
TVS
ZTF
THE UNIVERSITY of NORTH CAROLINA at CHAPEL HILL
Jetted Tidal Disruption Events
= I am talking about X-rays
= I am talking about optical
= I am talking about radio
Igor Andreoni
Playa del Carmen
December 6, 2024
Image credit: DESY

# Relativistic (jetted) TDEs

DESY

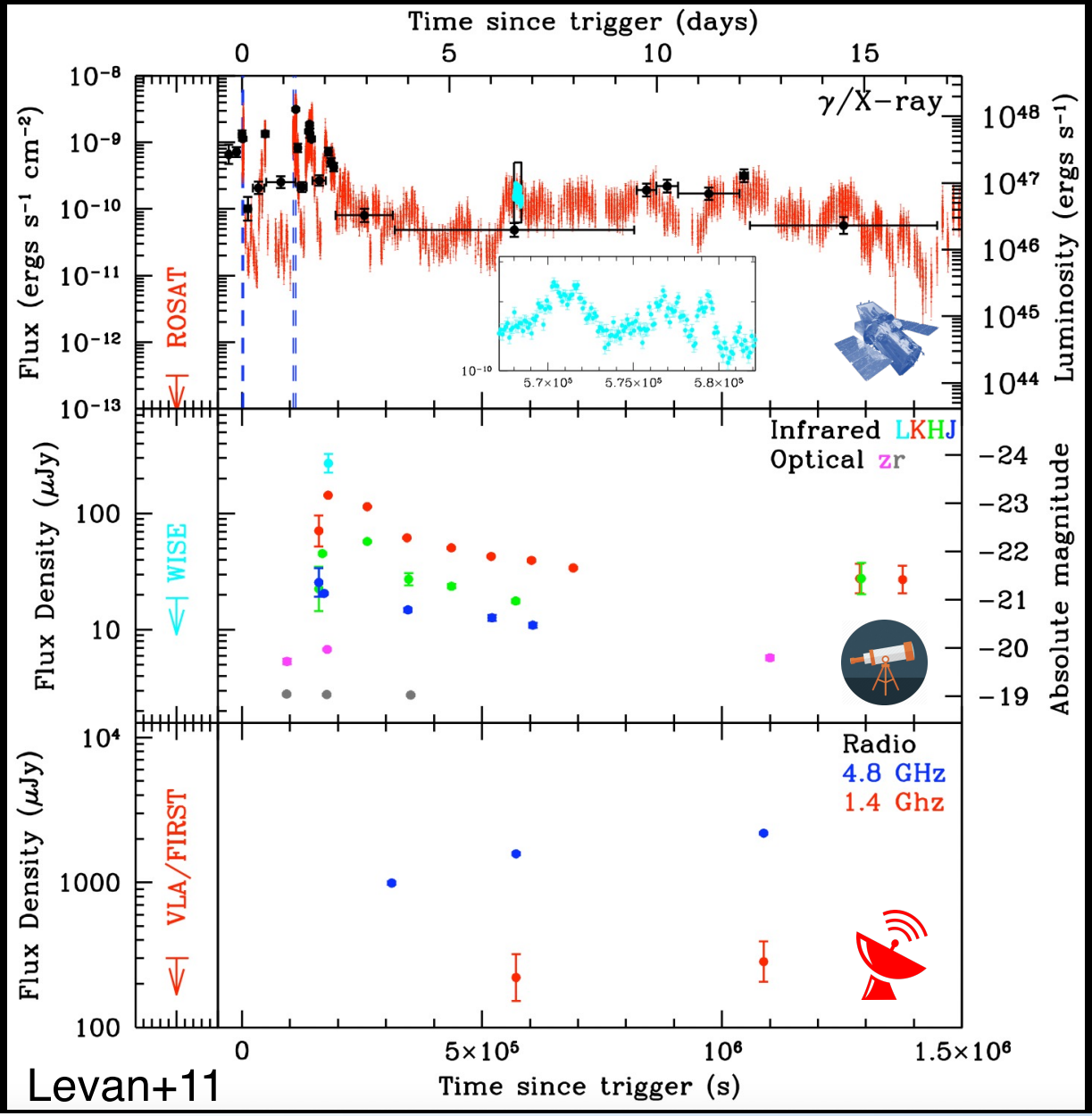
Best studied so far:
Swift J1644+57

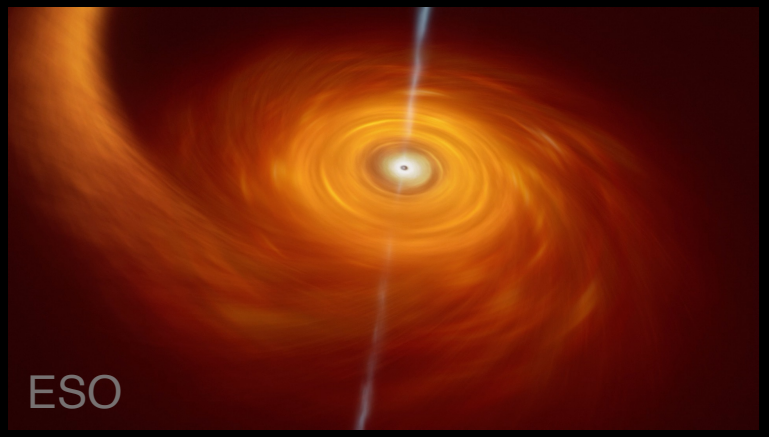
2–3 more candidates

See also: Bloom+11, Burrows+11, Zauderer+11, Cenko+12, Pasham+15, Brown+15, Mattila+18 Somalwar+23, …

Was EP240408a a jetted TDE? See **O'Connor**, Pasham, IA et al. (2024)

# Relativistic (jetted) TDEs

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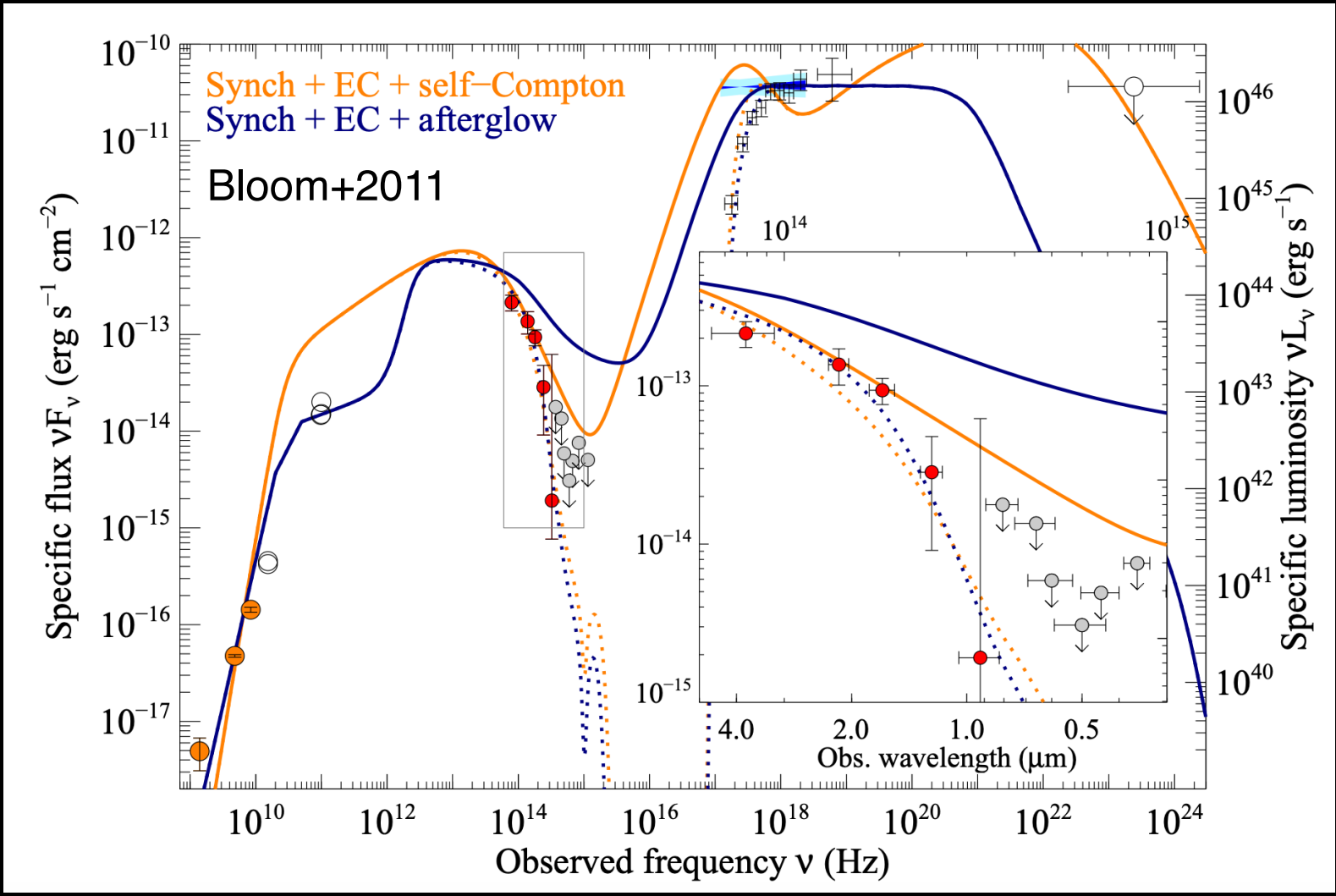
# Swift J1644+57

