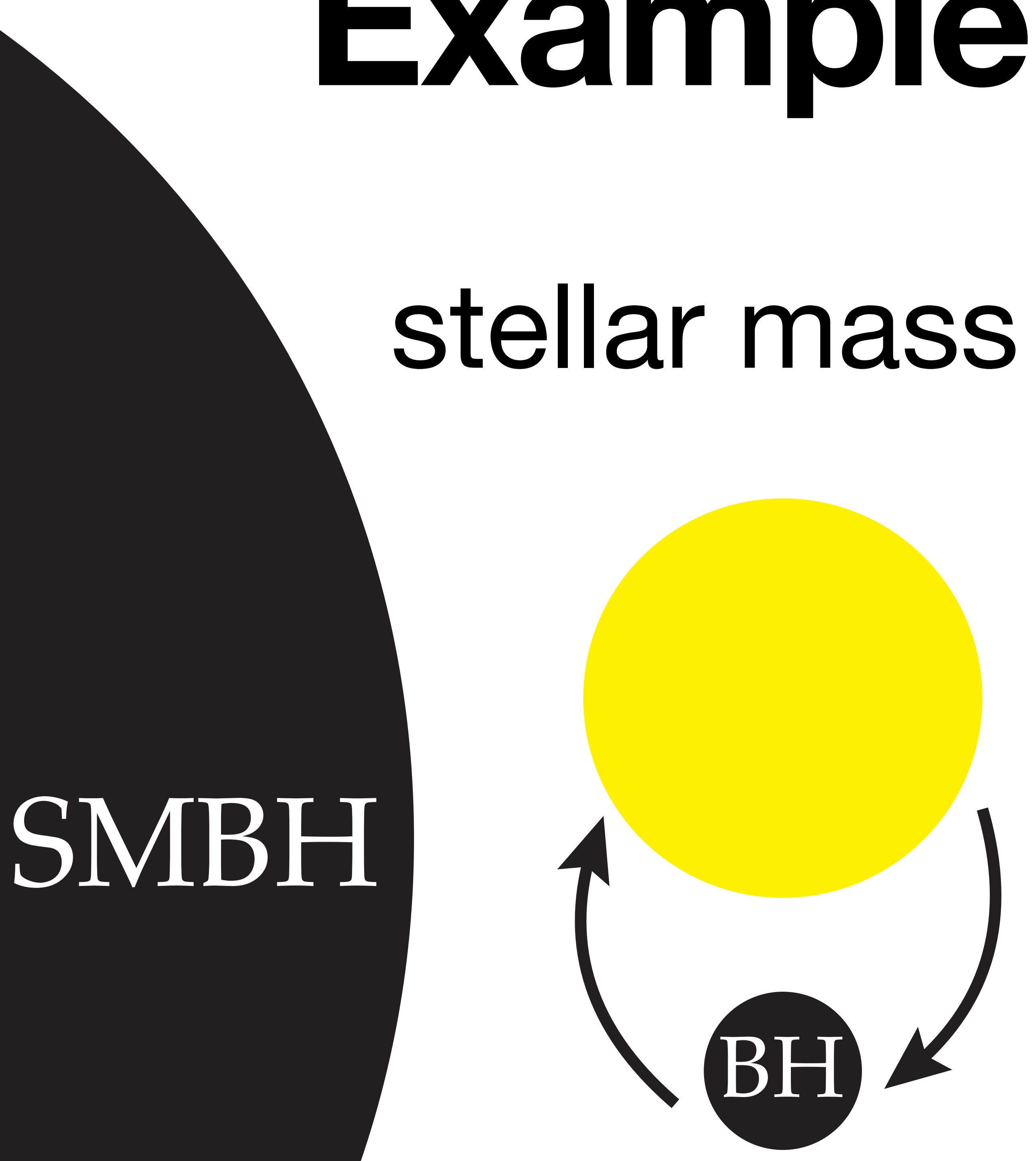
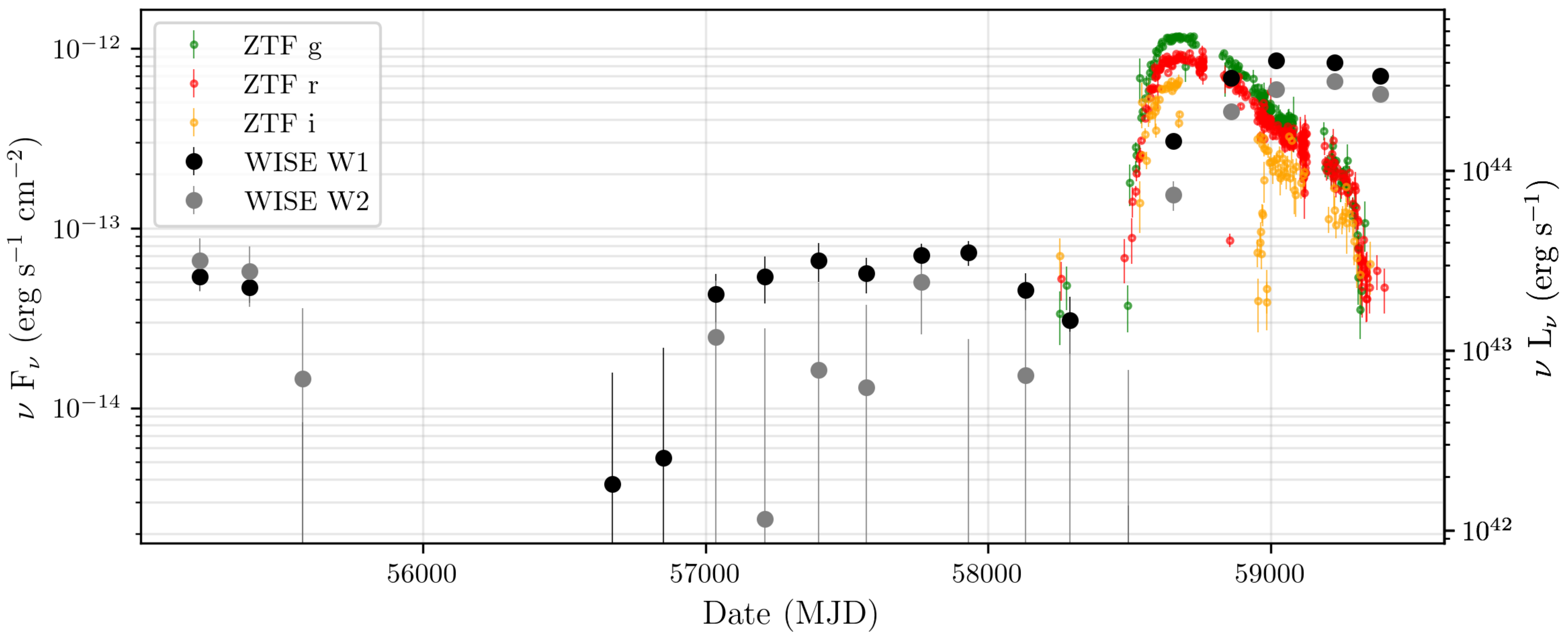


Maybe enhanced rate close to the SMBH due to pre-existing accretion disk

EM signature: Similar to TDEs, but SMBH mass above Hills mass for **bright** μTDEs

Faint μTDEs: unusual flaring in the AGN light curve



Literature candidate μTDE
ZTF19aailpwl (part of the sample)

Y. Yang+ 2022

Event type possibly observable as EM transients

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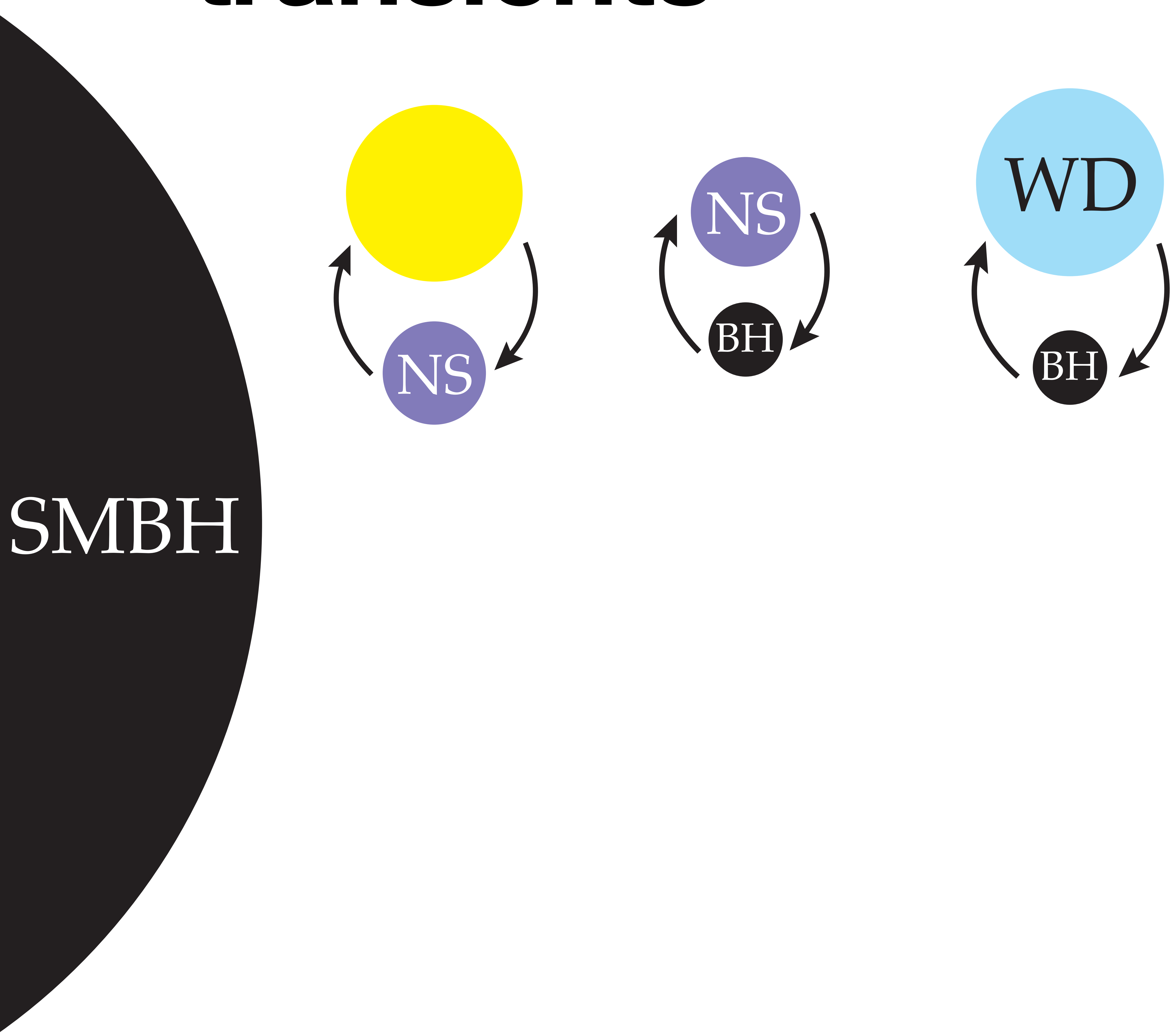
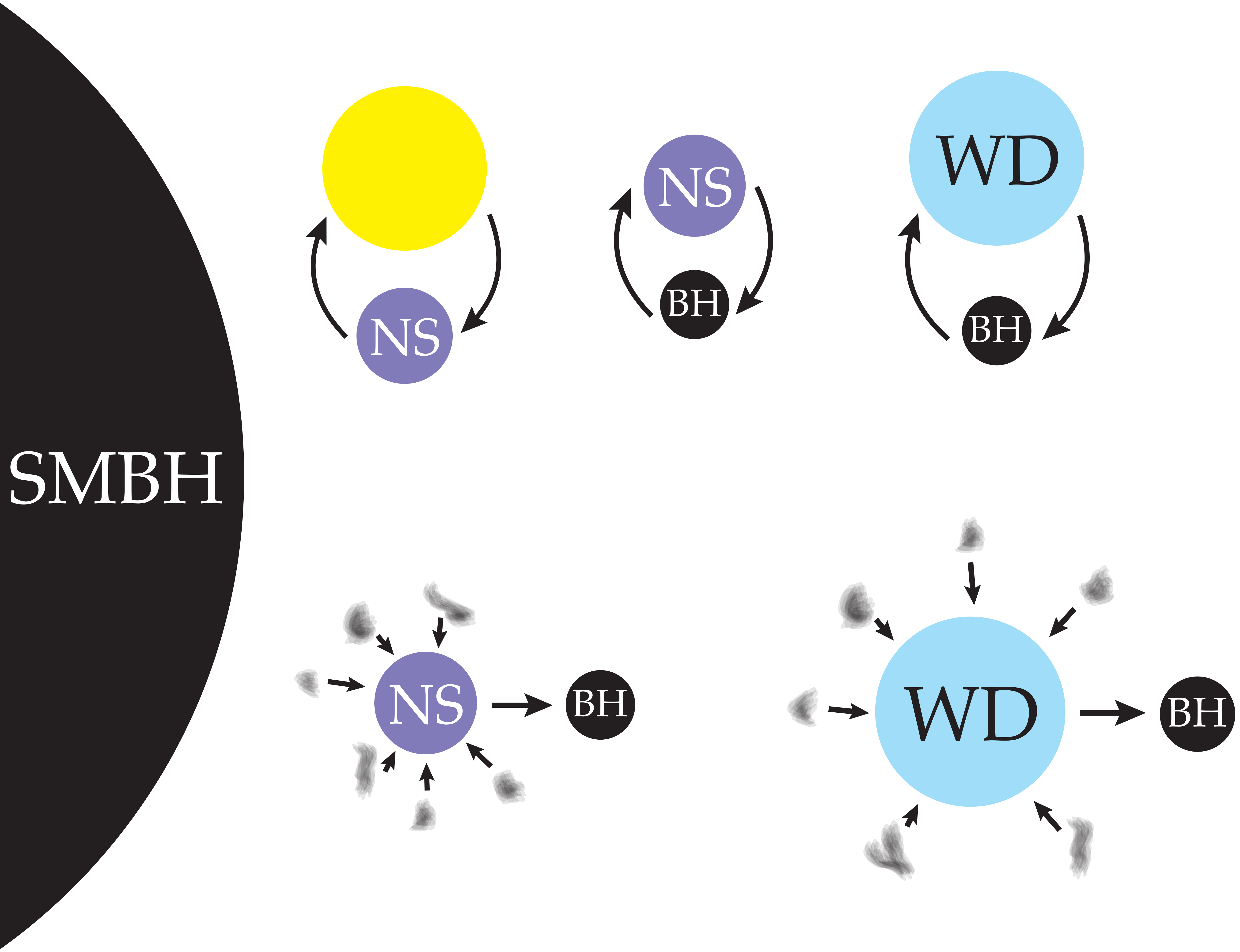


Other μTDE channels

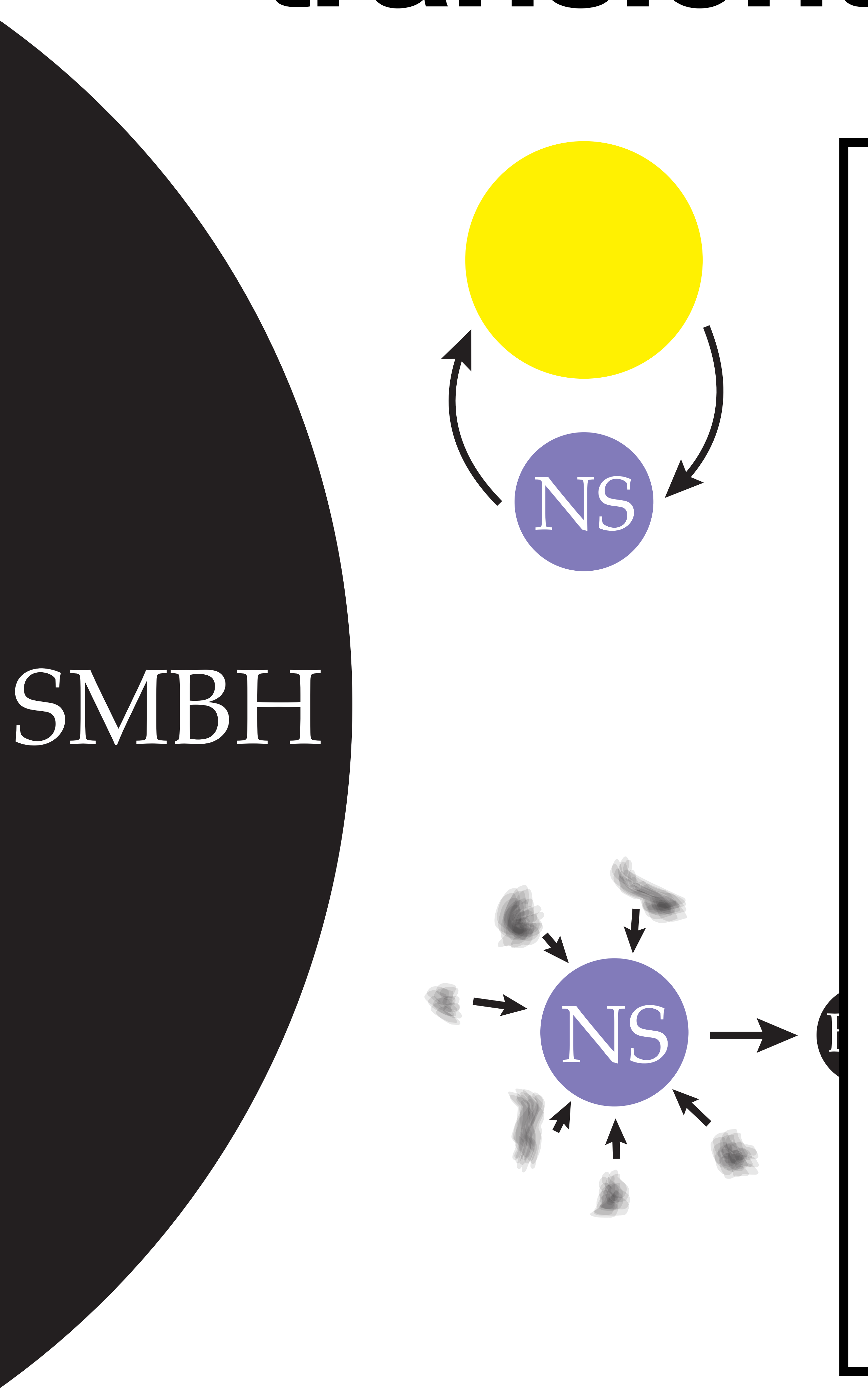
Event type possibly observable as EM transients



Other μTDE channels

Accretion induced collapse

Event type possibly observable as EM transients

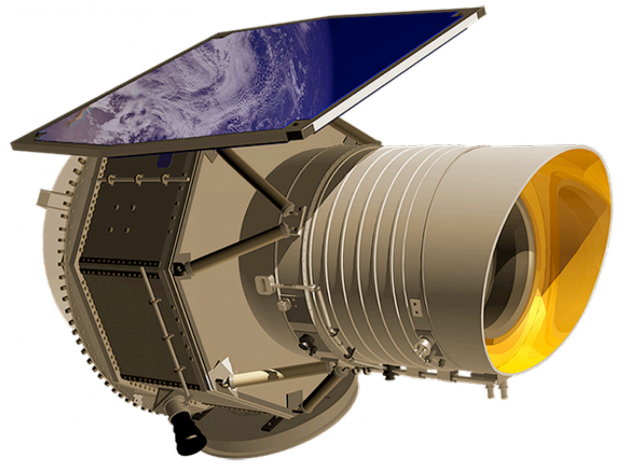


There should be some of these contained in the nuclear sample

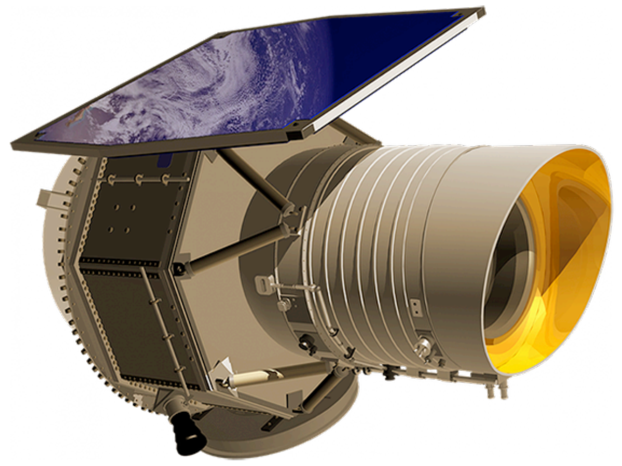
GW signals unlikely to be accessible to LVK

But one can potentially learn about BH evolution and binary formation in AGN disks

Nuclear sample: Created with AMPEL

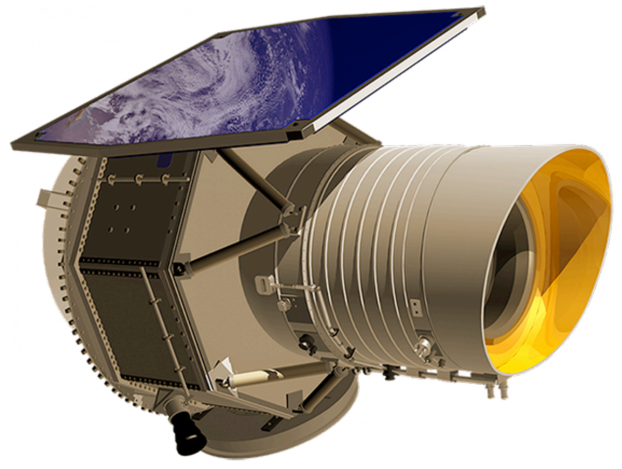


Nuclear sample: Created with AMPEL



User-specified pipeline

Nuclear sample: Created with AMPEL



User-specified pipeline

Science

There is so much more data to be combined

cta
cherenkov telescope array

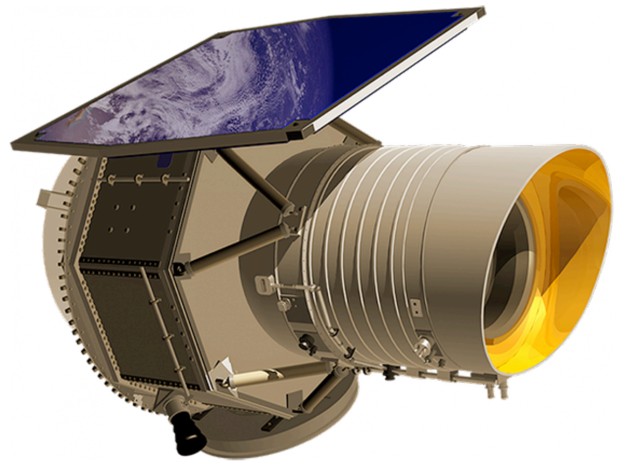
VERA C. RUBIN
OBSERVATORY

IceCube

ZTF

LIGO
VIRGO

ULTRASAT
Ultraviolet Transient Astronomy Satellite



→

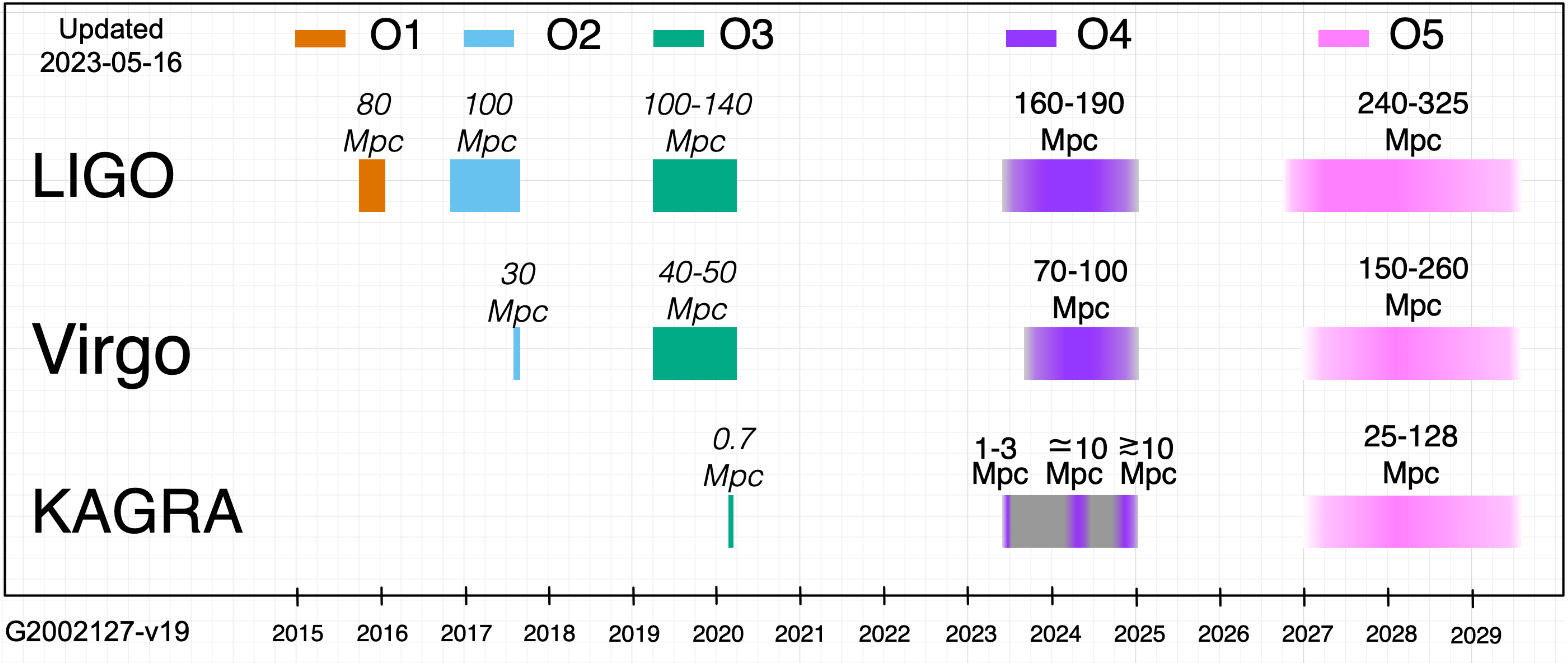
User-specified pipeline

→

Science

IV) Current ZTF O4 status

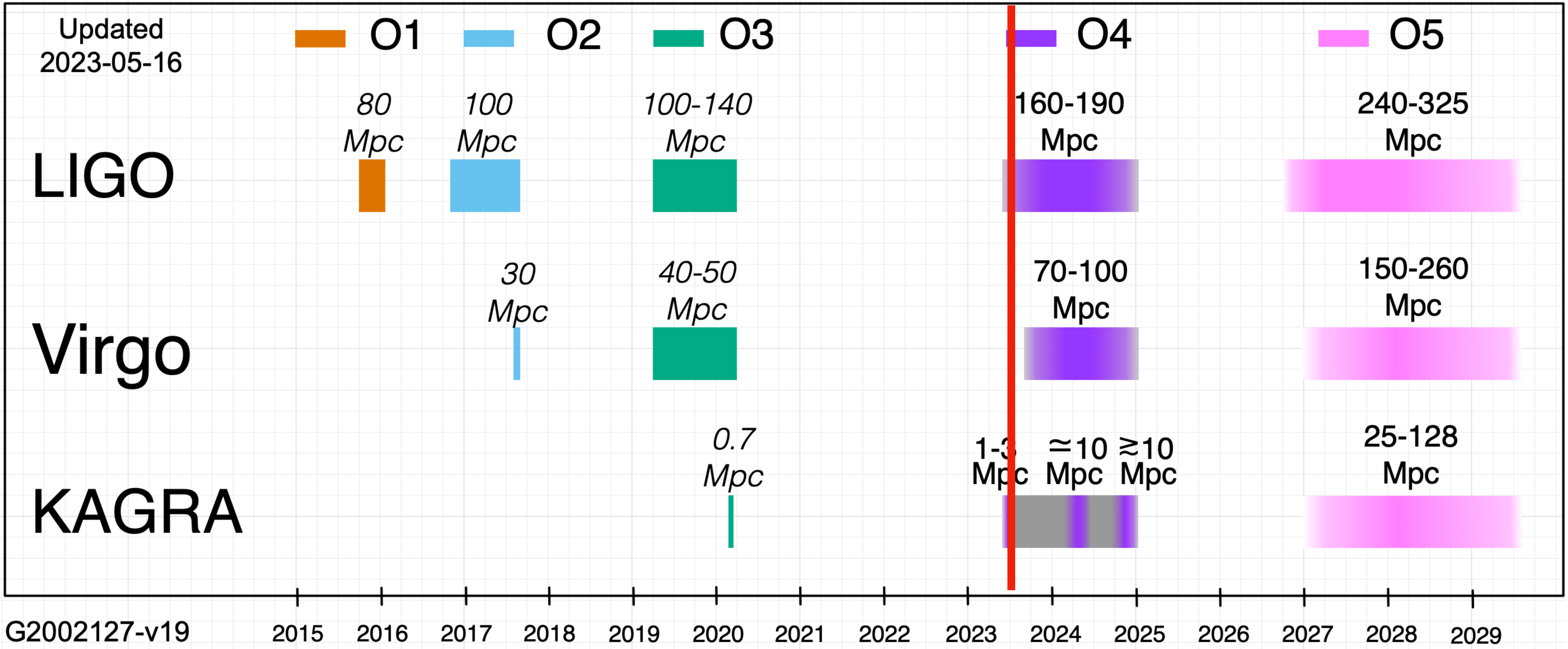
O4 Status



Updated 2023-05-16
O1
O2
O3
O4
O5
LIGO
80 Mpc
100 Mpc
100-140 Mpc
160-190 Mpc
240-325 Mpc
Virgo
30 Mpc
40-50 Mpc
70-100 Mpc
150-260 Mpc
KAGRA
0.7 Mpc
1-3 Mpc
≃10 Mpc
≳10 Mpc
25-128 Mpc
G2002127-v19
2015
2016
2017
2018
2019
2020
2021
2022
2023
2024
2025
2026
2027
2028
2029

O4 Status

We are here!



