# Optical and Infrared Hunt for Tidal Disruption Events

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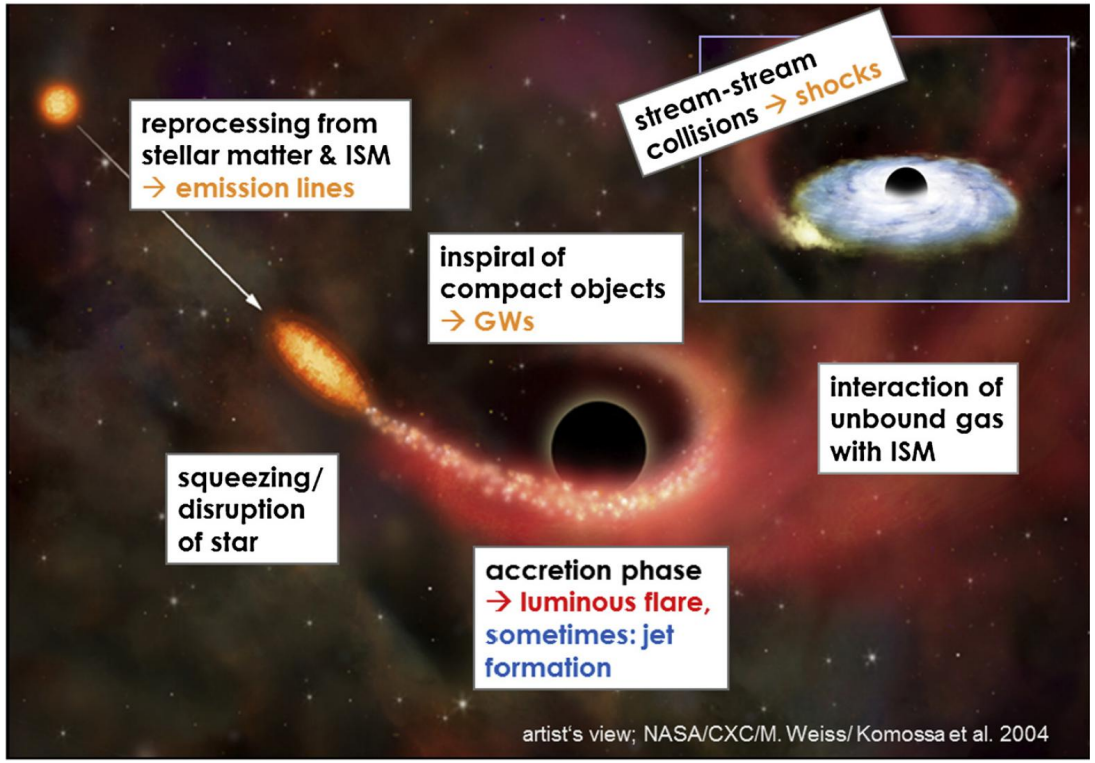
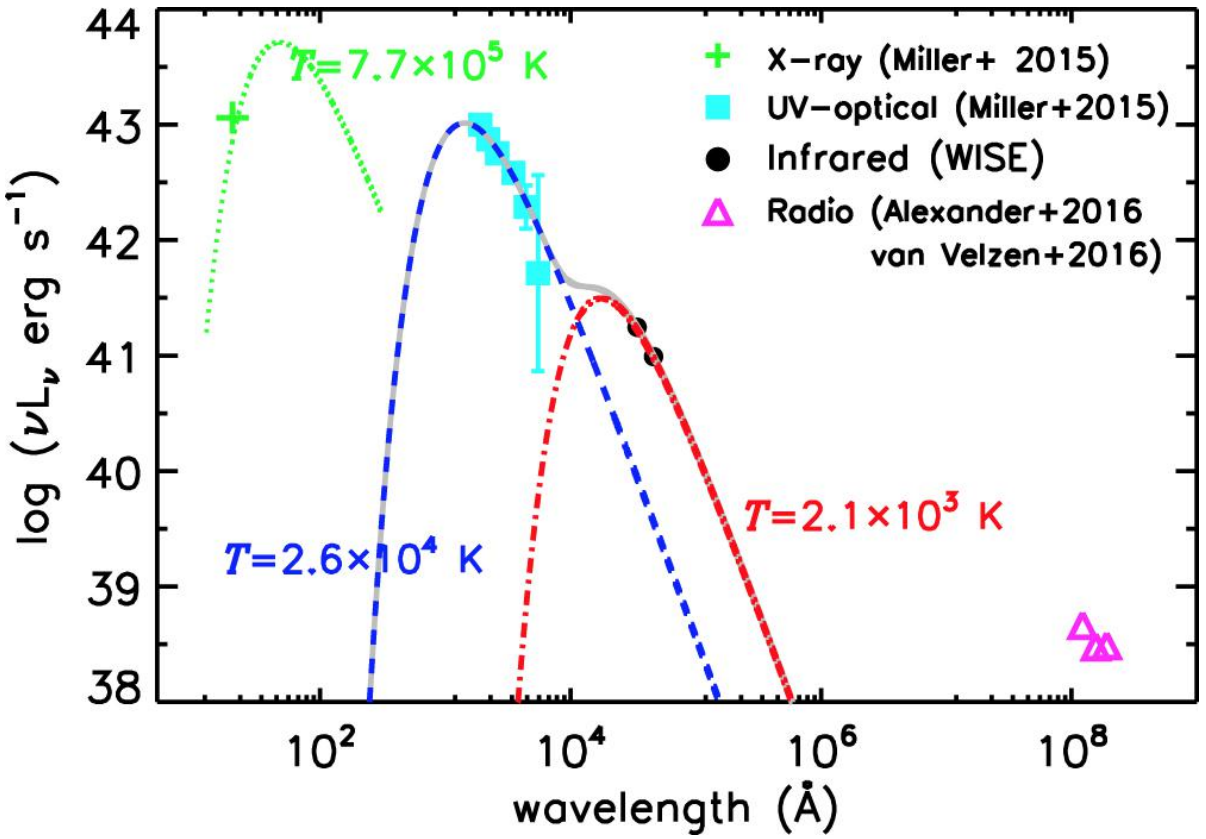
10/15/2024@TDLI
Transient Phenomena and Physical Processes Around Supermassive Black Holes

# TDE is a Multi-λ emitter




SED of ASASSN-14li (+36 days)

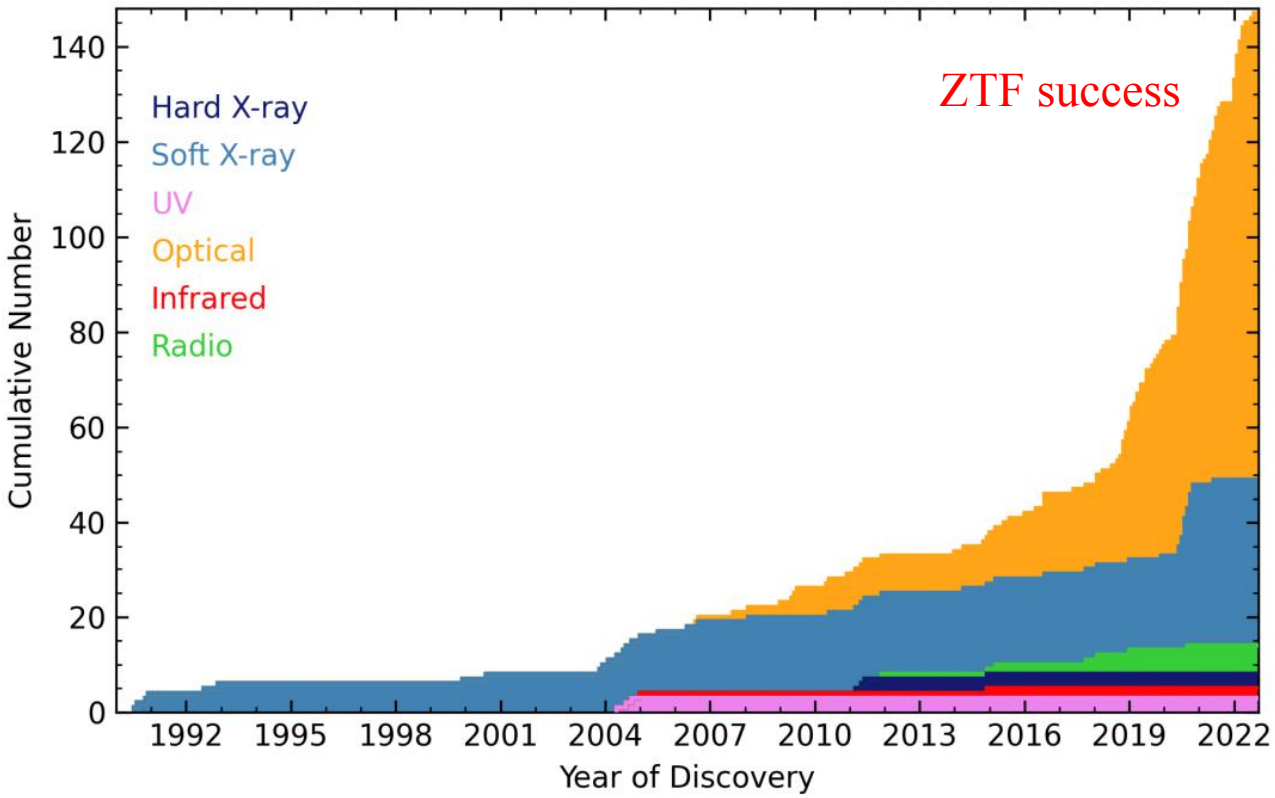



Jiang+2016

TDE can be found in multi-λ

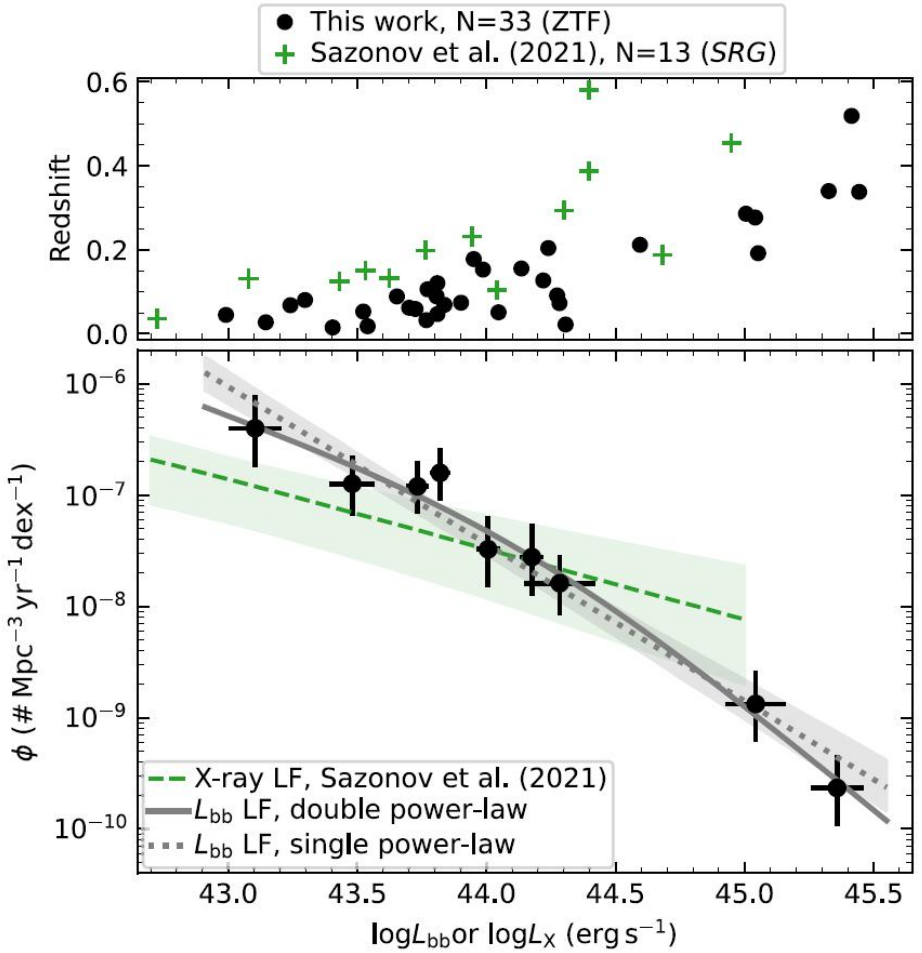
# Status of Observations

- discovery dominated by X-ray and optical
- IR and Radio contribute gradually and significantly