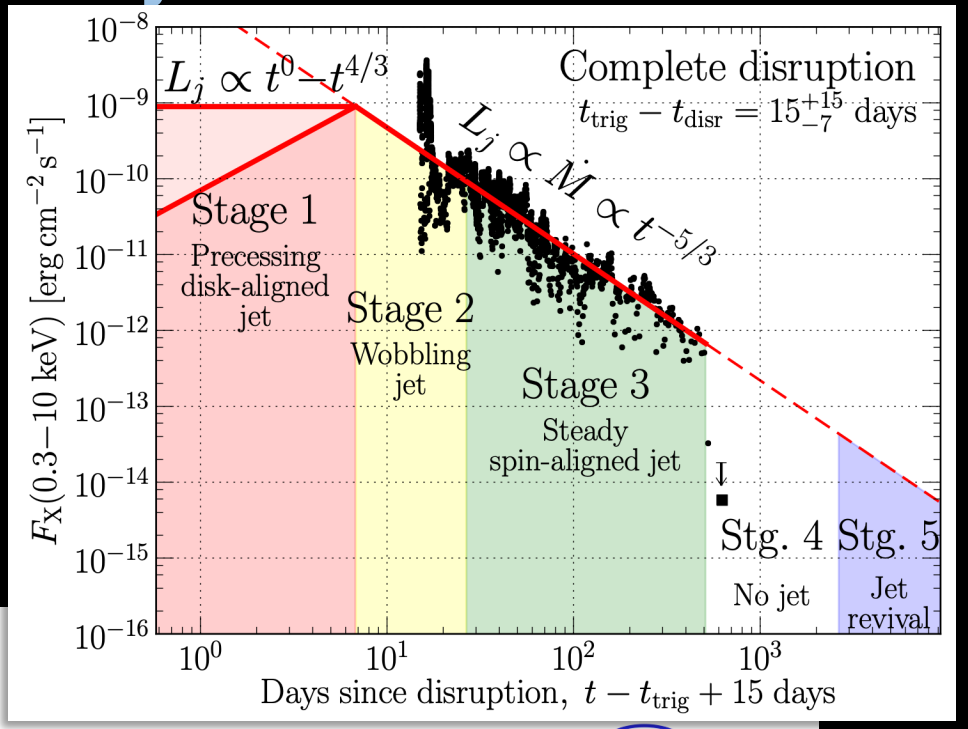



Low-density, magnetically-dominated jet (Burrows+2011)