O4 Status

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Expected range: 140 – 170 Mpc

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40% higher distance than O4, 2.6 the volume

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Expected event rates: 10 (+52/-10) BNS detections

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FAR rate:

low significance: FAR > 1/month (CBC) or > 1/year (burst)

significant: FAR < 1/month (CBC) or < 1/year (burst)

O4 Status

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40% higher distance than O4, 2.6 the volume

Expected event rates: 10 (+52/-10) BNS detections

FAR rate:

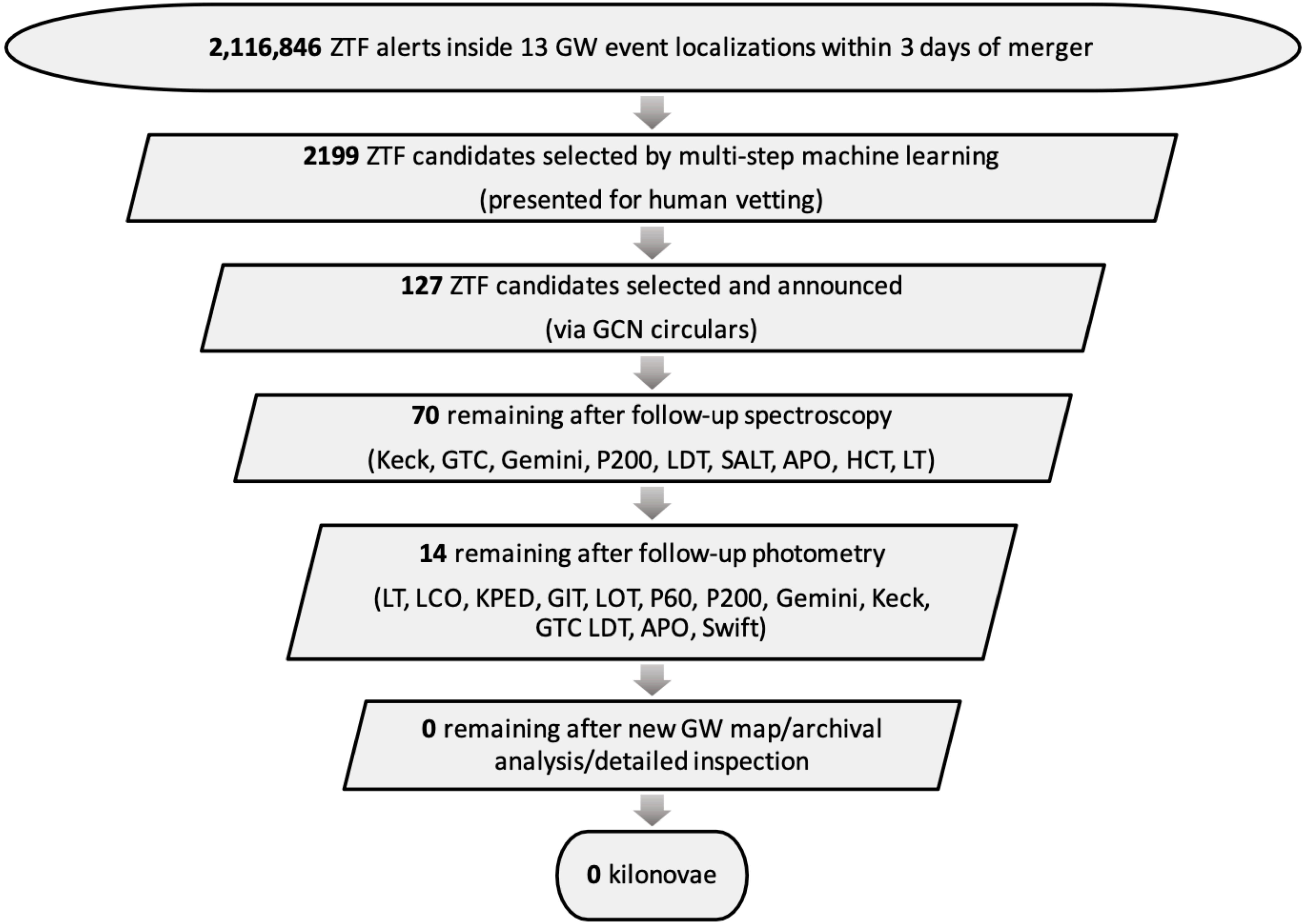
low significance: FAR > 1/month (CBC) or > 1/year (burst)

significant: FAR < 1/month (CBC) or < 1/year (burst)

Localization: **Comparable to O3**

Recap: O3 with ZTF

Or: How to go from 2.1 Million to zero 😭



O4 Trigger Strategy

Parameter	Go-deep	Go-wide	Deliberate	No Go
Strategy	300 sec Push distance	30 sec Push localization		
Frequency of triggers	1 per month 3 night	2 per month 5 nights		
FAR min(FAR) - ‘Best’	< 1 per century Any pipeline	< 1 per decade Any pipeline	1 per year - century	> 1 per year All pipelines
max(p-astro)	> 0.9	> 0.9	0.1-0.9	<0.1
HasNS	>0.9	>0.9	0.1-0.9	<0.1

Action Item:
human interaction

Redundant machinery for ZTF scanning

fritz.science
(Fritz database)

nuztf + AMPEL
(AMPEL DB)

emgwcave
(Kowalski DB)

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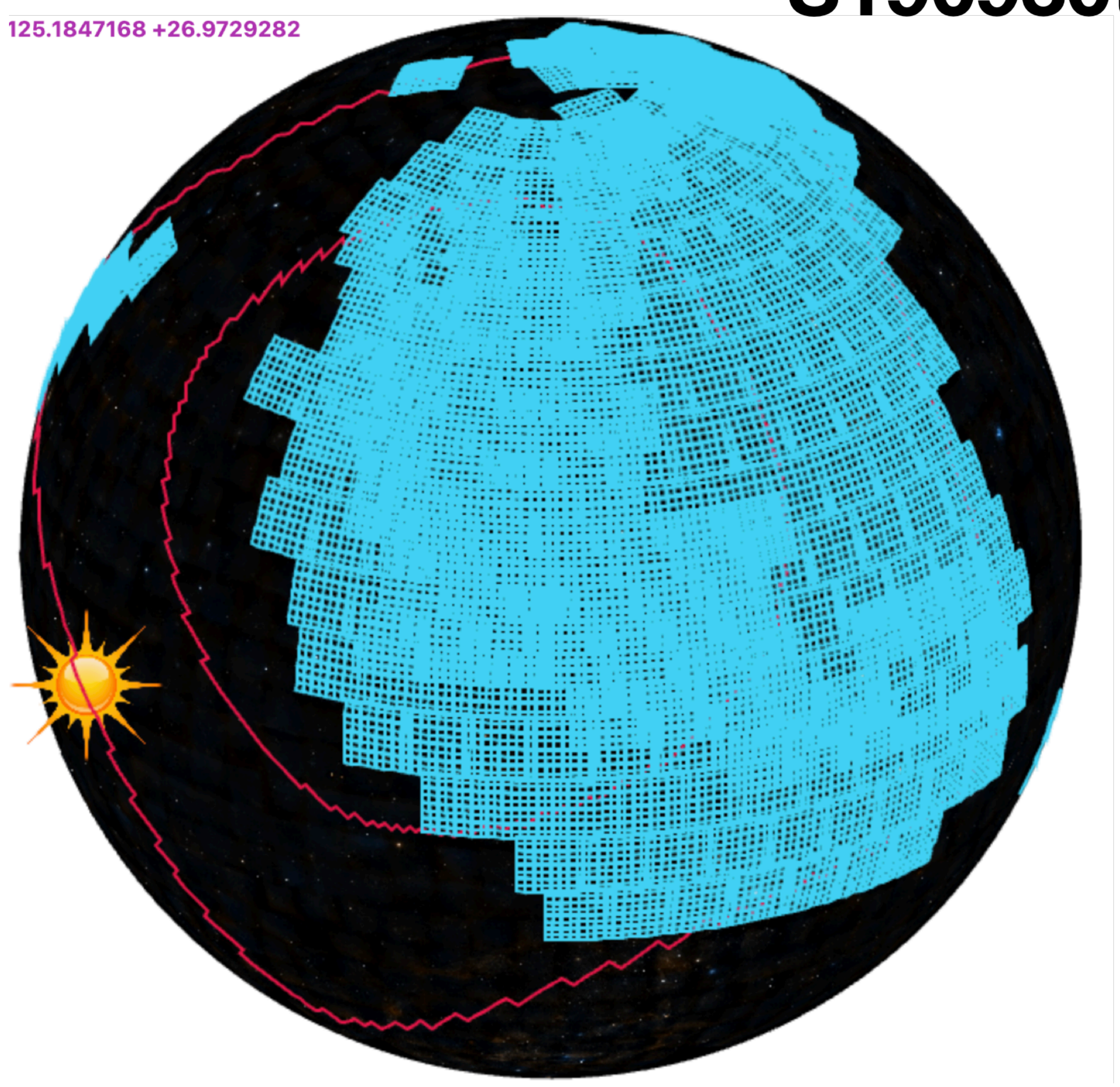
Example: nuztf + AMPEL

Example: nuztf + AMPEL

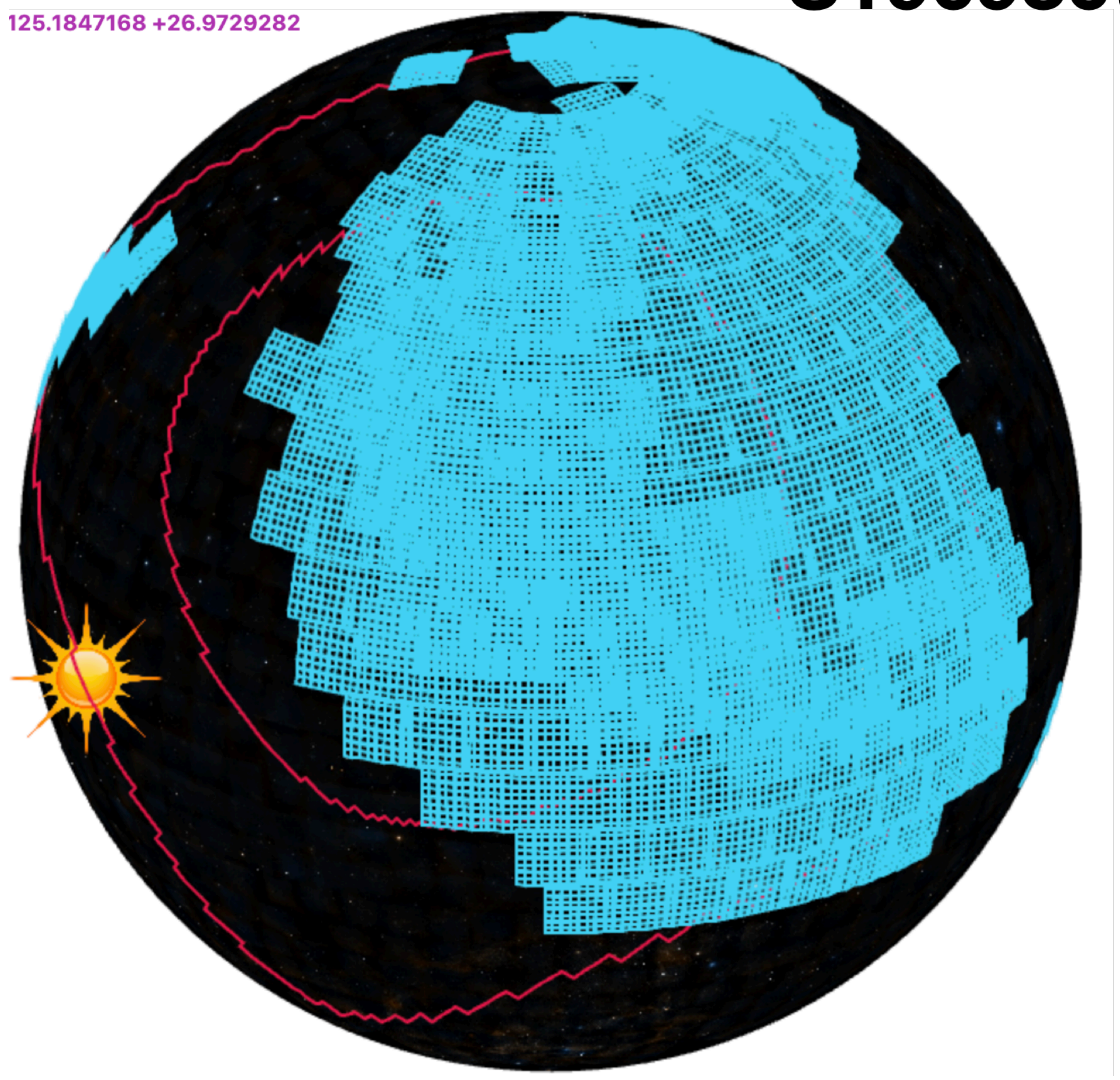
Scan **S190930t** comprising **24,000 sq. deg.** (3 day window)



Example: nuztf + AMPEL

Scan **S190930t** comprising **24,000 sq. deg.** (3 day window)

Retrieve 180,000 alerts in **7 min**
Filter them in **5 min**

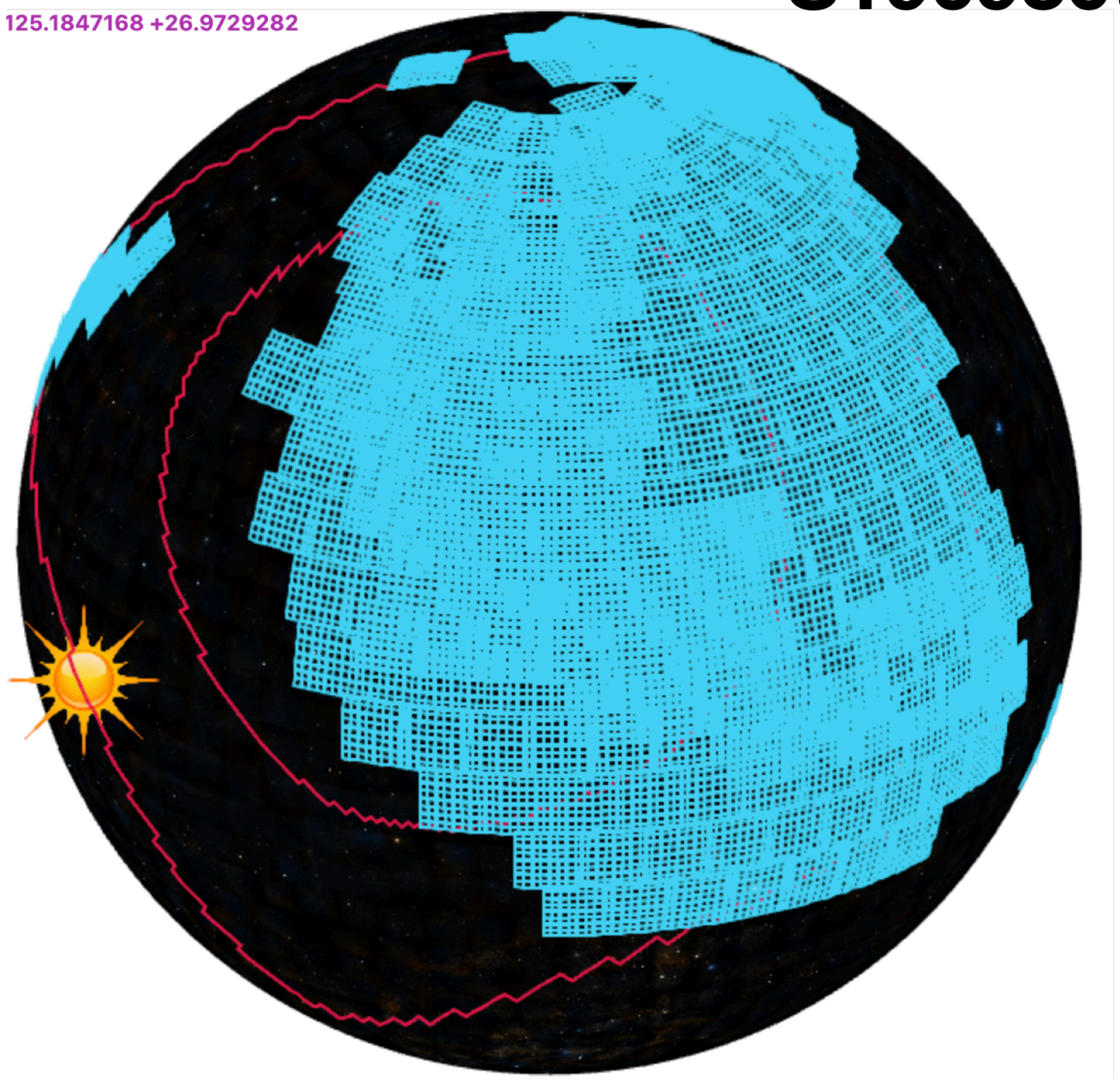


Example: nuztf + AMPEL

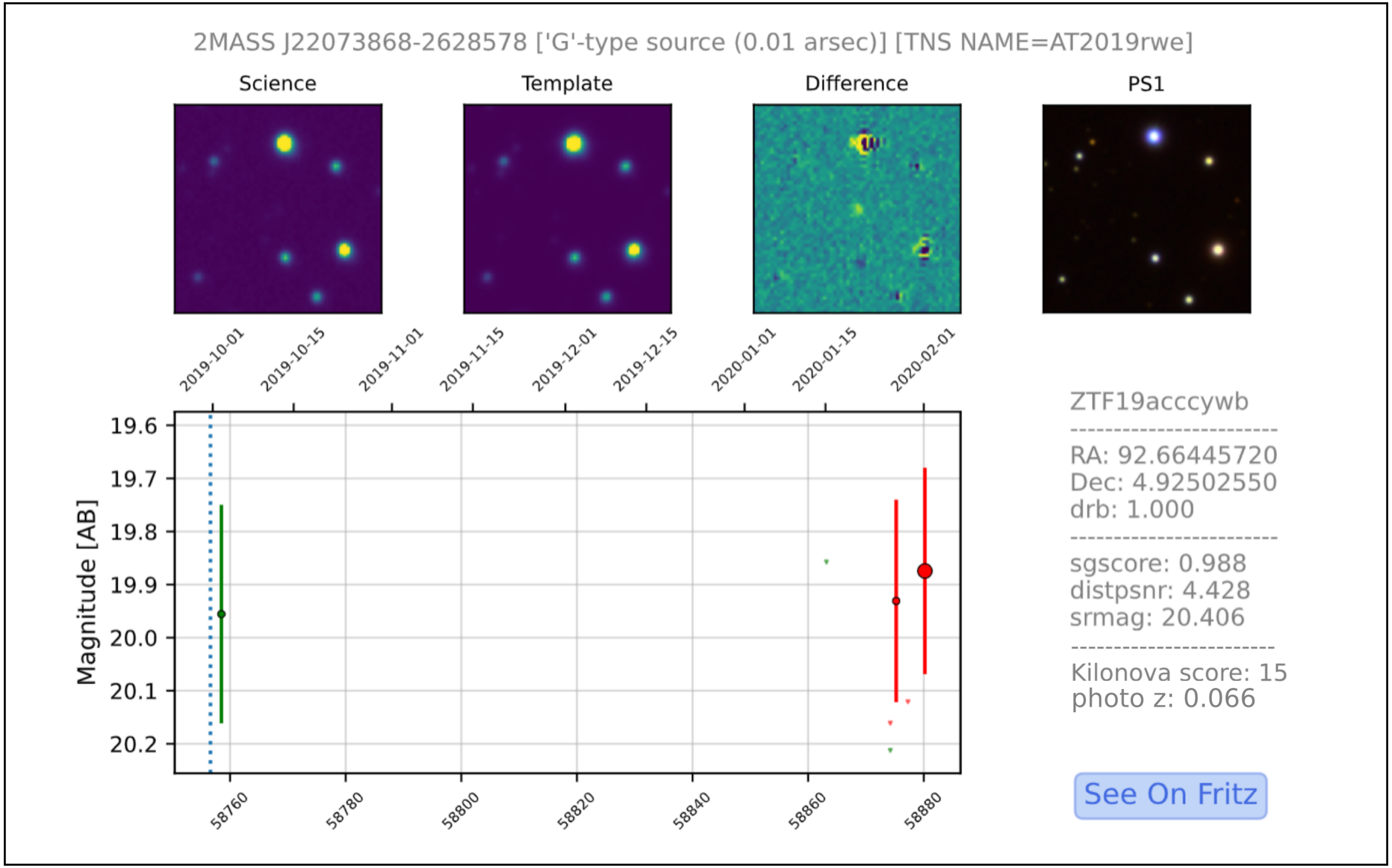
Scan **S190930t** comprising **24,000 sq. deg.** (3 day window)

Retrieve 180,000 alerts in **7 min**
Filter them in **5 min**

Photometry SQL database (although it is HEALPix indexed in several resolutions) - can output **~500 alerts/second**

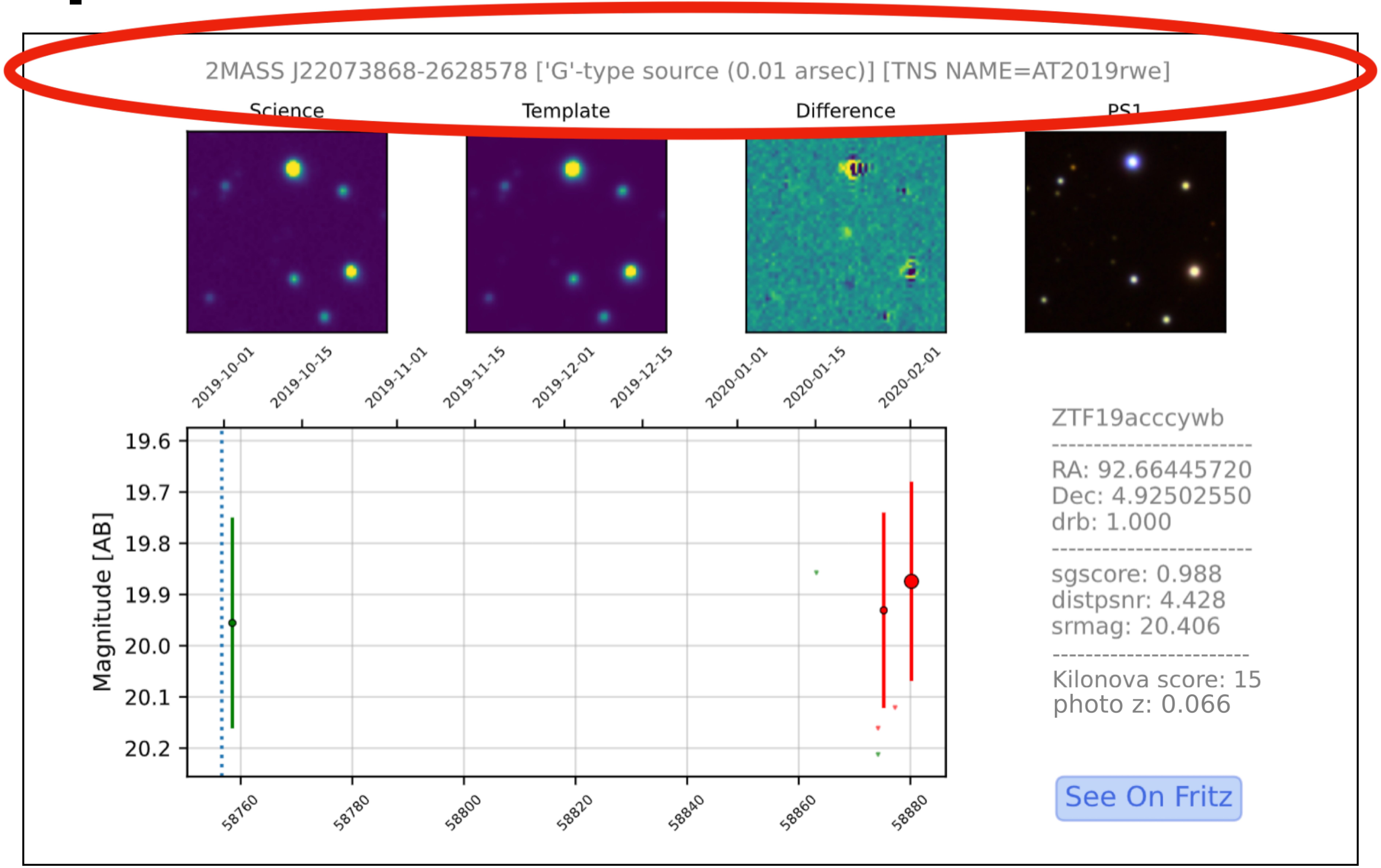


Example: nuztf + AMPEL

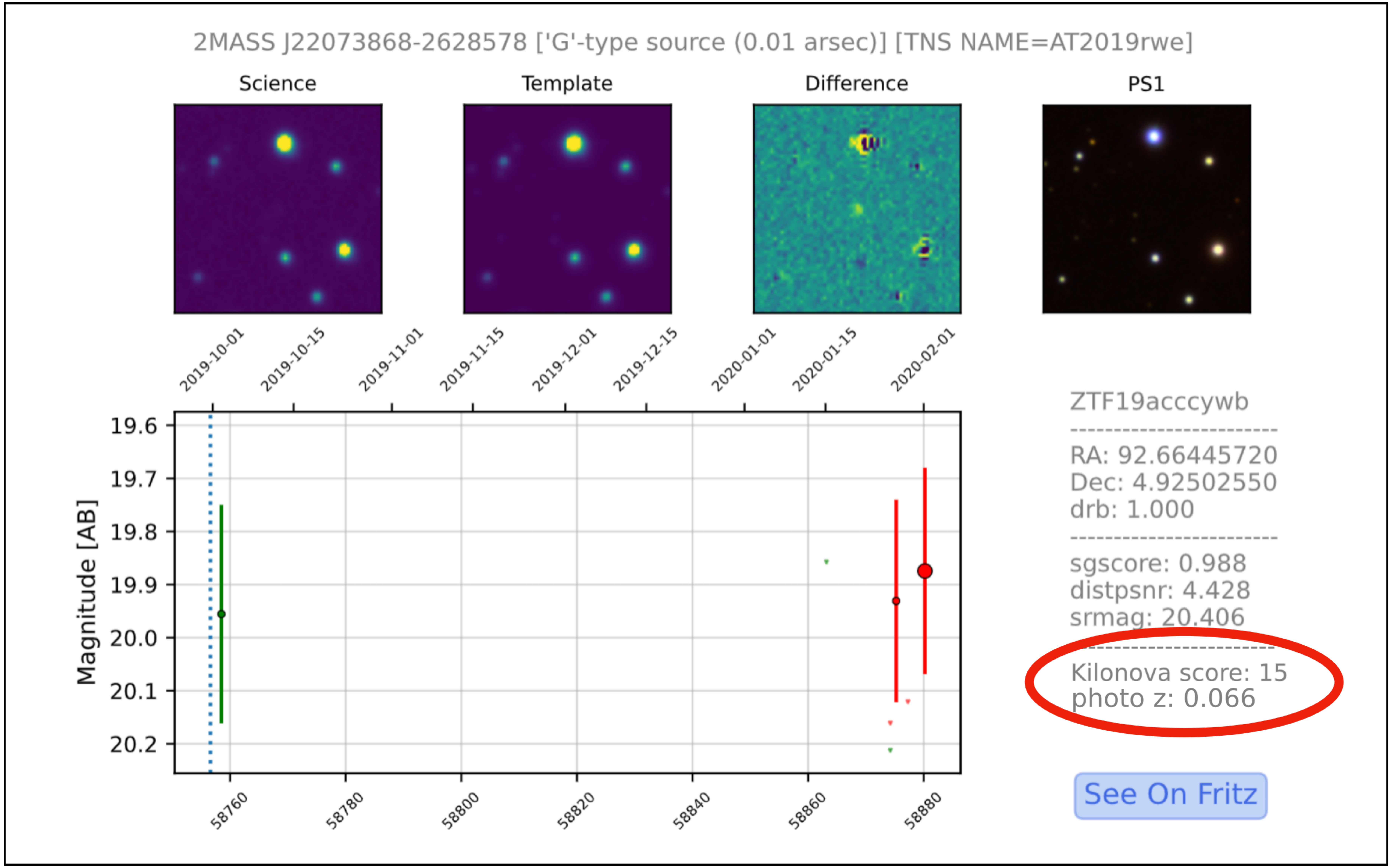


Example: nuztf + AMPEL

Crossmatch

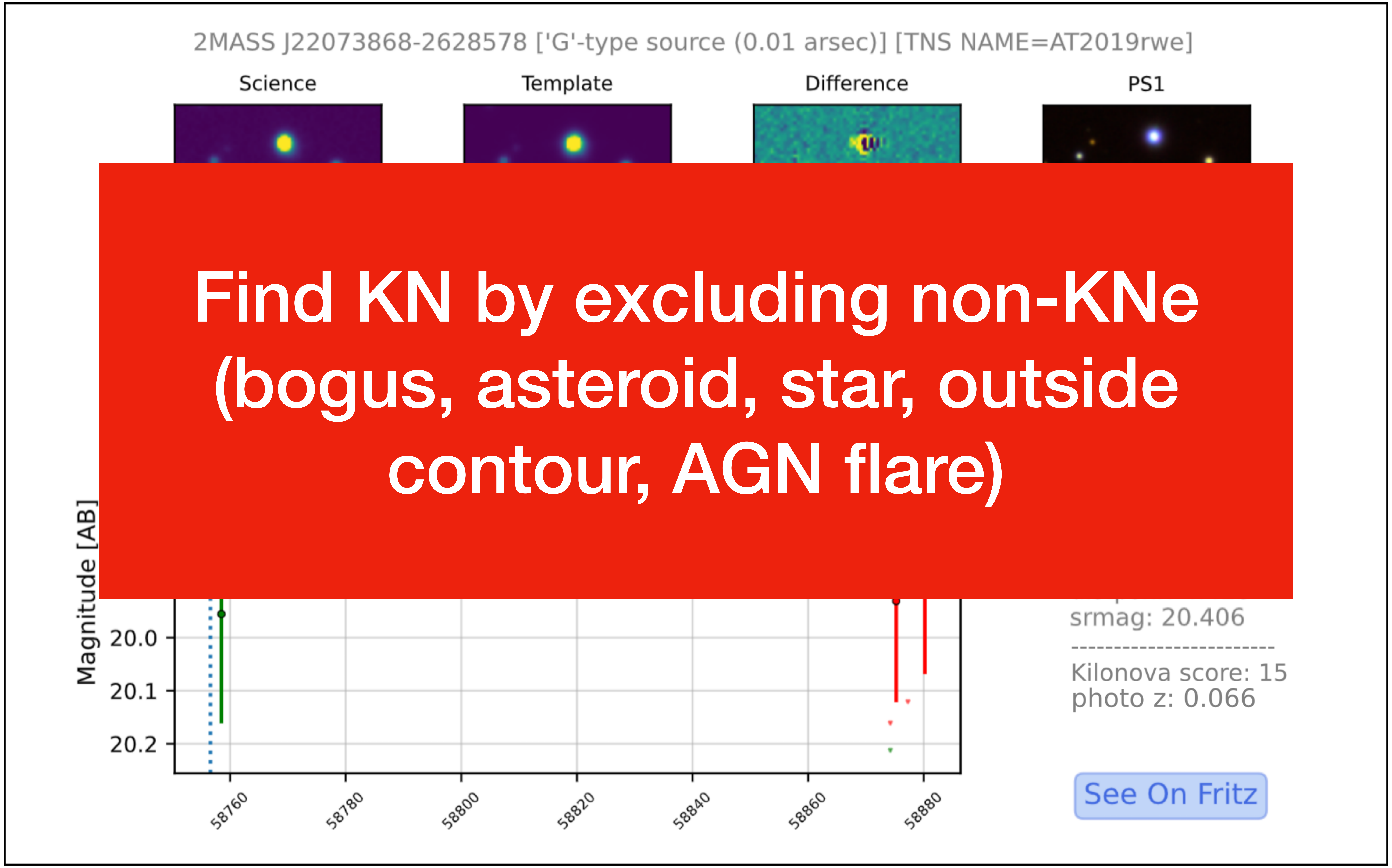


Example: nuztf + AMPEL



Metrics

Example: nuztf + AMPEL



Find KN by excluding non-KNe (bogus, asteroid, star, outside contour, AGN flare)

Redundant machinery for scanning

Weekly shifts

Always 5 people (US, Europe, India)

Already had a few GW alerts

Stay tuned! 🤓

Summary

Image credit: Palomar Observatory

Summary

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ZTF has vastly increased the TDE sample

Summary

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Created a flux-limited, unbiased sample of nuclear events

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Classification effort ongoing

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🚦AMPEL enables all this

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Image credit: Palomar Observatory

ZTF has vastly increased the TDE sample

Created a flux-limited, unbiased sample of nuclear events

Classification effort ongoing

Explore the wealth of transients contained in the sample

🚦AMPEL enables all this

O4 underway!