Yao+2023, an incomplete statistic

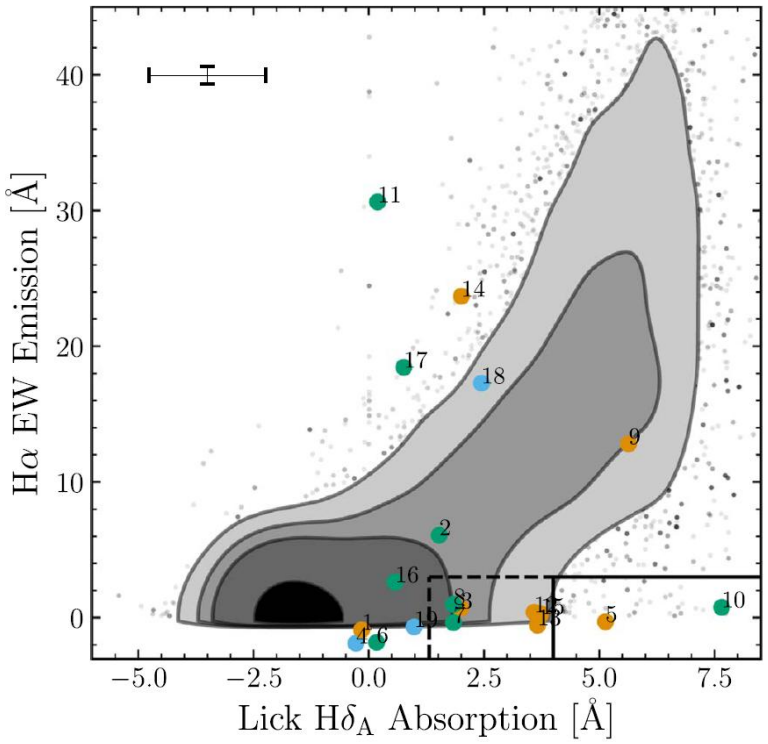
Luminosity function

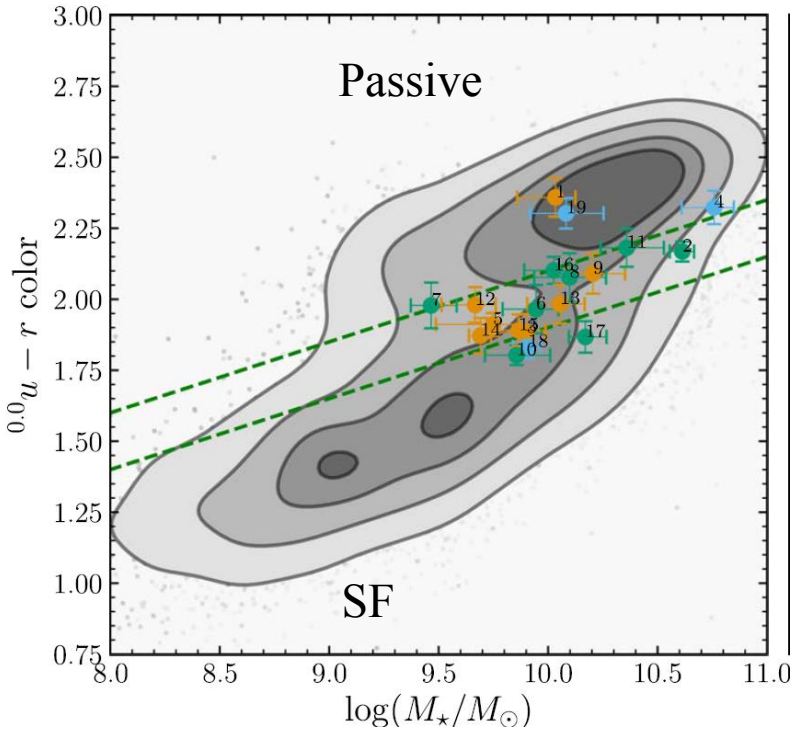



ZTF rate: $3.2\times10^{-5}$ galaxy$^{-1}$ yr$^{-1}$

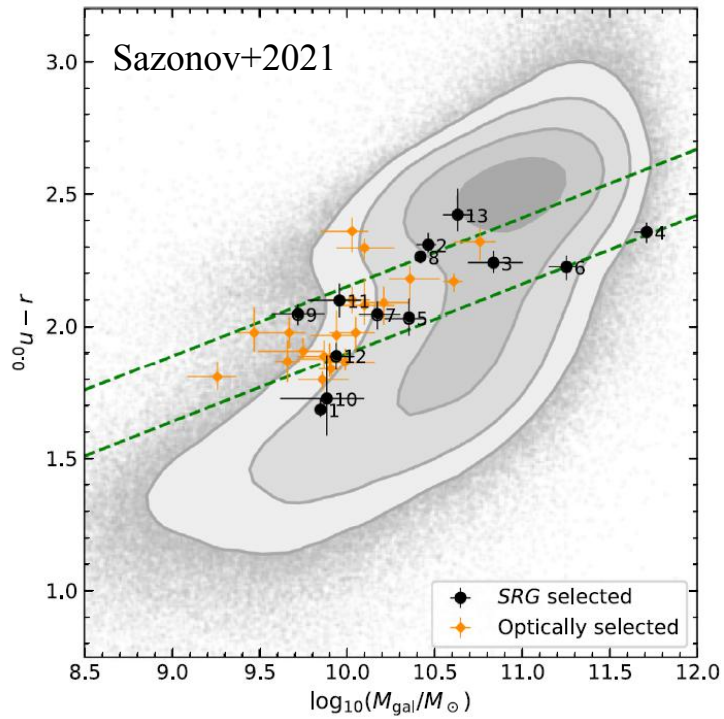
# Preference of host galaxies

- ZTF sample Hammerstein+2021




- eROSITA sample

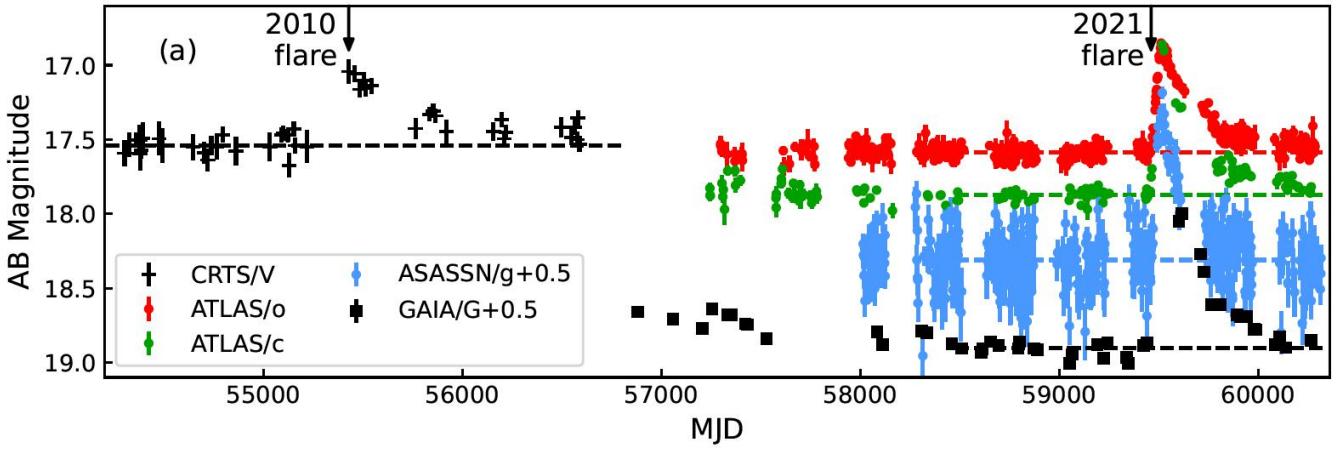



- overpresented in E+A (post-starburst) / green valley (Arcavi+2014, French+2016)
- current optical/X-ray search is far from complete

# Recurring flares: repeating partial TDE?

IRAS F01004-2237

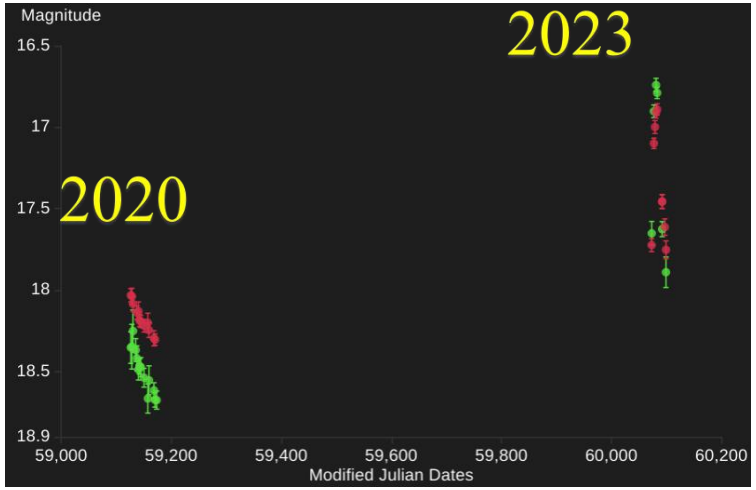
Sun,Jiang+2024 (arxiv:2410:09720)




high TDE rate or pTDEs?

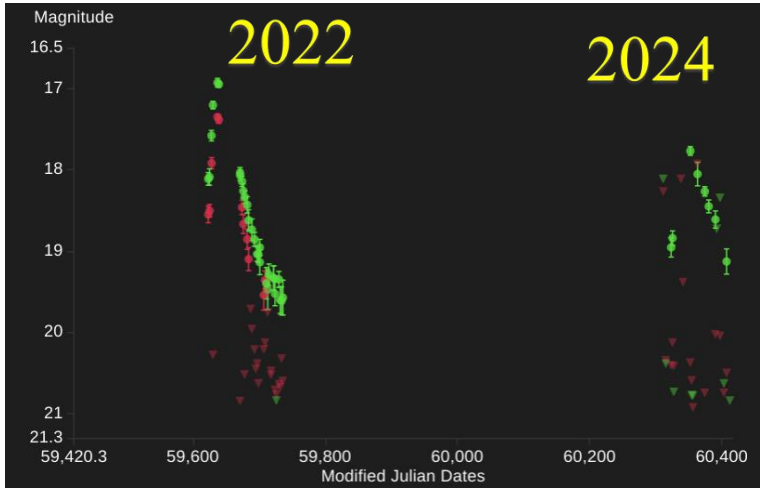
This is key for TDE demography

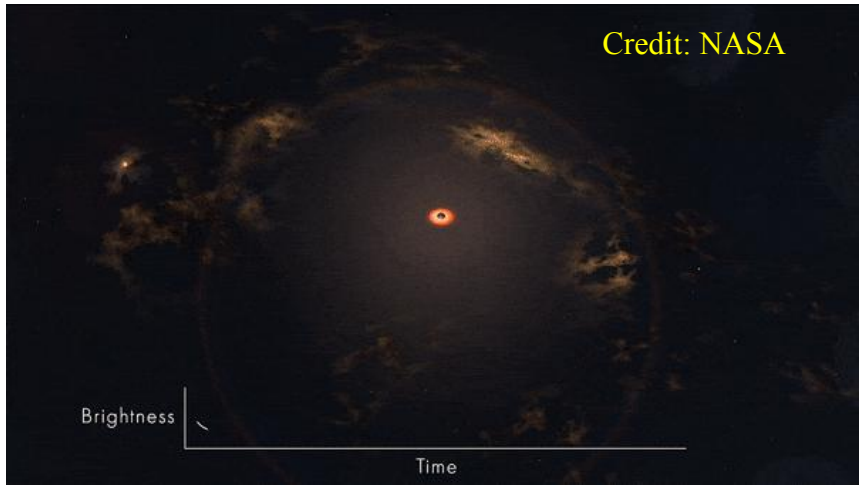
AT2020vdq




Somalwar+2023, under review

AT2022dbl



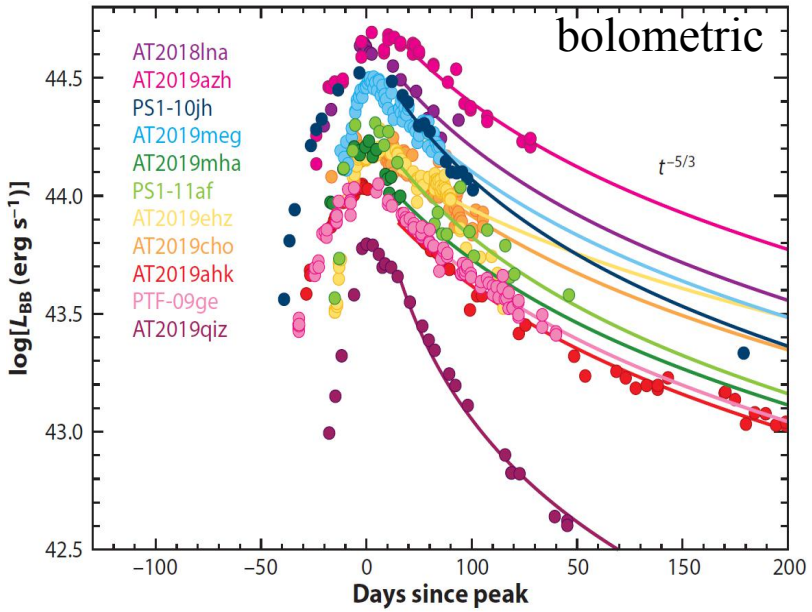




Lin,Jiang+2024 (Z.Y. Lin's talk)

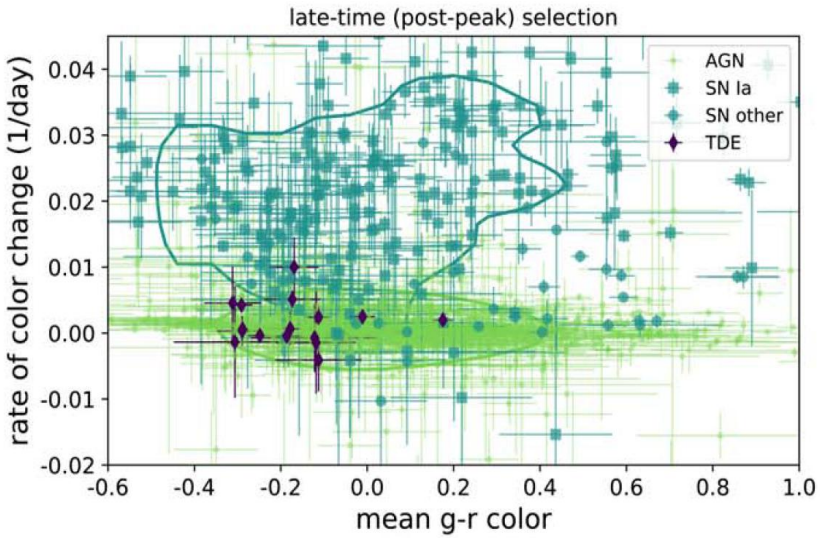
# Optical selection: blue nuclear transients

- fast rising (~one month)
- slow (months-year) power-law declining
- blue (>$10^4$K) and constant color
- broad (~$10^4$ km/s) emission (H, He, H+He)