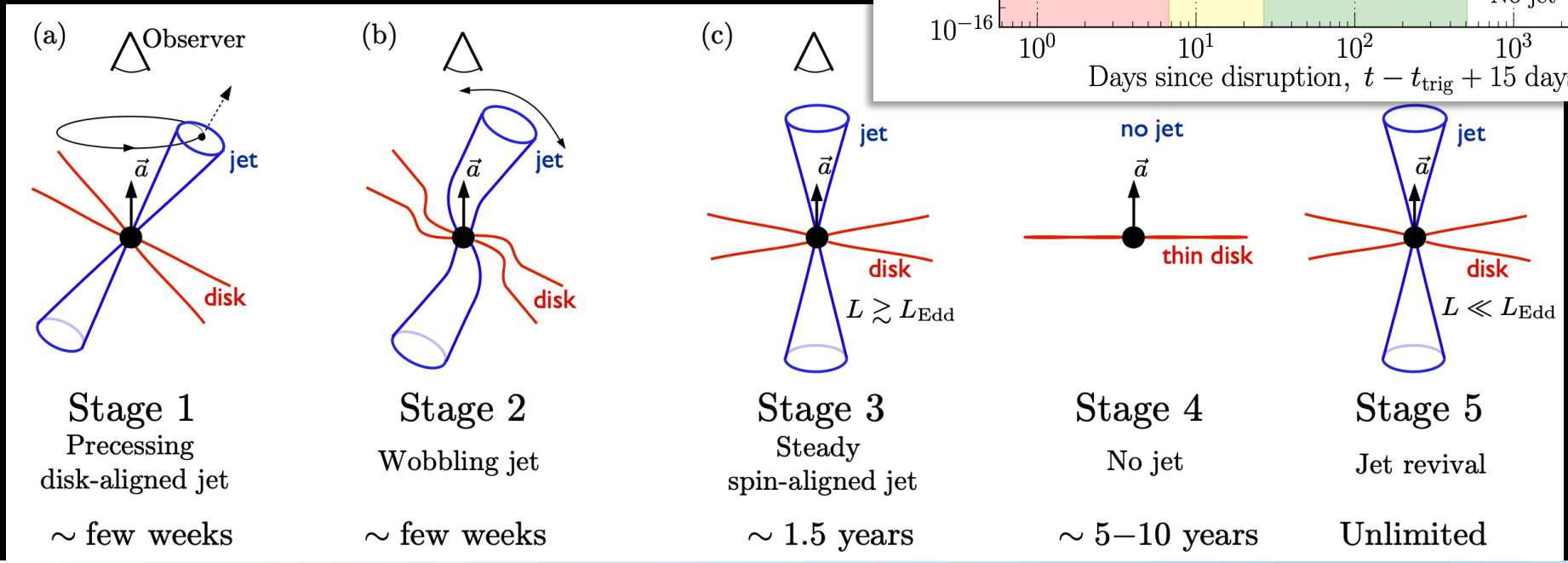
~21deg off-axis jet? Beniamini+2023

Gone MAD? Tchekhovskoy+2014

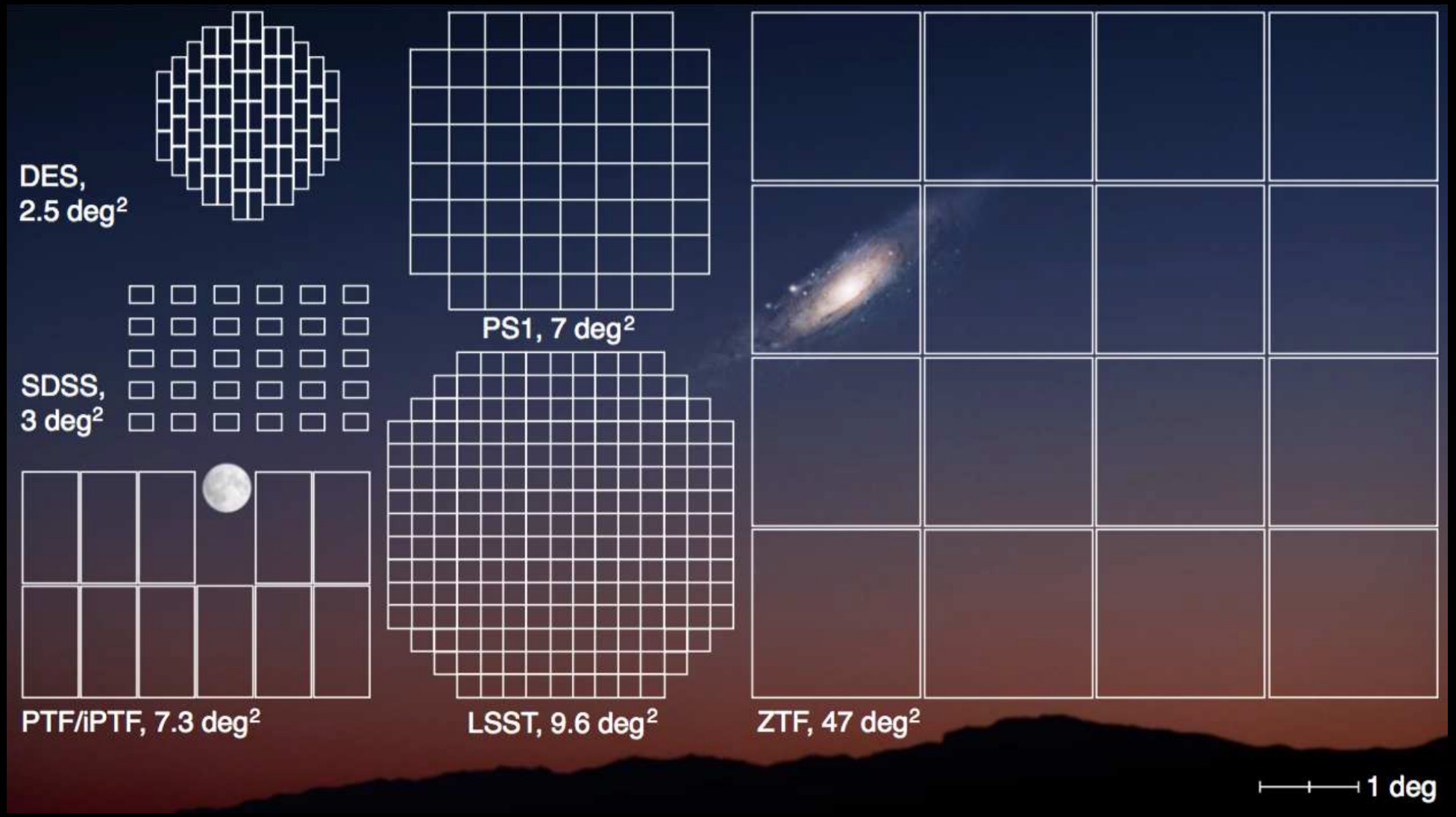
# Jet from a magnetically arrested disk




Tchekhovskoy+2014



# Zwicky Transient Facility

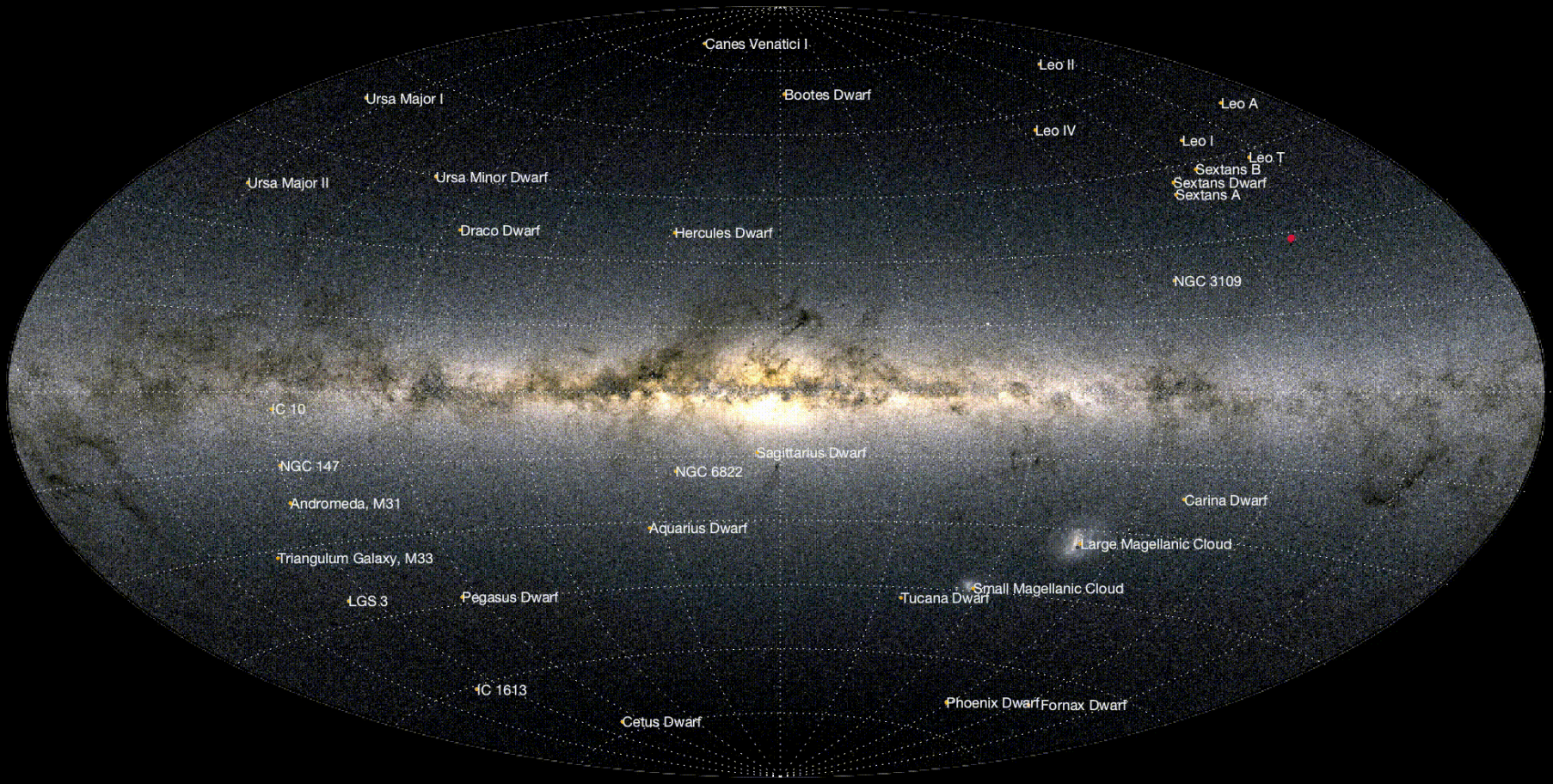



Credit: Laher et al.