Bonus

To ponder

Wealth of data should increase the likelihood of serendipitous discovery

➡ But only if we have the right tools for it!

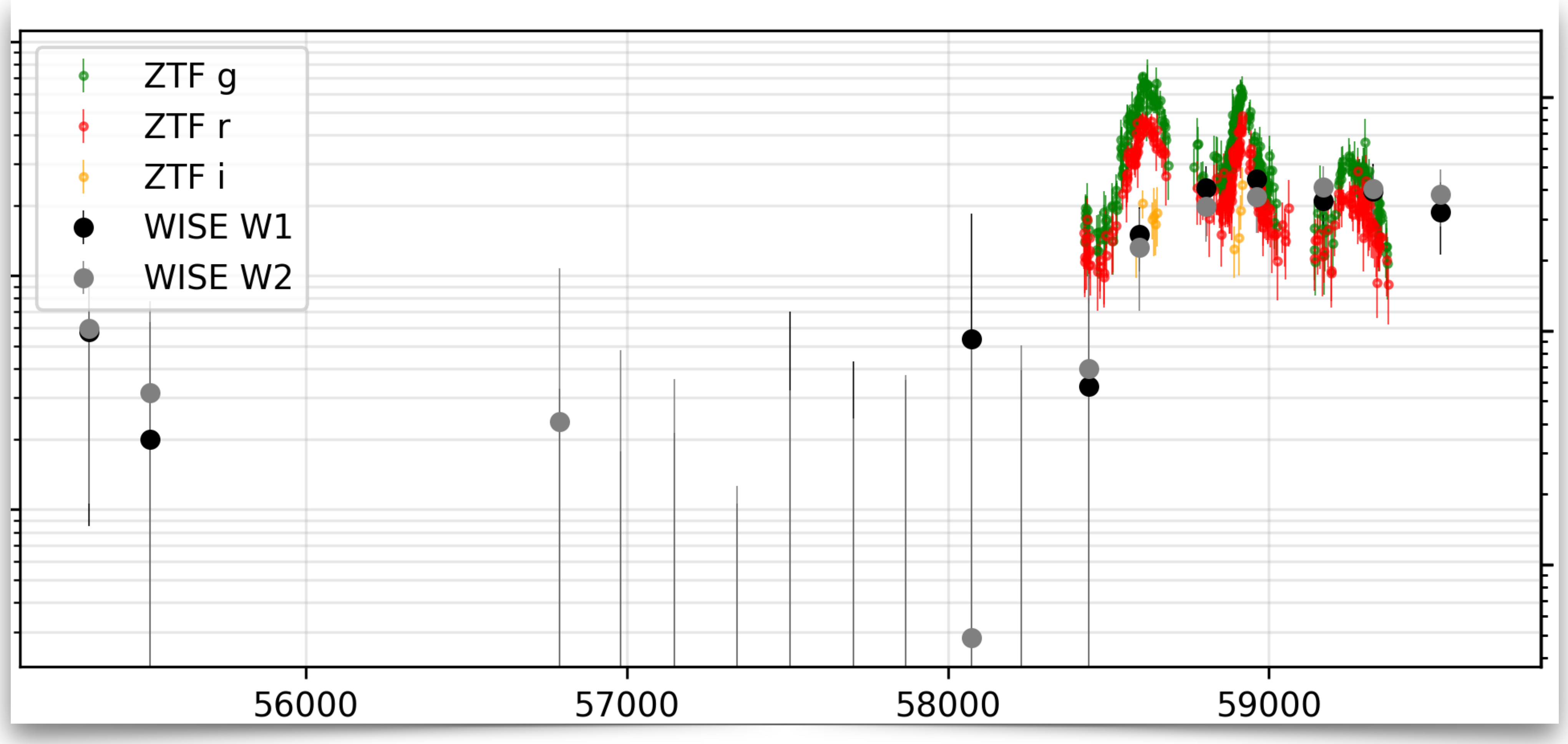
Rapid follow up is great! But maybe there is something to be gained from archival studies

How about automatic coincidence searches for **all** O4 alerts?

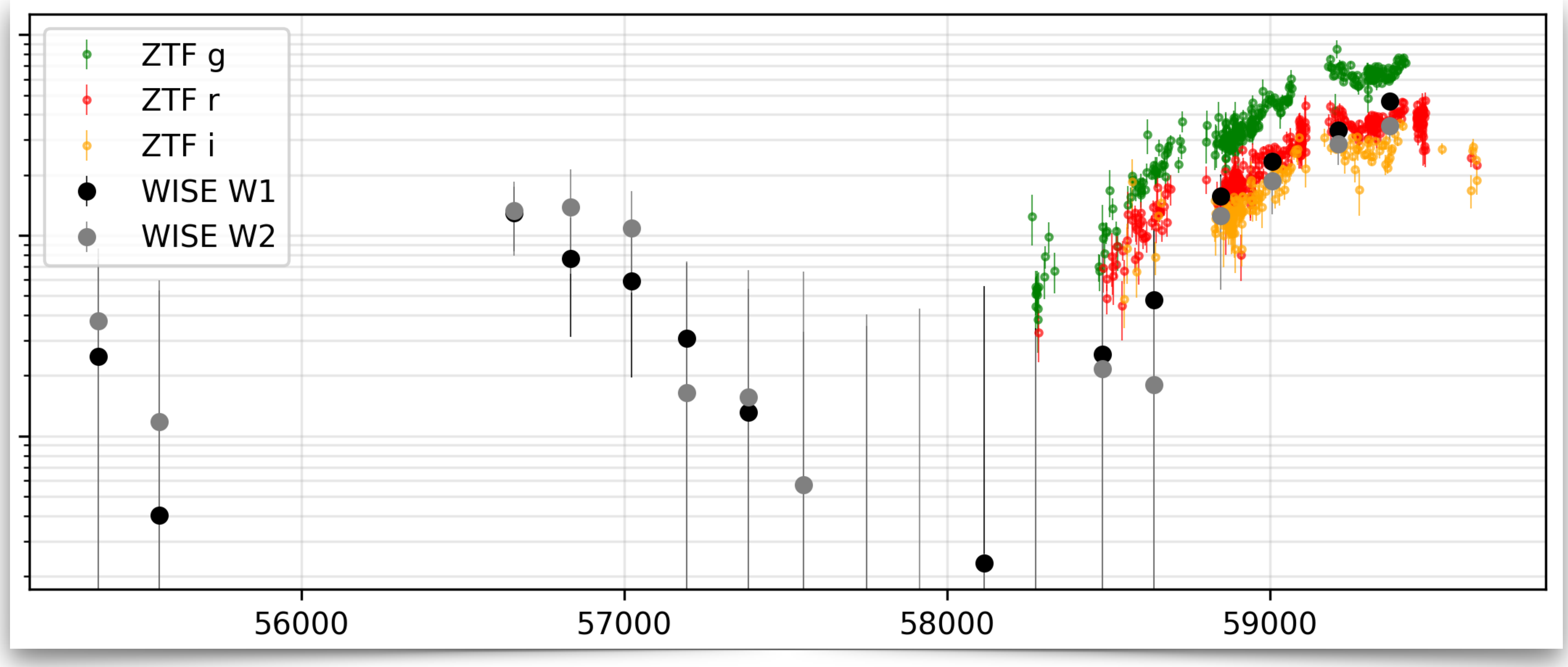
🕵️Background studies using the normal survey ("blind")

IR transients: Filtered by IR

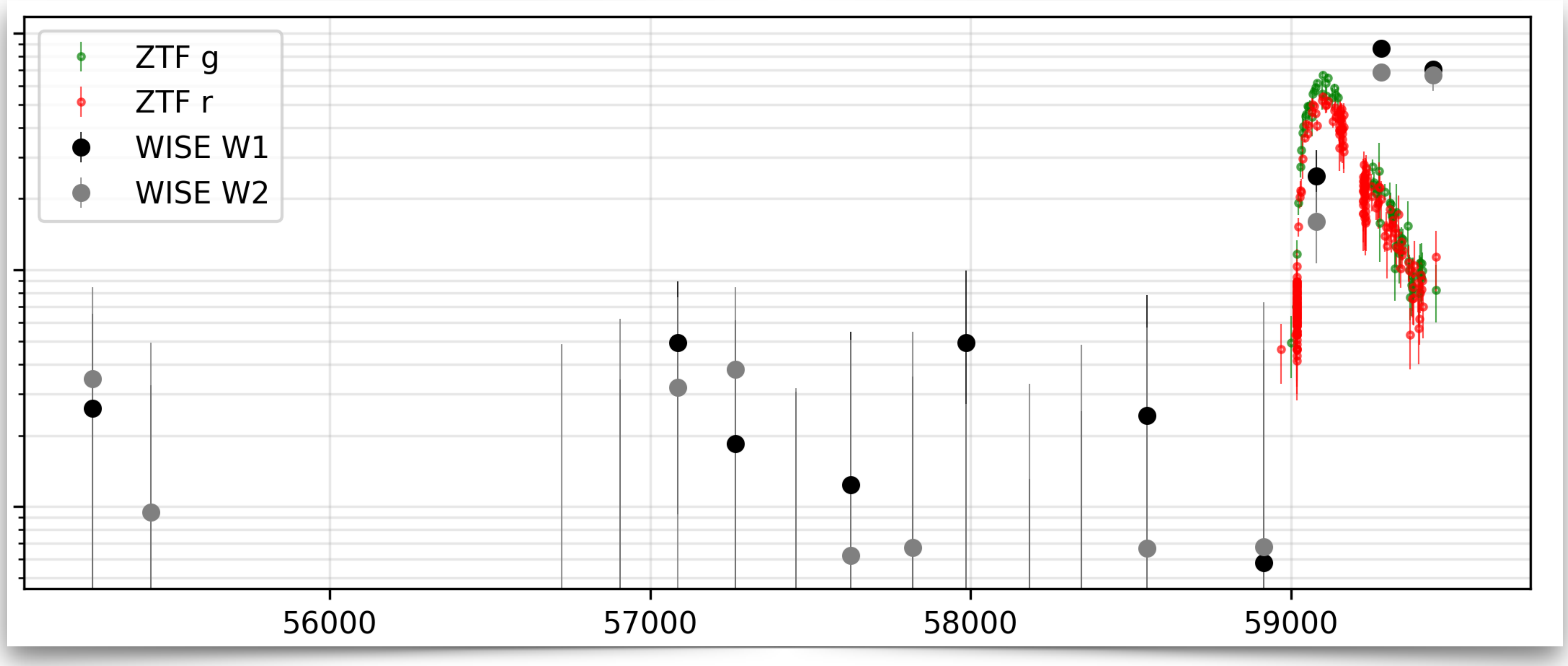
Blazar candidates



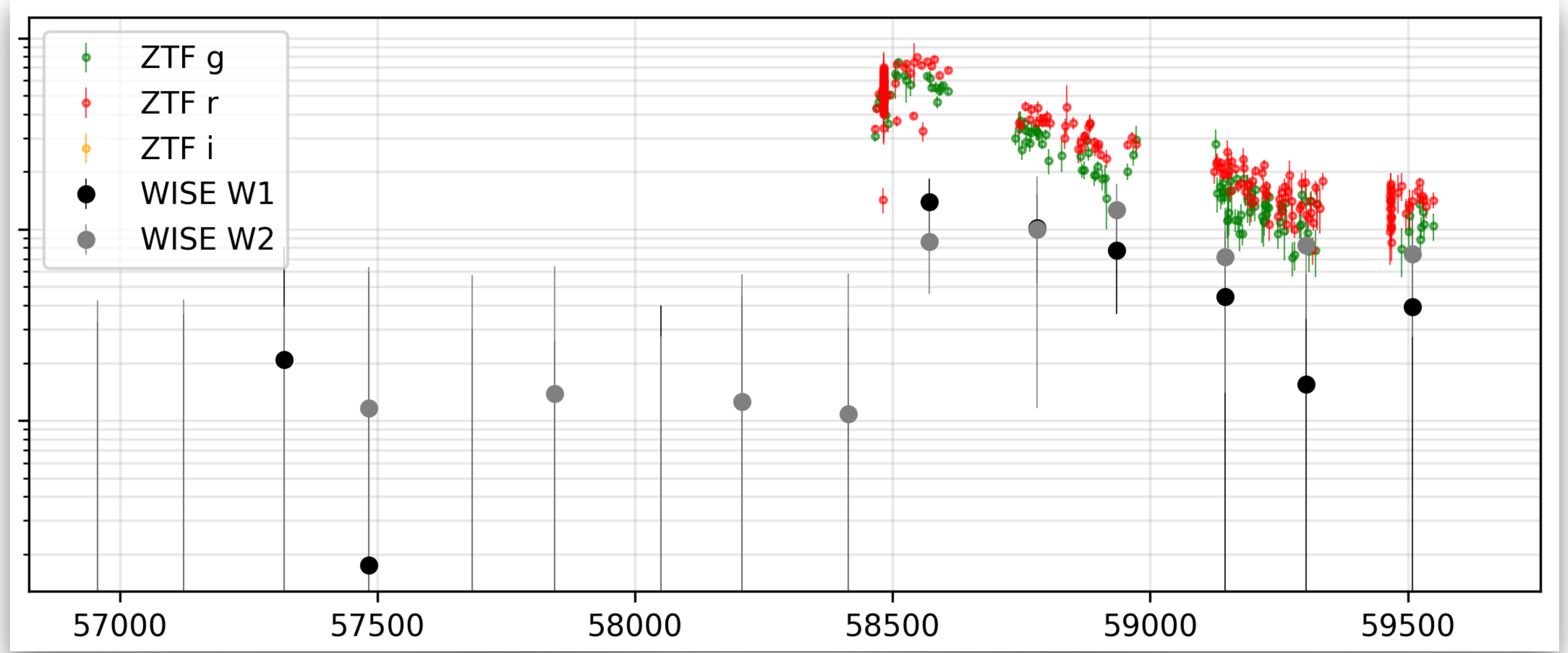
slow rise, simultaneous IR rise



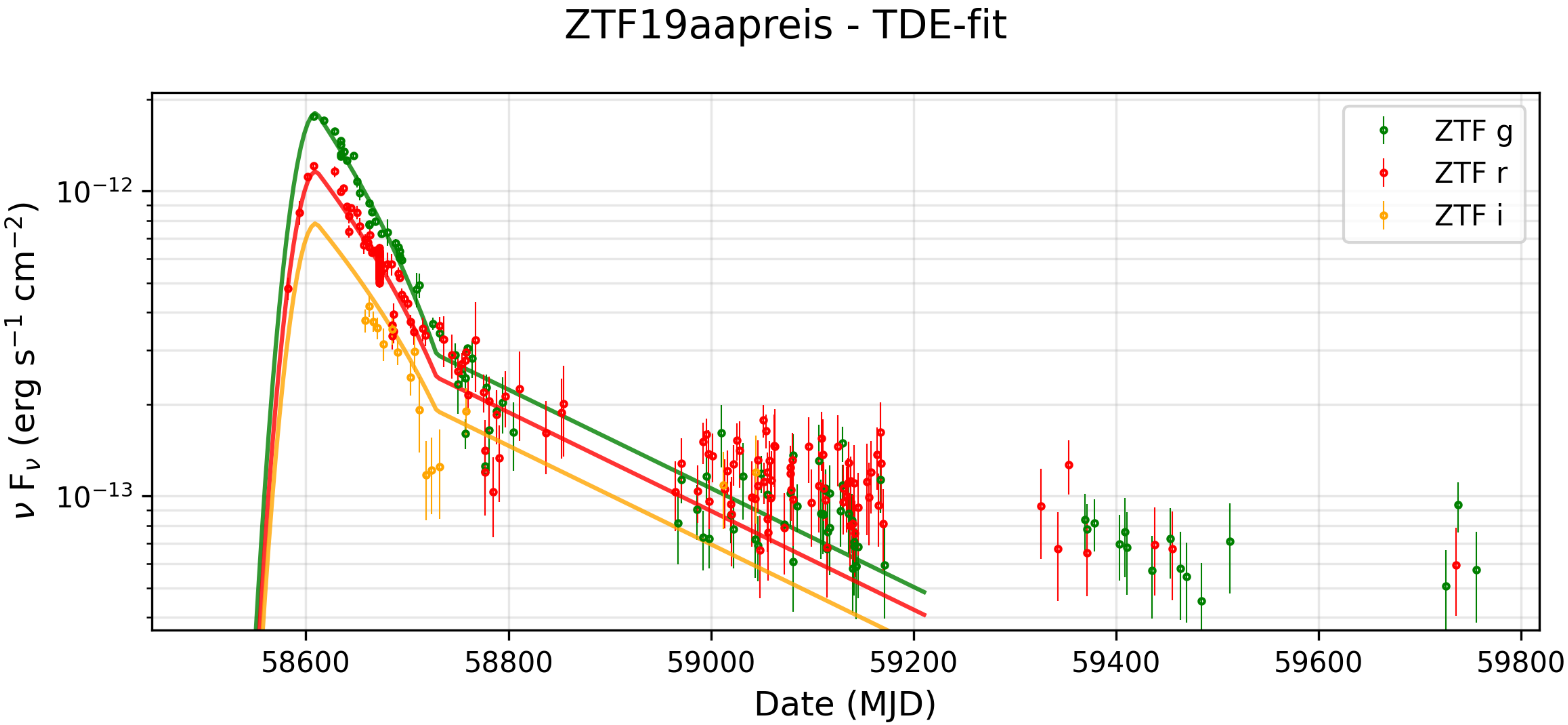
TDE candidate



Tywin-like



Feature extraction: TDE Fit



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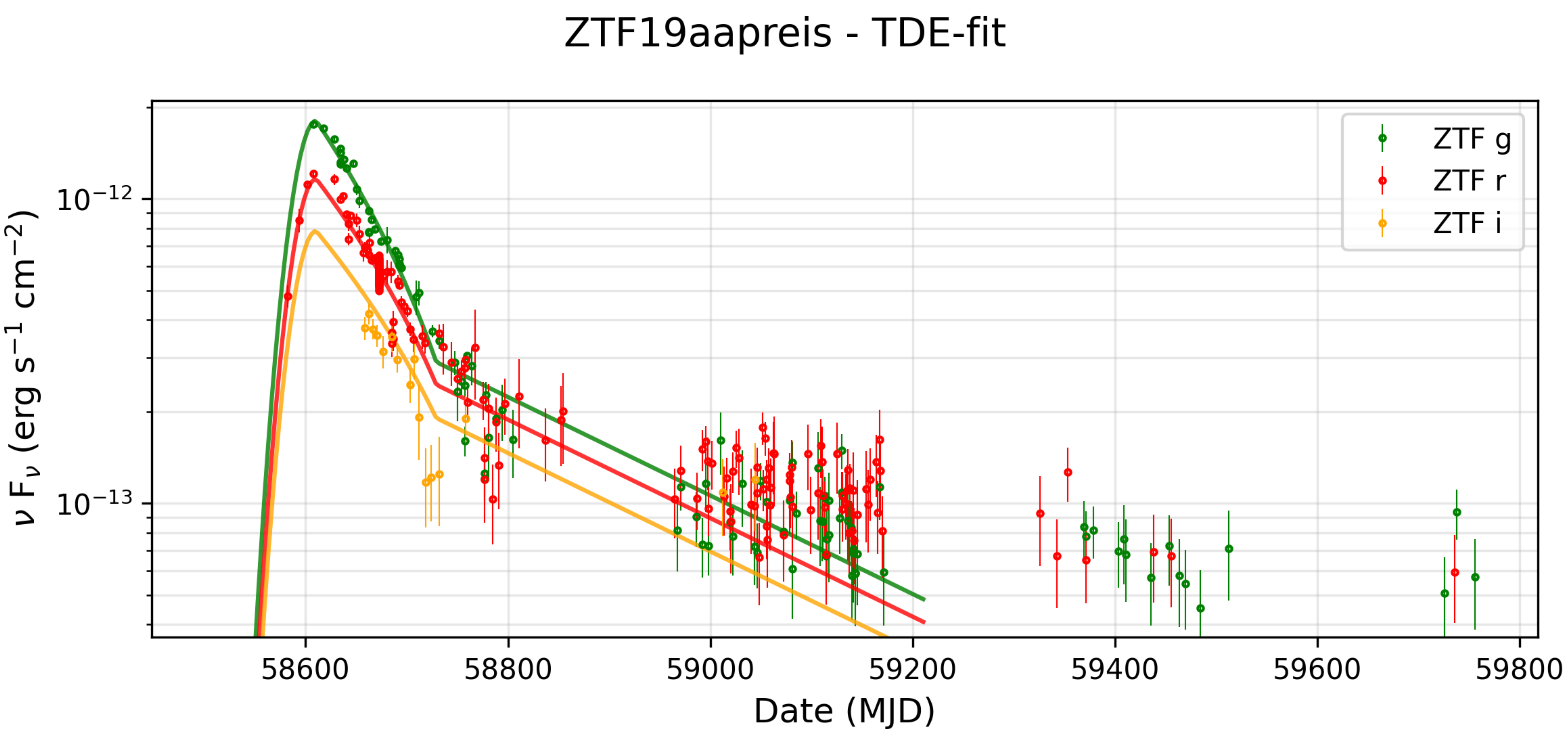
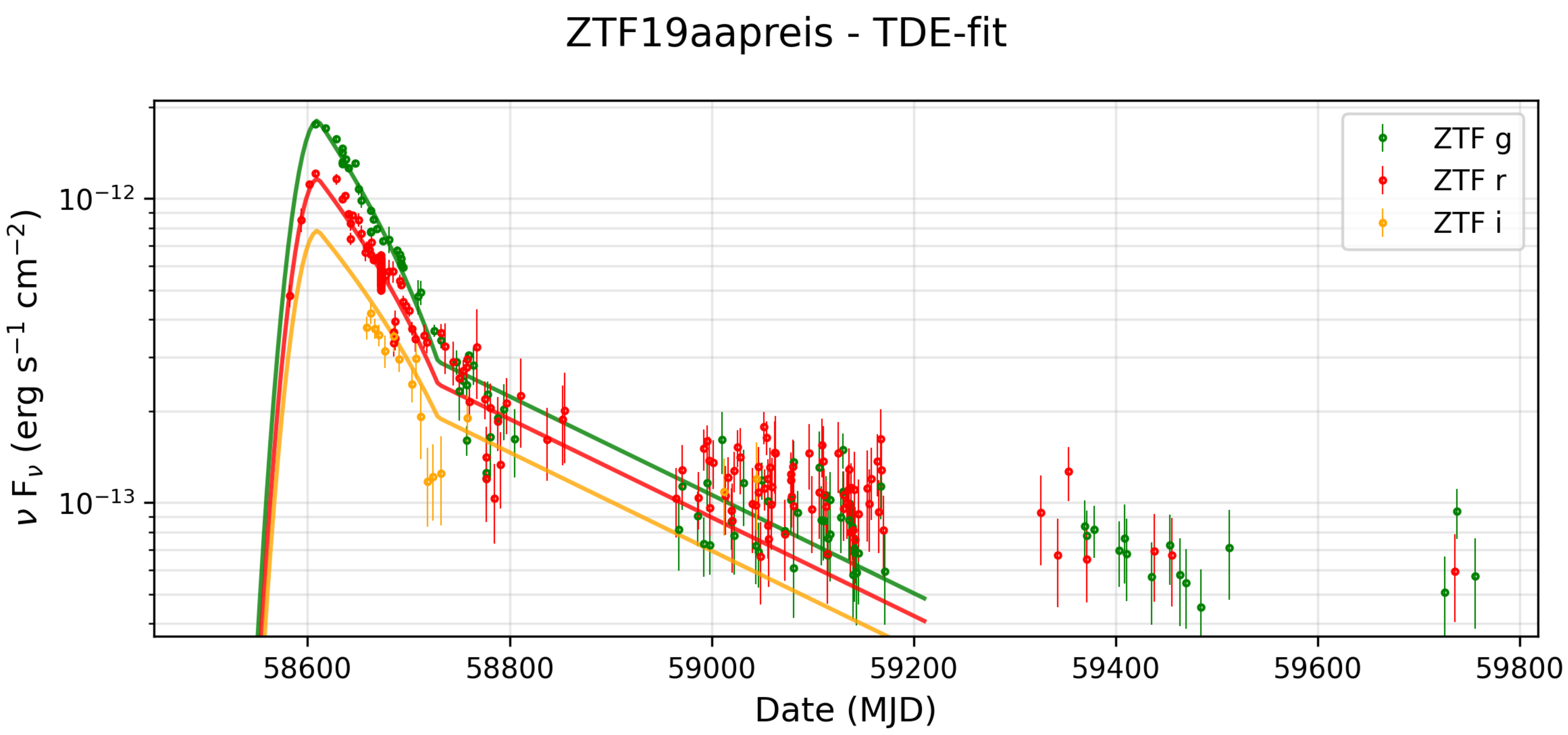