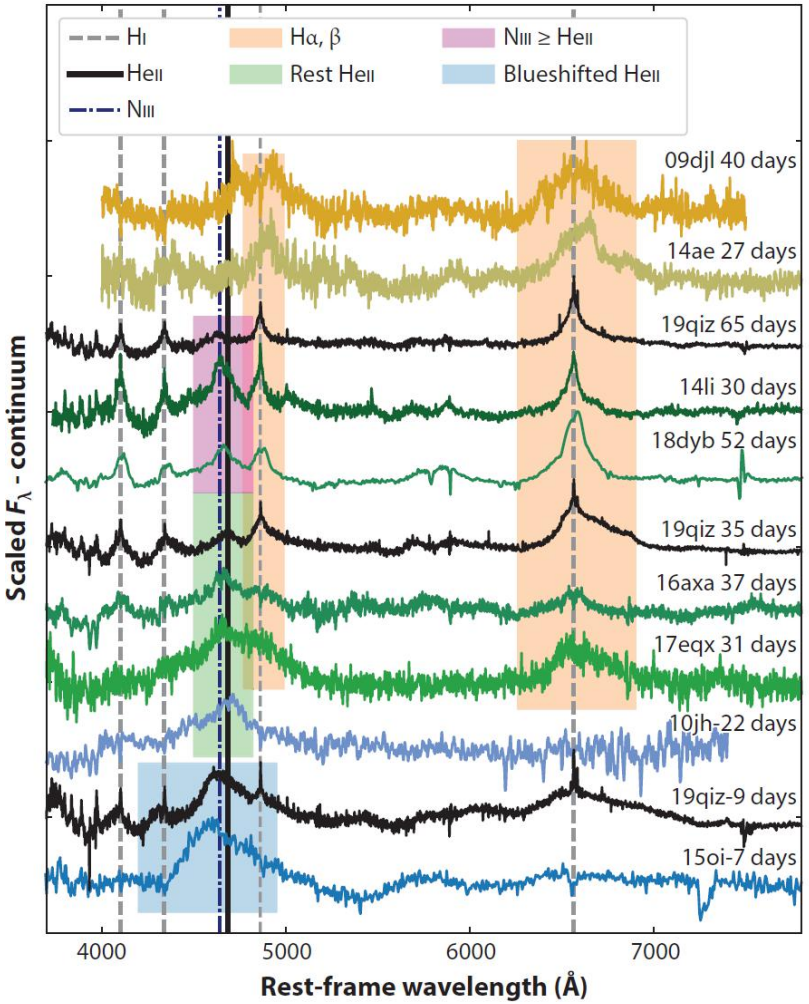
empirically ruling out SN, AGN!
needs TDE physics, more types are possible!




Gezari+2021



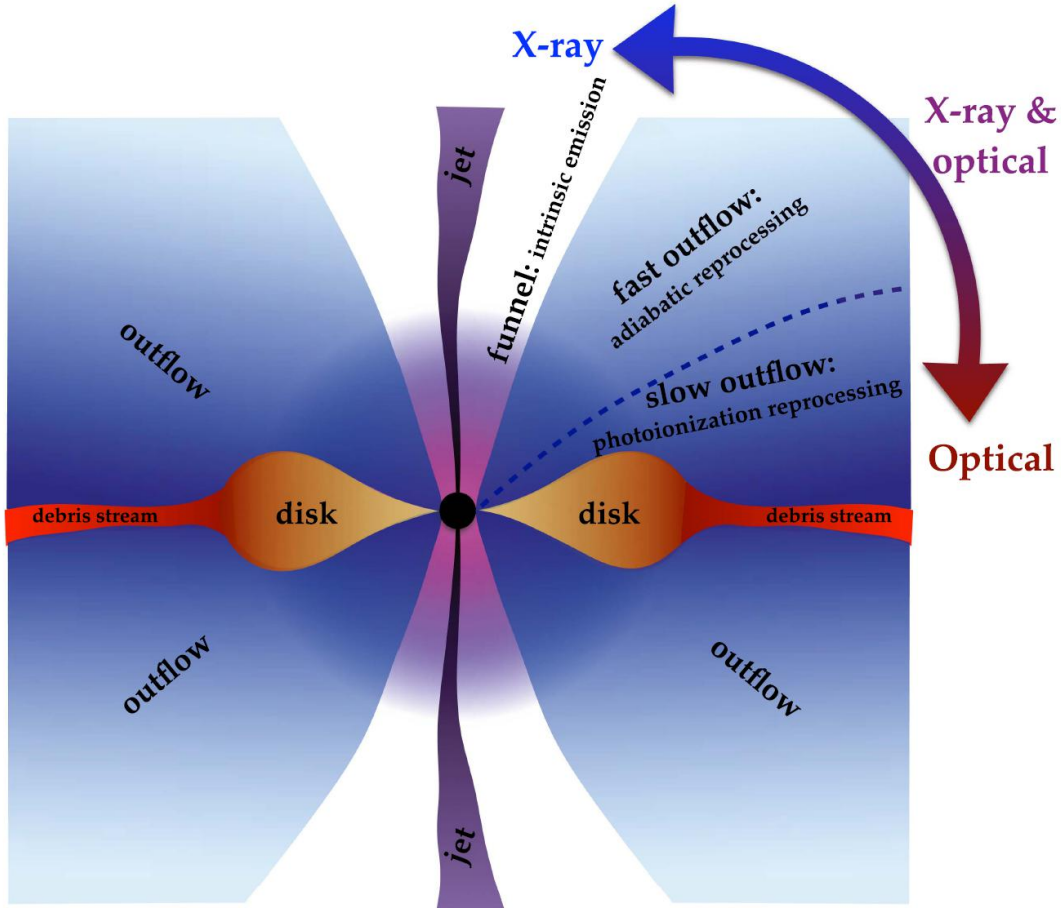

van Velzen+21




Gezari+2021, van Velzen+2021, Hammerstein+2023

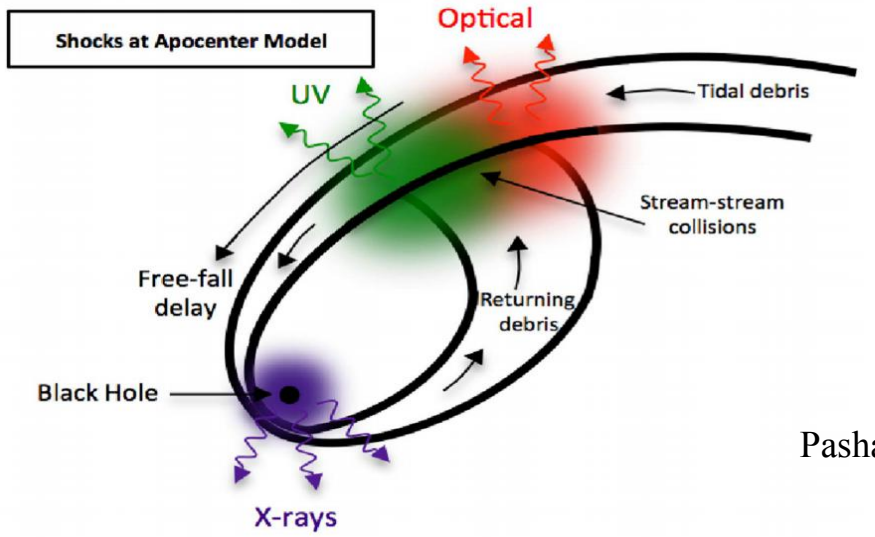
# Origin of optical emission: two (main) competing models

- reprocessing




Dai+2018

- stream-stream collision




Pasham+2018

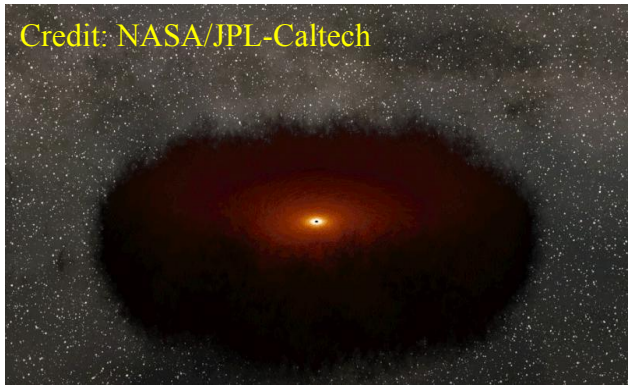
The uncertain origin of optical emission hinders the application of TDEs, i.e., measuring the BH mass, spin and probing the accretion physics

# Our work

for a more complete sample and more complete light curve

## Infrared search （band）

$$e^{-\tau_{UV}} \frac{L(t_r)}{4\pi R^2} \pi a^2 Q_{UV} = \langle Q_{abs} \rangle_P \, 4\pi a^2 \sigma T^4$$




- The SED of TDE is very sensitive to dust
- dust can obscure, but can also unveil TDEs via IR echo

- The low-end luminosity funciton is not well constrained
- The rising light curves are not well observed

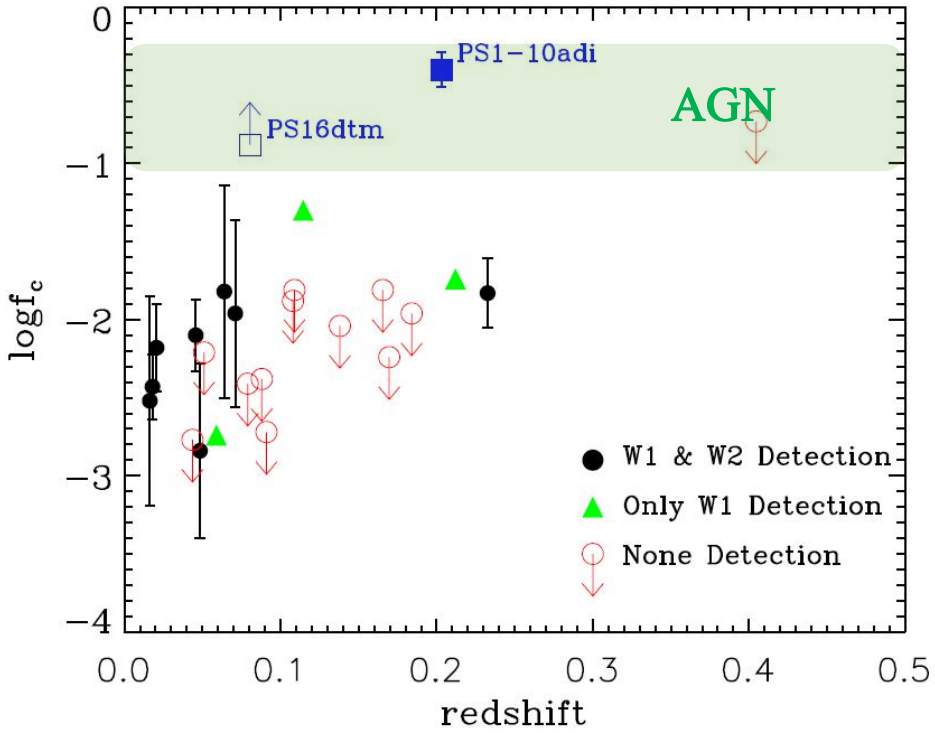
## More efficient Optical Search（depth and cadence）