# Un-triggered ZTF transient searches

Supernovae Classified: **1**

Date: 21-Feb-2017

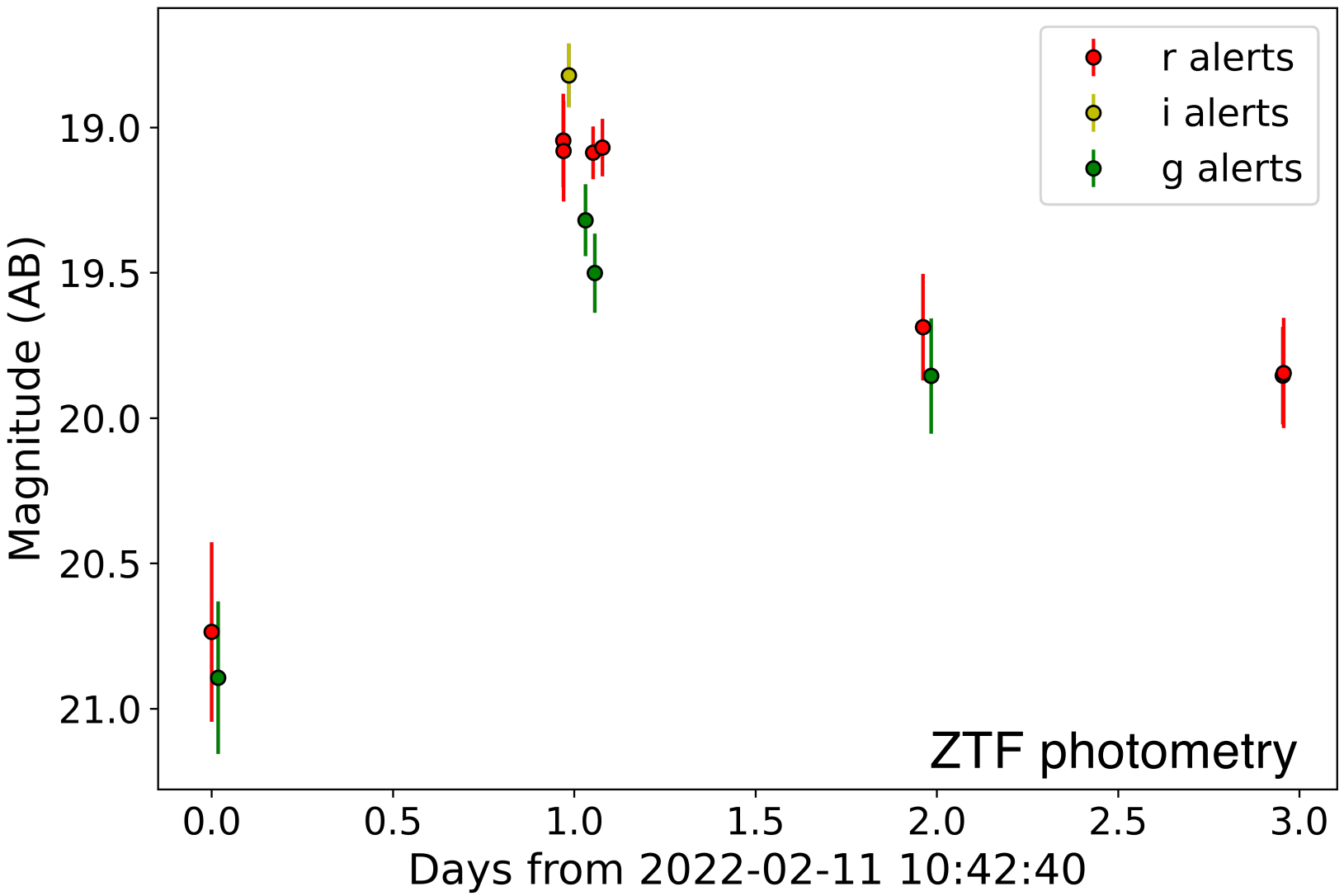



Underlying image credit: ESA/Gaia/DPAC

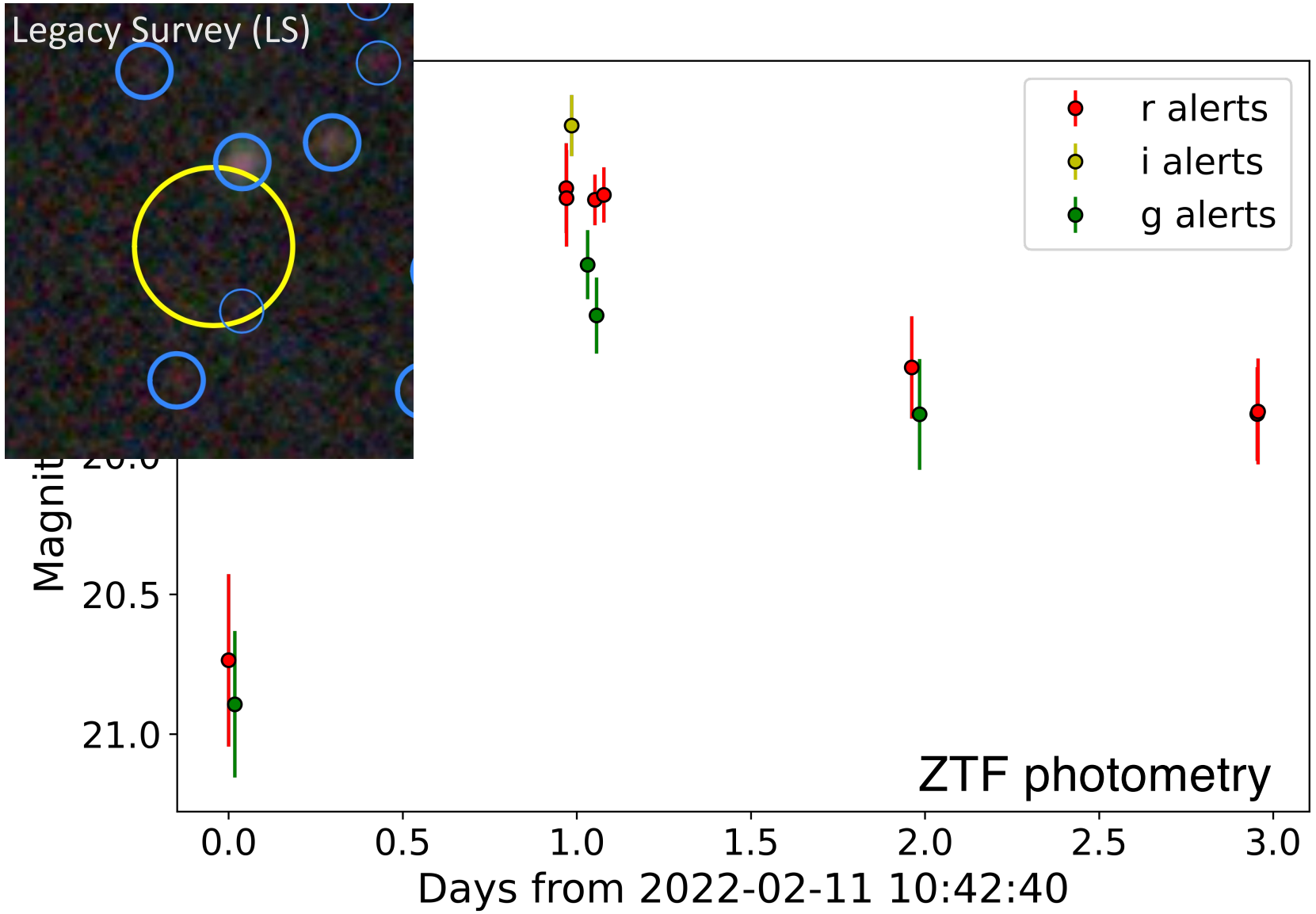
Caltech

DR 22: 58 million images, 888 billion source detections

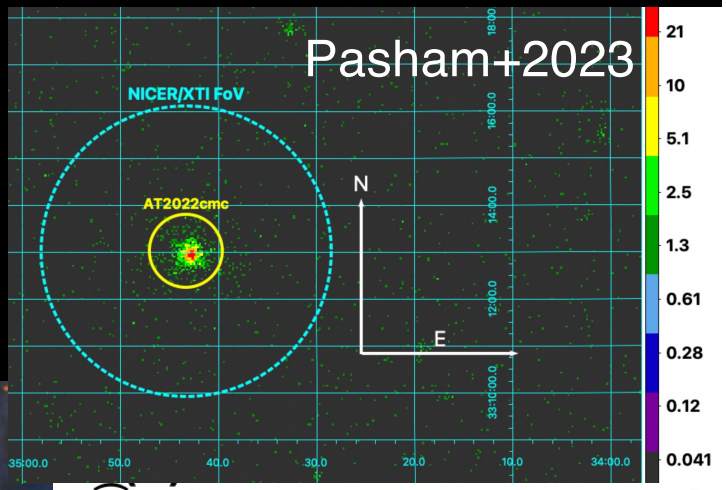
# AT2022cmc: ZTF Discovery

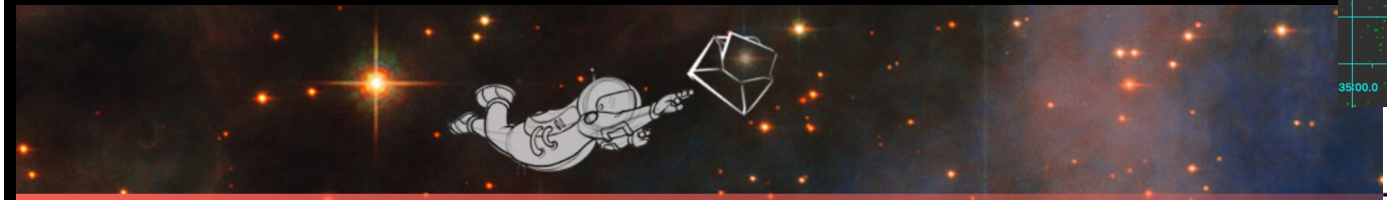


# AT2022cmc: ZTF Discovery



# AT2022cmc: multi-band observations



## AstroNote 2022-38

AstroNotes | Stats

2022-02-14 18:46:09 Type: Object/s-Discovery/Classification Bibcode: 2022TNSAN..38....1A

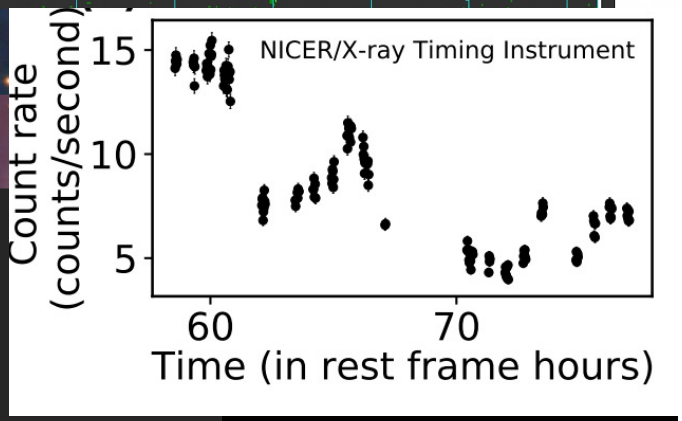
ZTF22aaajecp/AT2022cmc: Zwicky Transient Facility discovery of a fast and red optical transient

Authors: Igor Andreoni (JSI), Michael Coughlin (UMN), Tomas Ahumada (UMD), Mansi Kasliwal (Caltech), Daniel Perley (LJMU), Eric Burns (LSU), Mattia Bulla (OKC), Brad Cenko (NASA/GSFC), Shreya Anand (Caltech), Erik Kool (OKC)