Fit parameters:

risetime
decaytime
BB temp
BB d_temp
t_evo time

Feature extraction: TDE Fit

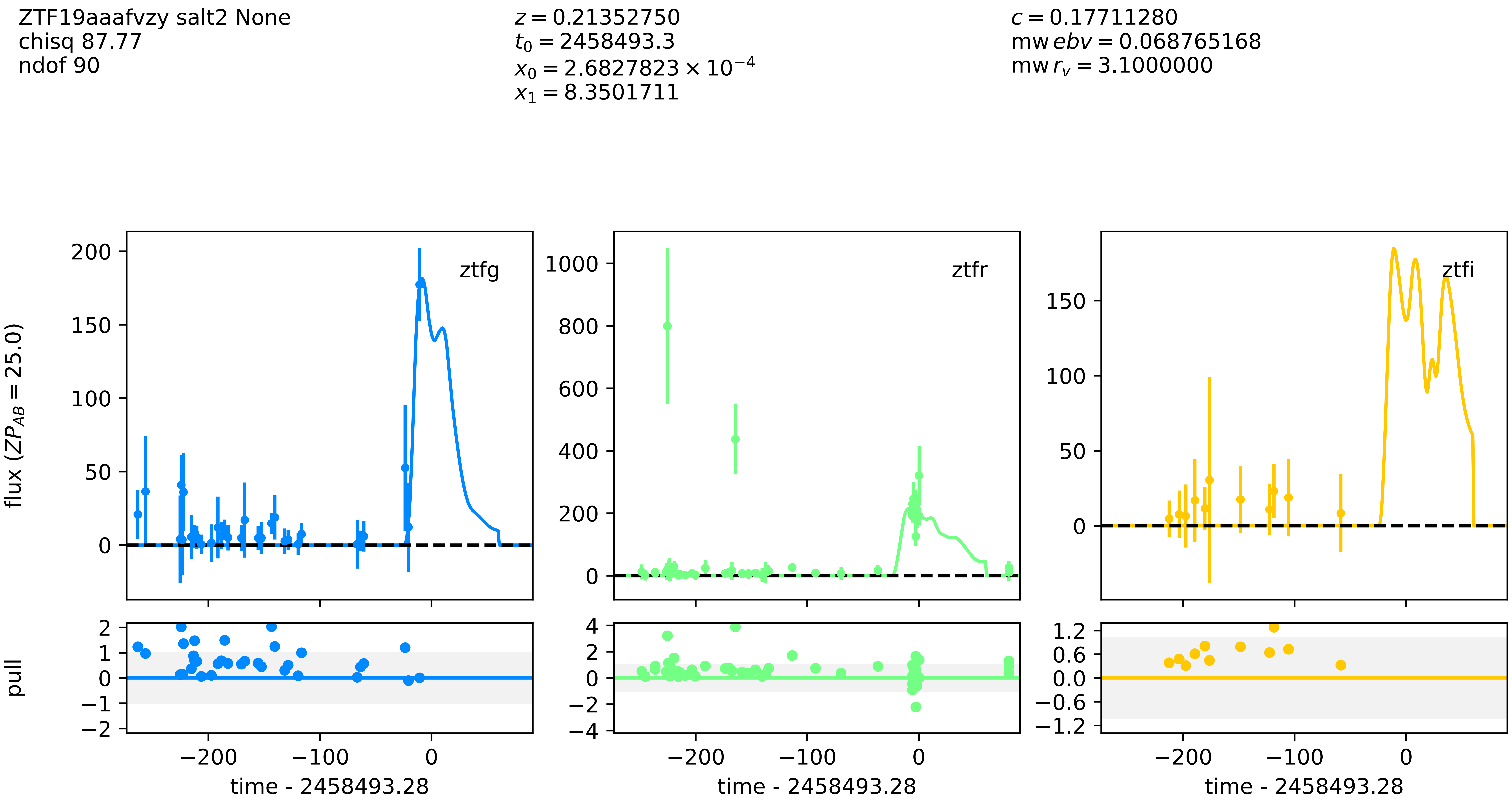


Fit parameters:

risetime
decaytime
BB temp
BB d_temp
t_evo time

Fitted twice (stability)
Problem: T runaway (no UV)

Feature extraction: SALT Fit (SN Ia)

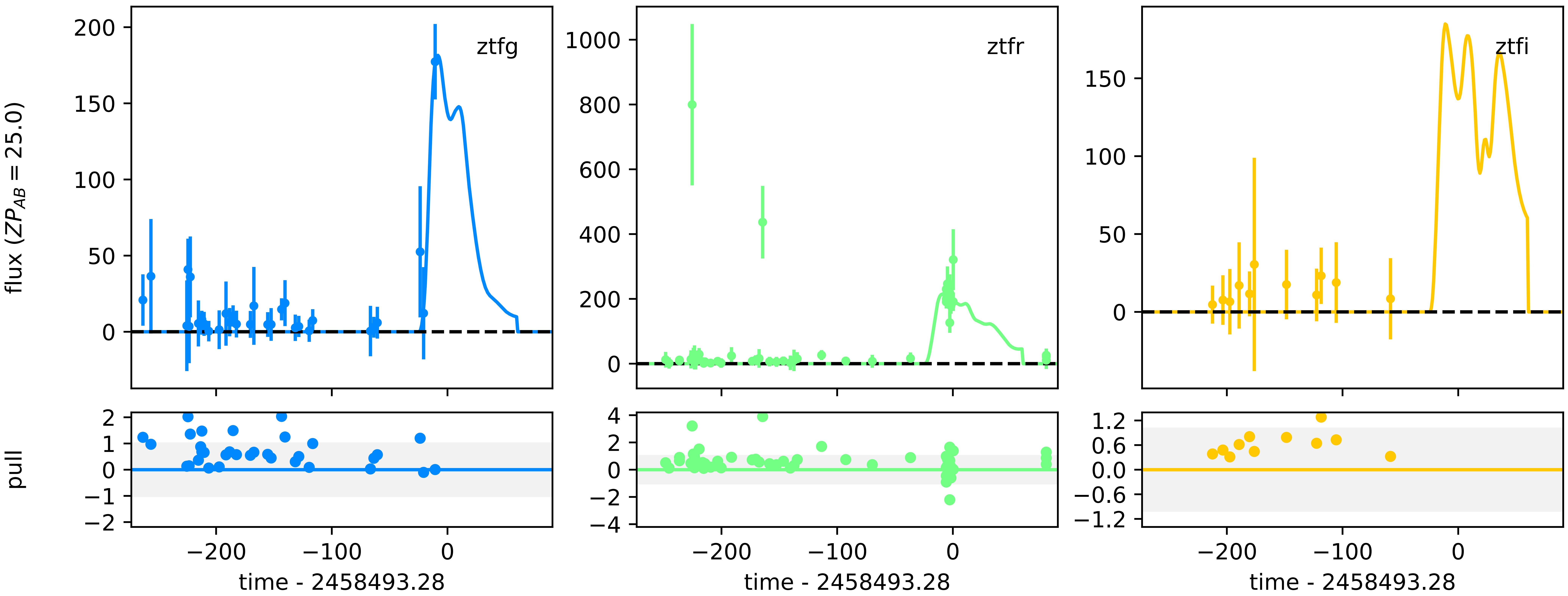


Feature extraction: SALT Fit (SN Ia)

ZTF19aaafvzy salt2 None
chisq 87.77
ndof 90

$z = 0.21352750$
$t_0 = 2458493.3$
$x_0 = 2.6827823 \times 10^{-4}$
$x_1 = 8.3501711$

$c = 0.17711280$
$\mathrm{mw}\,ebv = 0.068765168$
$\mathrm{mw}\,r_v = 3.1000000$

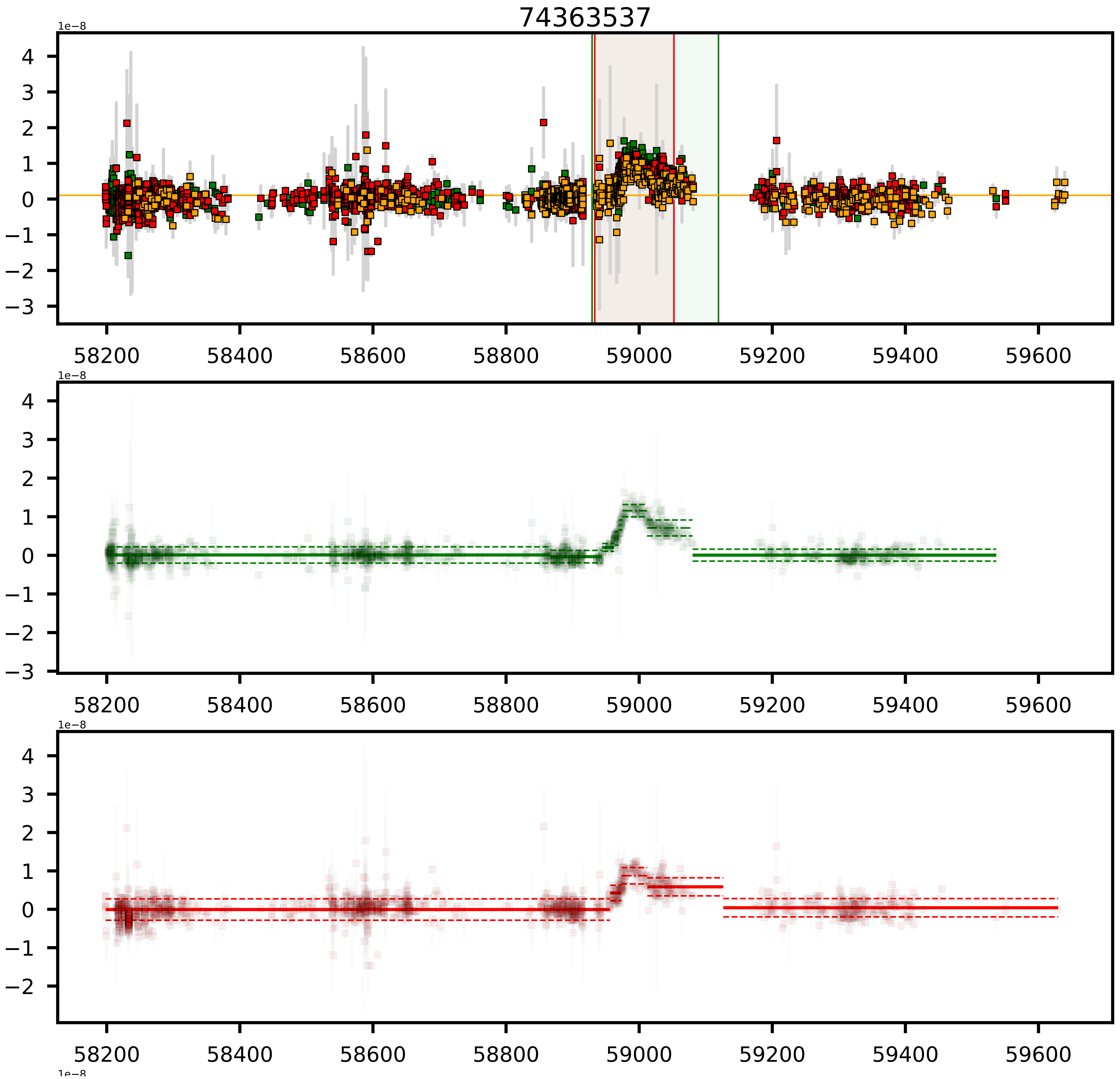


Feature extraction

all bands

g-band

r-band

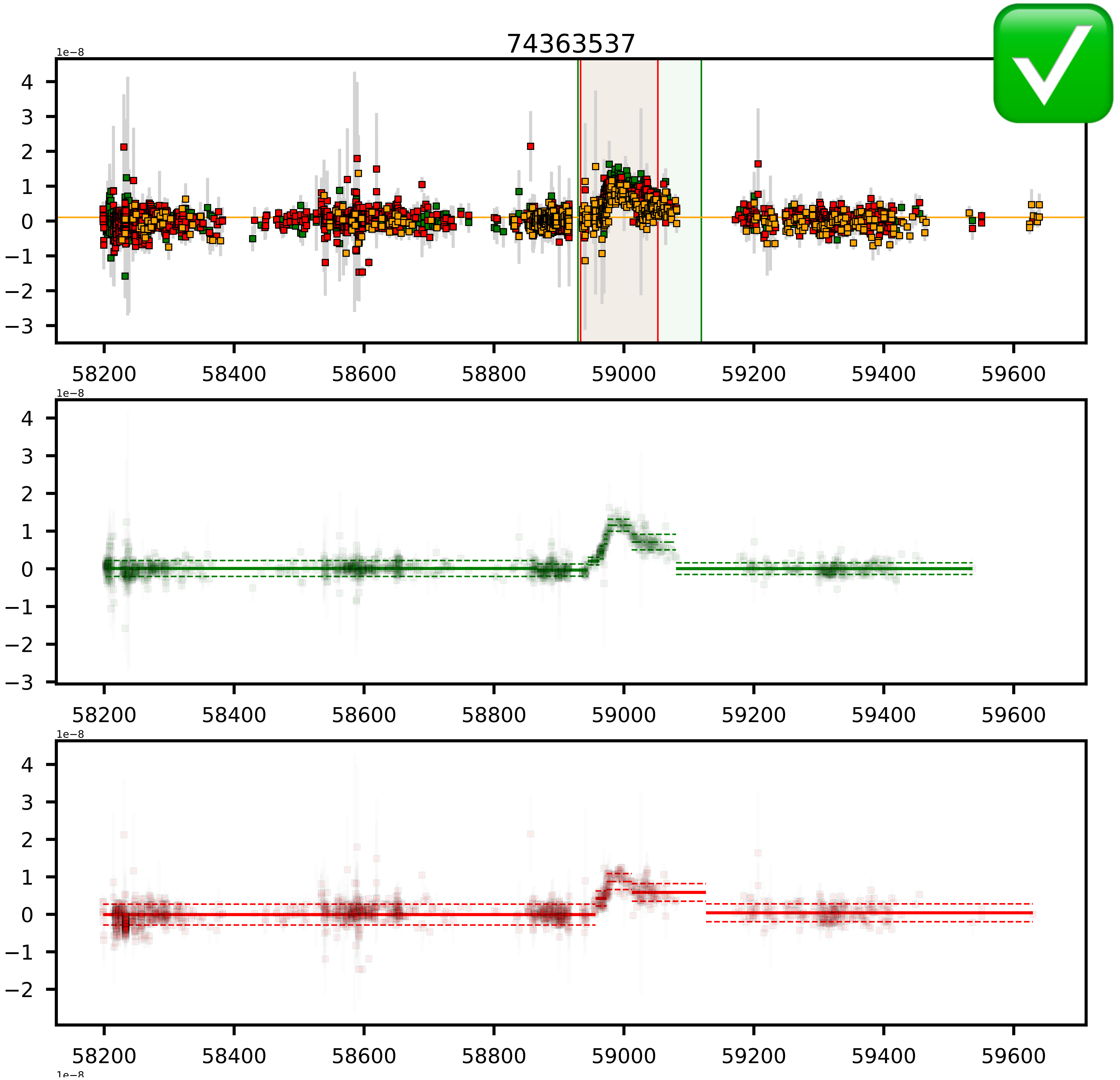


Feature extraction

all bands

g-band

r-band

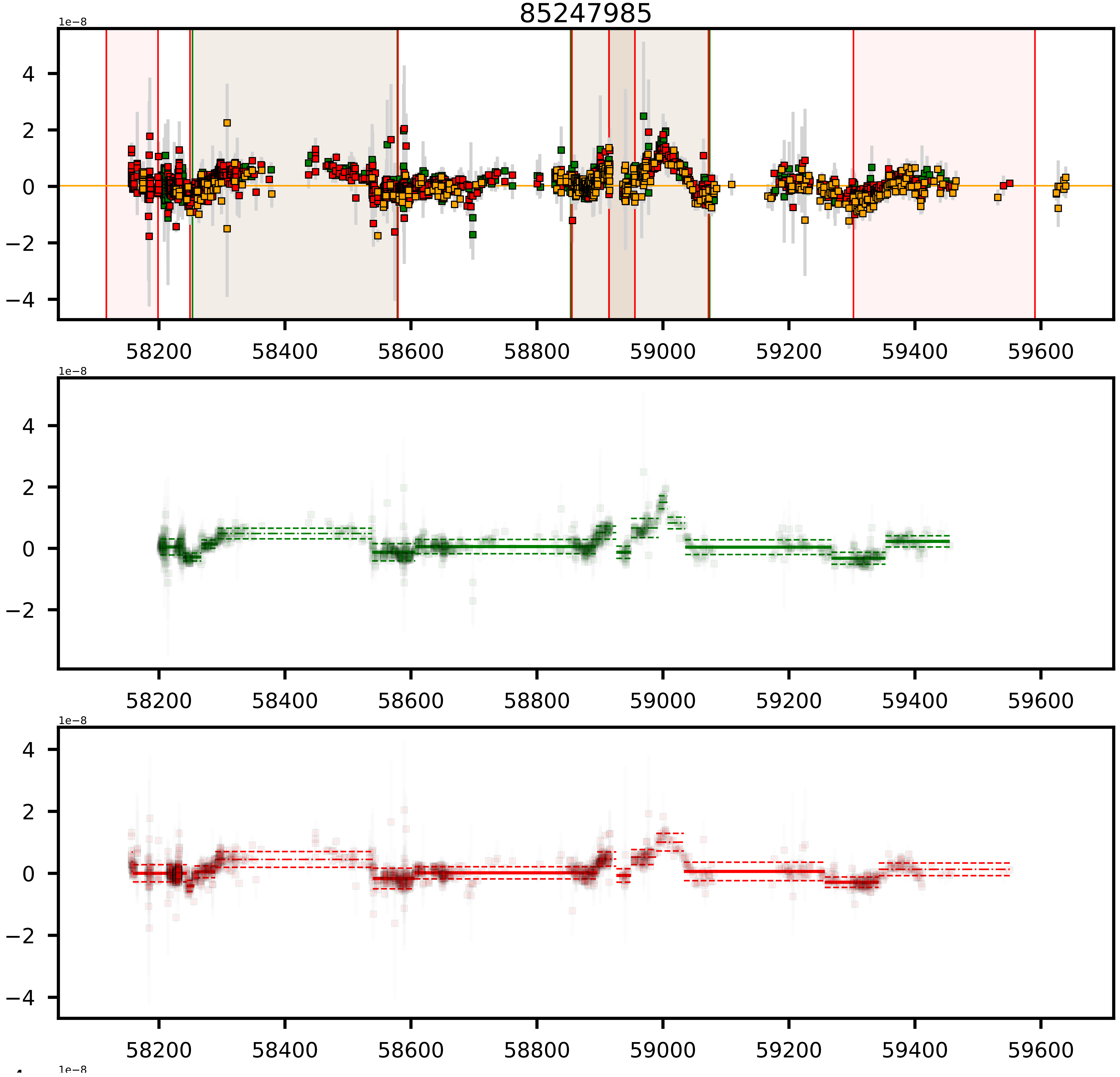


Feature extraction

all bands

g-band

r-band

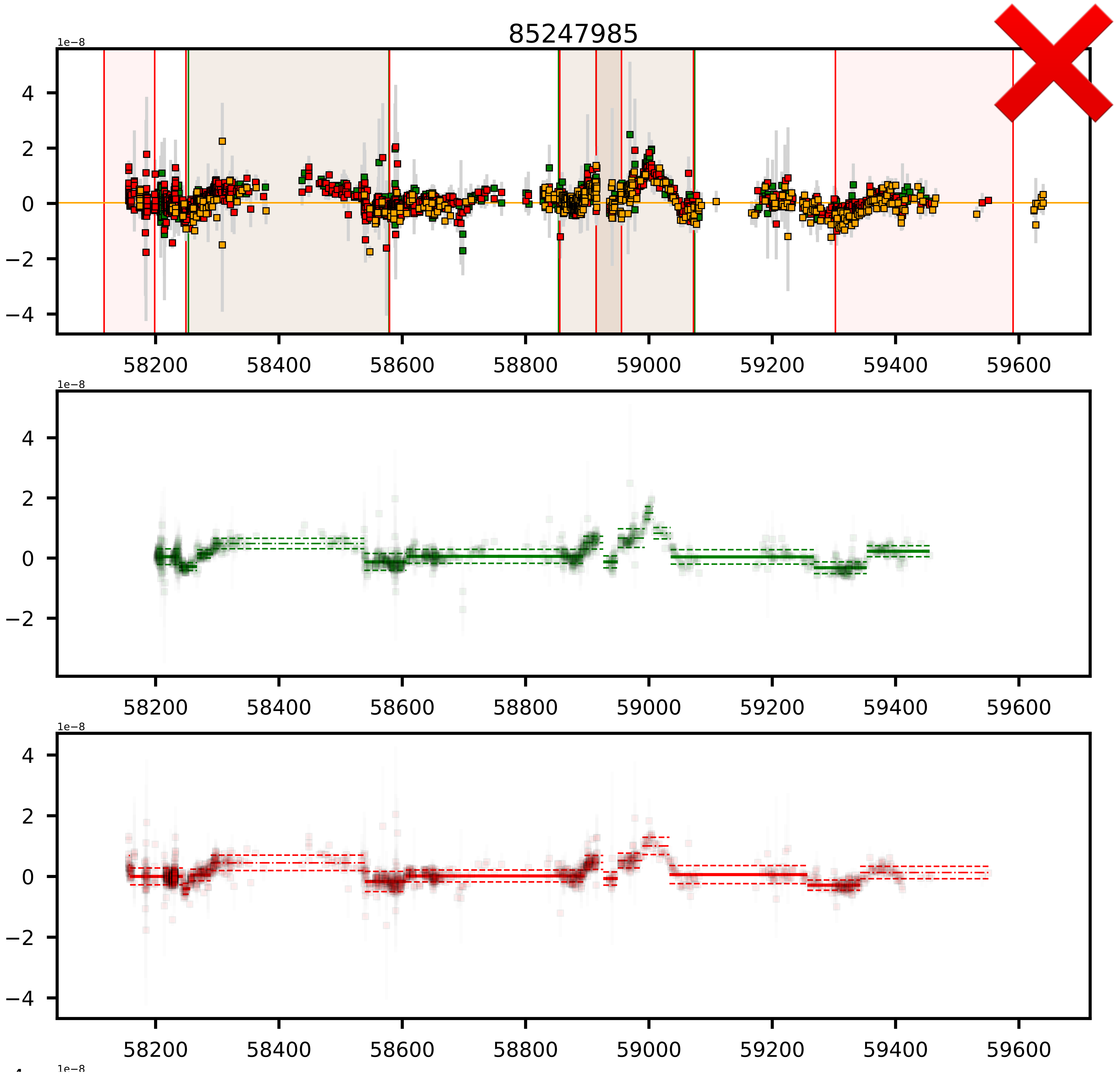


Feature extraction

all bands

g-band

r-band



Features used (20 in total)

peak apparent mag

sgscore

WISE colors (with scatter for noisified child lightcurves)

SALT fit results (c, x_0, x_1)

TDE fit results (rise, decay, temp, d_temp)

distnr (core distance, scaled for noisified child lightcurves)

Bayesian block analysis: overlapping regions

no z (only indirectly for some of the SALT fits)

Noisification

K-correct (bandpasses see different flux depending on object redshift)

Redshift

Random dropout

Wiggle time a bit

Generate child lightcurves:

SN Ia: 12683 **TDE**: 10231 **SN $\neq$ Ia**: 10852 **AGN**: 8220 **star**: 505

Children per object

SN Ia: 4 **TDE**: 155 **SN $\neq$ Ia**: 10 **AGN**: 94 **star**: 0

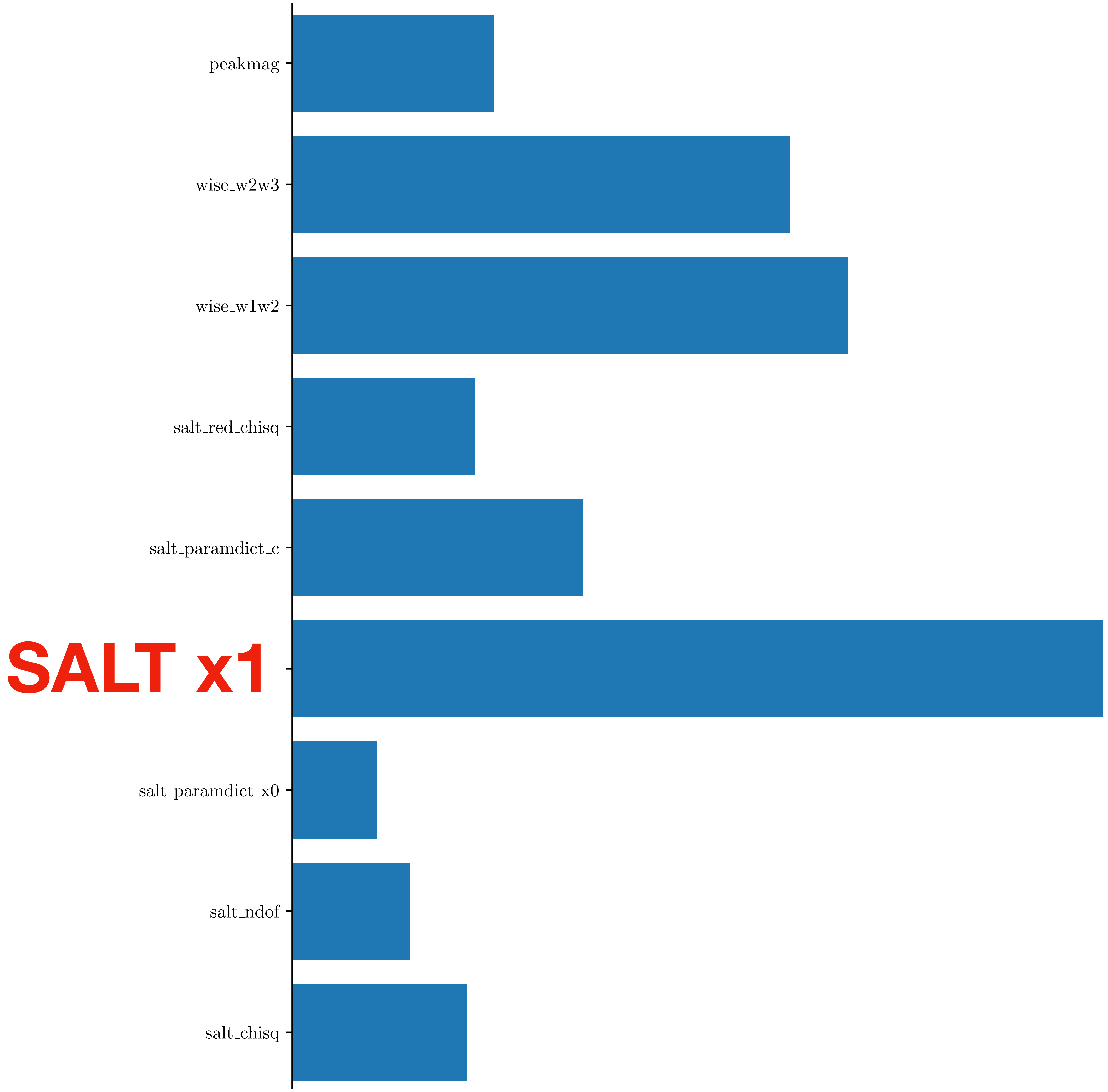
Train XGBoost

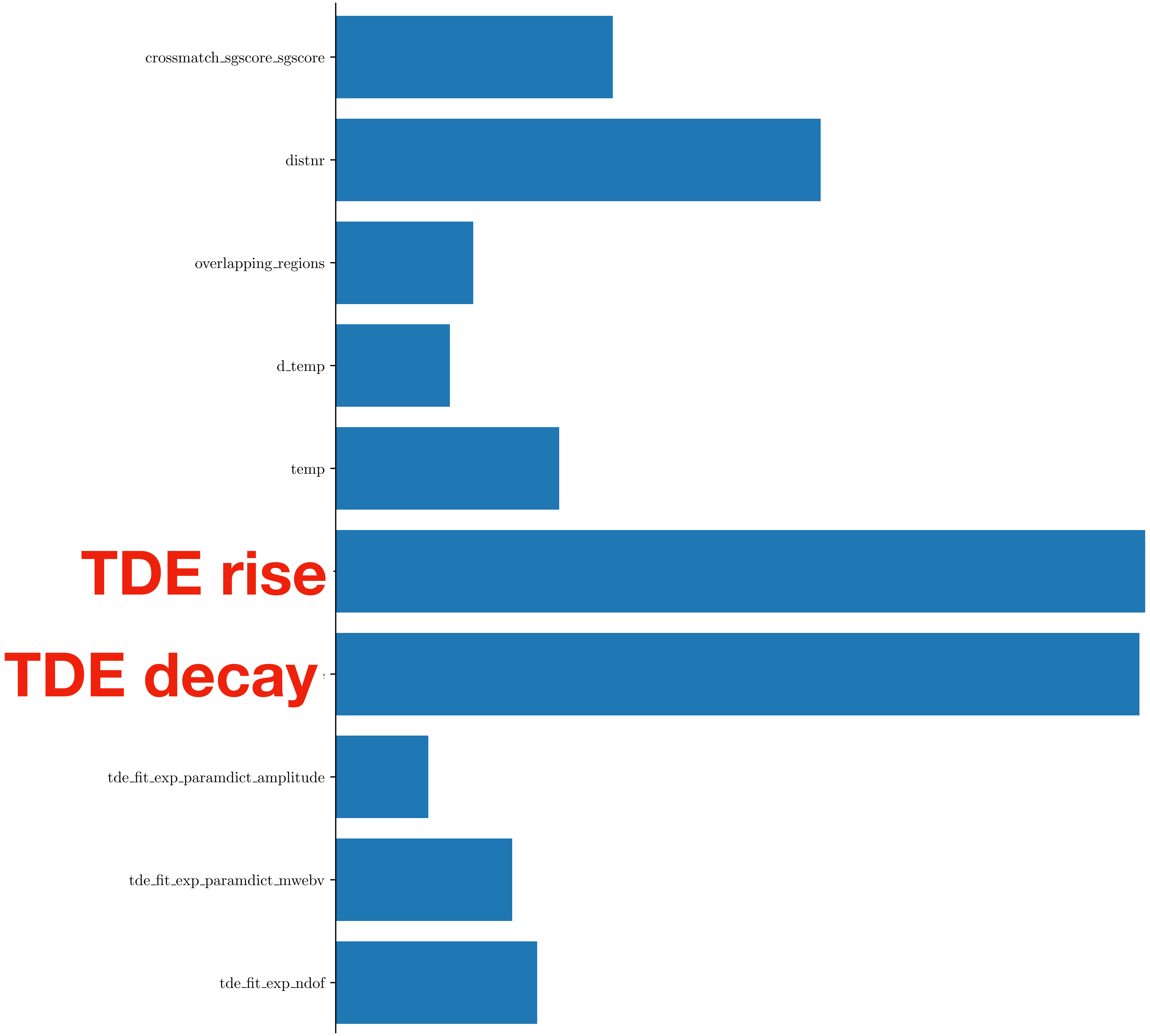
train-validation fraction = 0.7

test fraction = 0.3

hyper parameter search (9 parameters) with 50 iterations

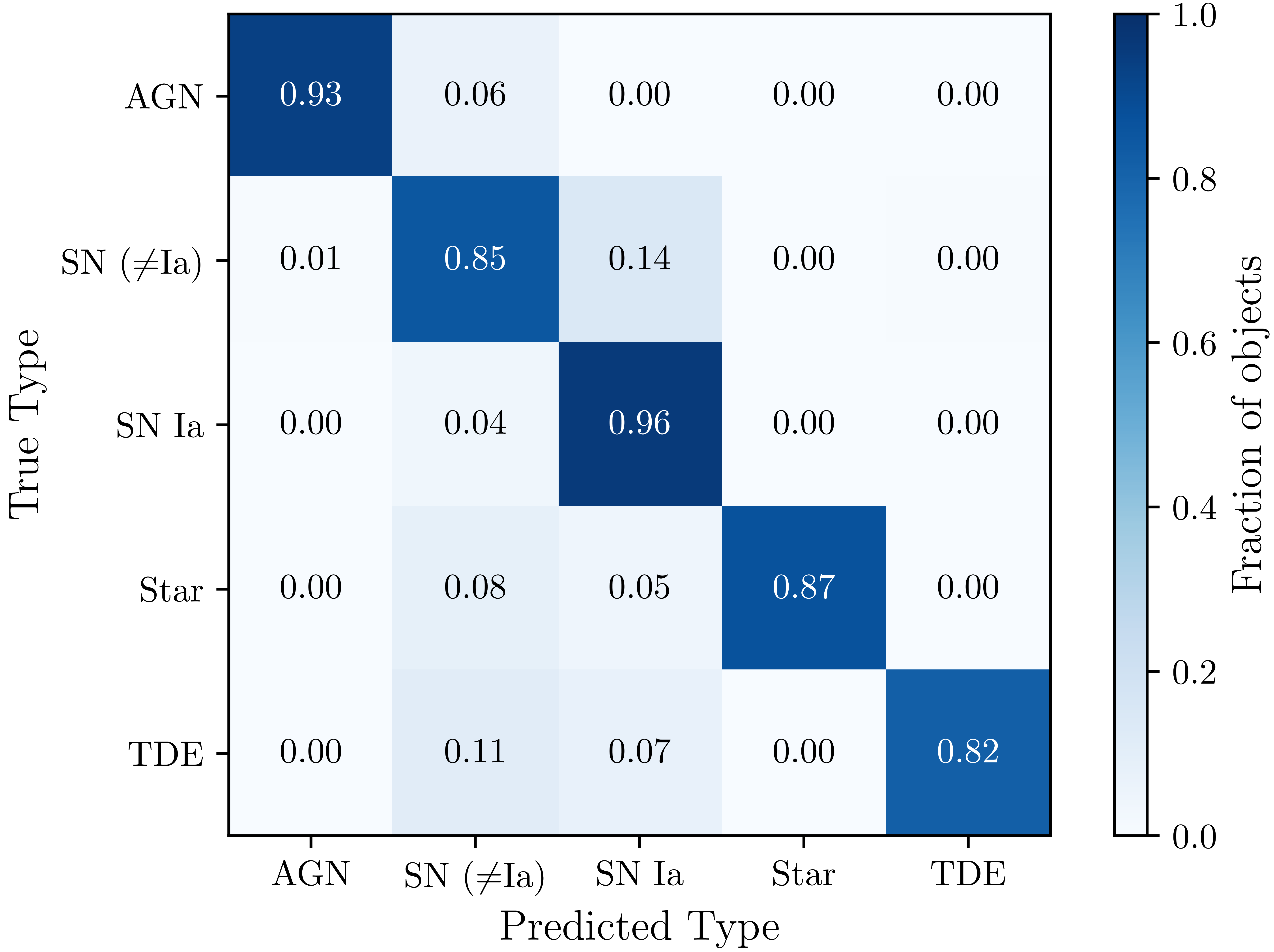
XGBoost feature importance





Evaluation with test sample

Including noisified lightcurves in the test sample



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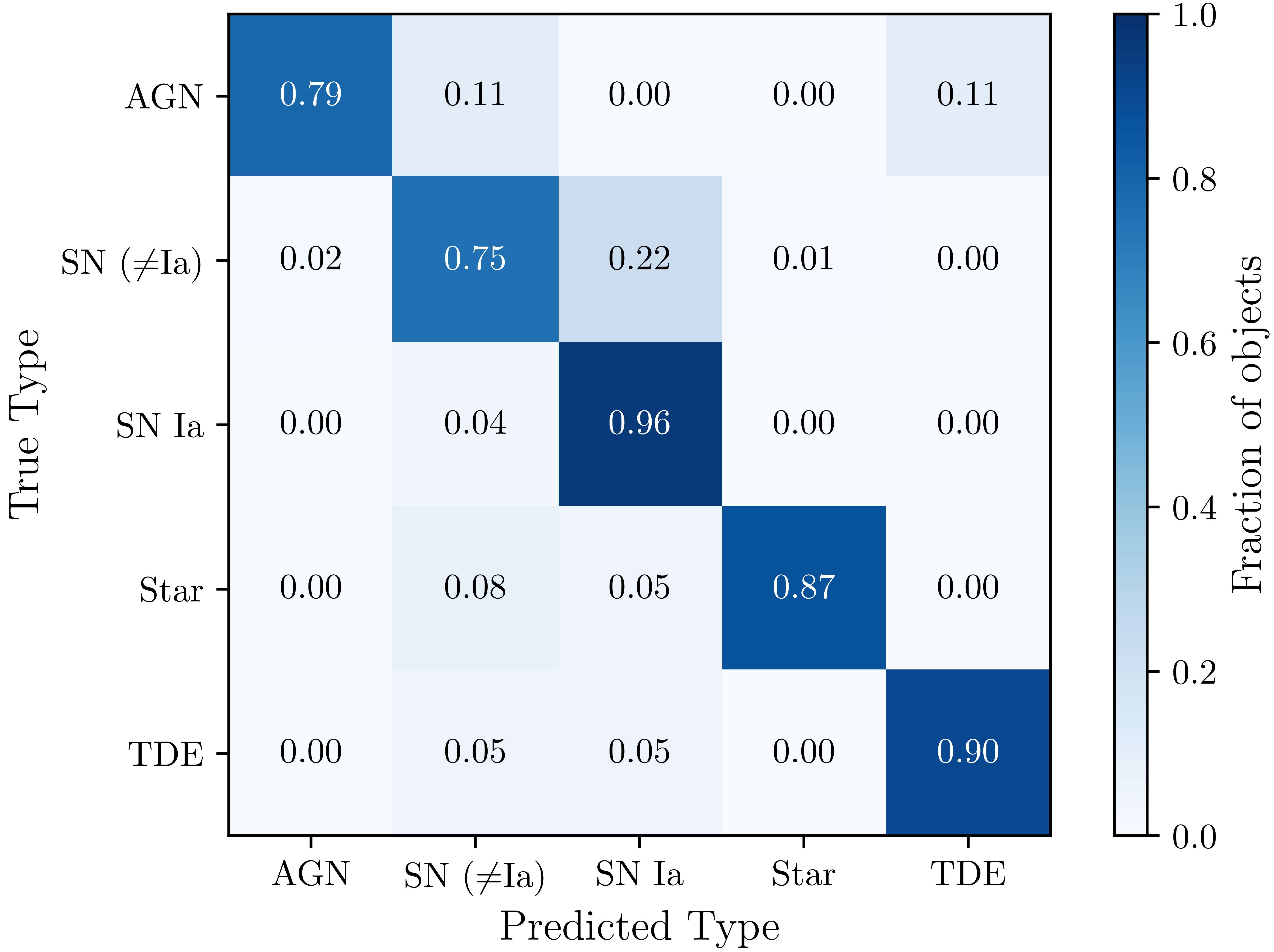
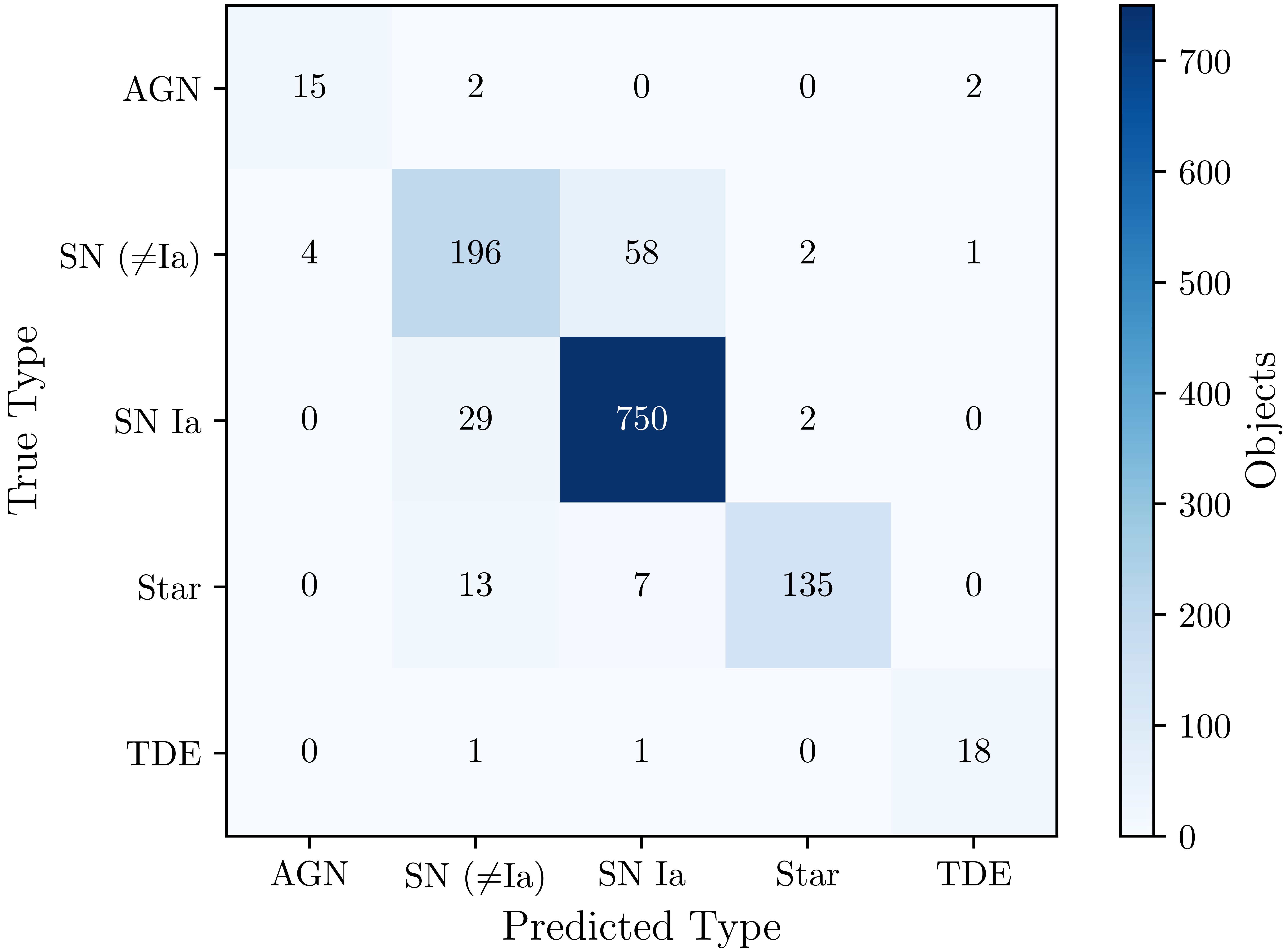


Evaluation with test sample

Not including noisified lightcurves in the test sample

absolute numbers



Evaluation with test sample

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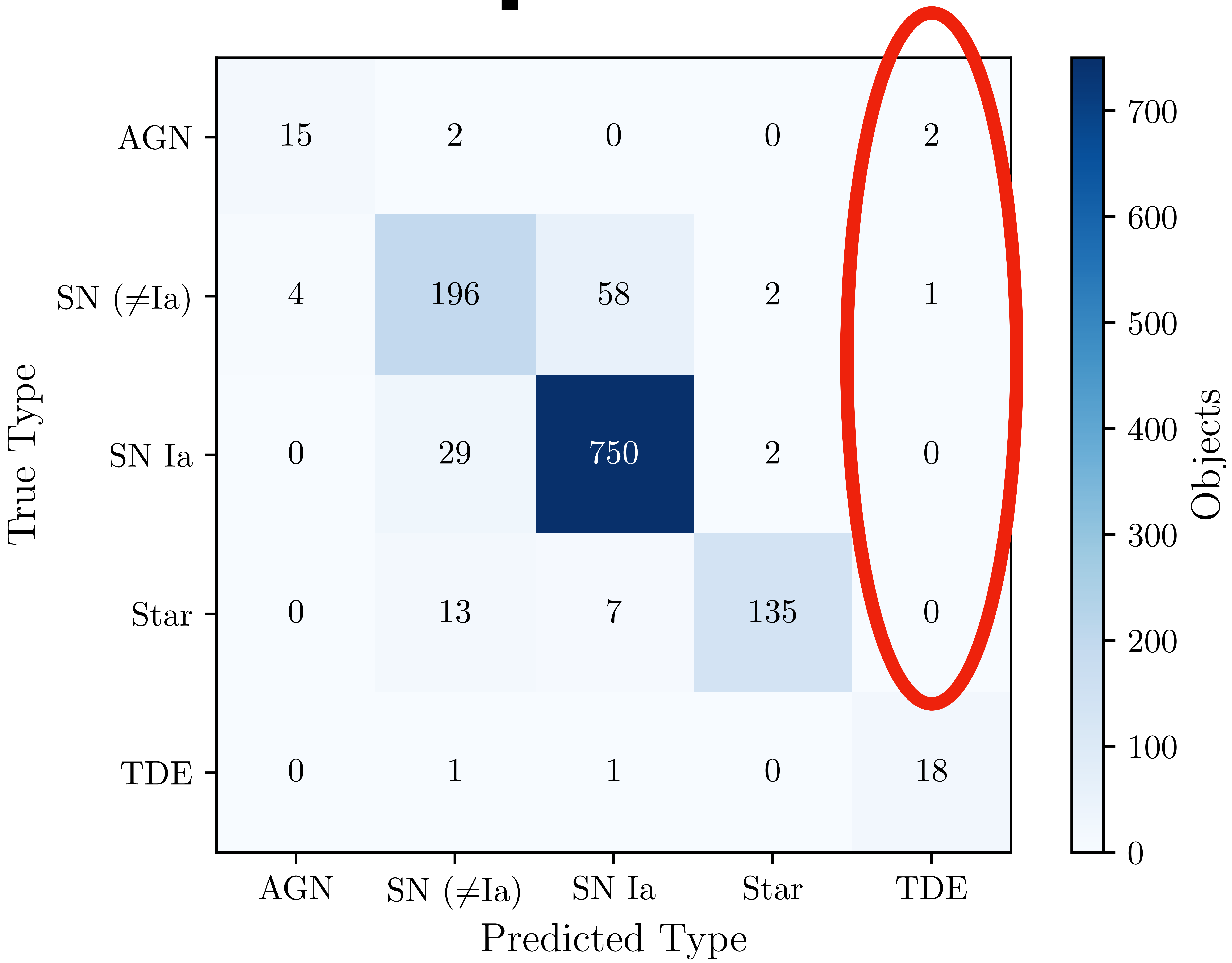
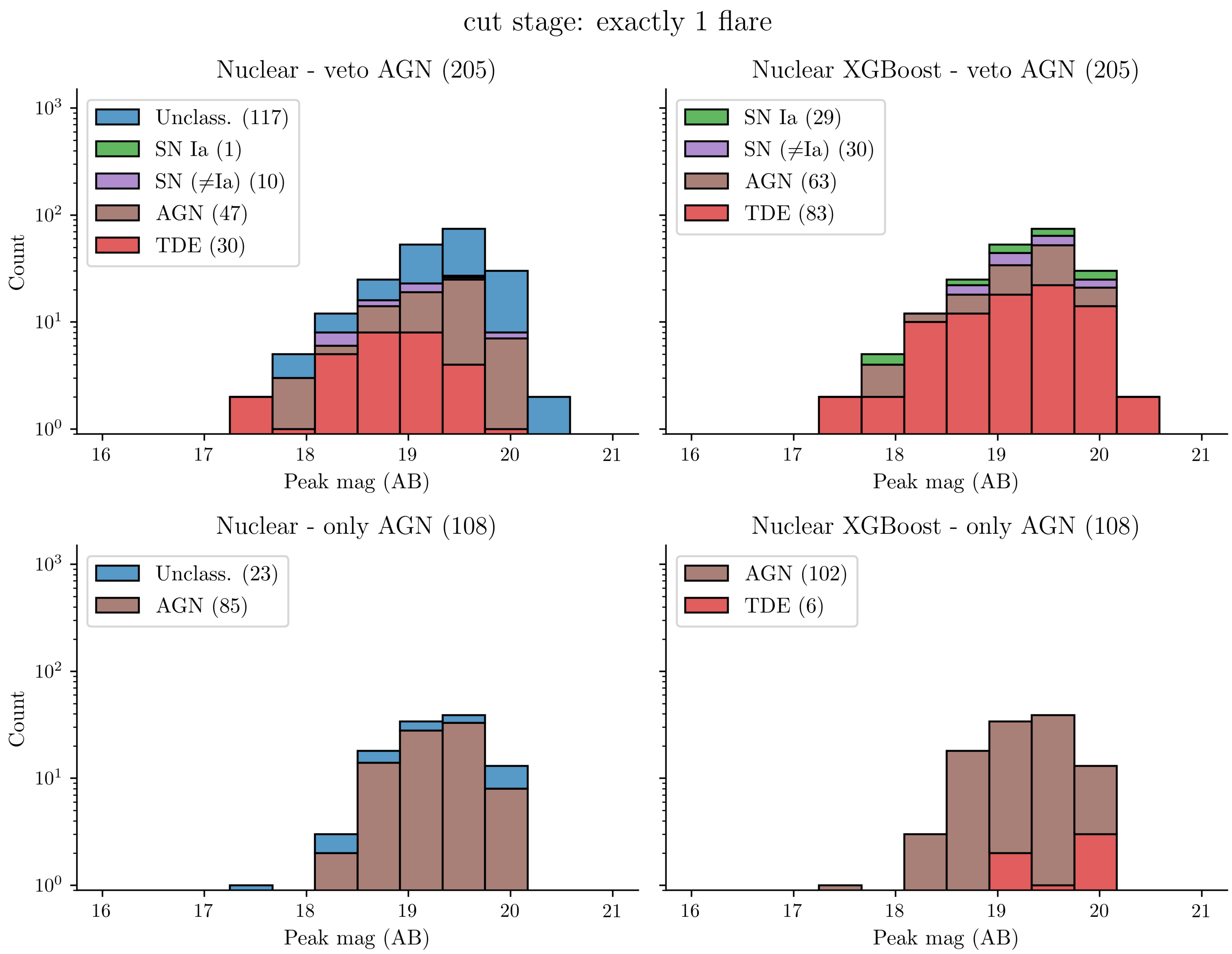
absolute numbers



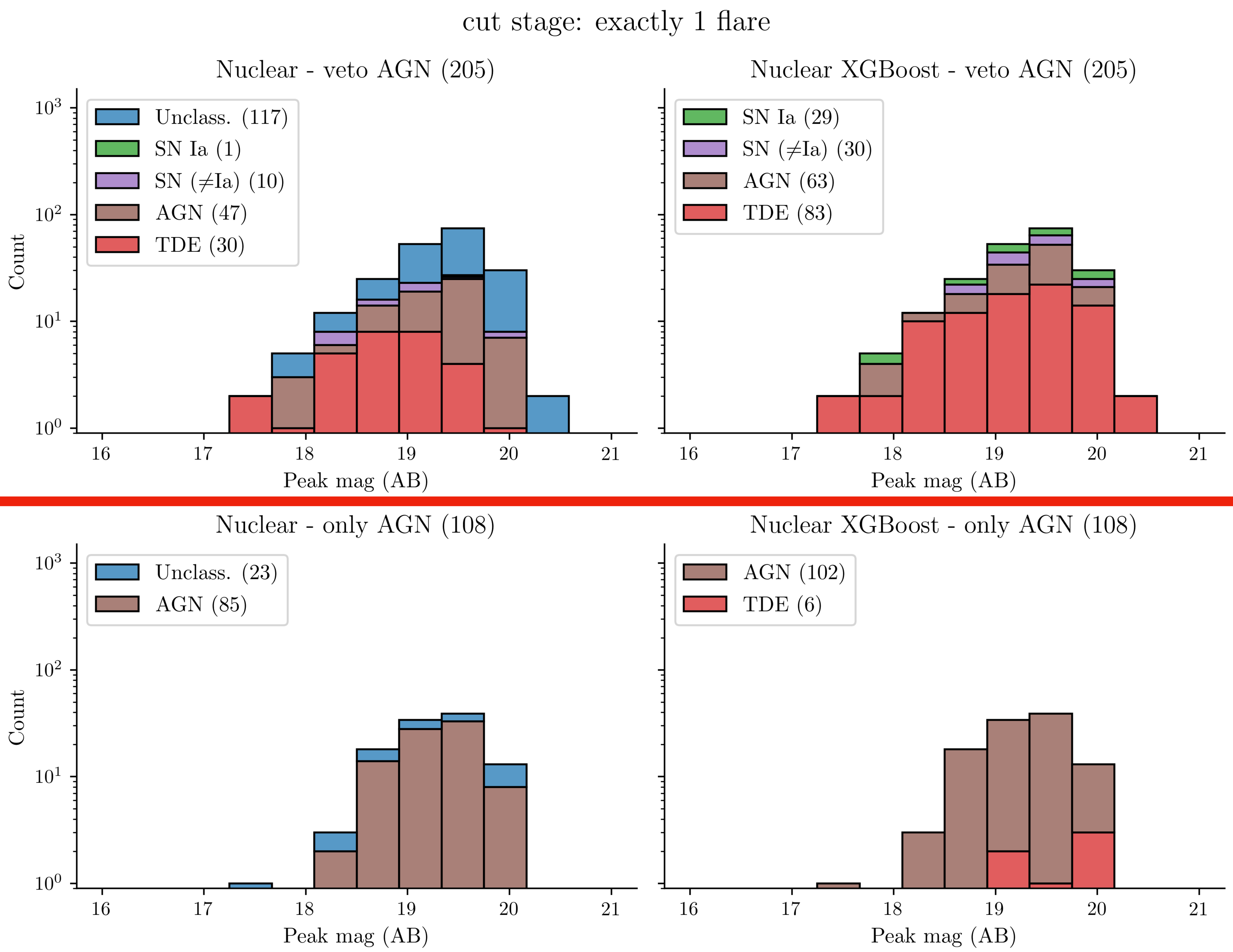
No we apply the classifier to the nuclear sample

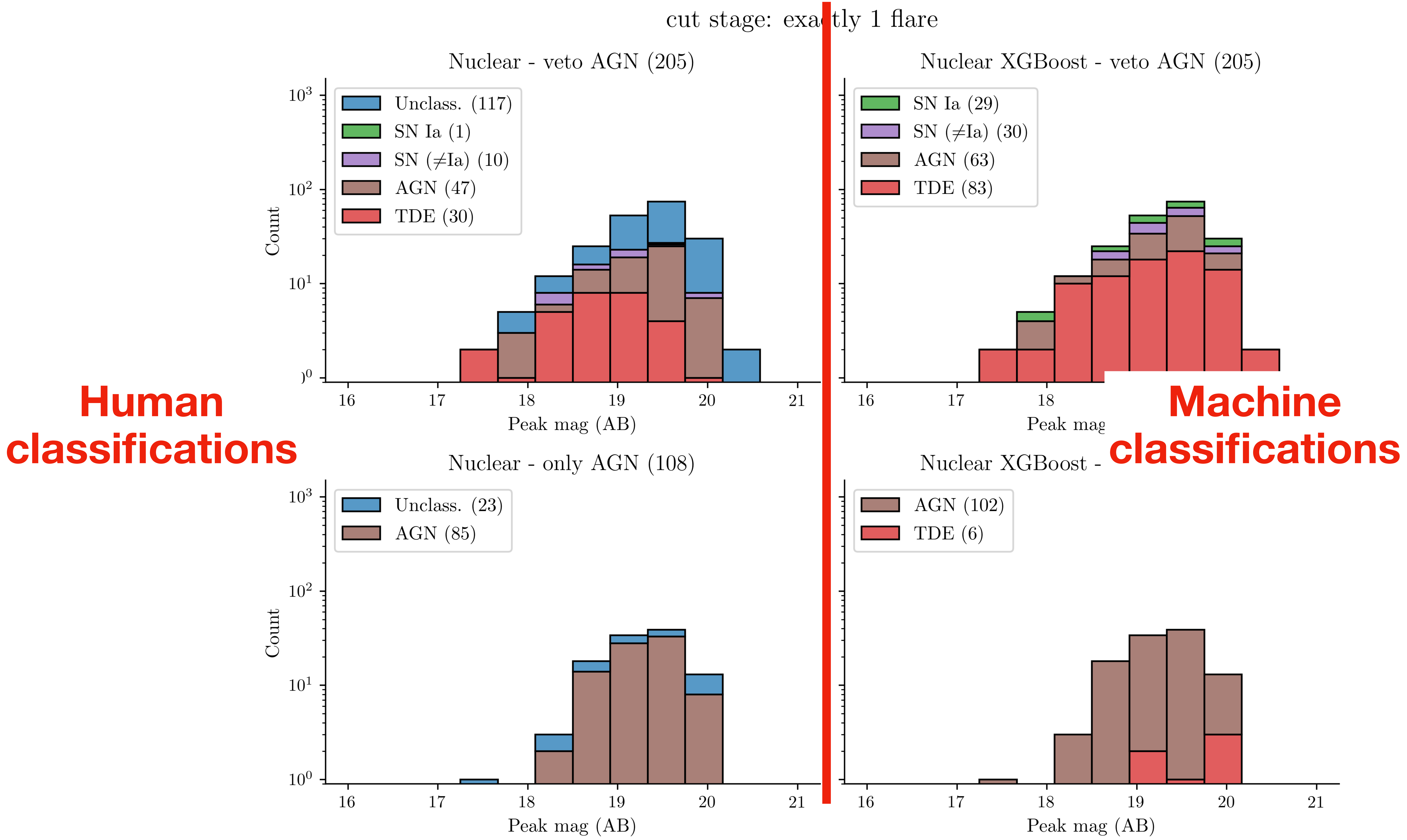
after all cuts

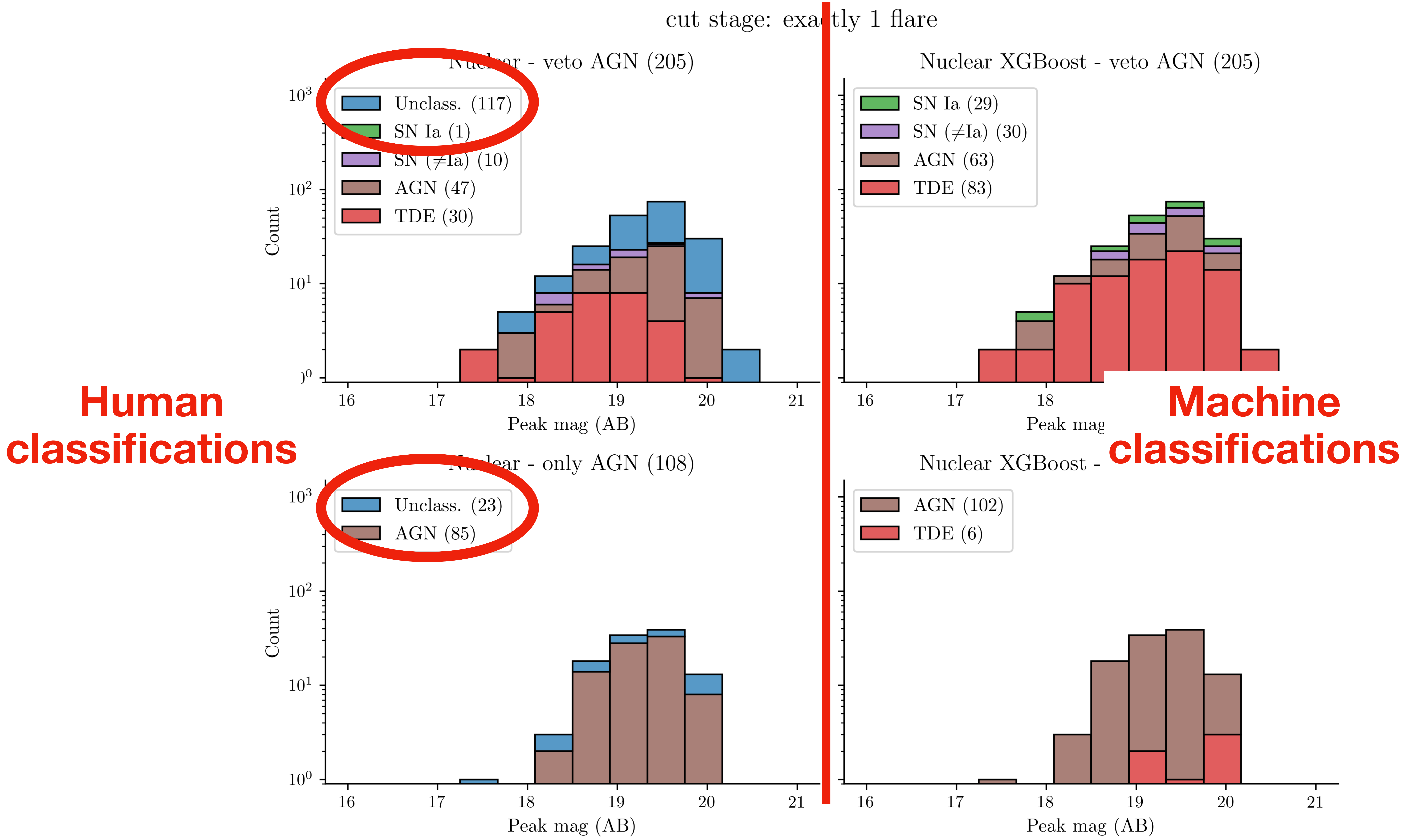


no Milliquas match (not AGN)

has Milliquas match (AGN)