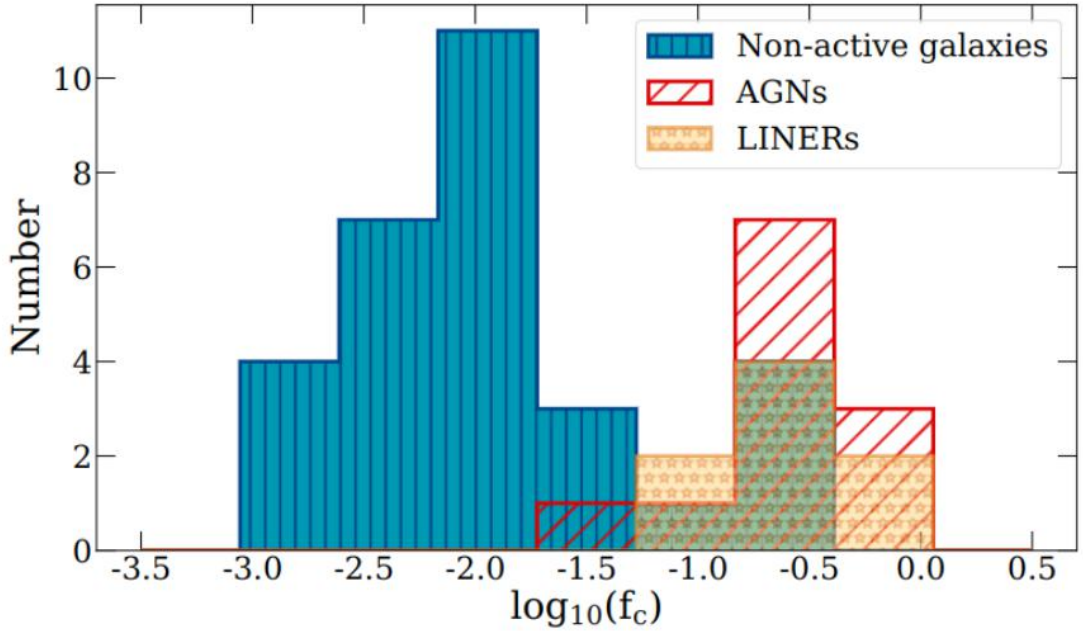

# weak IR echoes for optical TDEs

Optical surveys prefer to find TDEs in dust-poor environment

$$f_c = L_{\mathrm{dust,peak}} / L_{\mathrm{BB,peak}}$$

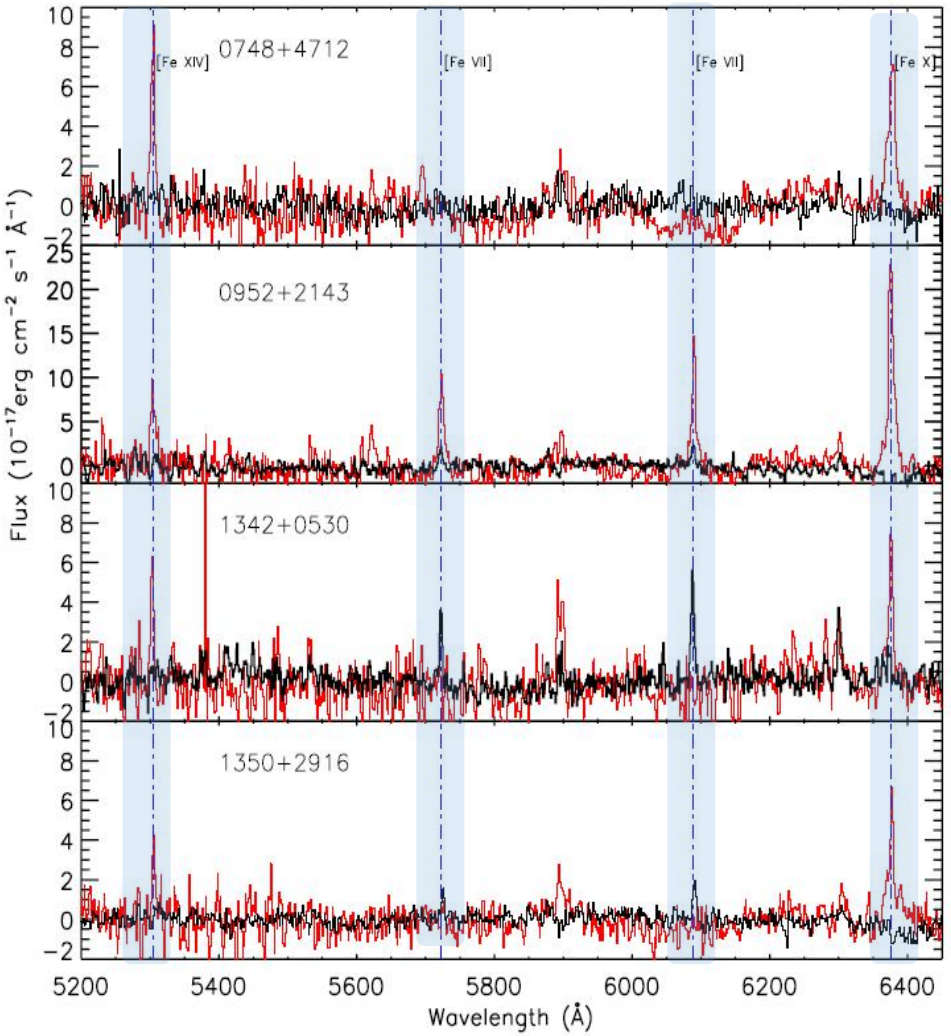
- IR echo of optical TDEs (Jiang+2016,2017,2019,2021b)



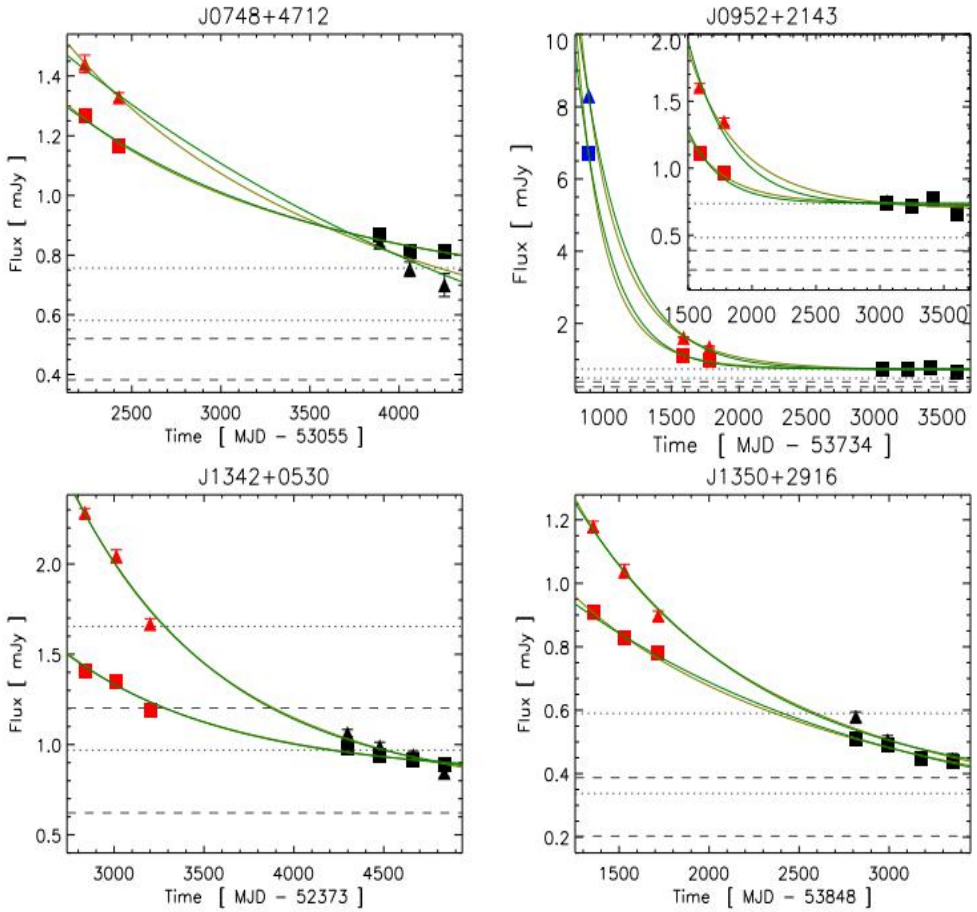

Huang,Jiang+2023

# Strong IR echoes in coronal-line selected TDEs




Wang+12, Yang+13, Hinkle+2024

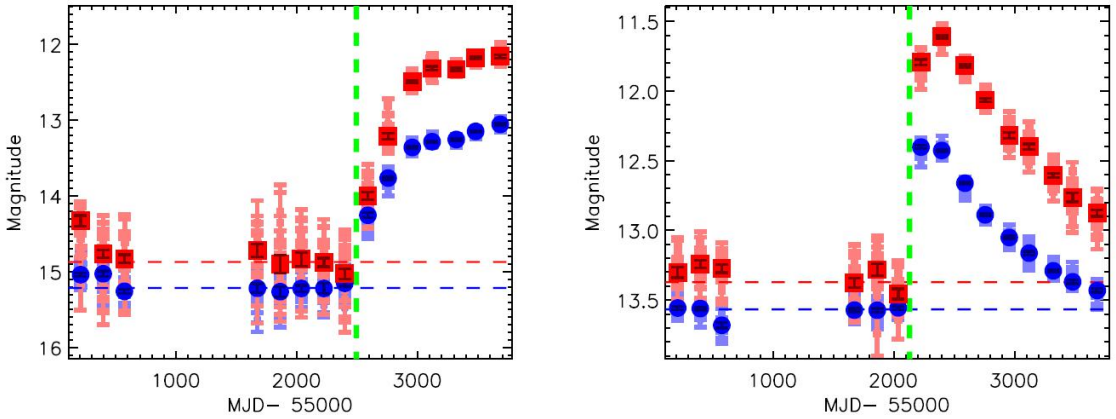
IR echoes could be a powerful tool to find TDEs in gas(dust)-rich environments!




Dou,Wang,Jiang+16

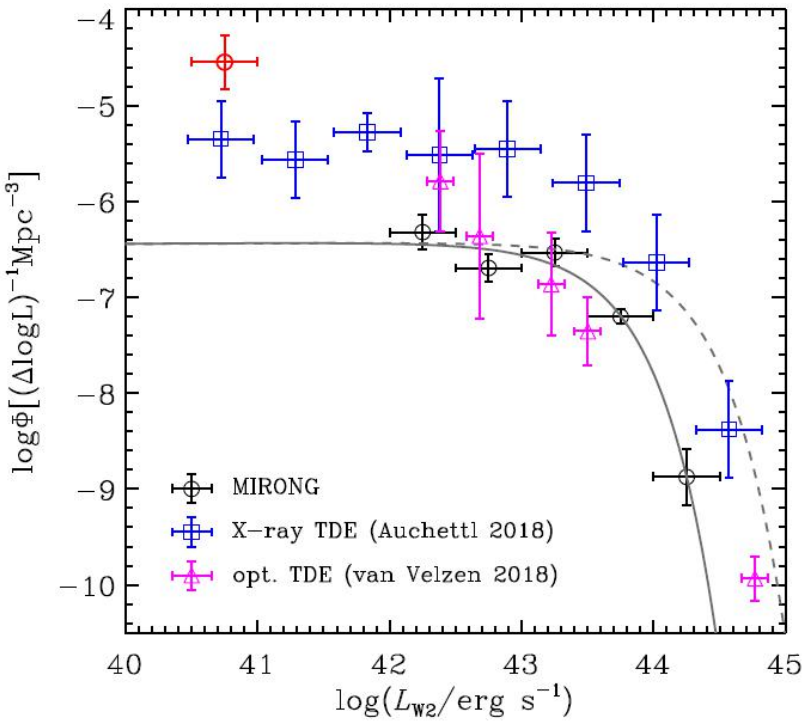
# Mid-Infrared Outbursts in Nearby Galaxies (MIRONG)

"MIRONG" (谜烽) means "puzzling flames" in Chinese, the first systematical search of IR TDEs (since 2016)




- at galactic center
- radio-quiet, half are not AGNs
- only ~10% noticed in optical
- MIR luminosity >> SNe

- 137 sources up to 2018 selected from SDSS spectroscopic galaxies
- 311 objects in our newest sample

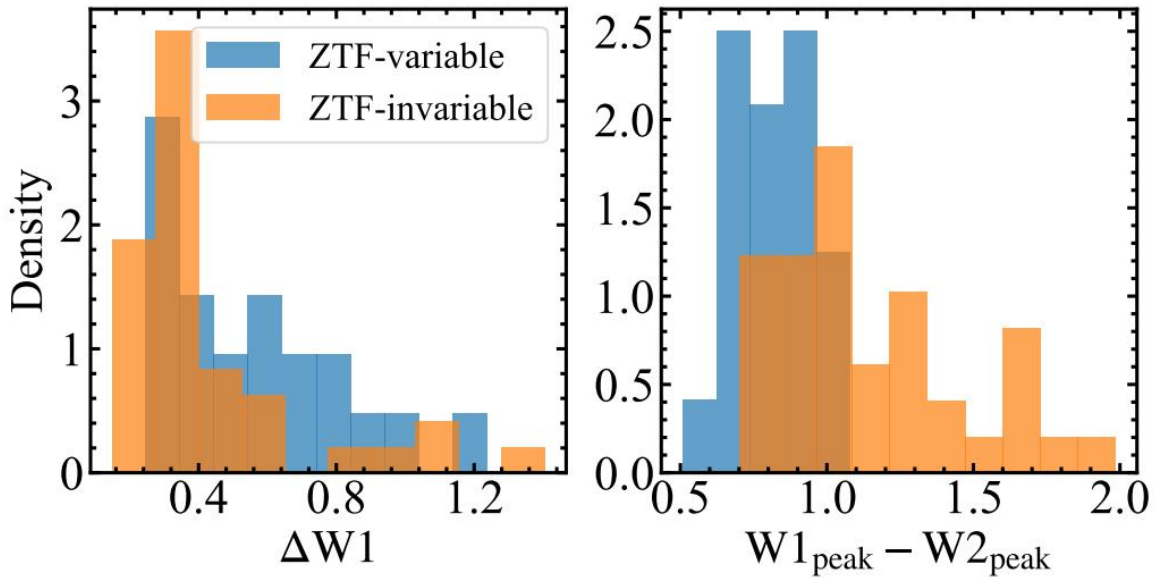


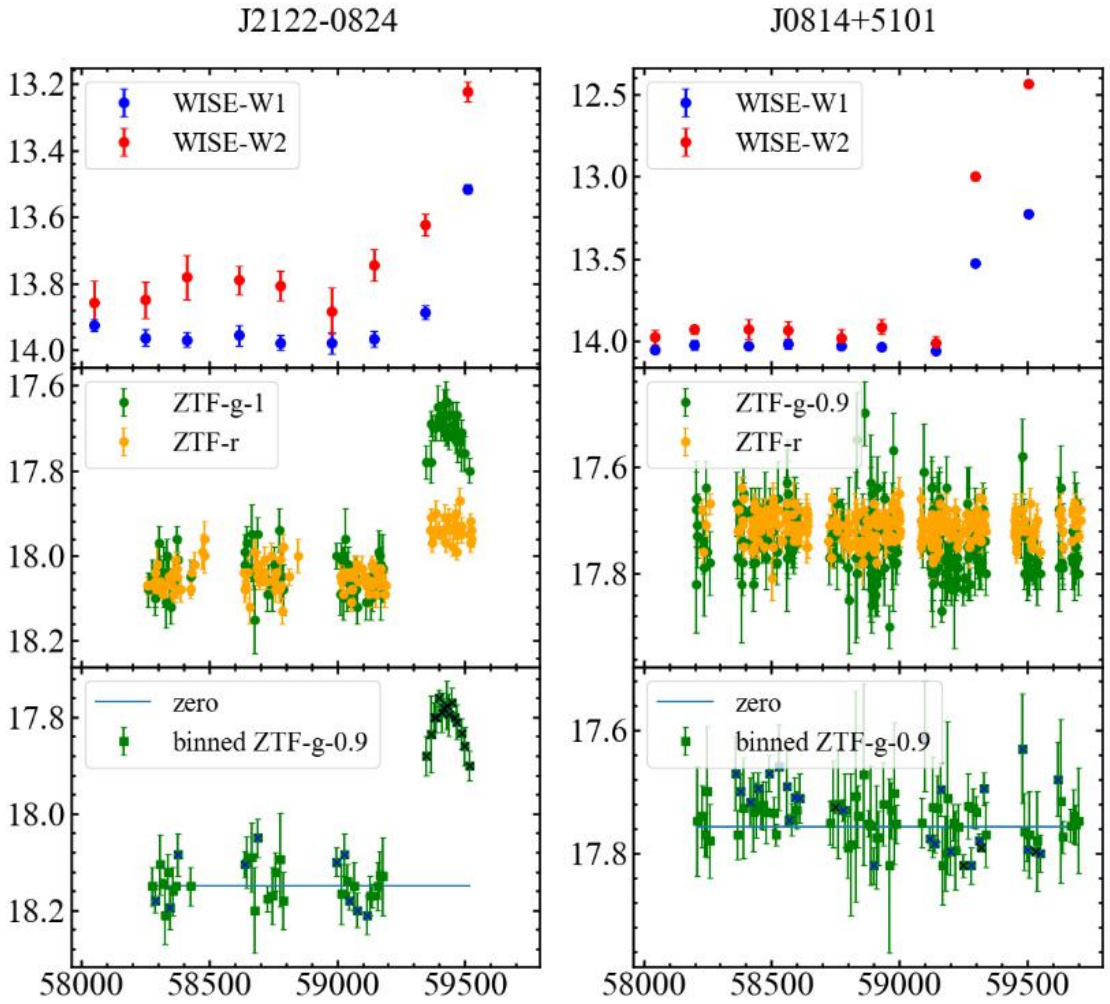

Jiang+2021a

a nonnegligible population!