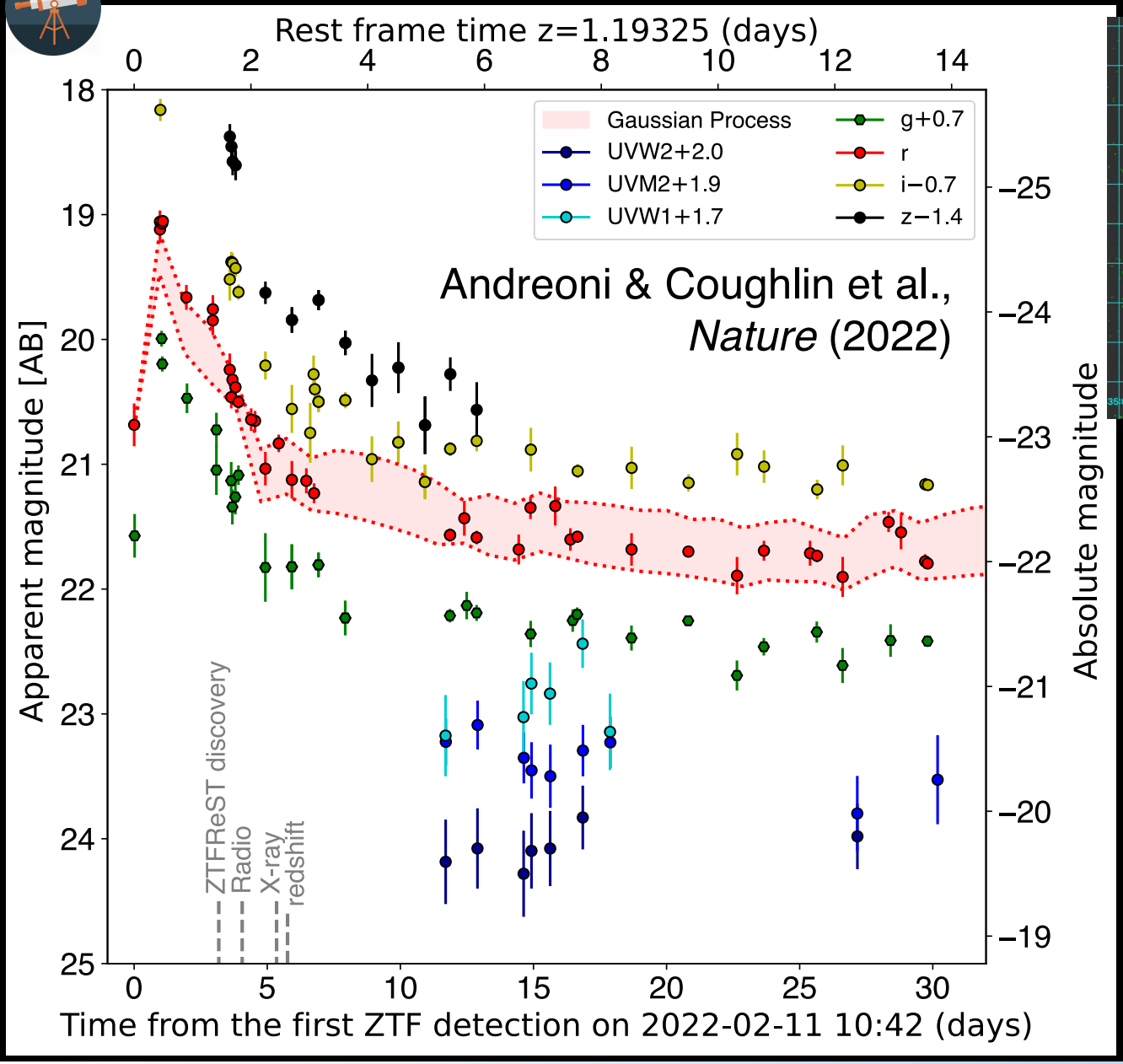
Source Group: ZTF

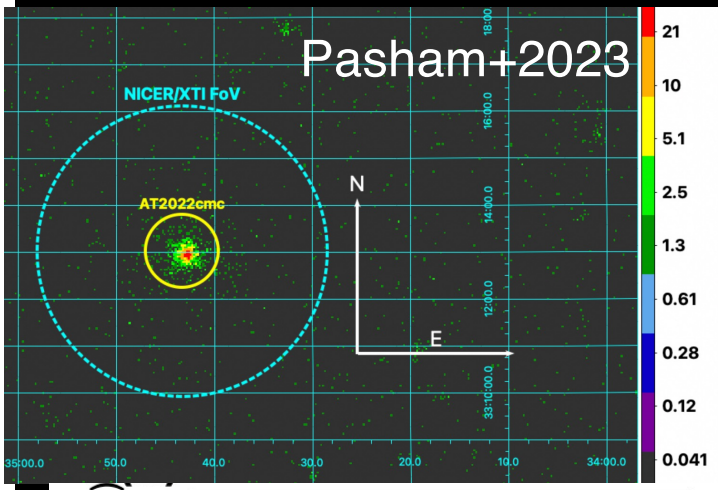
Keywords: Transient, Optical

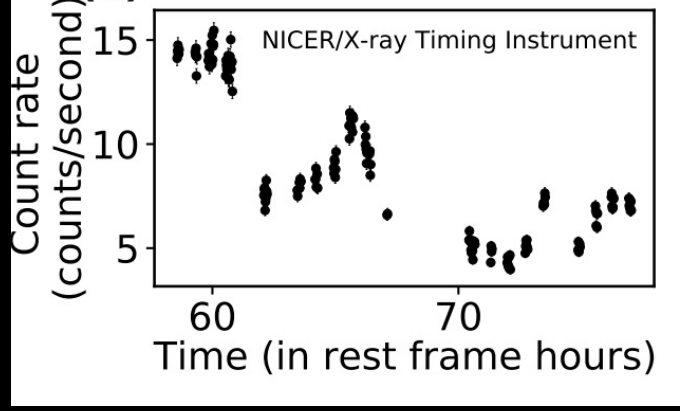
Abstract: We report the discovery of the fast, red optical transient ZTF22aaajecp/AT2022cmc with the Zwicky Transient Facility (ZTF, Bellm et al. 2019, Graham et al. 2019). ZTF22aaajecp was first detected on 2022-02-11 10:42 UT at r=20.73 +- 0.3 mag. ZTF22aaajecp increased its luminosity to r=19.04 +- 0.16 mag in 23.2 hours, then it faded by 0.8 mag in the following 48 hours. The latest detection of ZTF22aaajecp occurred on 2022-02-14 09:40 UT, r=19.84 +- 0.19 mag. The color of ZTF22aaajecp appears to be red, with g-r~0.25 mag and g-i~0.5 mag at the observed peak on 2022-02-12. The source is located at a high Galactic latitude of b=78.85 deg. ZTF22aaajecp does not have any cataloged underlying source in deep Legacy Survey DR9 images. Follow-up observations are strongly encouraged.