cut stage: exactly 1 flare
Nuclear - veto AGN (205)
Unclass. (117)
SN Ia (1)
SN (≠Ia) (10)
AGN (47)
TDE (30)
Nuclear XGBoost - veto AGN (205)
SN Ia (29)
SN (≠Ia) (30)
AGN (63)
TDE (83)
Nuclear - only AGN (108)
Unclass. (23)
AGN (85)
Nuclear XGBoost -
AGN (102)
TDE (6)
Count
Peak mag (AB)
Human classifications
Machine classifications



cut stage: exactly 1 flare
Nuclear - veto AGN (205)
Unclass. (117)
SN Ia (1)
SN (≠Ia) (10)
AGN (47)
TDE (30)
Count
Peak mag (AB)
Nuclear XGBoost - veto AGN (205)
SN Ia (29)
SN (≠Ia) (30)
AGN (63)
TDE (83)
Nuclear - only AGN (108)
Unclass. (23)
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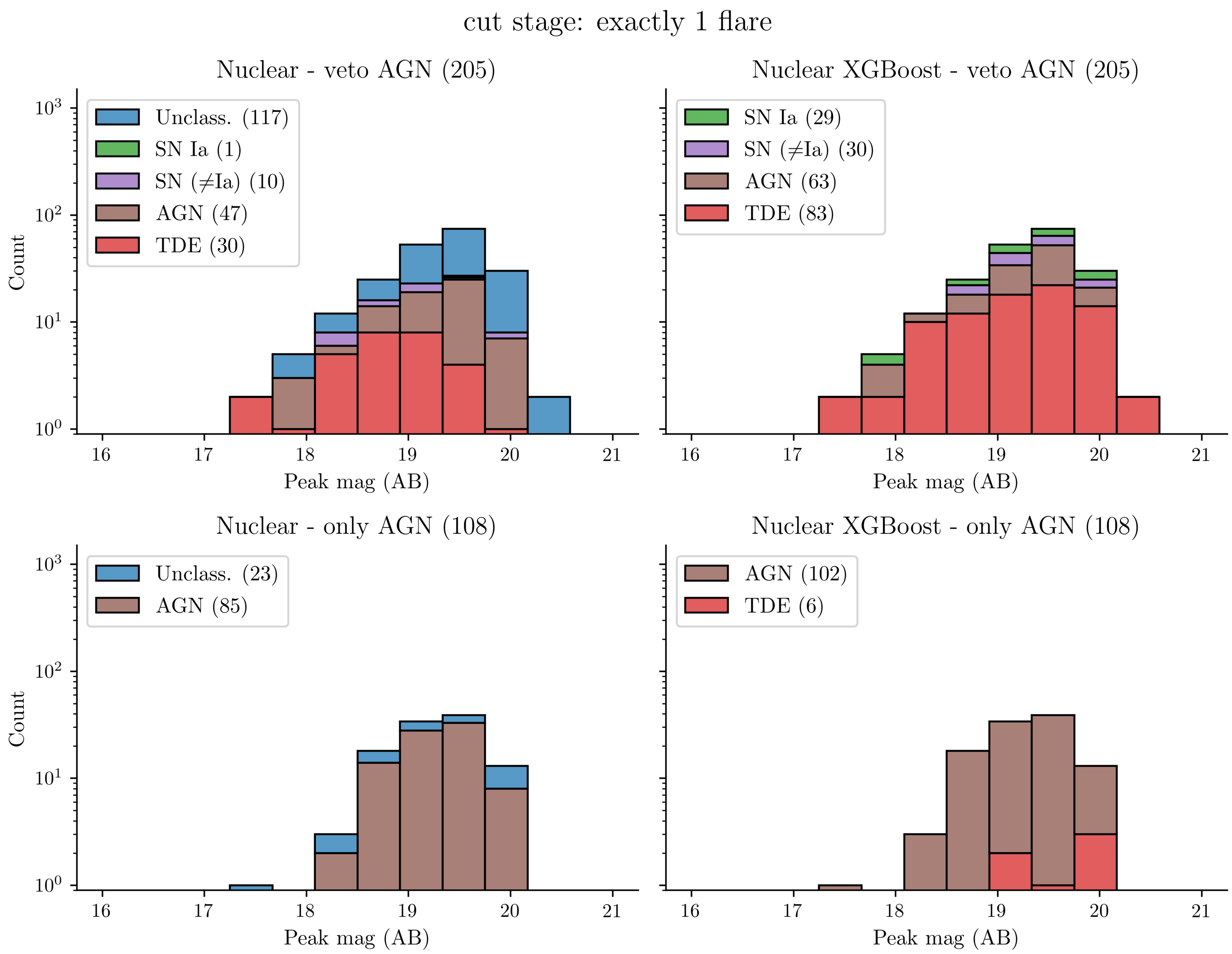
AGN (102)
TDE (6)
Human classifications
Machine classifications


cut stage: exactly 1 flare
Nuclear - veto AGN (205)
Unclass. (117)
SN Ia (1)
SN (≠Ia) (10)
AGN (47)
TDE (30)
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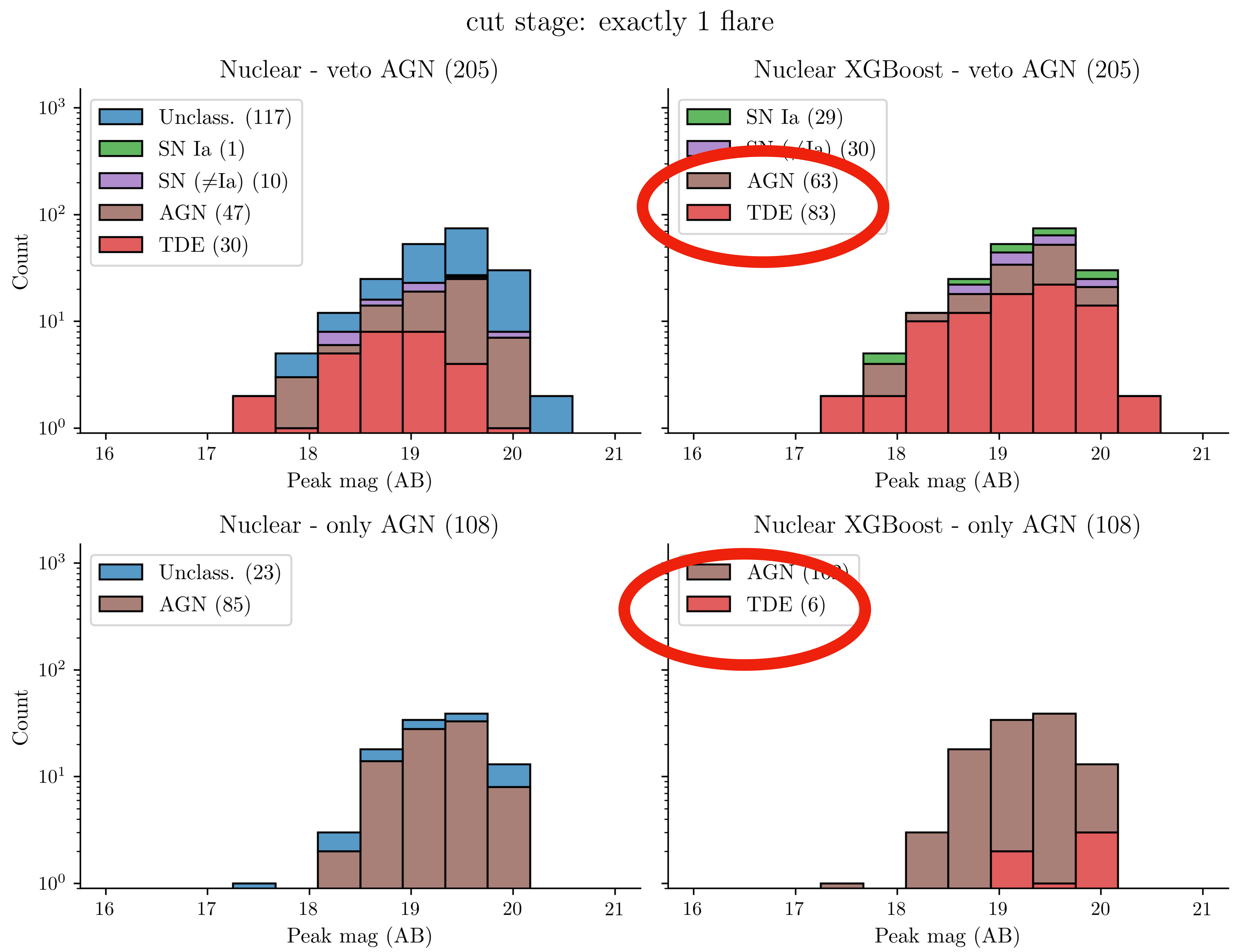
Unclass. (23)
AGN (85)
Nuclear XGBoost - only AGN (108)
AGN (102)
TDE (6)
Count
Peak mag (AB)



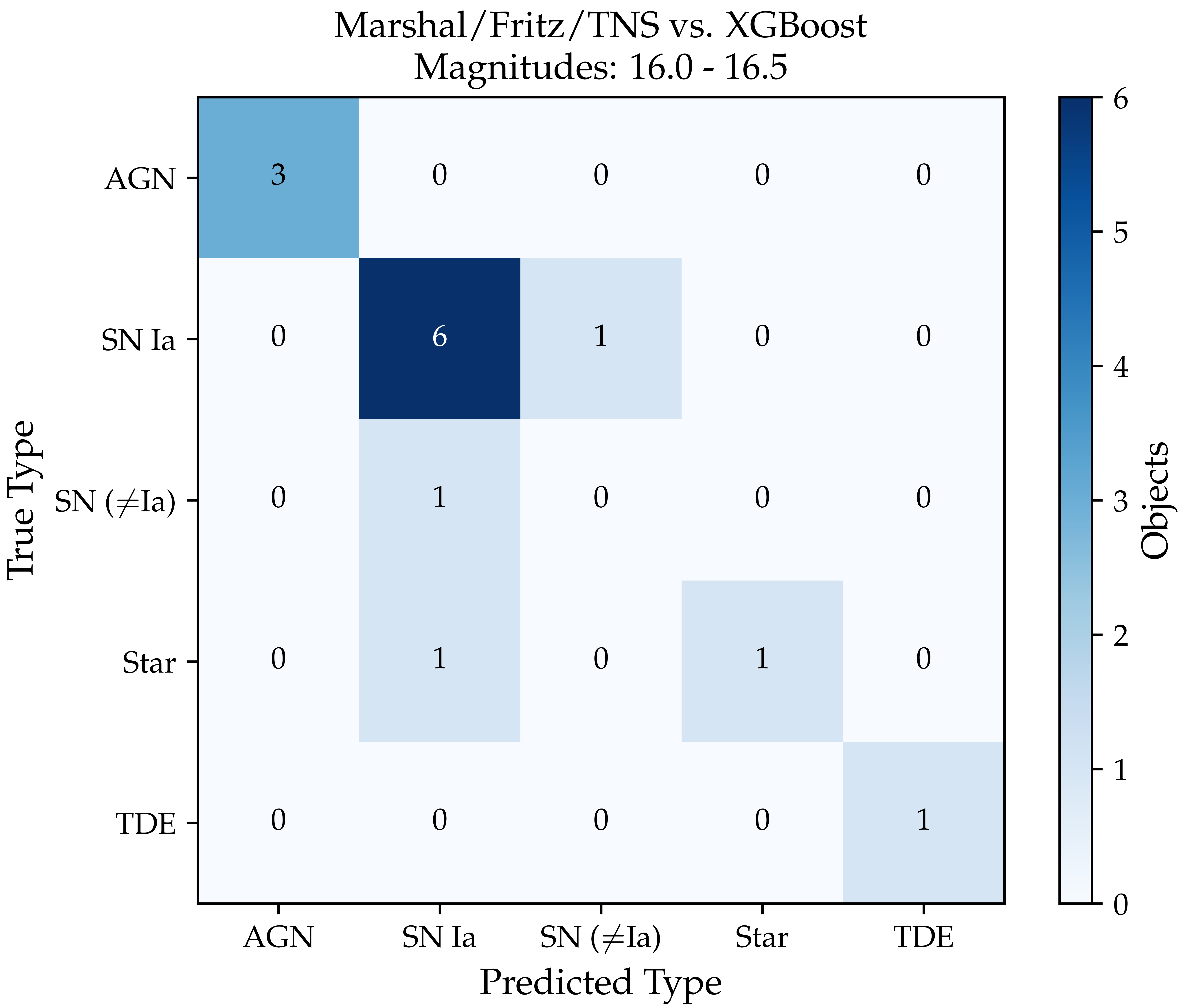
cut stage: exactly 1 flare
Nuclear - veto AGN (205)
Unclass. (117)
SN Ia (1)
SN (≠Ia) (10)
AGN (47)
TDE (30)
Nuclear XGBoost - veto AGN (205)
SN Ia (29)
(30)
AGN (63)
TDE (83)
Nuclear - only AGN (108)
Unclass. (23)
AGN (85)
Nuclear XGBoost - only AGN (108)
AGN
TDE (6)
Count
Peak mag (AB)

Compare to unsecure classifications pulled from the internet

Evaluation with unsecure truth

Mag:

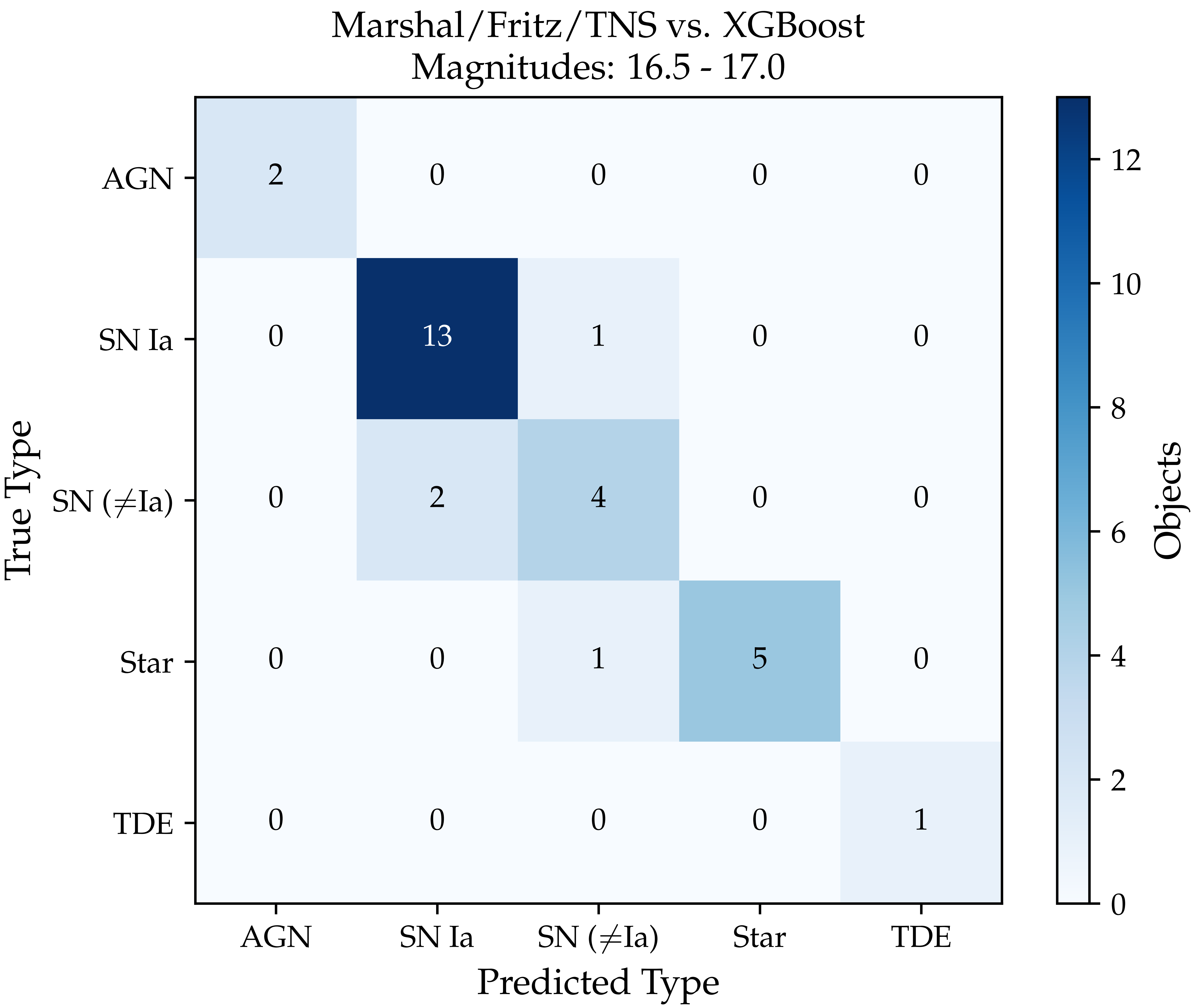
16.0-16.5



Evaluation with unsecure truth

Mag:

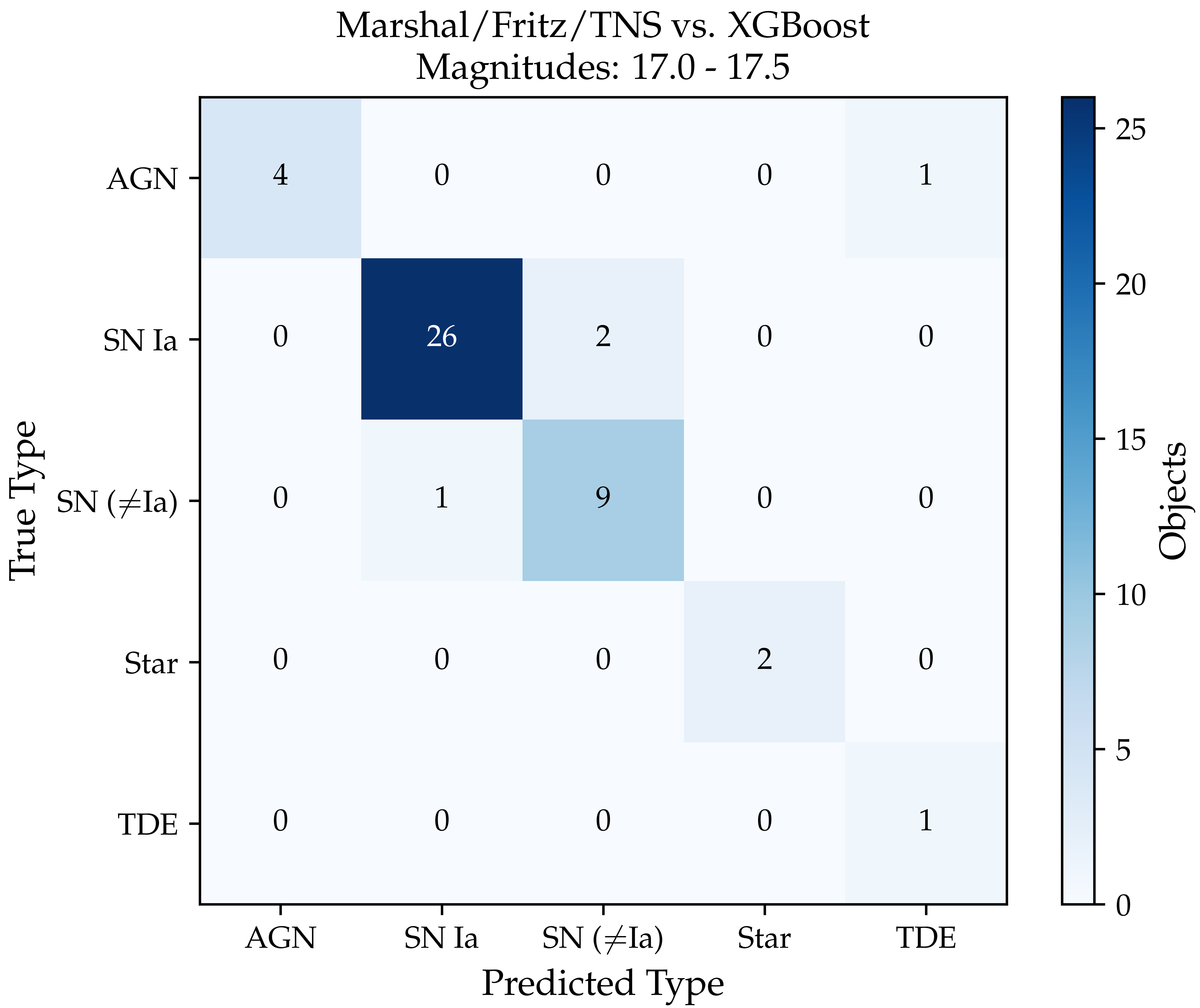
16.5-17.0



Evaluation with unsecure truth

Mag:

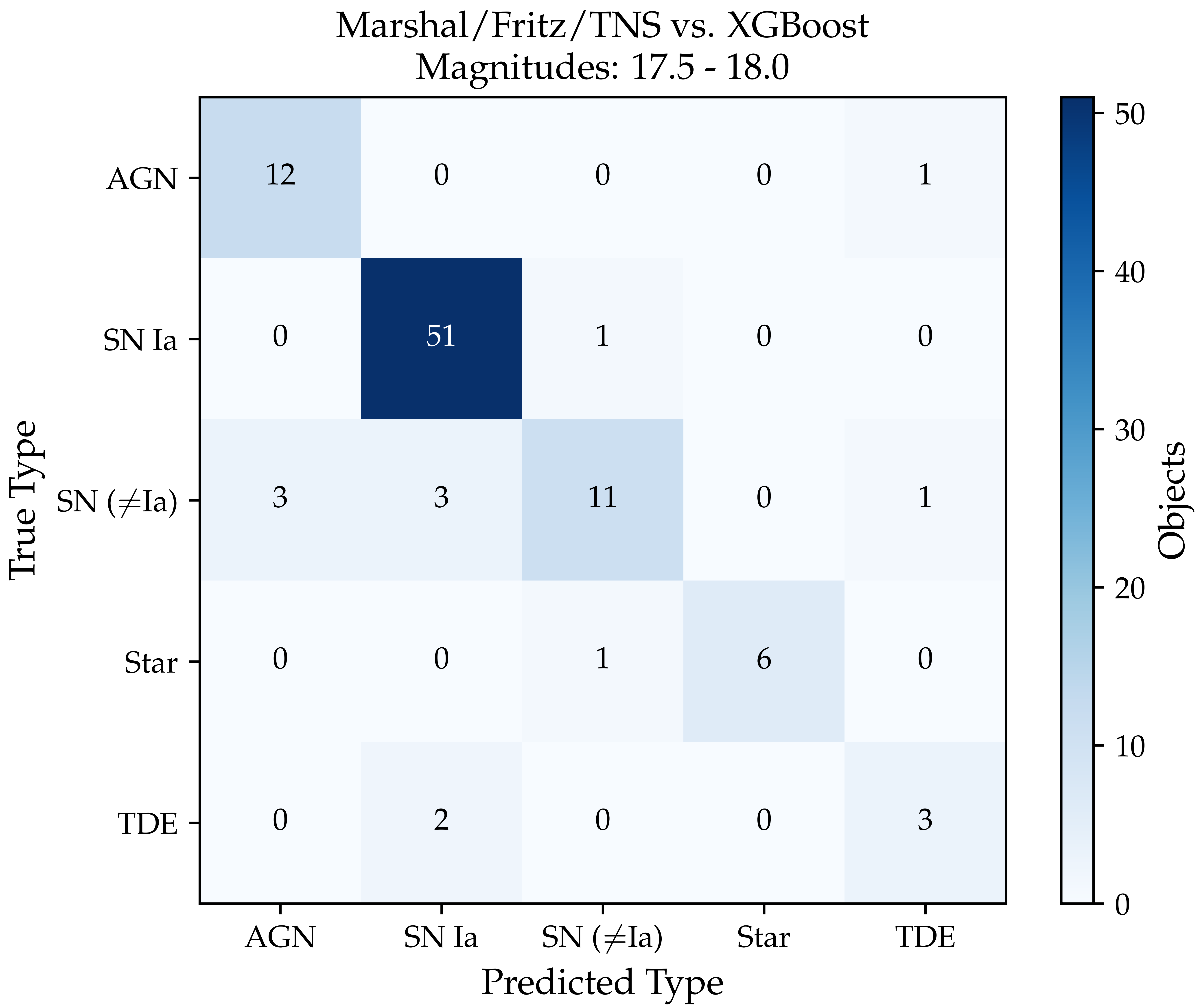
17.0-17.5



Evaluation with unsecure truth

Mag:

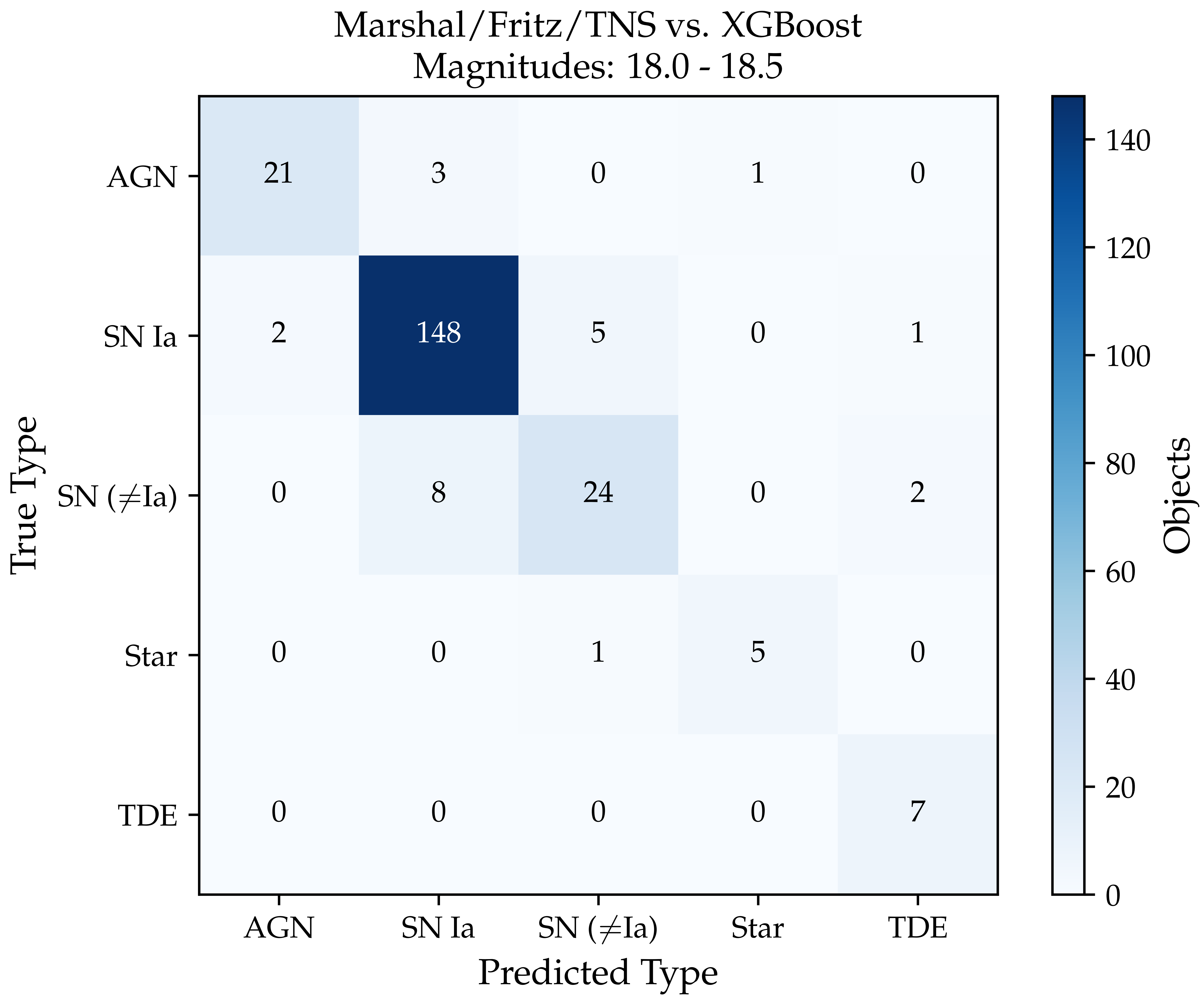
17.5-18.0



Evaluation with unsecure truth

Mag:

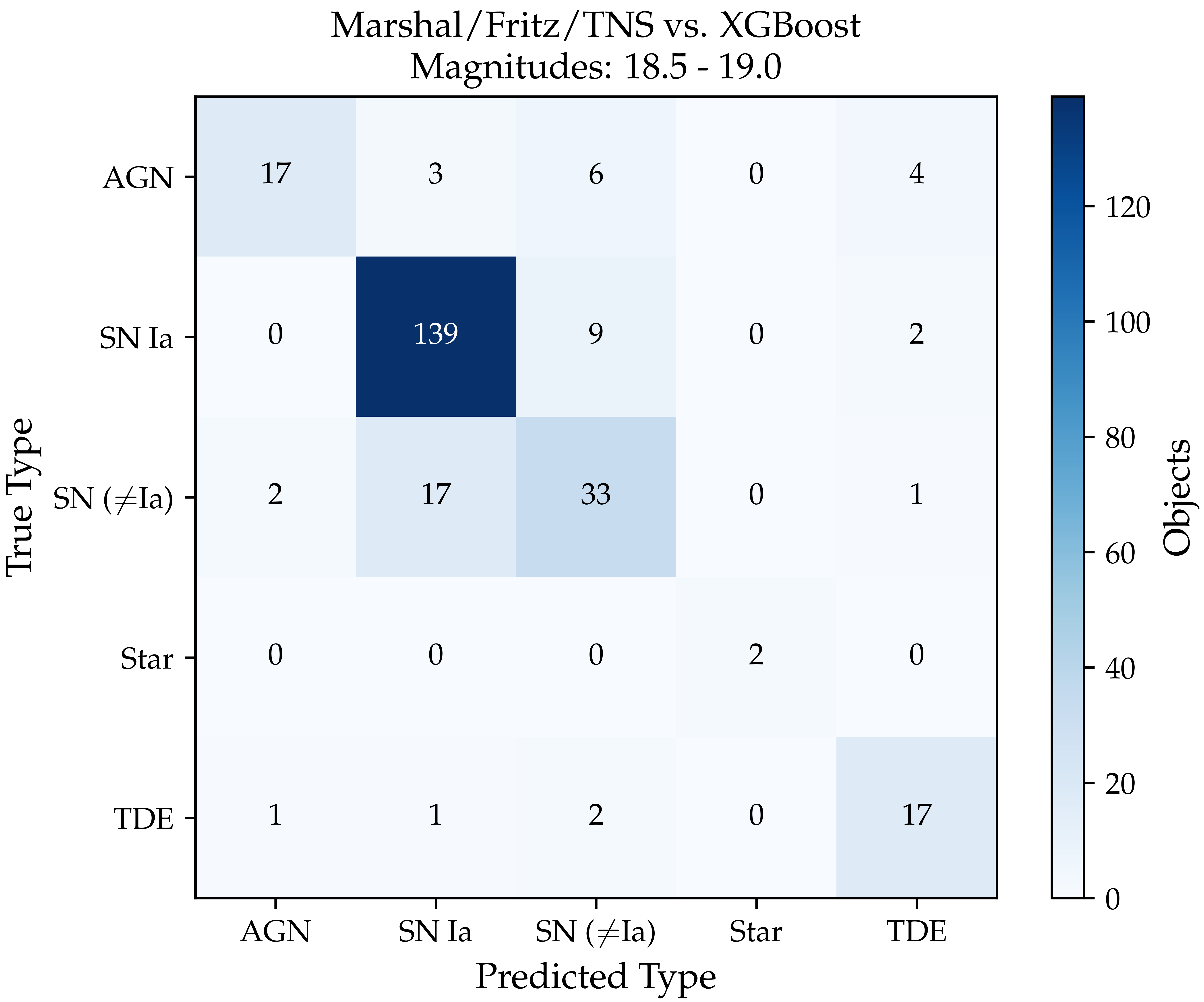
18.0-18.5



Evaluation with unsecure truth

Mag:

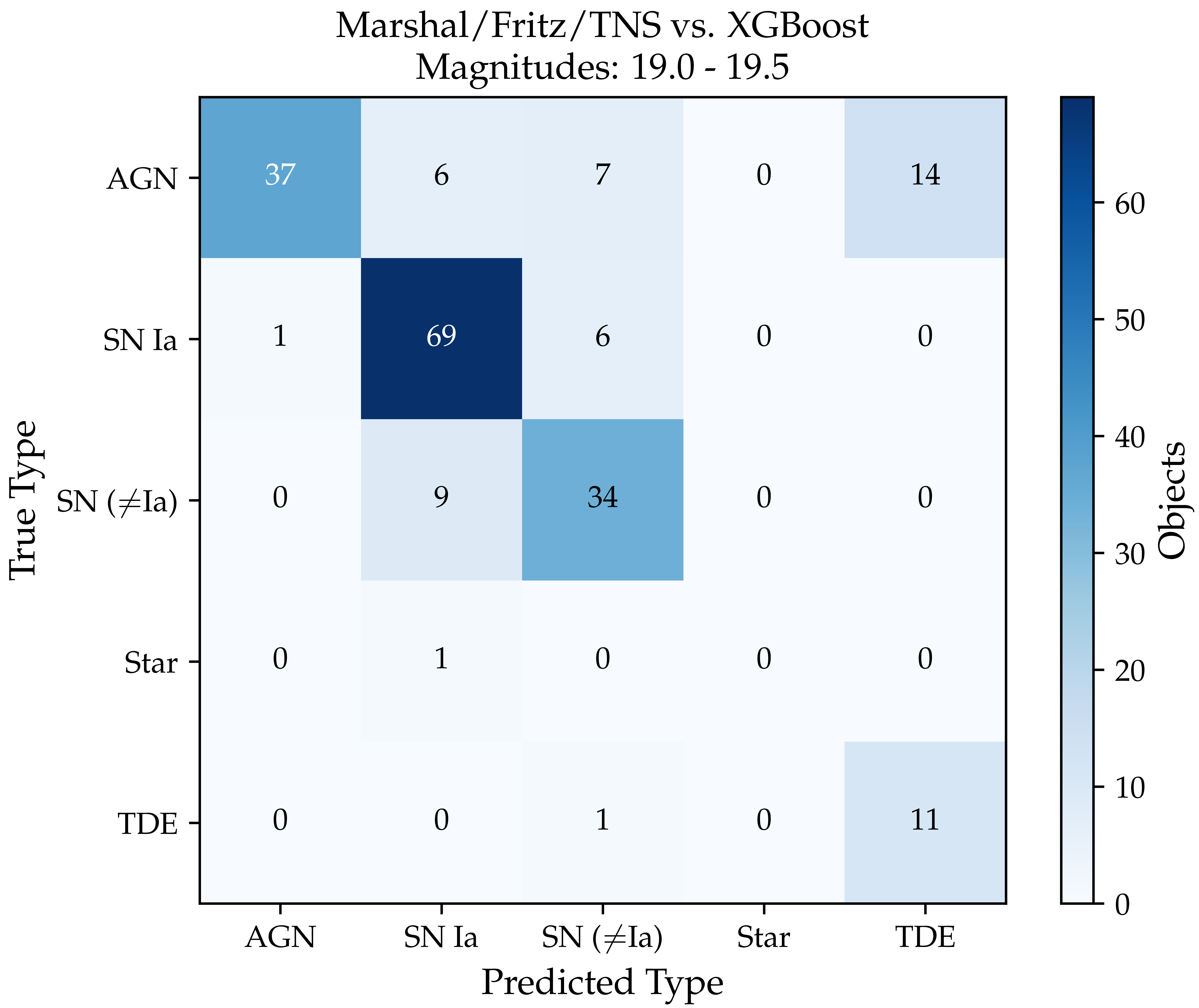
18.5-19.0



Evaluation with unsecure truth

Mag:

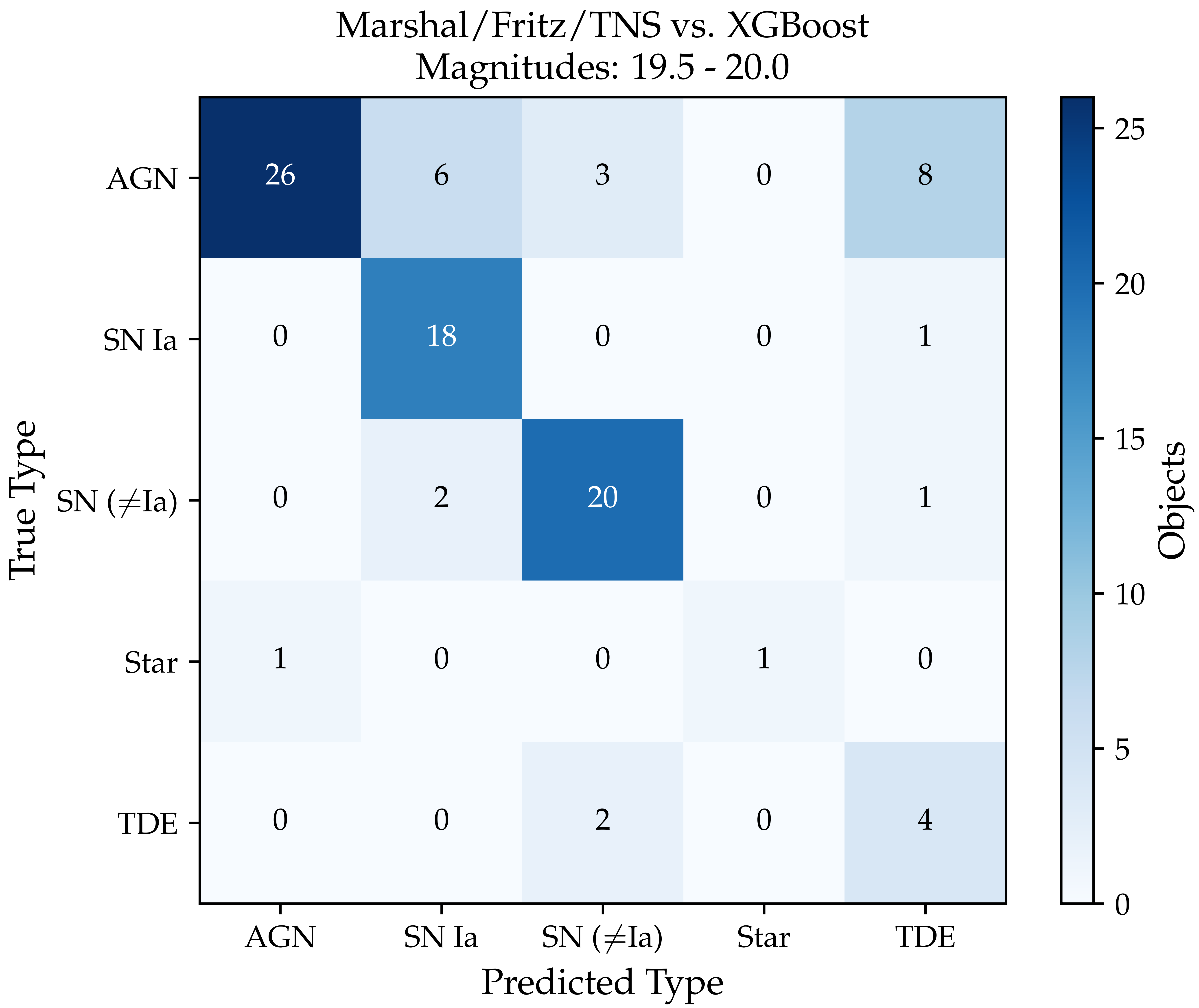
19.0-19.5



Evaluation with unsecure truth

Mag:

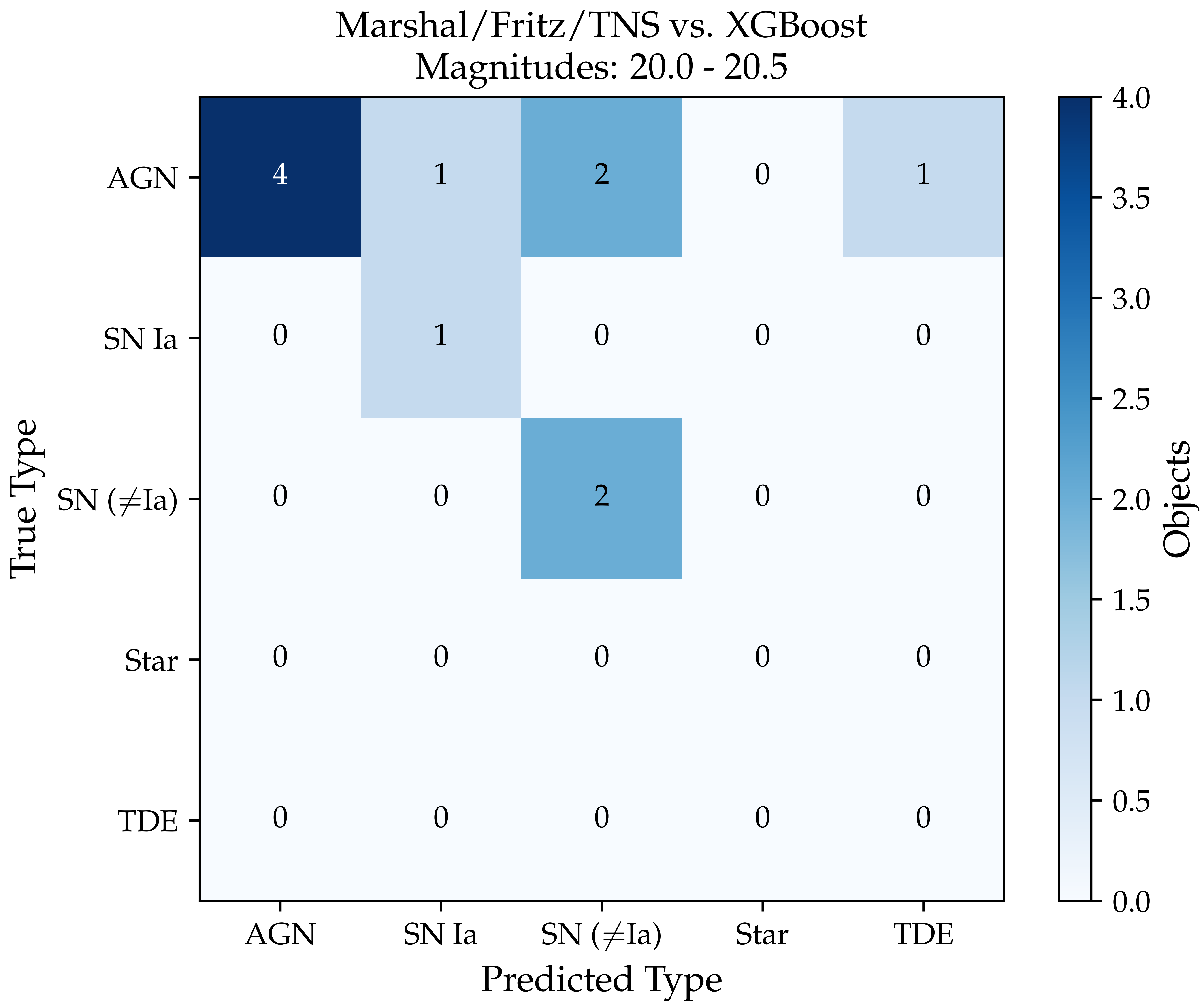
19.5-20.0



Evaluation with unsecure truth

Mag:

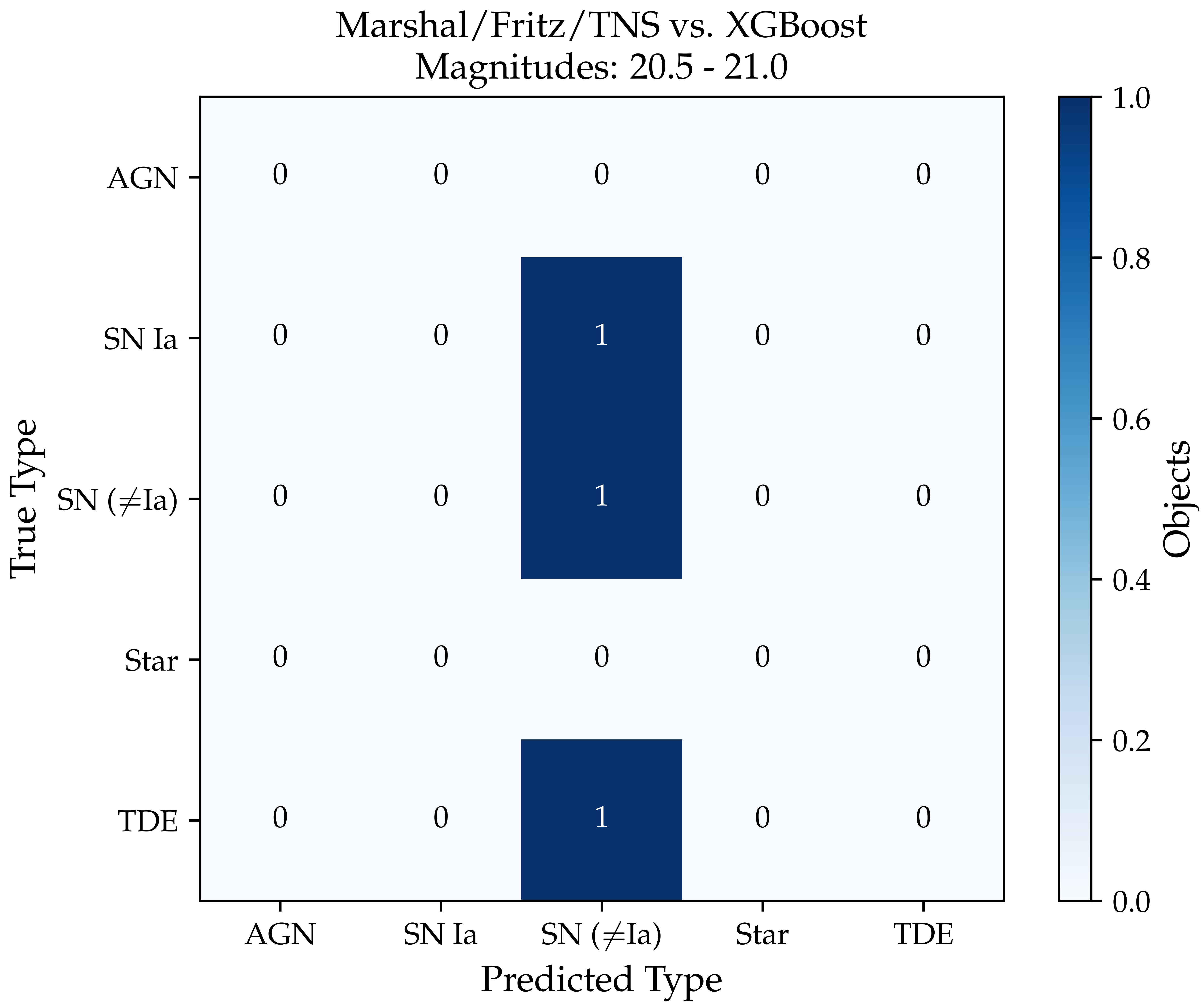
20.0-20.5



Evaluation with unsecure truth

Mag:

20.5-21.0



Questions

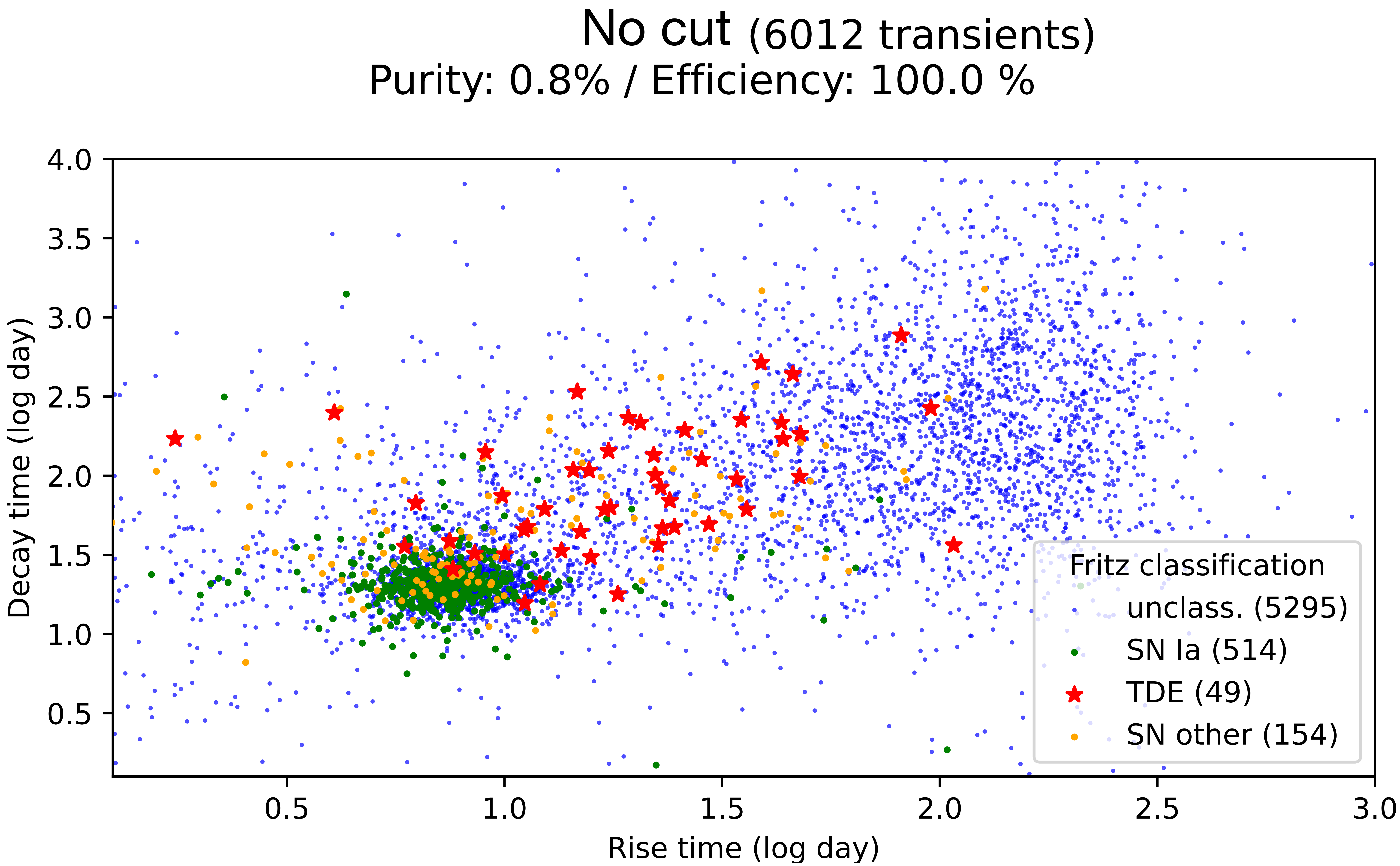
How to address uncertain classifications?

Way to discard "bad" predictions?

Waterfall plots?

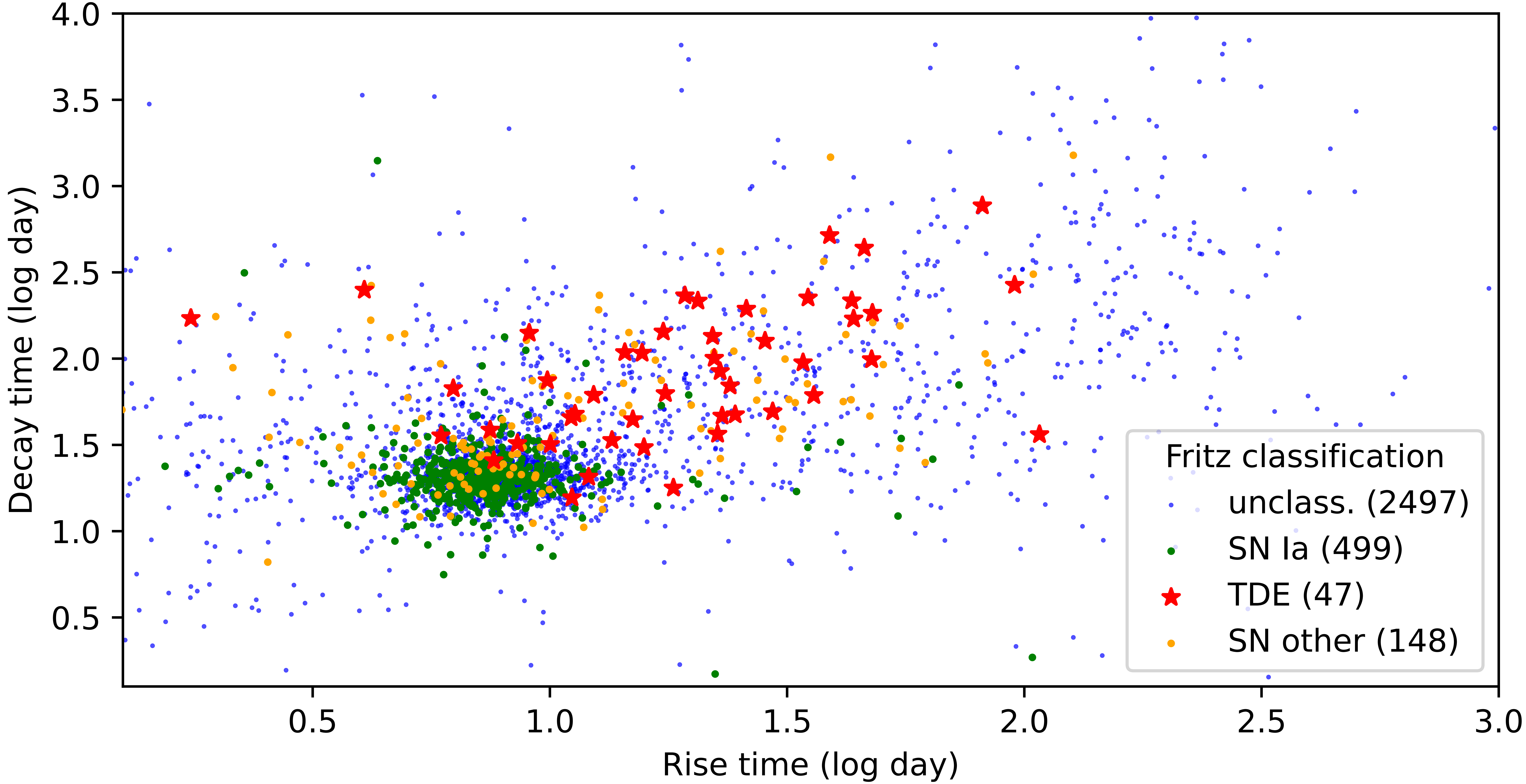
Suggestions to improve on the training? E.g: normalization of features (numerical values)?

Anomaly detection?


No cut (6012 transients)
Purity: 0.8% / Efficiency: 100.0 %
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
Decay time (log day)
0.5
1.0
1.5
2.0
2.5
3.0
Rise time (log day)
Fritz classification
unclass. (5295)
SN Ia (514)
TDE (49)
SN other (154)

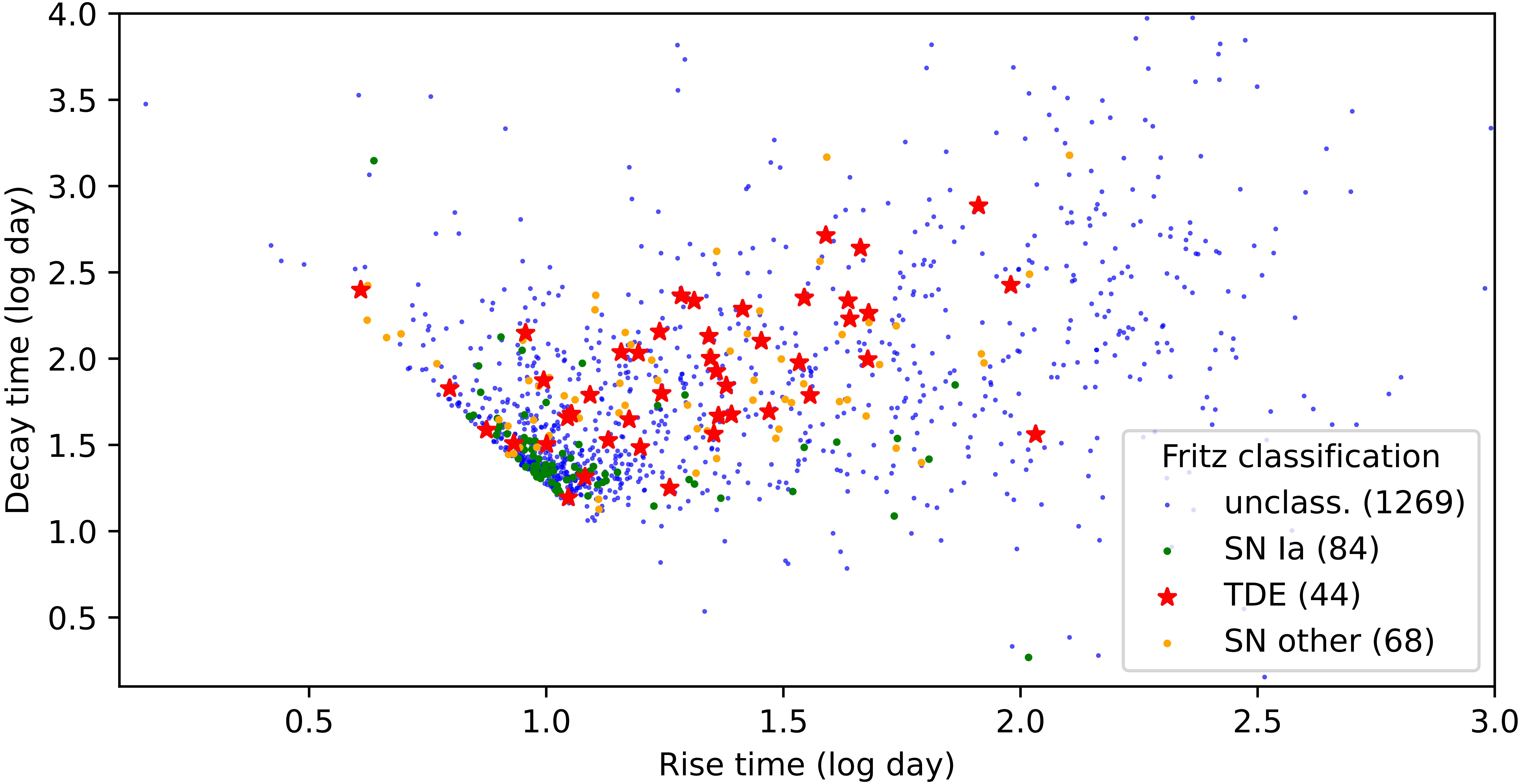
WISE colors (3191 transients)