# Optical counterpart of MIRONG

- The better cadence and depth of ZTF give the opportunity to catch the faint optical signals
- about half detected by ZTF, the undetected ones might be more obscured

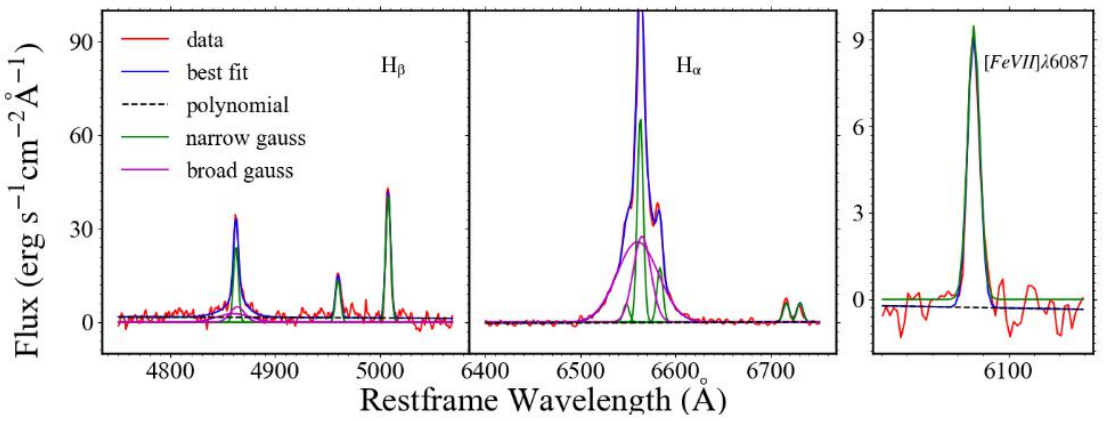



Wang et al in prep.

# Optical Spectroscopic Follow-up of MIRONG

- we have spectroscopically monitored 53 sources in our initial sample since 2017
- 22 show spectral change: 14 TDEs, 2 turn-on AGNs, 6 AGN flares
- On-going: 89 objects now
  21 TDEs, 8 turn-on AGNs…

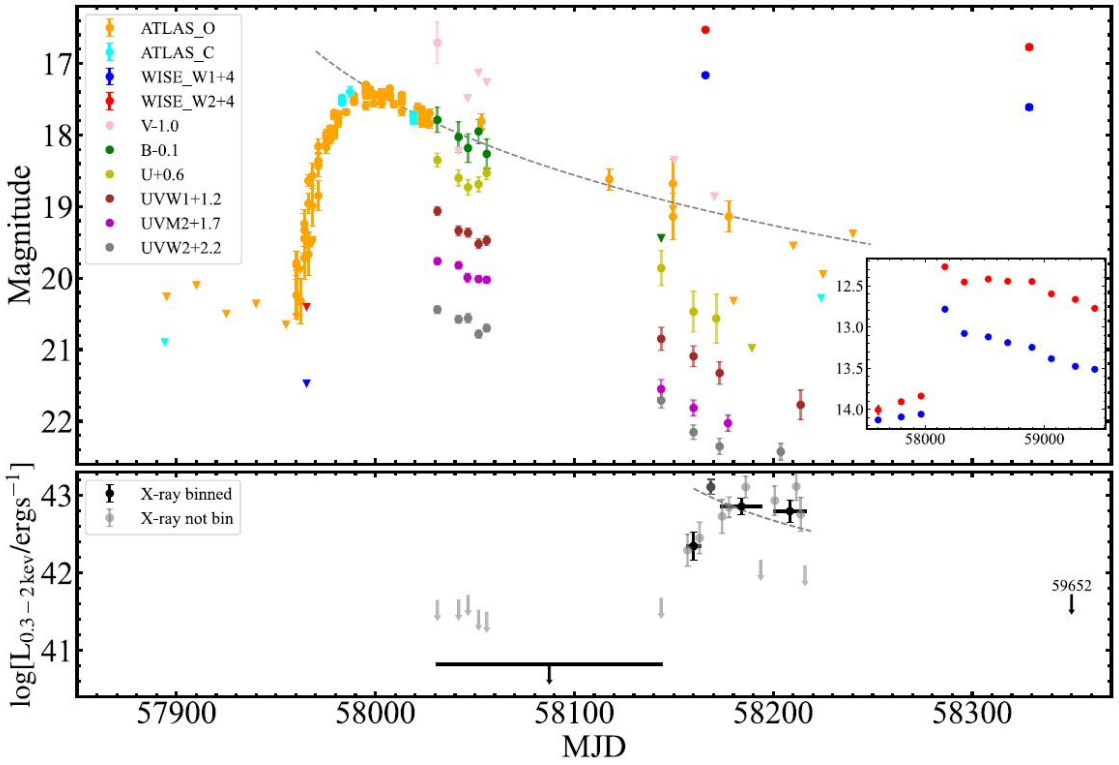



We classify with the evolution of characteristic emissions (broad Balmer, HeII, NIII and iron CLs)

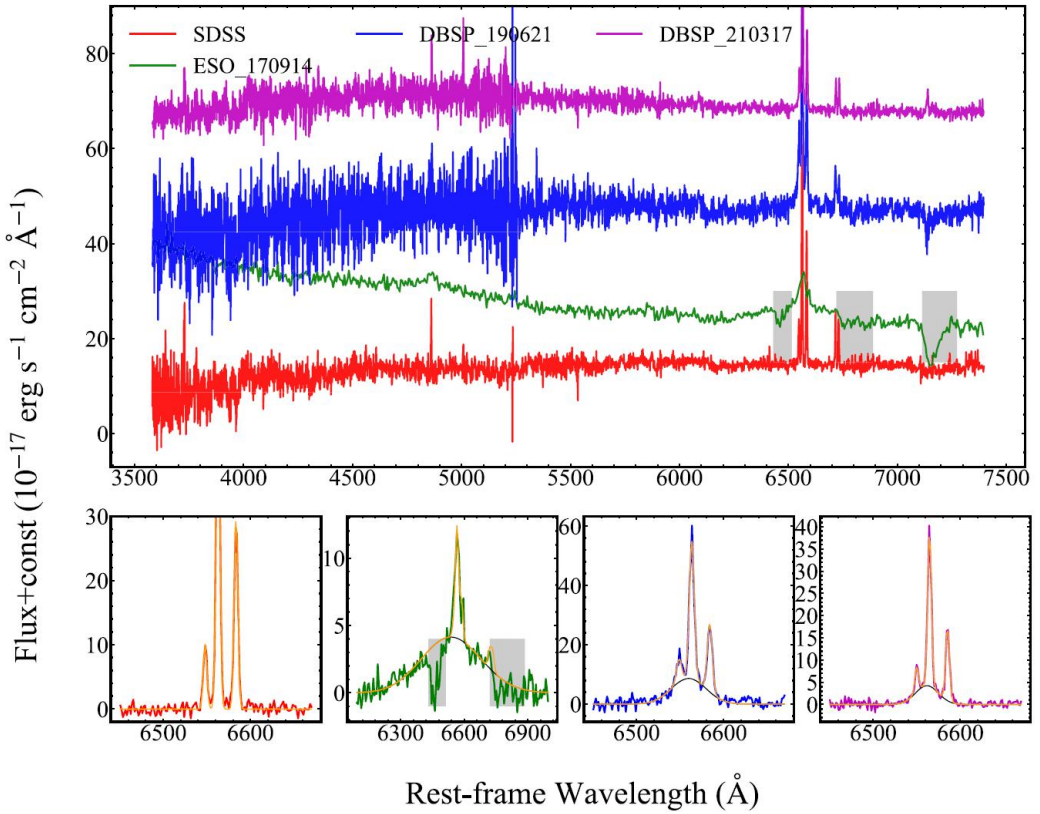
| Name | BPT | Time Coverage | $H_{\alpha,B}$ Behavior | Iron CLs | He II$\lambda$4686 | N III$\lambda$4640 | Interpretation |
|---|---|---|---|---|---|---|---|
| (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
| J0205+0004 | SF | 2017-2021 | Restored | × | × | × | TDE |
| J0859+0922 | SF | 2018-2021 | Declining | × | × | × | TDE |
| J1549+3327 | SF | 2017-2020 | Restored | √ | √ | × | TDE |
| J1620+2407 | SF | 2019-2021 | Declining | × | × | × | TDE |
| J1647+3843 | SF | 2018-2021 | Declining | × | × | × | TDE |
| J1043+2716 | Composite | 2017-2021 | Declining | √ | × | × | TDE |
| J1111+5923 | Composite | 2018-2020 | Declining | × | × | × | TDE |
| J1442+5558 | Composite | 2017-2021 | Maintain | √ | √ | √ | Turn-on |
| J1513+3111 | Composite | 2017-2021 | Declining | √ | √ | √ | TDE |
| J2203+1124 | Composite | 2017-2019 | Declining | √ | √ | × | TDE |
| J1315+0727 | Composite(b) | 2017-2017 | Rising | × | × | × | AGN Flare[3] |
| J1332+2036 | Composite(b) | 2017-2021 | Declining | × | × | × | AGN Flare |
| J1133+6701 | LINER(b) | 2018-2021 | Restored | × | × | × | AGN Flare |
| J1115+0544 | LINER | 2016-2021 | Restored | √ | × | × | TDE |
| J1632+4416 | LINER | 2017-2018 | Restored | × | × | × | TDE |
| J1003+0202 | Seyfert 2 | 2018-2021 | Maintain | × | × | × | Turn-on |
| J1238+0815 | Seyfert 2 | 2017-2017 | Declining | × | × | × | AGN Flare |
| J1657+2345 | Seyfert 2 | 2017-2021 | Declining | √ | √ | × | TDE |
| J0120-0829 | Seyfert 1(b) | 2017-2018 | Restored[2] | × | × | × | AGN Flare |
| J1105+5941 | Seyfert 1(b) | 2017-2021 | Declining | √ | √ | × | TDE |
| J1402+3922 | Seyfert 1(b) | 2017-2021 | Restored[1] | √ | √ | × | TDE |
| J1537+5814 | Seyfert 1(b) | 2017-2021 | Restored[1] | × | × | × | AGN Flare |

Wang, Jiang+2022a

# A robust opt./X-ray/IR bright TDE in a SF galaxy (ATLAS17jrp)



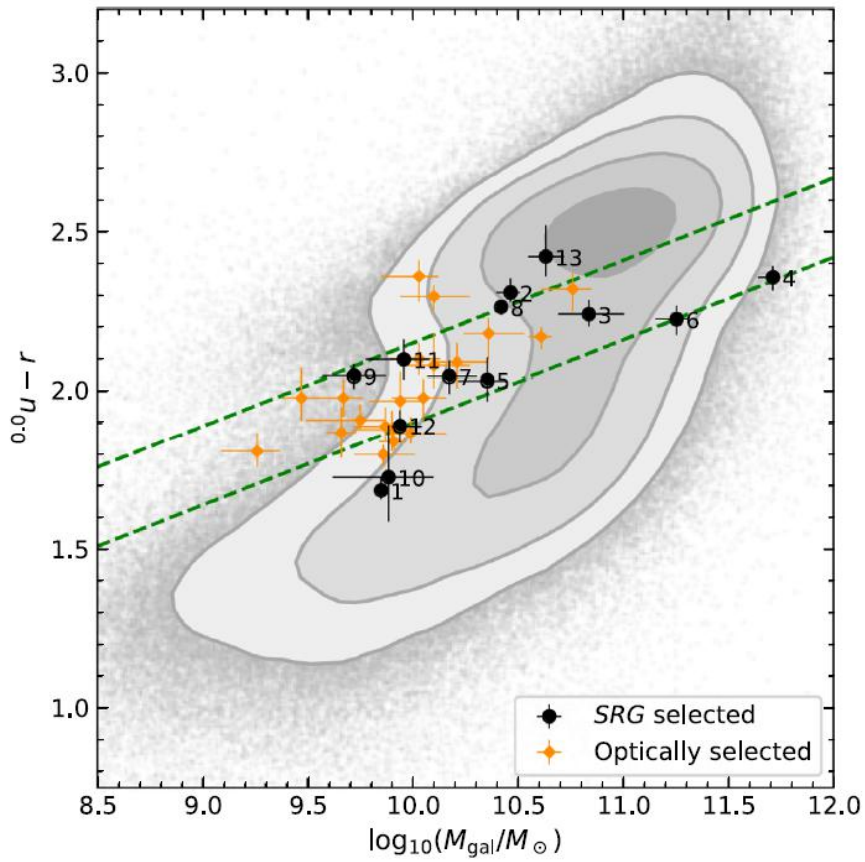

- fast rise and powerlaw decline
- blue and constant color
- delayed soft X-ray
- broad Ha emission (~15,000km/s)