# AT2022cmc: multi-band observations

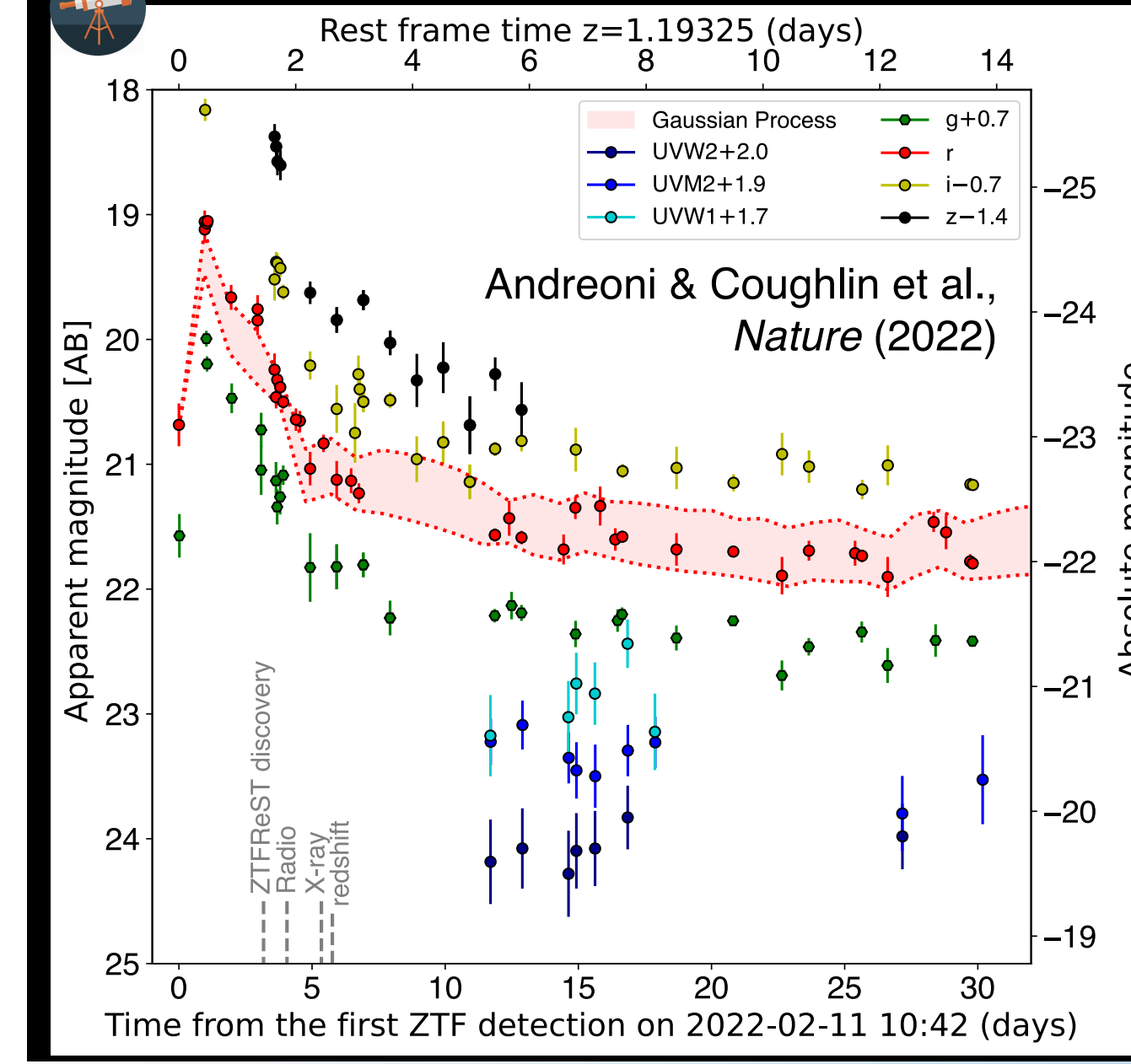


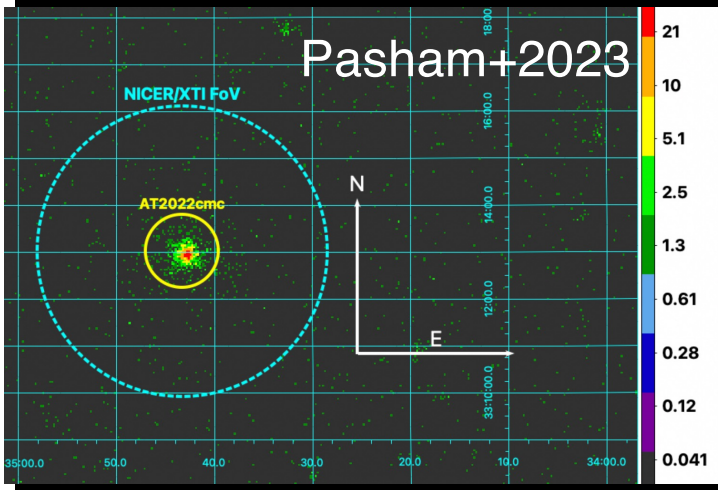



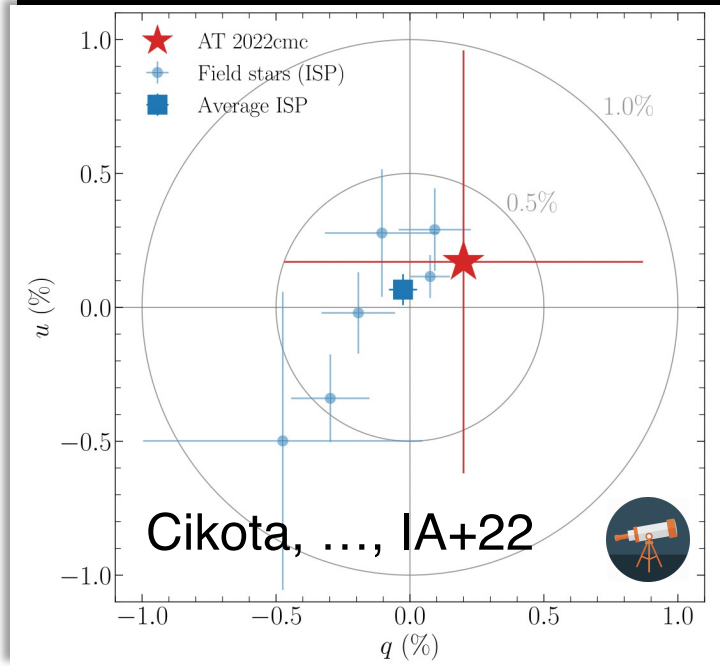




The furthest TDE ever observed, first jetted TDE identified by an optical survey

# AT2022cmc: multi-band observations

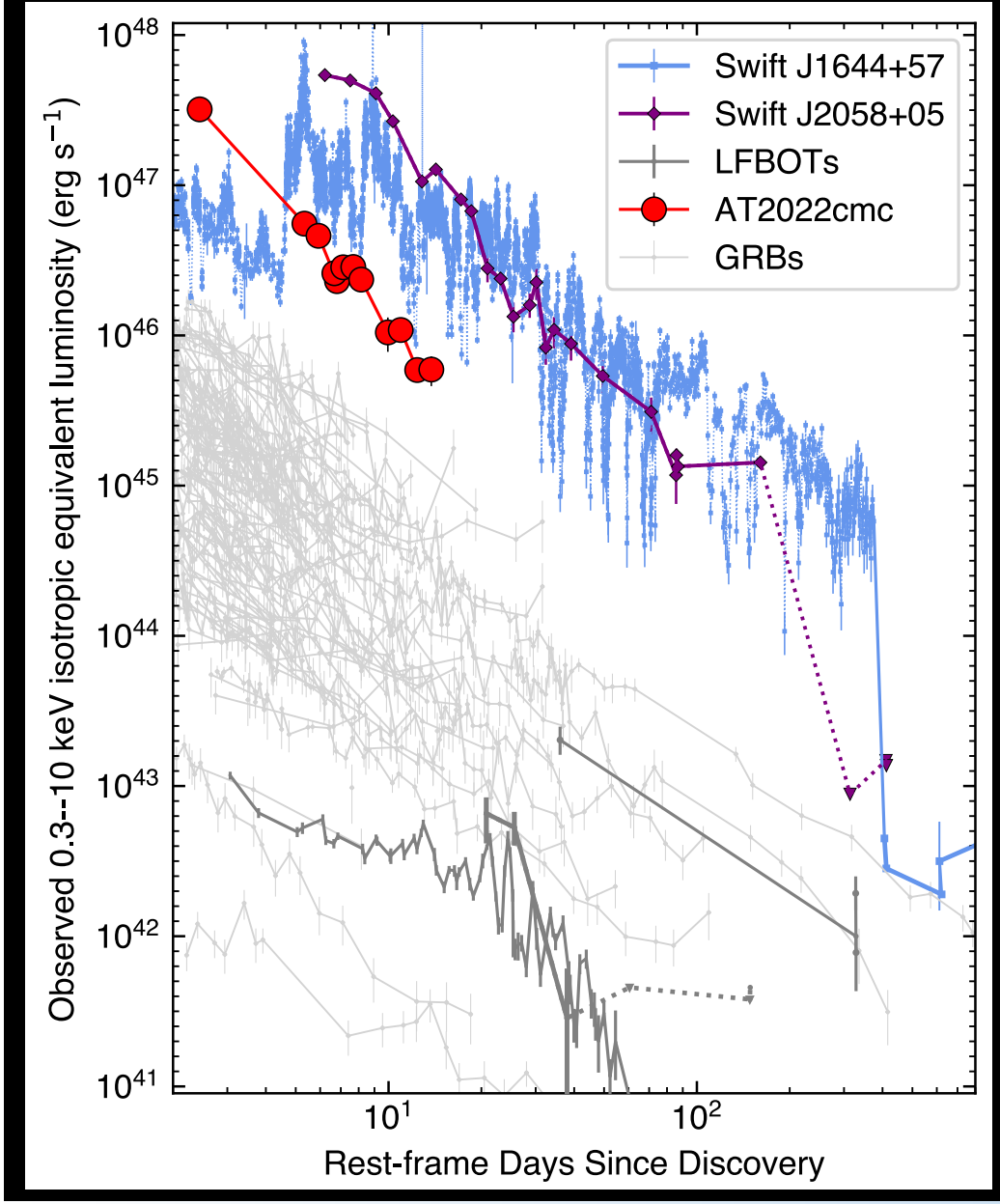