Purity: 1.5% / Efficiency: 95.9 %



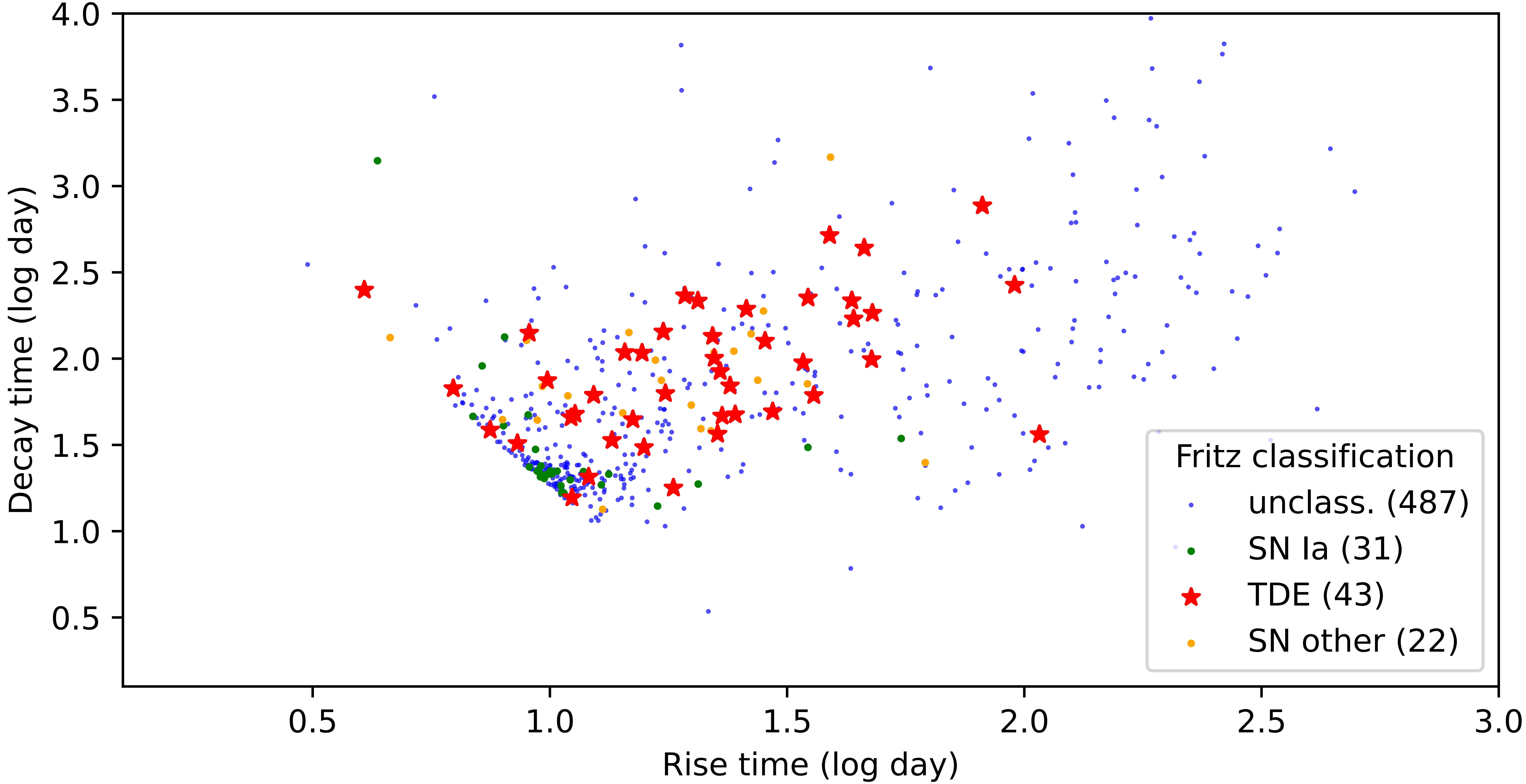
Diagonal cut (1465 transients)

Purity: 3.0% / Efficiency: 89.8 %



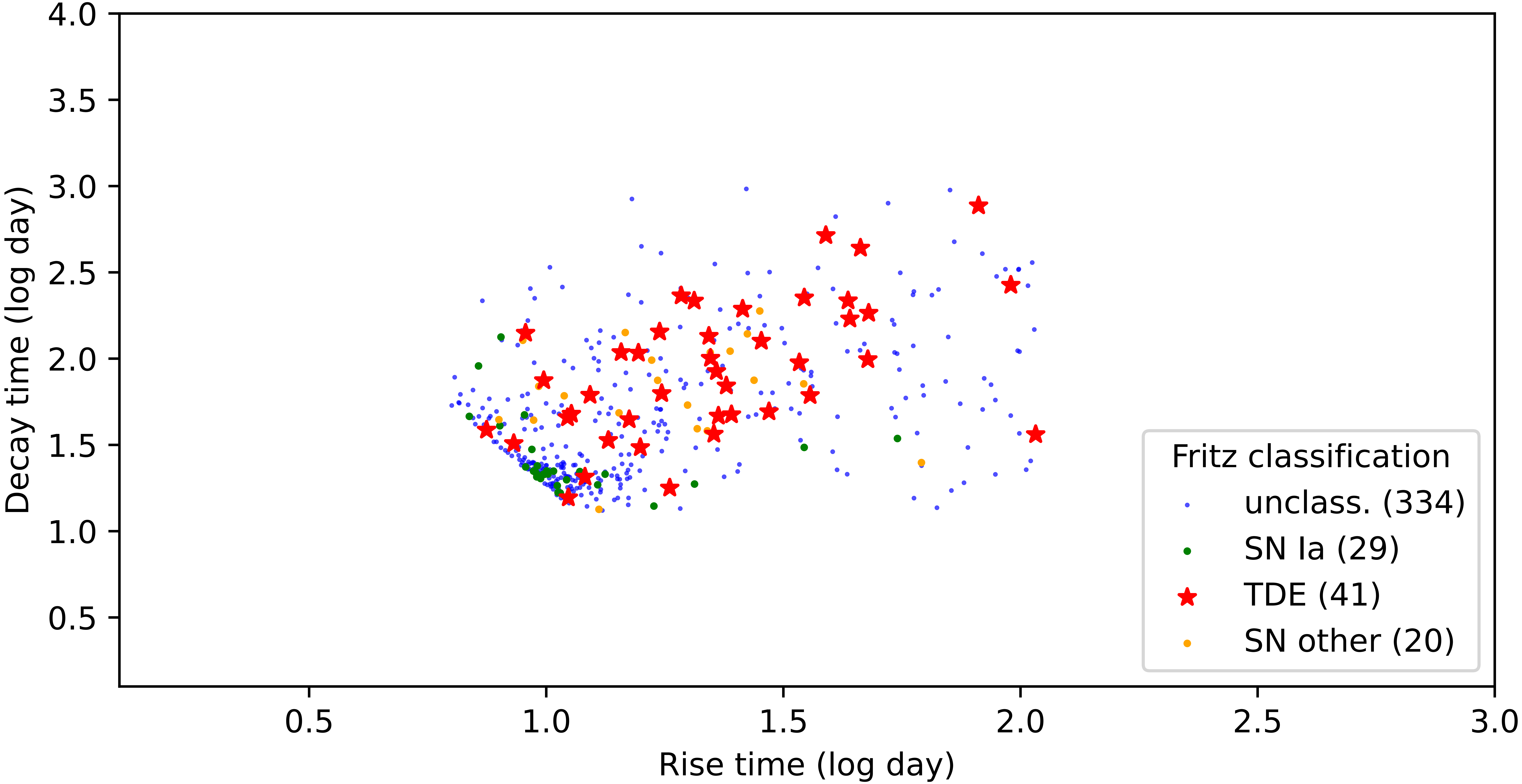
Temperature cut (583 transients)

Purity: 7.4% / Efficiency: 87.8 %



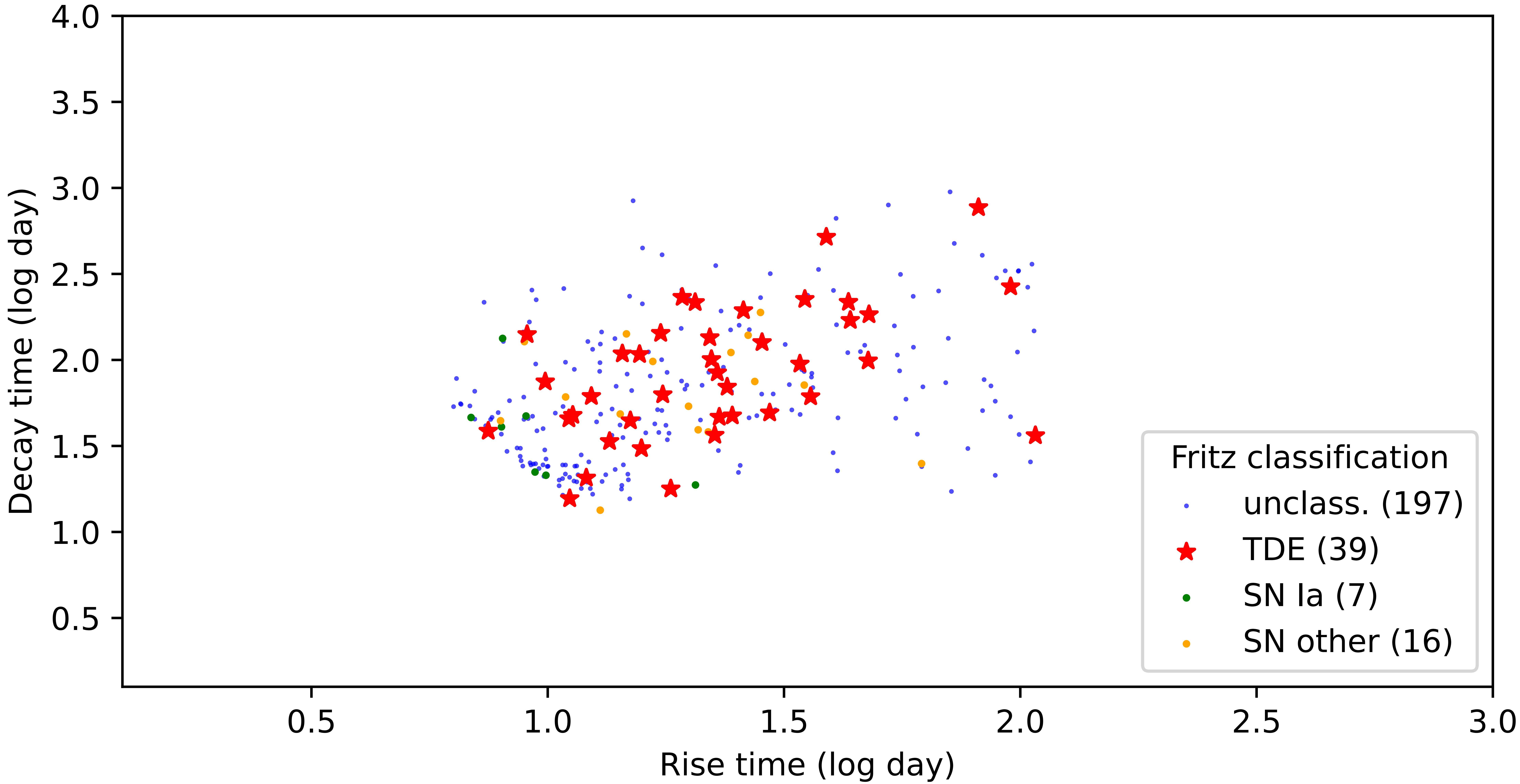
Rise-decay cut (424 transients)

Purity: 9.7% / Efficiency: 83.7 %



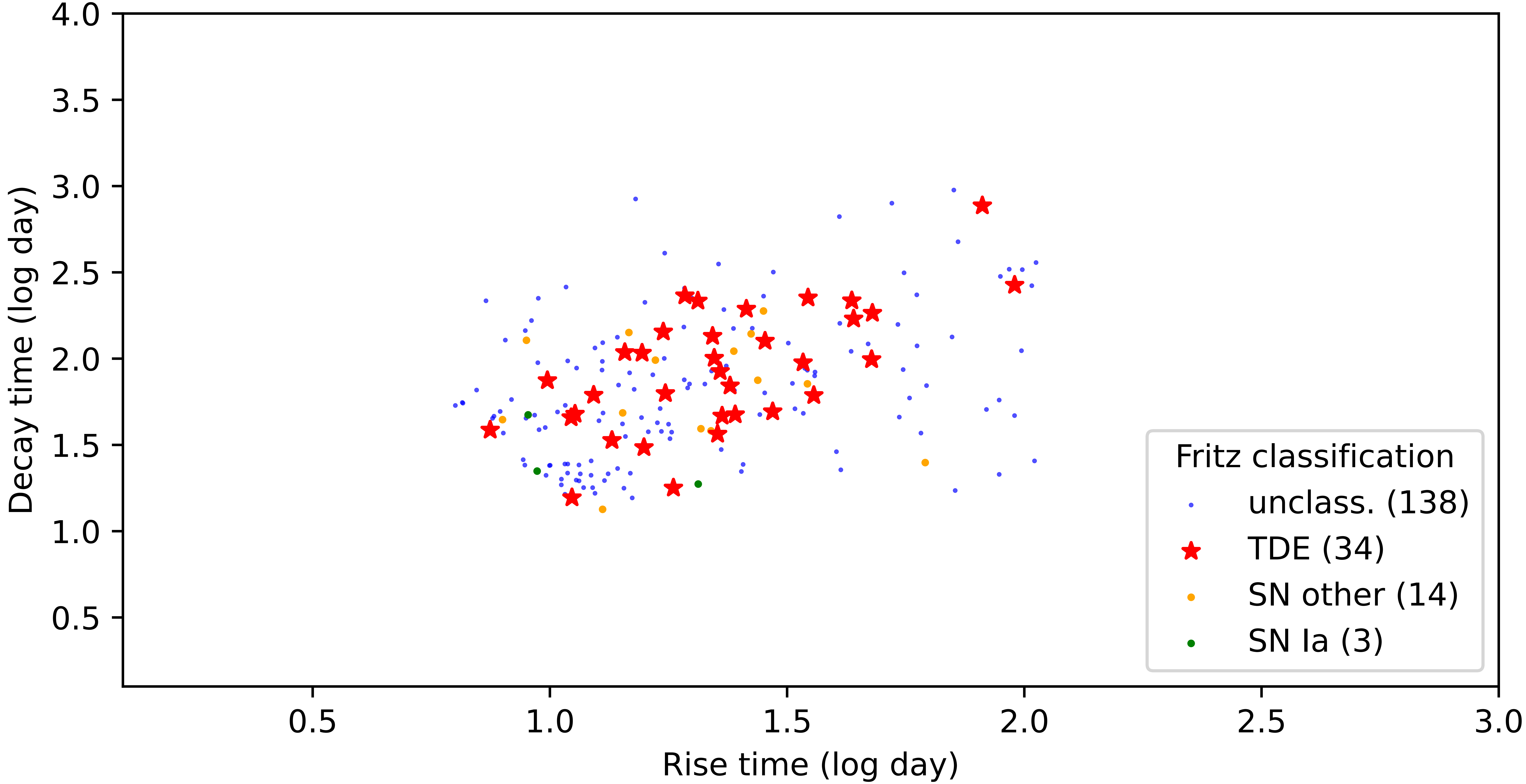
Chisquare cut (259 transients)

Purity: 15.1% / Efficiency: 79.6 %

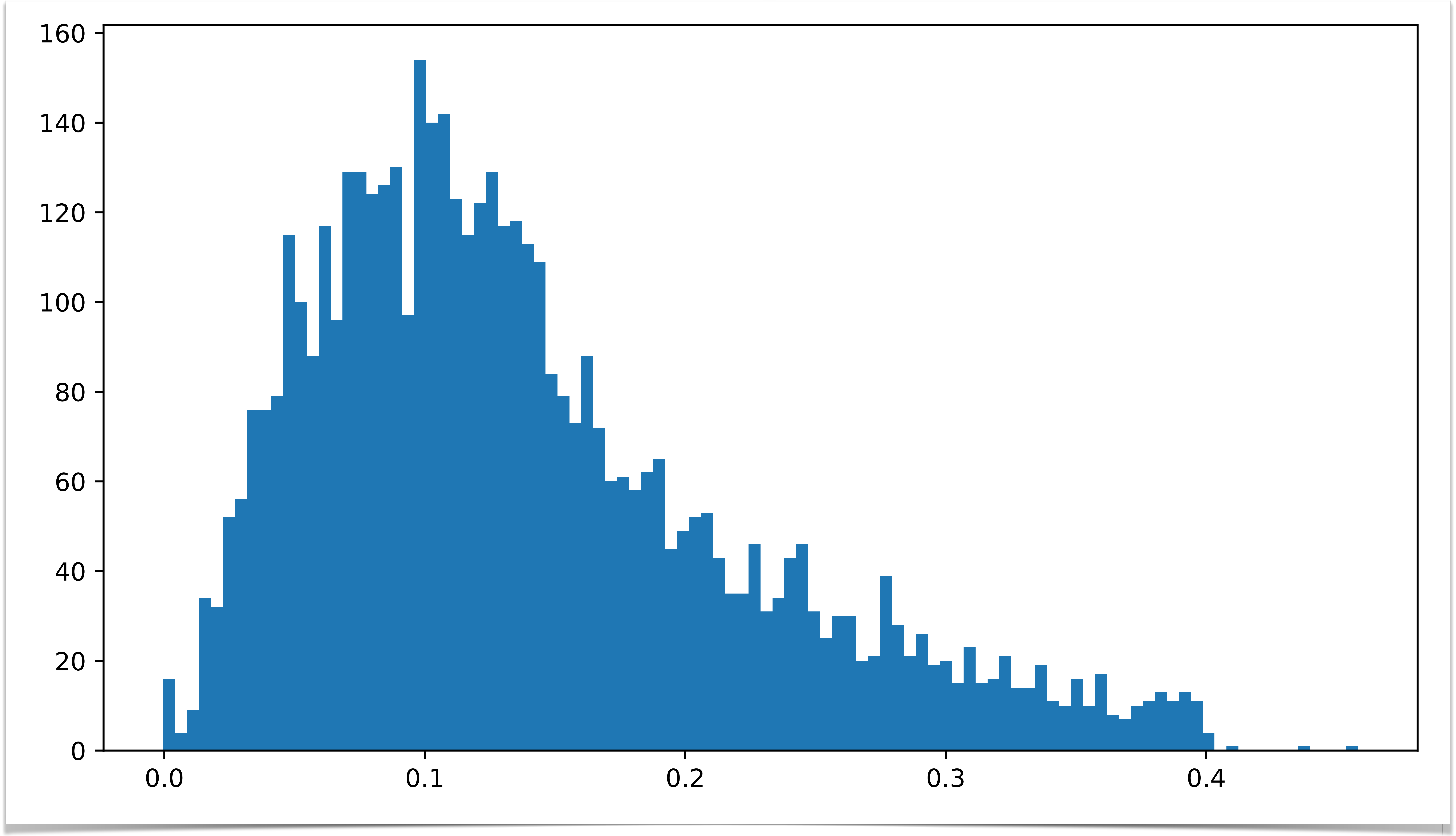


Bayesian block cut (189 transients)

Purity: 18.0% / Efficiency: 69.4 %

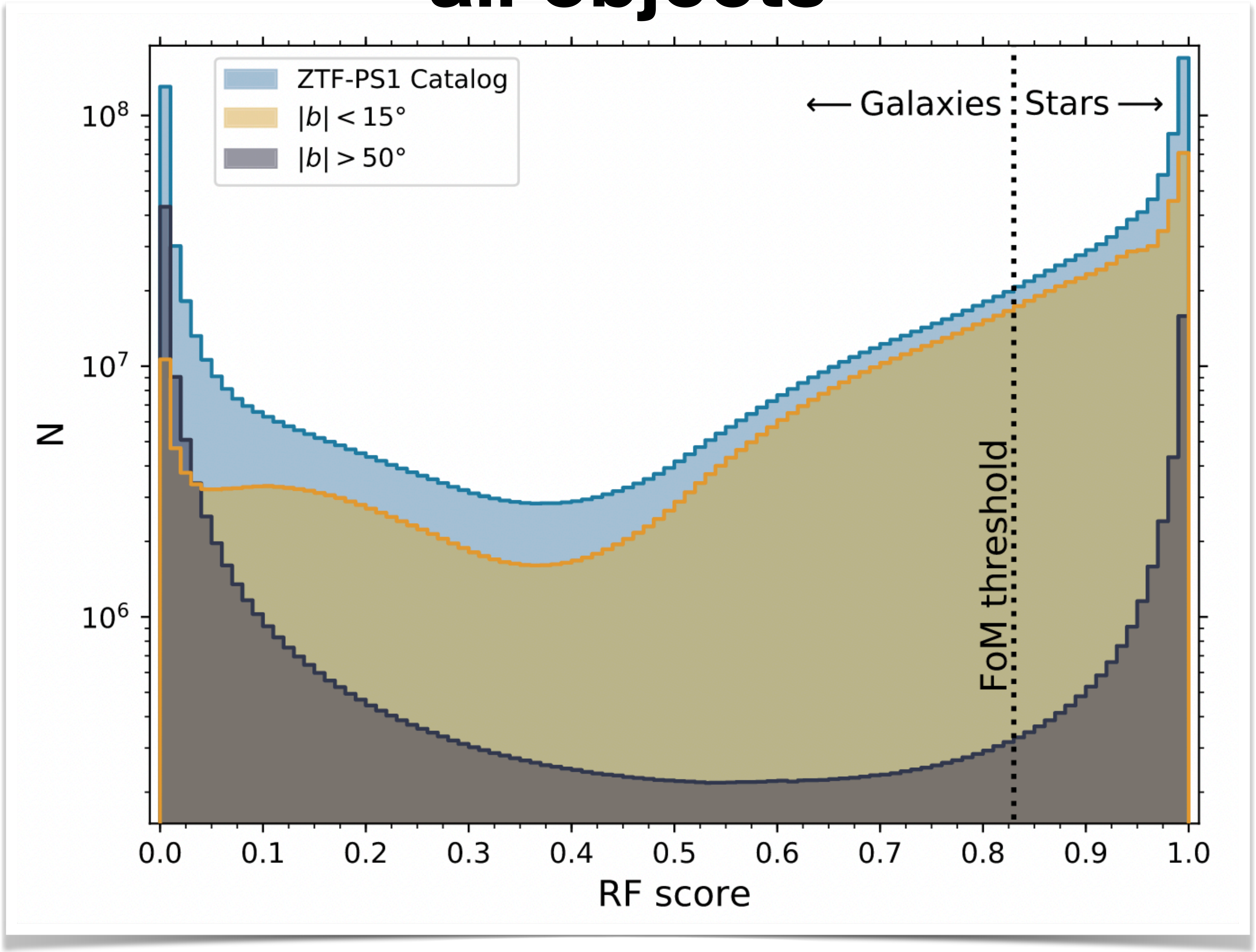


Redshift distribution (including photoz, n=4883)

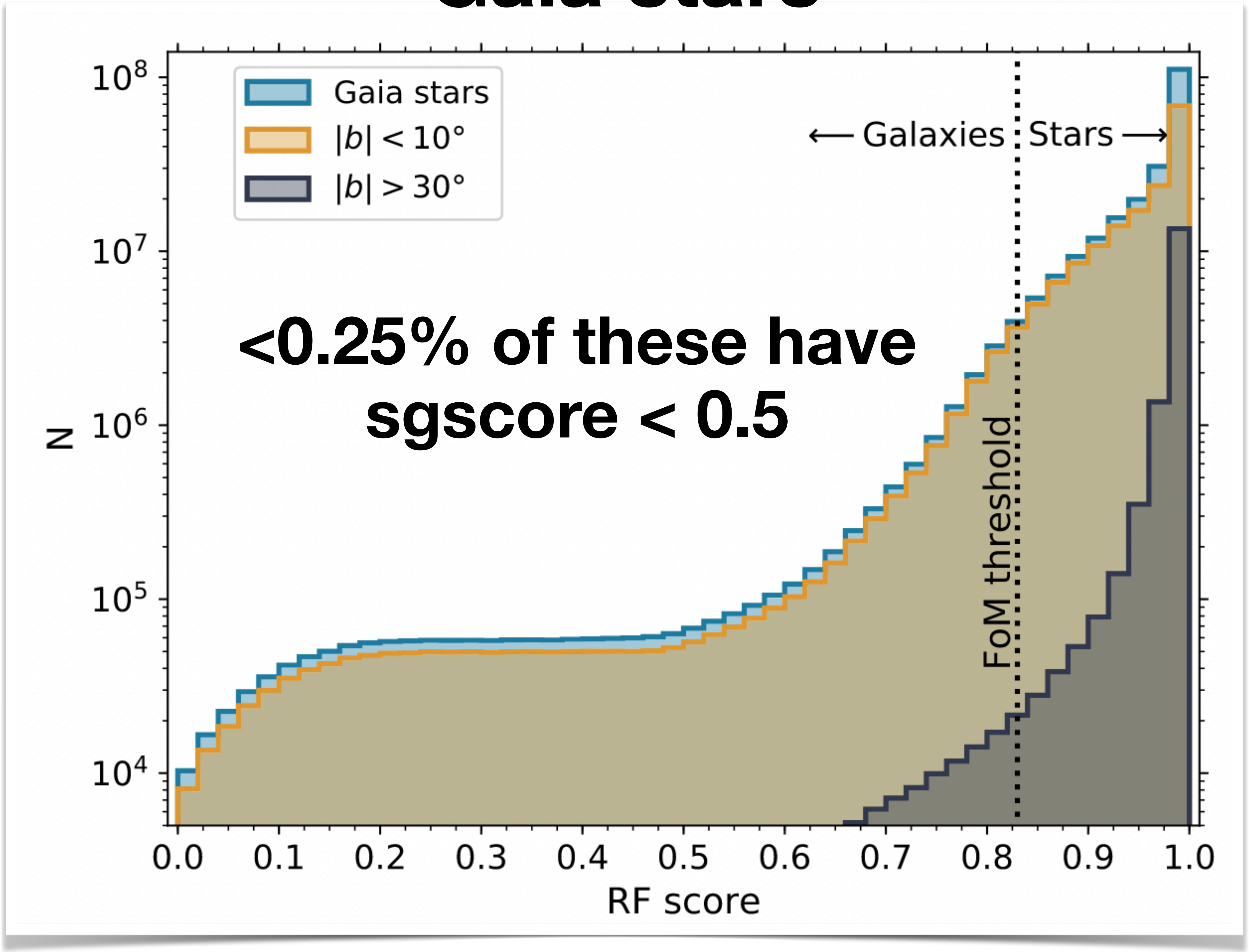


`sgscore` distribution

all objects

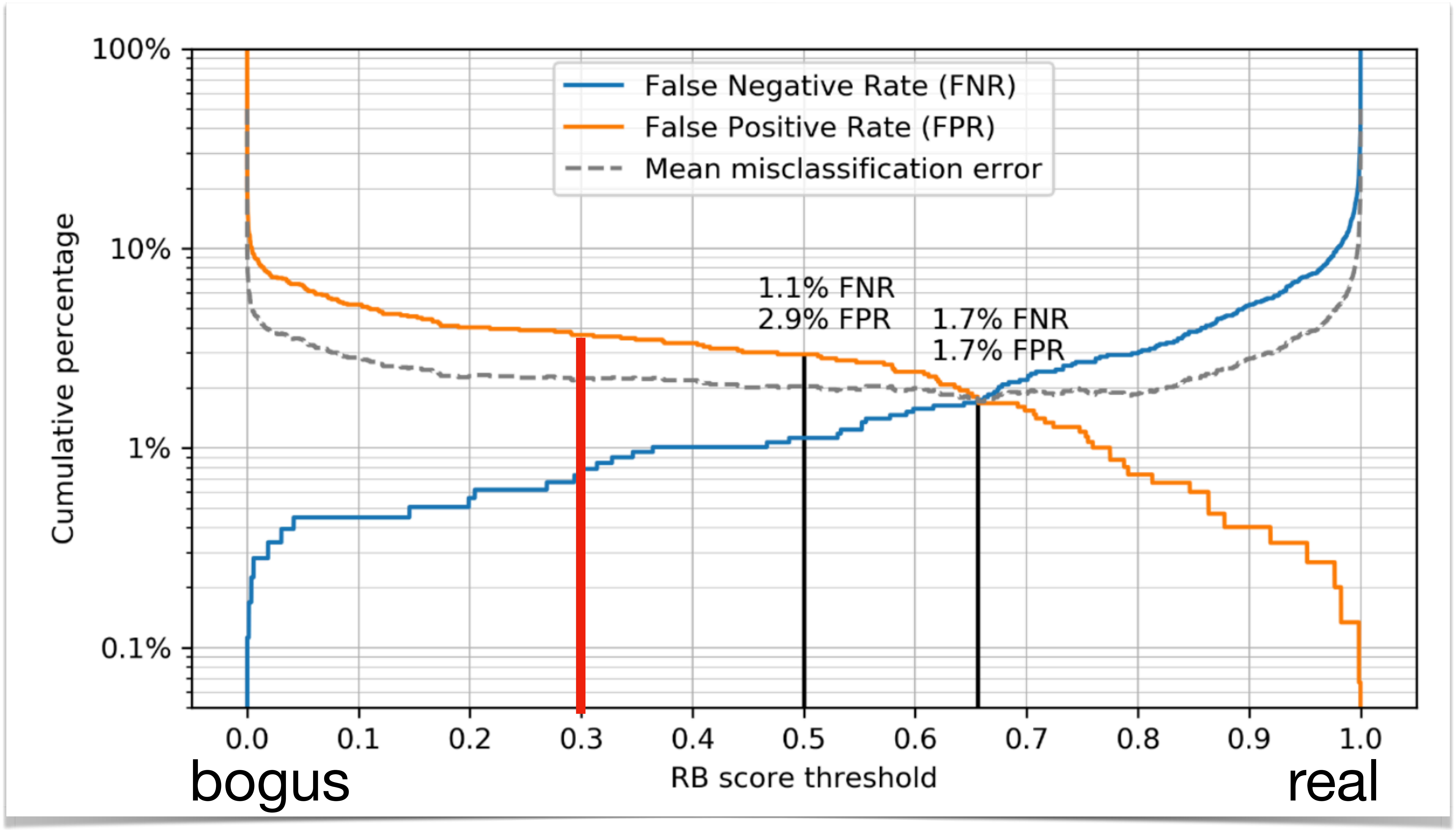


Gaia stars



Tachibana & Miller, 2018 (PASP)

rb distribution



0.7% FNR
4 % FPR

Duev et al., 2019 (MNRAS)