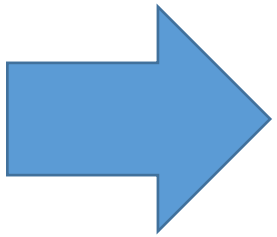


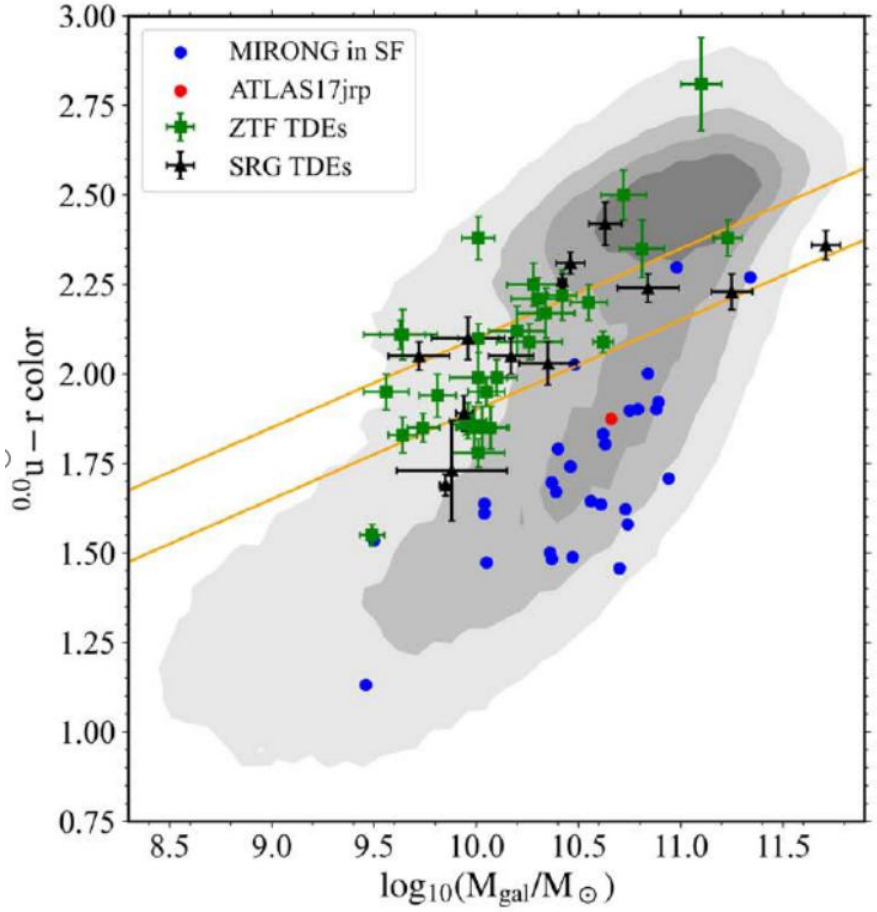

its high dust-covering factor (~0.2) implies that dust extinction could play an important role in the absence of optical TDEs in SF galaxies

Wang, Jiang+2022b

# Dusty TDEs might account for the missing in SF galaxies



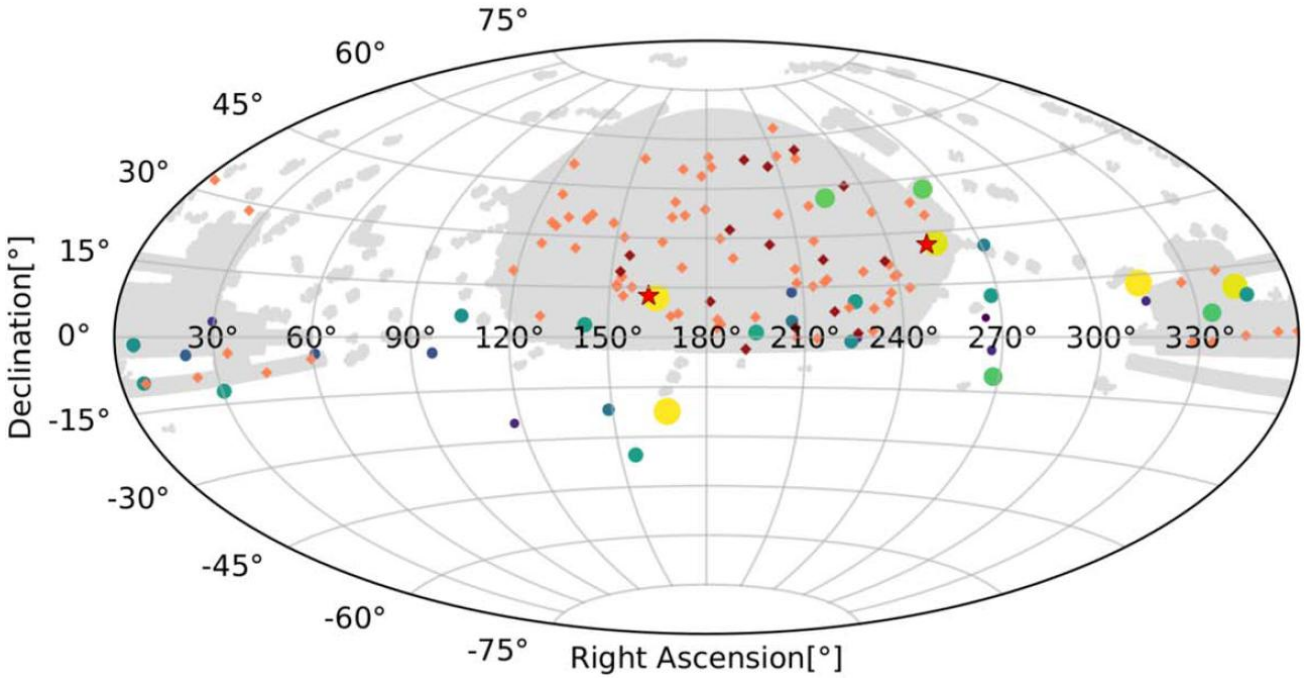


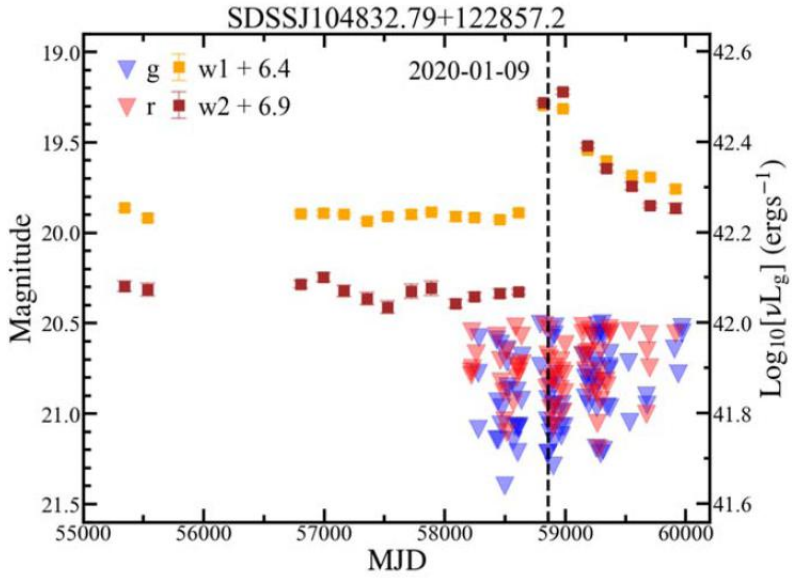

Sazonov+2021

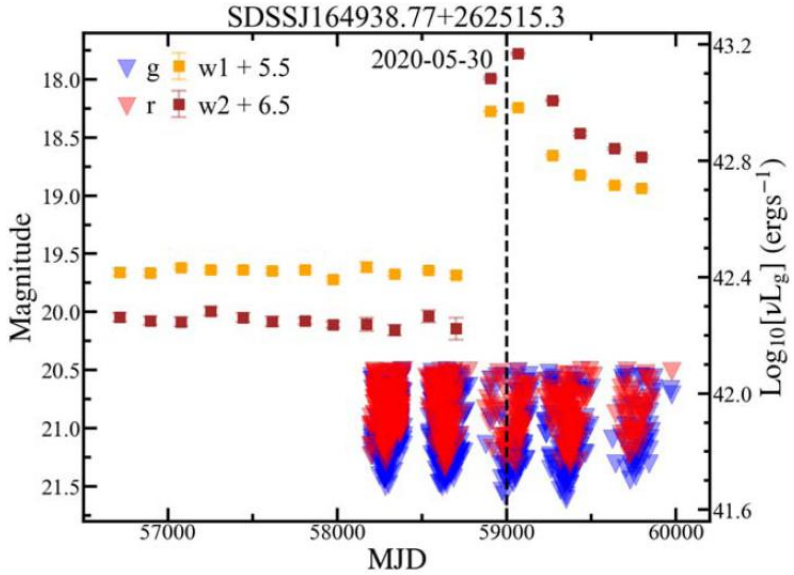
Wang, Jiang+2022b

# Two candidate obscured TDEs coincident with high-energy neutrinos

- Three known neutrino-concident TDEs (or candidates) all have strong IR echoes
- We find two more coincidences in the MIRONG sample (chance probability ~ 0.1%)
- No optical counterparts, might be obscured TDEs



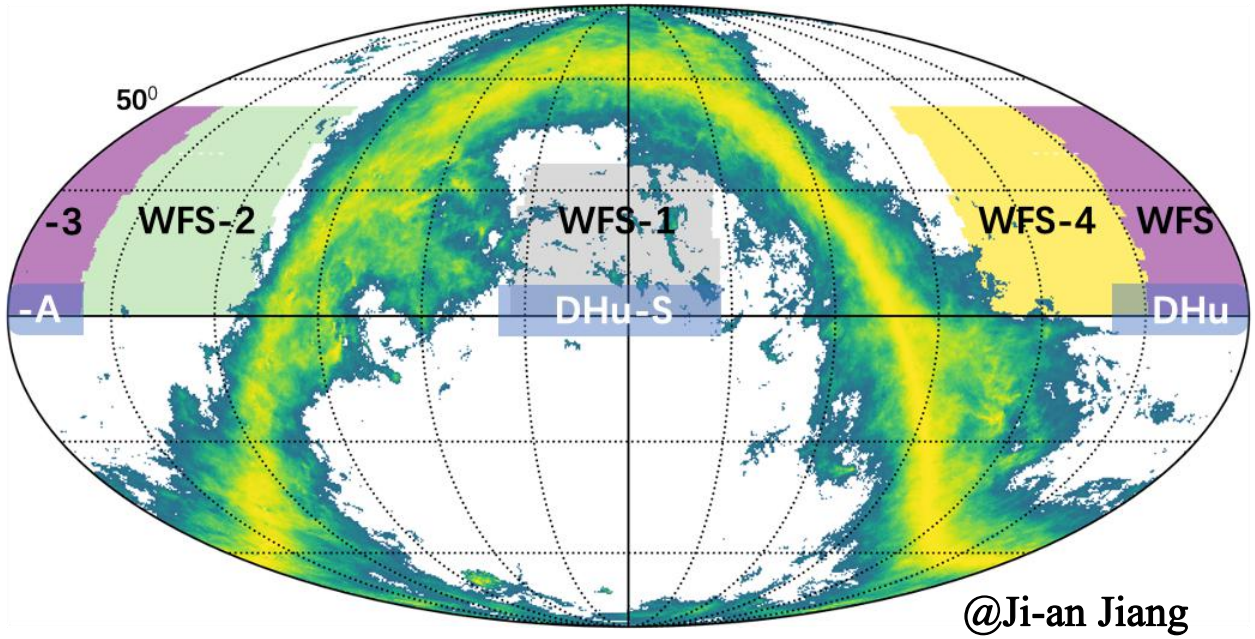




Jiang+2023

# Wide-Field Survey Telescope (WFST) — “Mozi”(墨子)

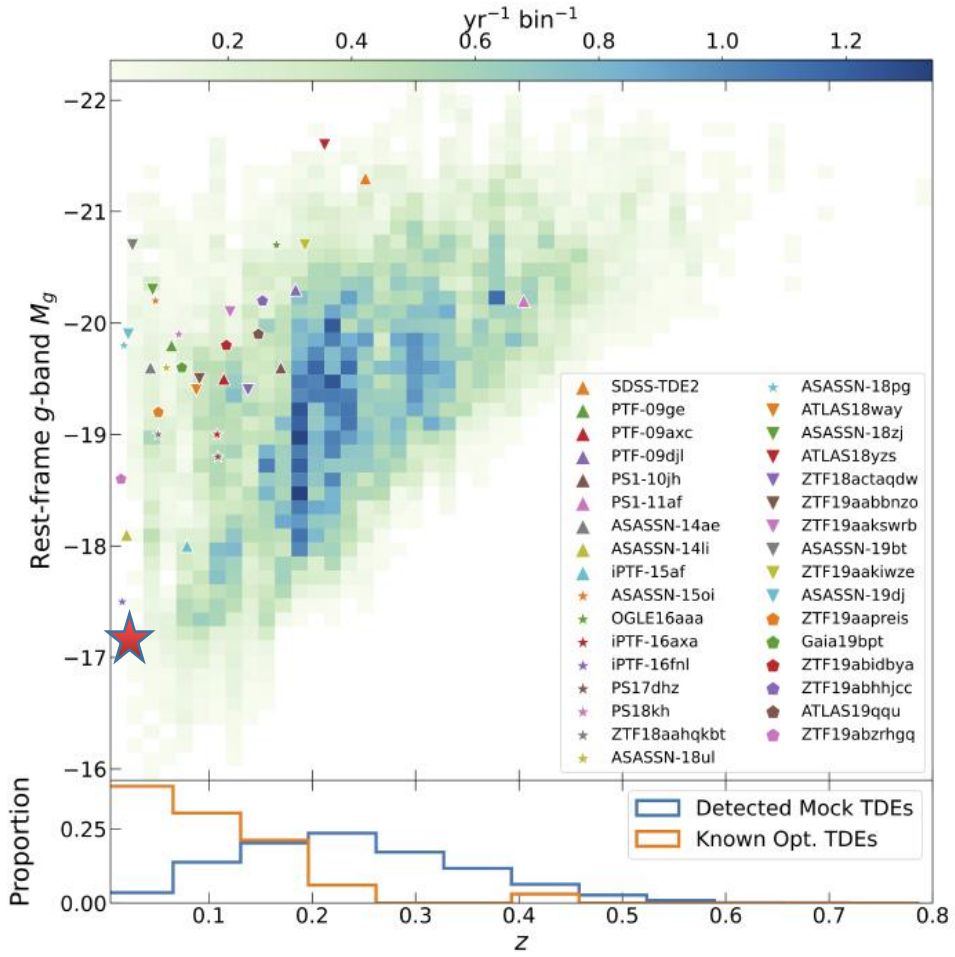
- FoV: ~6 deg$^2$, 9*9k*9k CCD
- Filter: *ugriz (w)*
- depth: g~22 (5sigma, 30s)
- Site: Lenghu（complements to LSST）