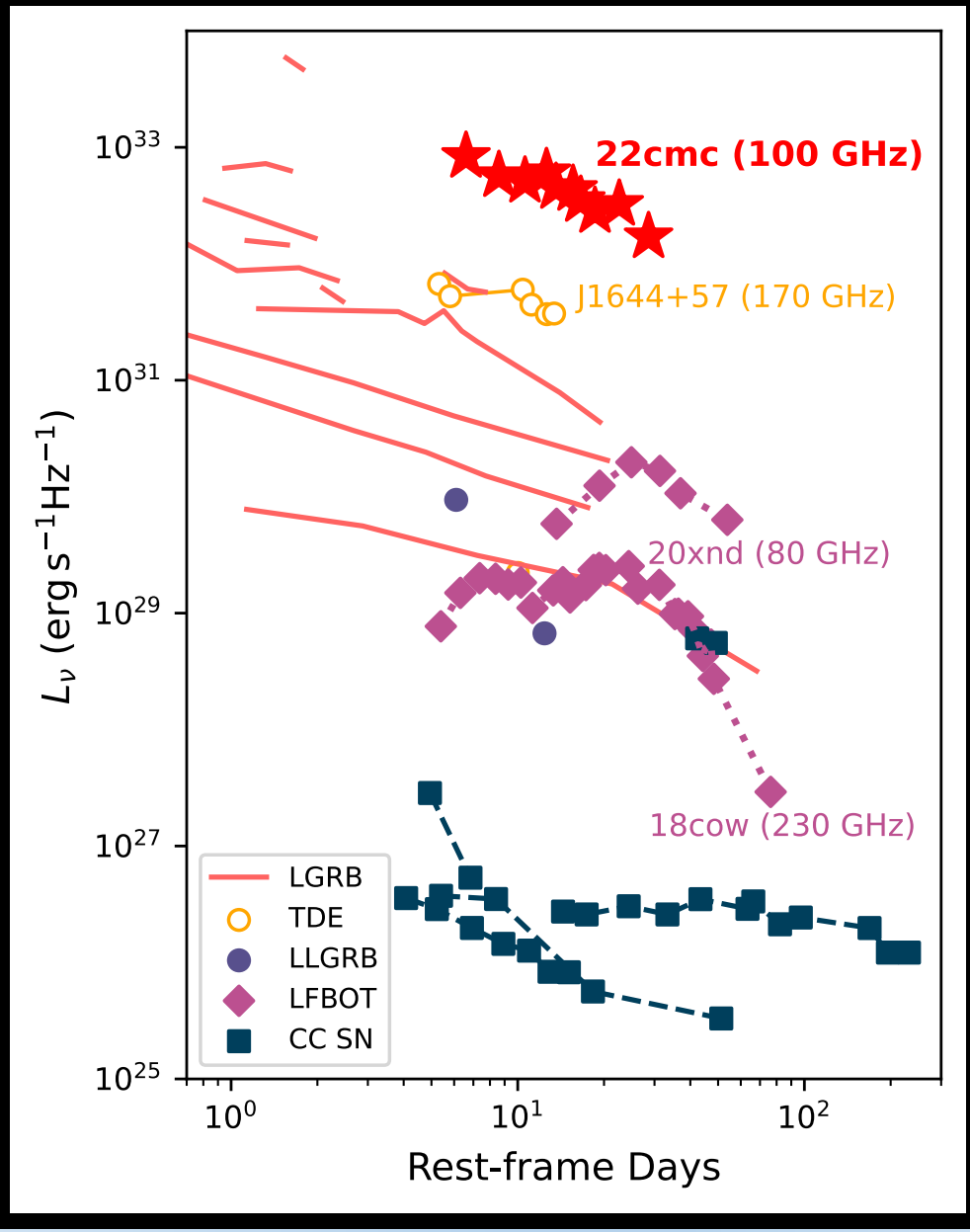




The furthest TDE ever observed, first jetted TDE identified by an optical survey

# X-rays and radio/mm comparison

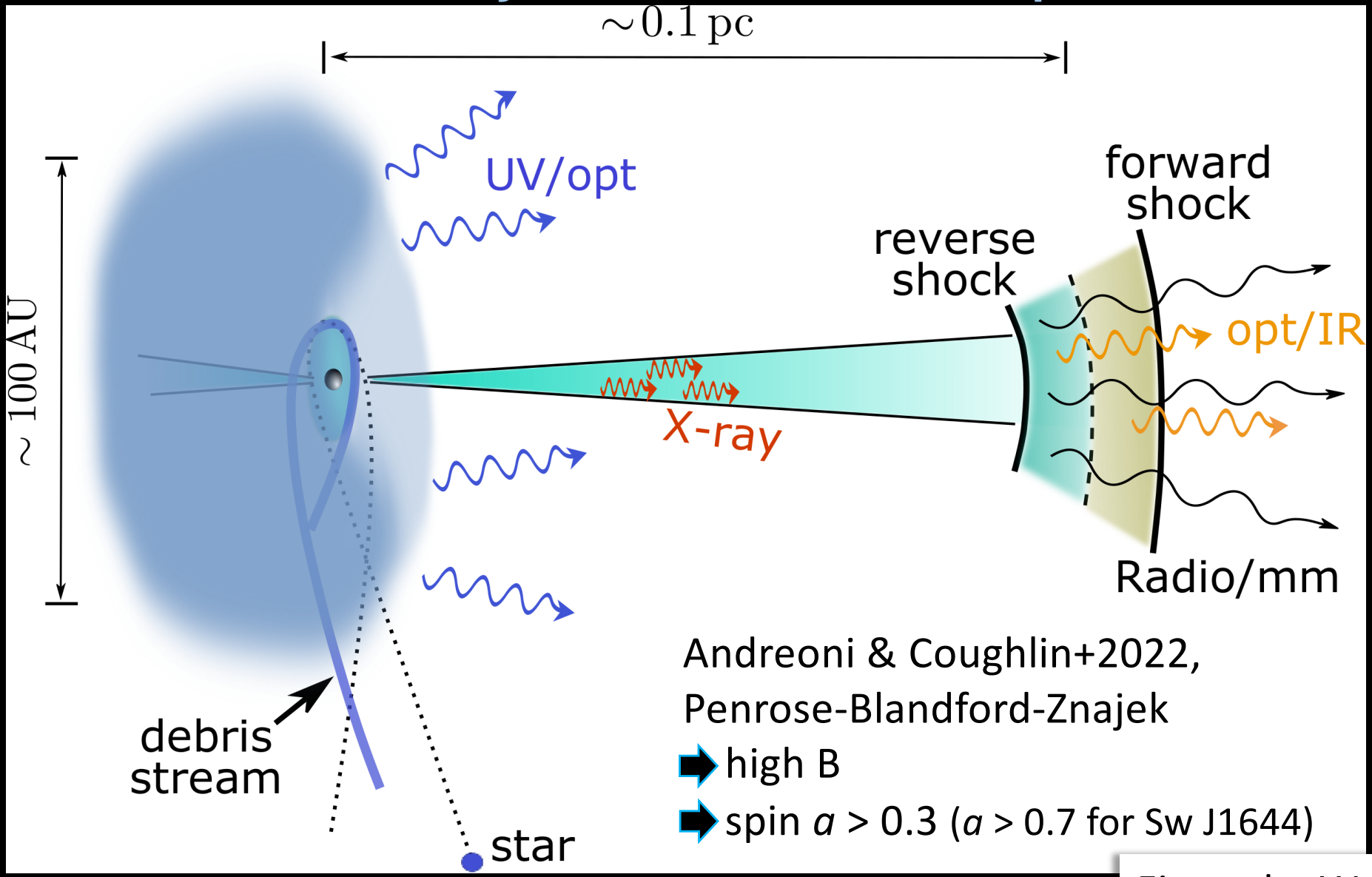



Andreoni & Coughlin+2022

*Igor Andreoni*

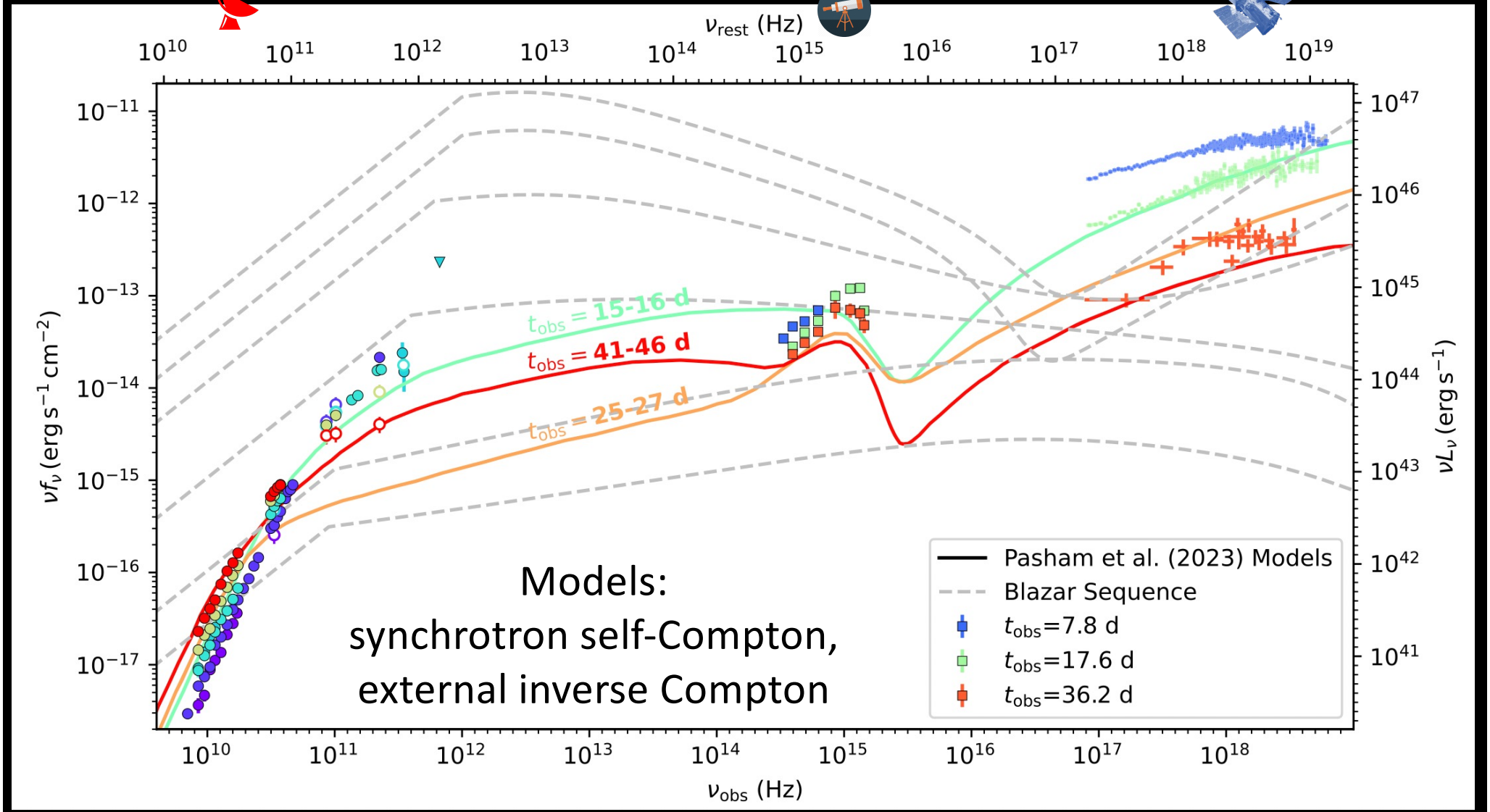
# AT2022cmc: a jetted tidal disruption event