- Science:：High-energy transients (SN, TDE...)
- Wide-field Survey（WFS）：30s, (semi-)weekly, 8000deg$^2$
- Deep, high-cadence survey（DHu）：90s, daily, 720deg$^2$

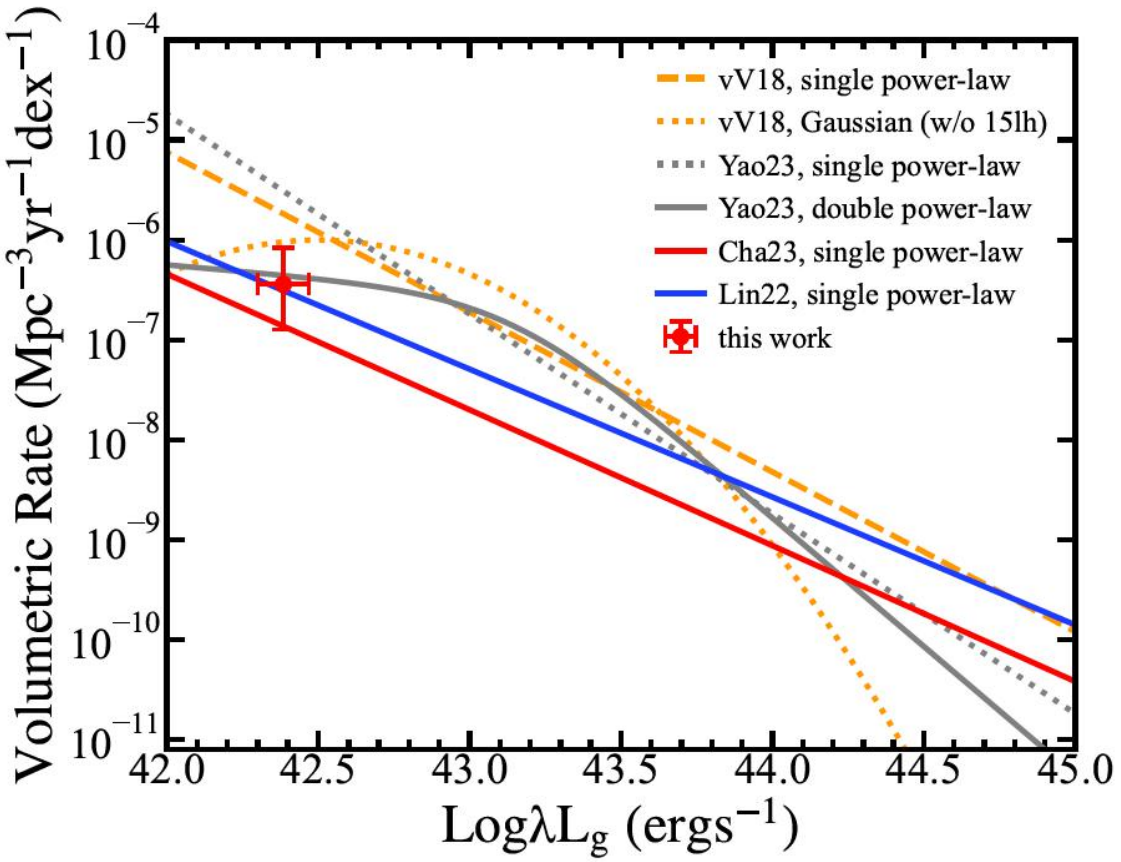



# The capability of WFST: towards a more complete sample

- the low end of the luminosity funciton can be constrained much better
- calling for numerous spectroscopic resources to identify, especially for faint sources



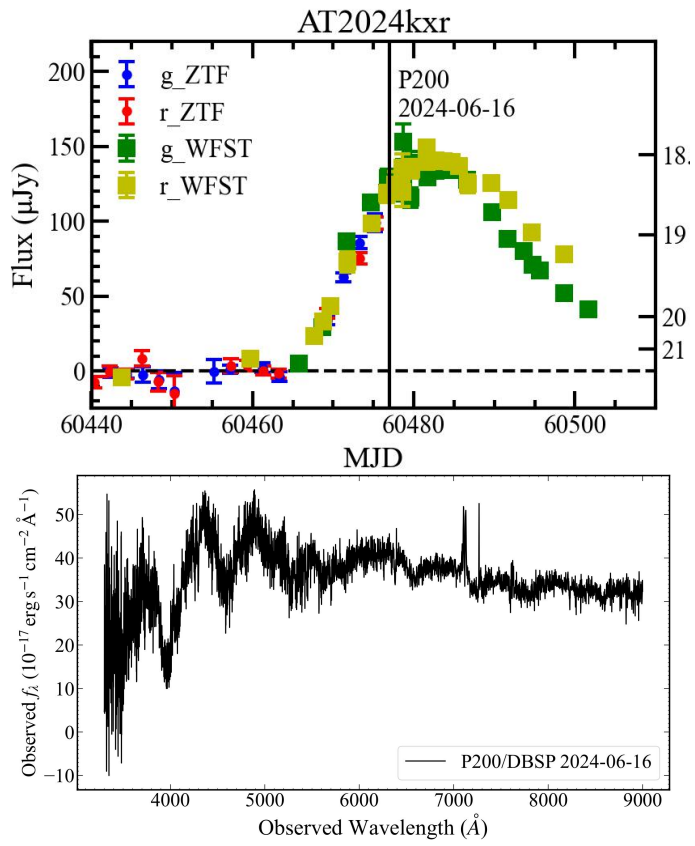

Lin,Jiang,Kong 2022



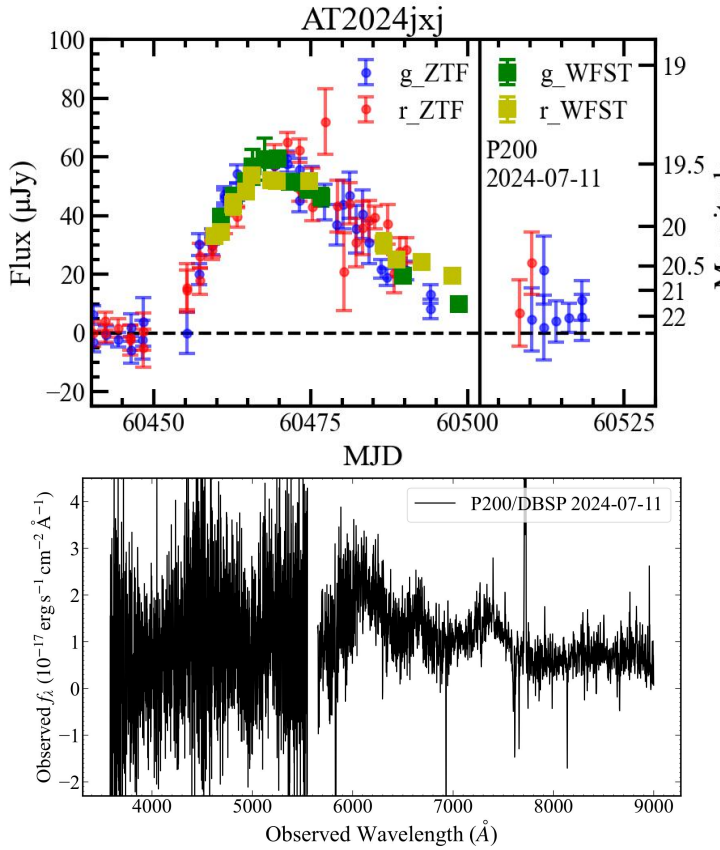

Zhu, Jiang, Wang+23

# TDE search in WFST Pilot Survey (2024.3-2024.7)

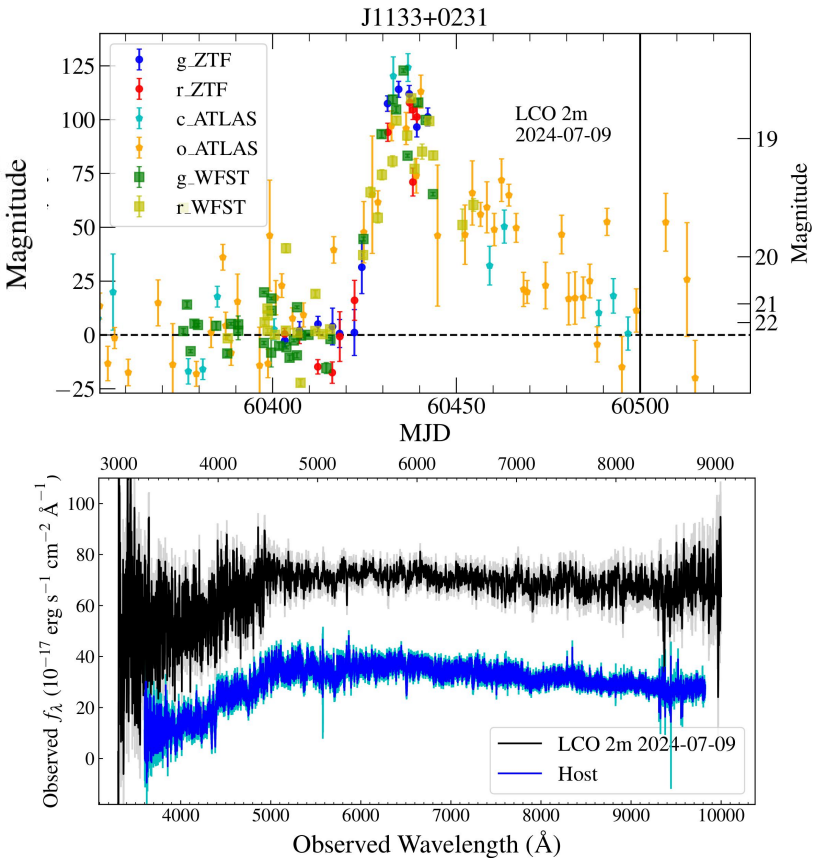
- TDE Selection：blue nuclear flares (not AGNs). Need spectra to exclude supernova contamination
- ~ 20 candidates：most without timely spectroscopic observations due to limited resources




TAP/P200: a SN at z=0.08

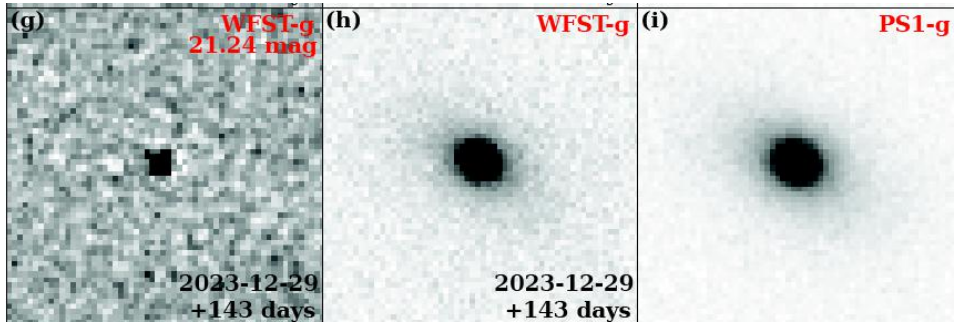


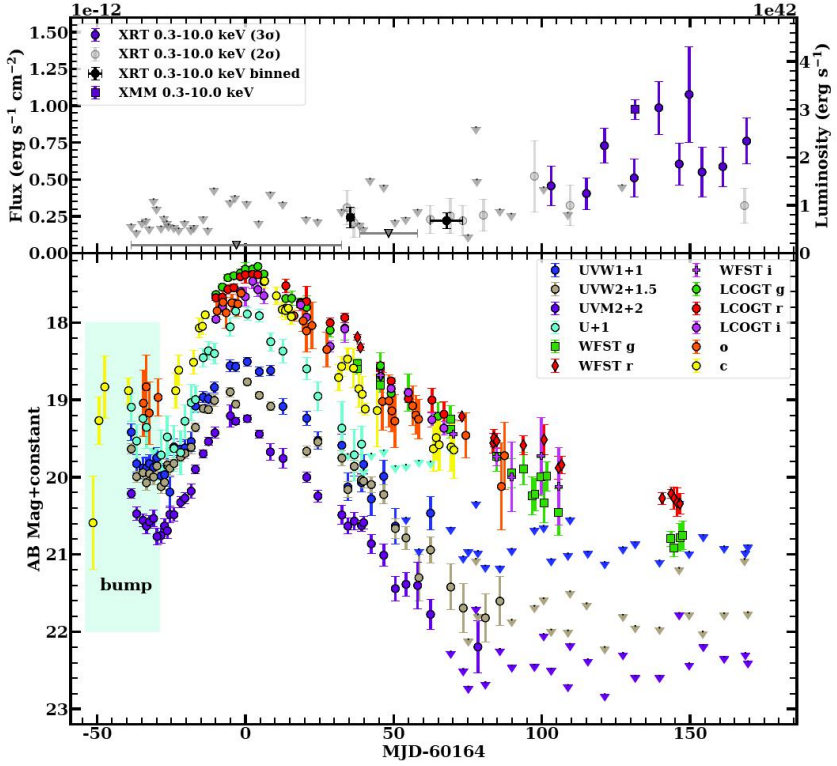

ZTF/P200: a SLSN?



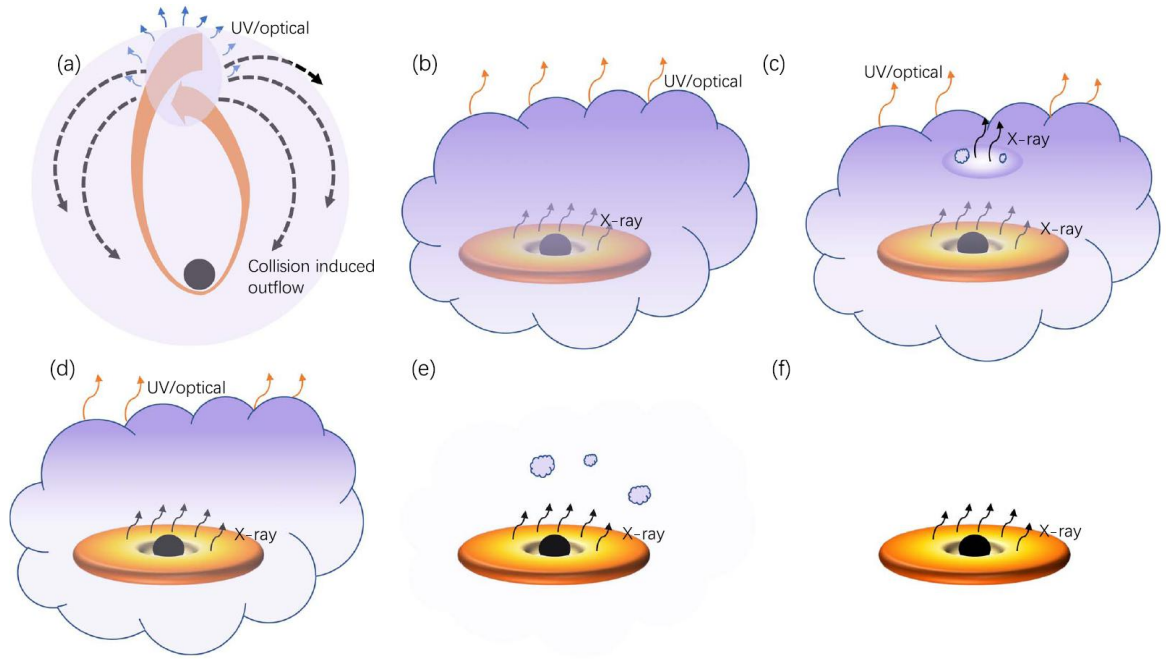

LCO 2m, too low S/N

# High-cadence monitoring of a unique TDE AT2023lli



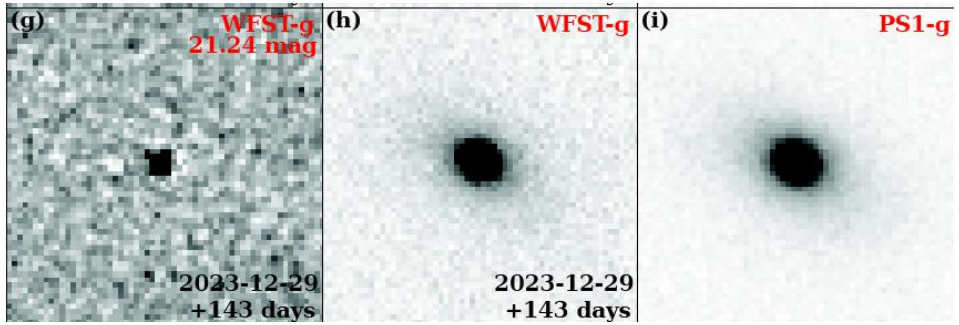

- New phenomenon：the most notable early bump before optical peak and episodic X-ray emission post peak, giving strong evidence for the two-phase model
- WFST：providing the key late photometry and revealing the steepest decline rate with aid of its high sensitivity.

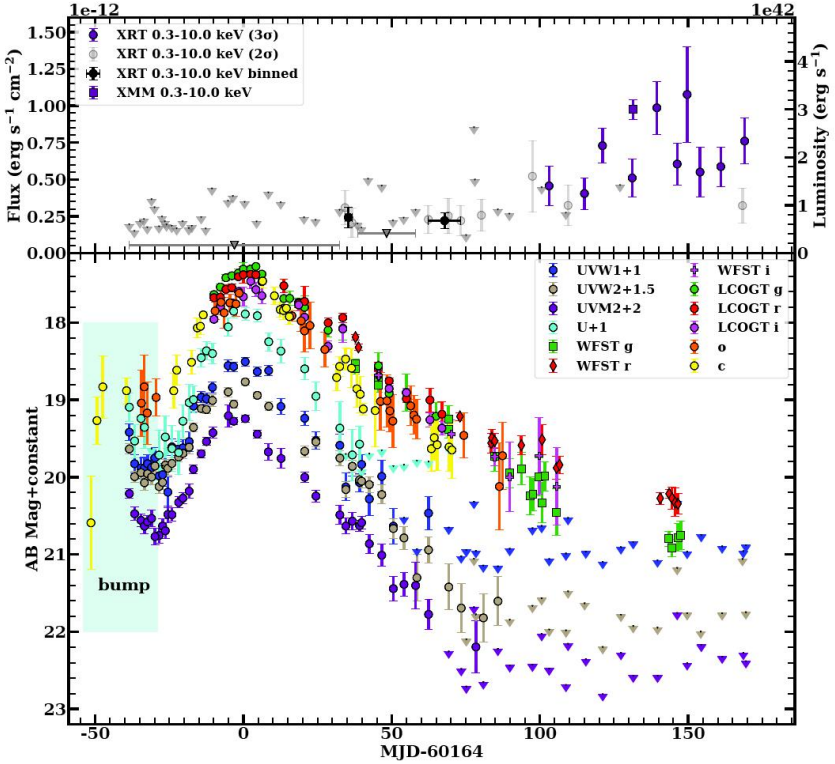


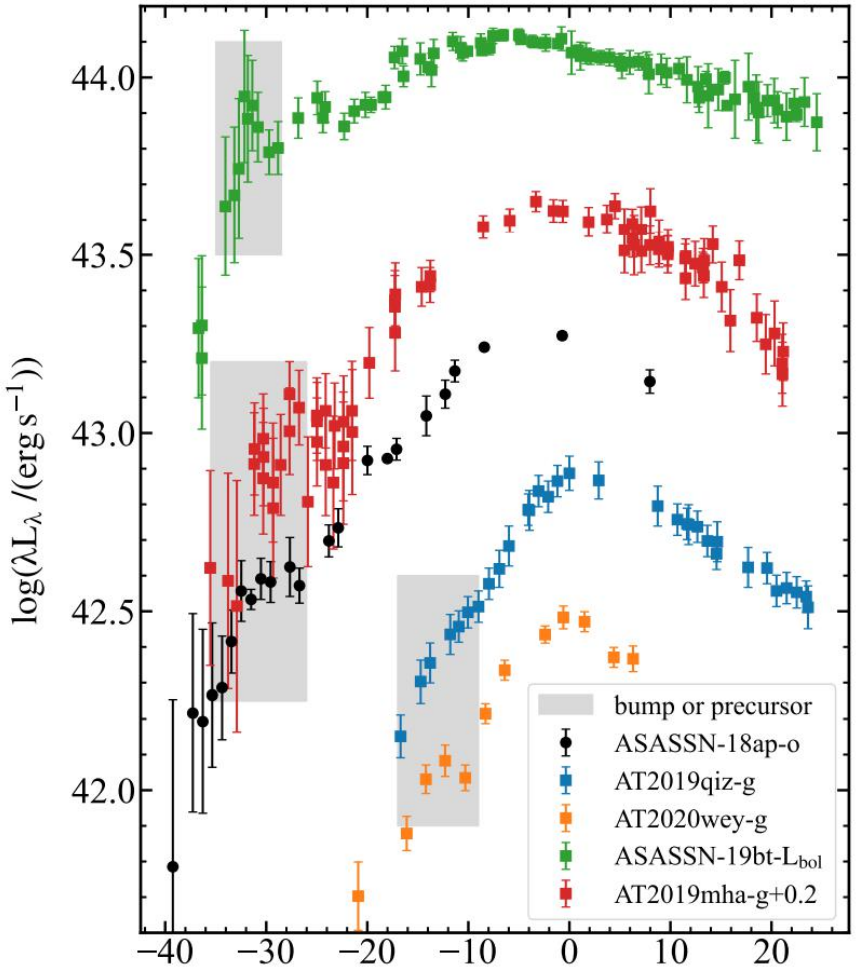

Huang,Jiang+2024,ApJL,964,L22

# Early bumps of TDEs

- early bump ( precursor) feature is likely very common
- lacking color information, physics unclear

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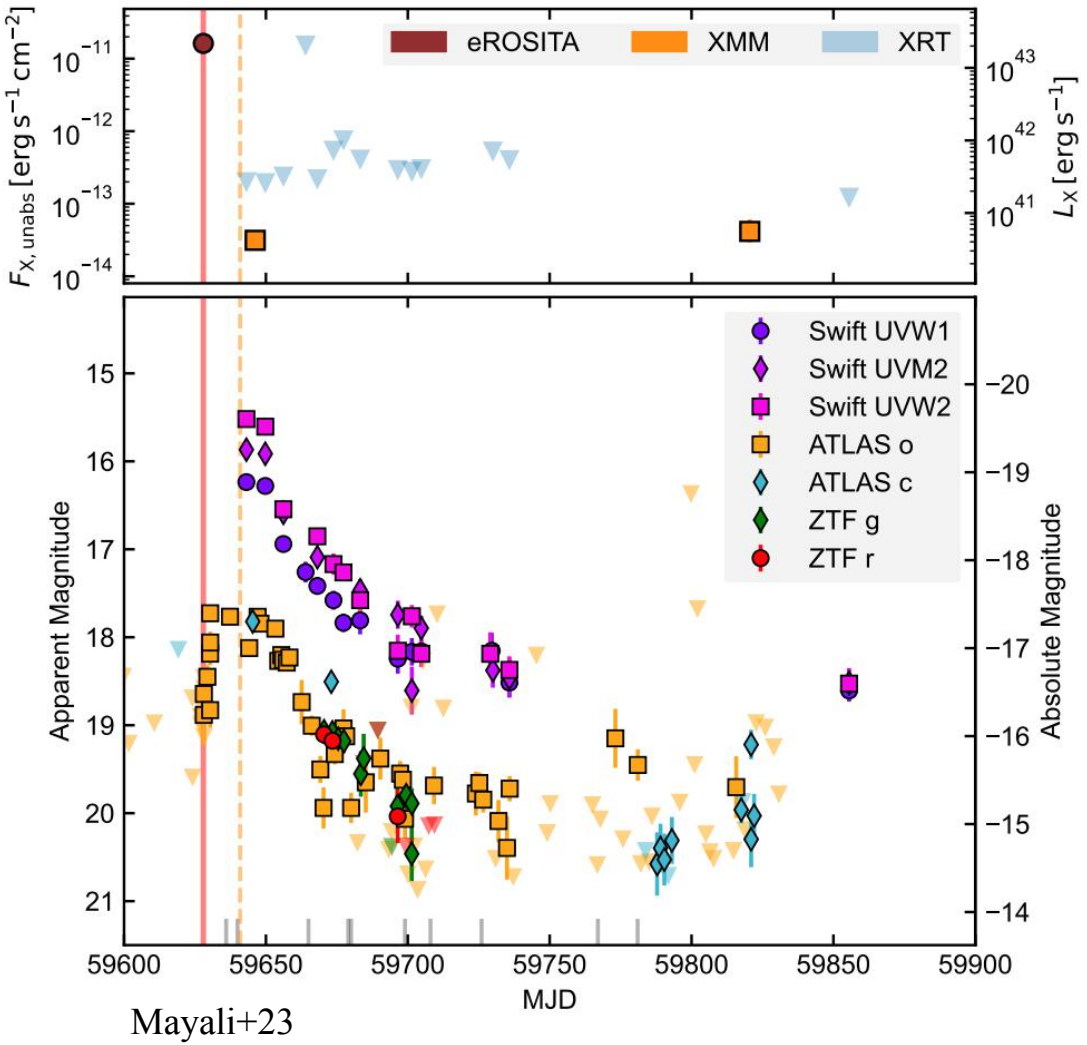
# Still rare early X-ray observation of opt. TDEs

triggering is too late!

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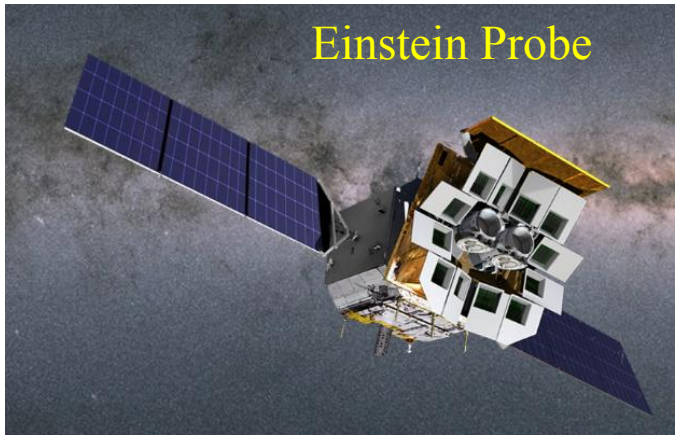
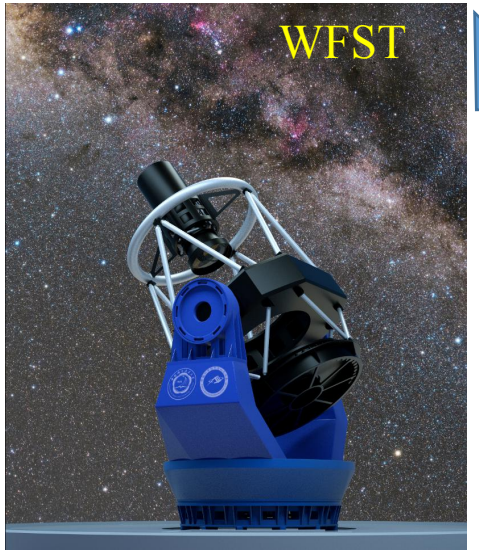
We need high-cadence surveys!




For nearby TDEs, we may obtain long-term high-cadence optical and X-ray light curves simultaneously

# Summary

- Optical surveys have dominated the discovery of TDEs, leading not only to an increasing number and diversity of TDEs, but also to many unresolved open questions.
- We have conducted a systematic search for TDEs using the novel dust IR echoes (MIRONG project), which have revealed a large sample of dusty TDE candidates missed by optical surveys.
- The WFST will be a promising facility for TDE science (e.g., complete sample, early rising light curves), and we have done some  pilot studies.

**Thank you!**

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