Andreoni & Coughlin+2022

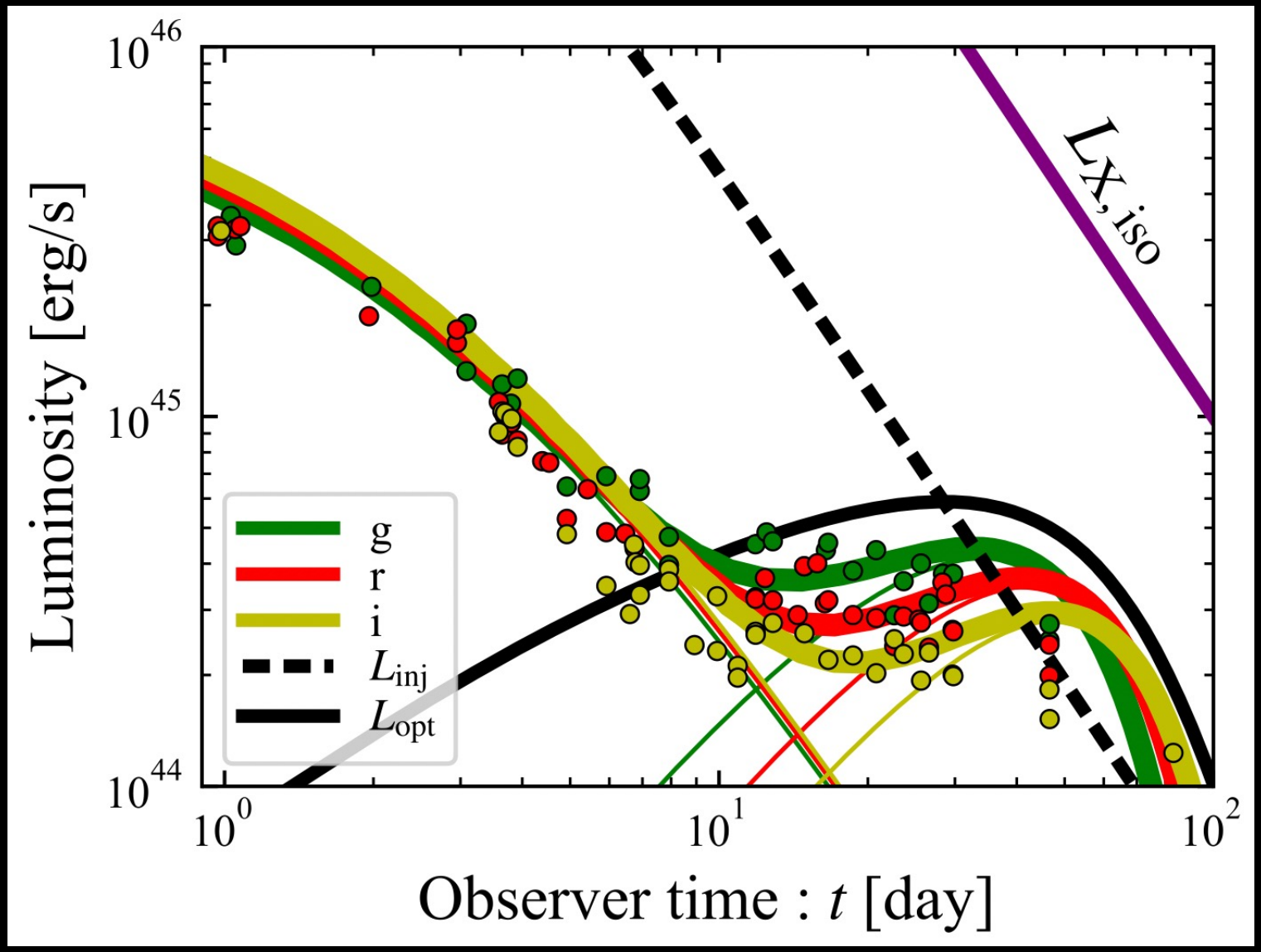
Figure by W. **Lu**

# Broadband Spectral Energy Distribution



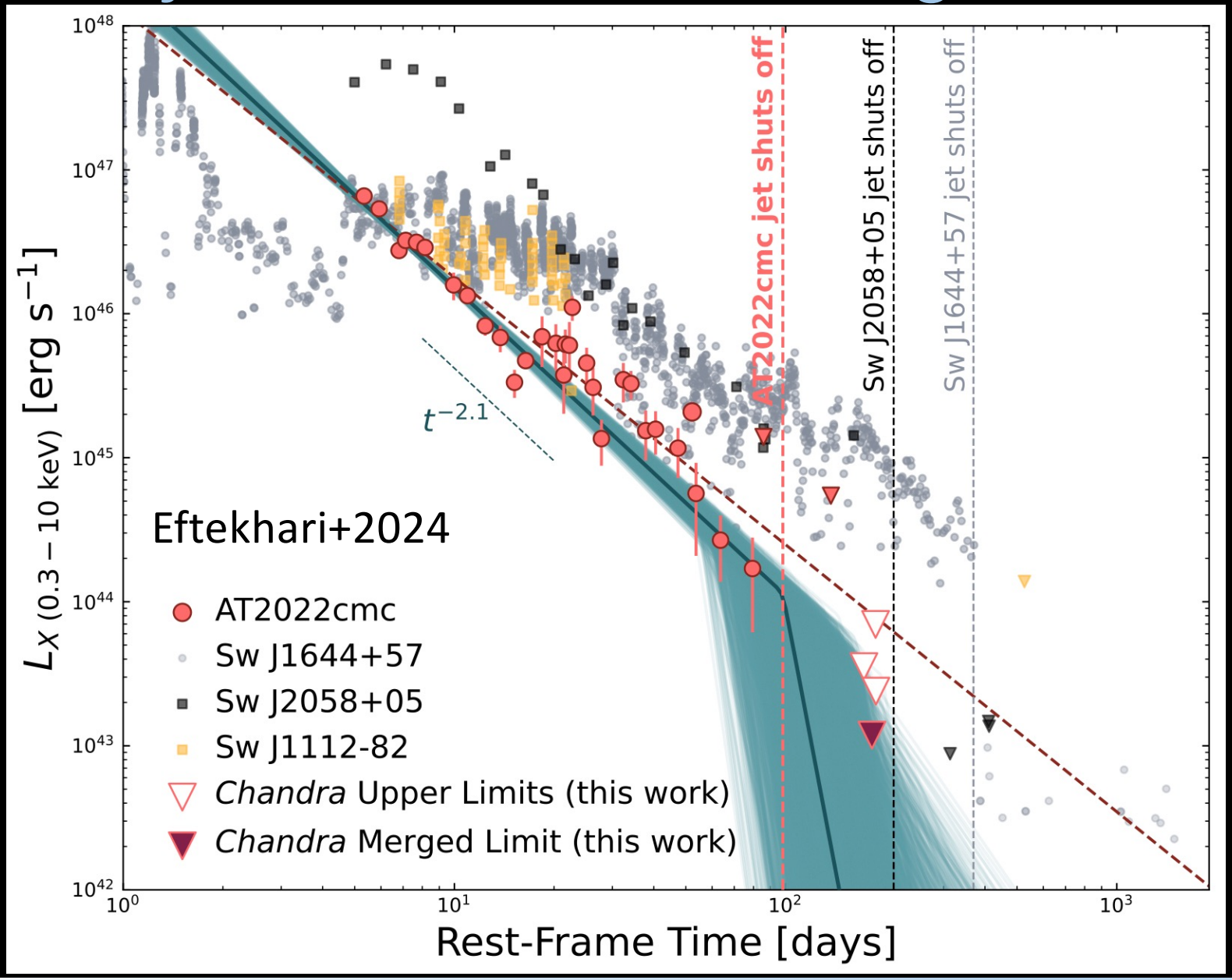

Yao+24, see also Pasham+23

# AT2022cmc: an engine-powered supernova?

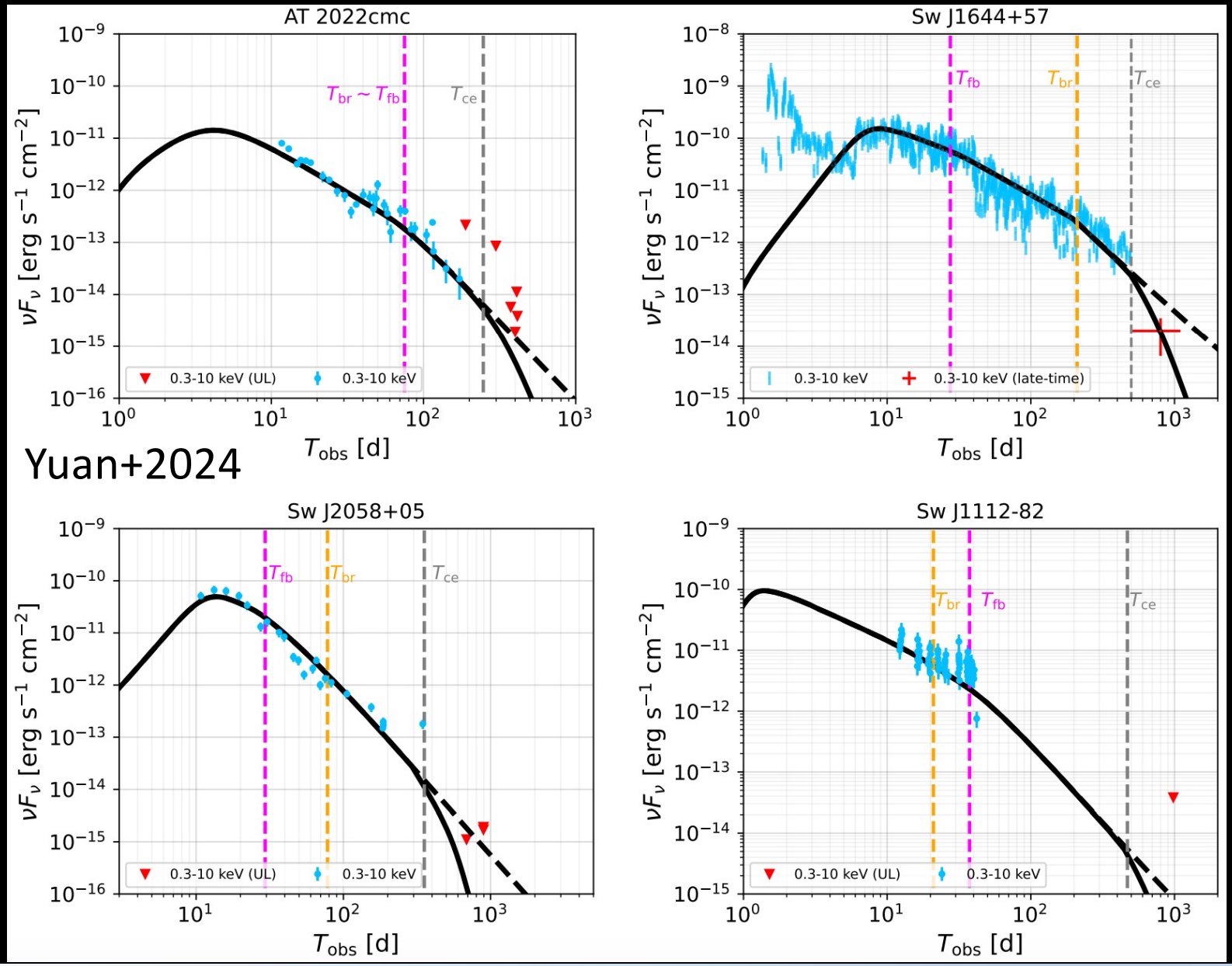



Matsumoto & Metzger (2023)

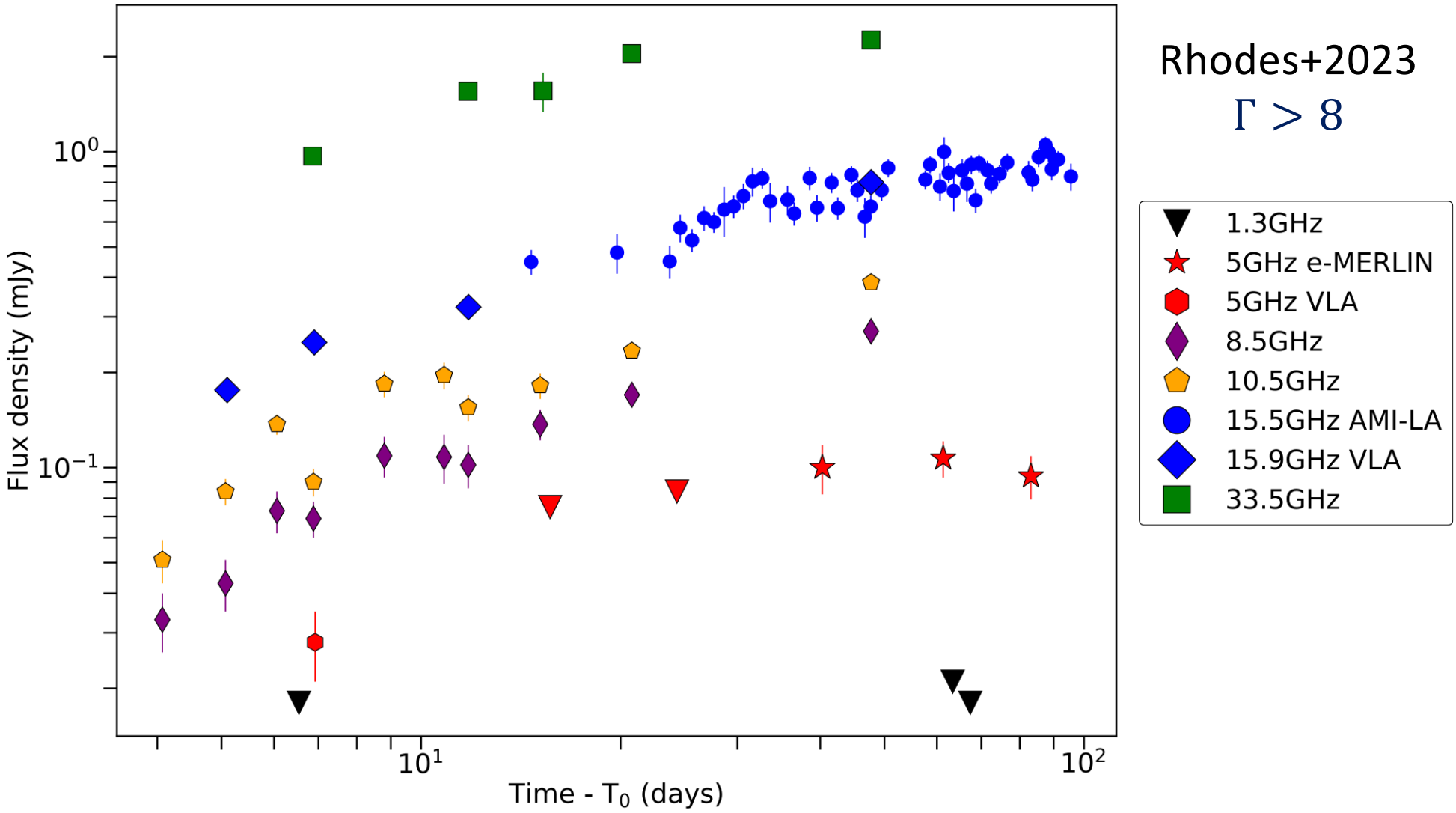
# X-ray shut off: $\dot{M}$ < Eddington rate



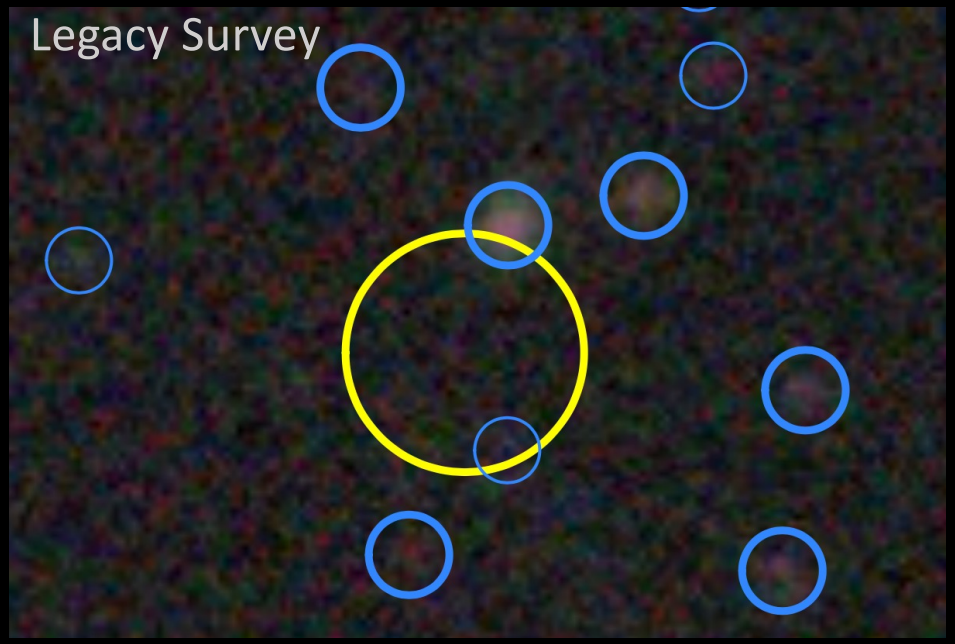
# X-ray shut off: also jet break?

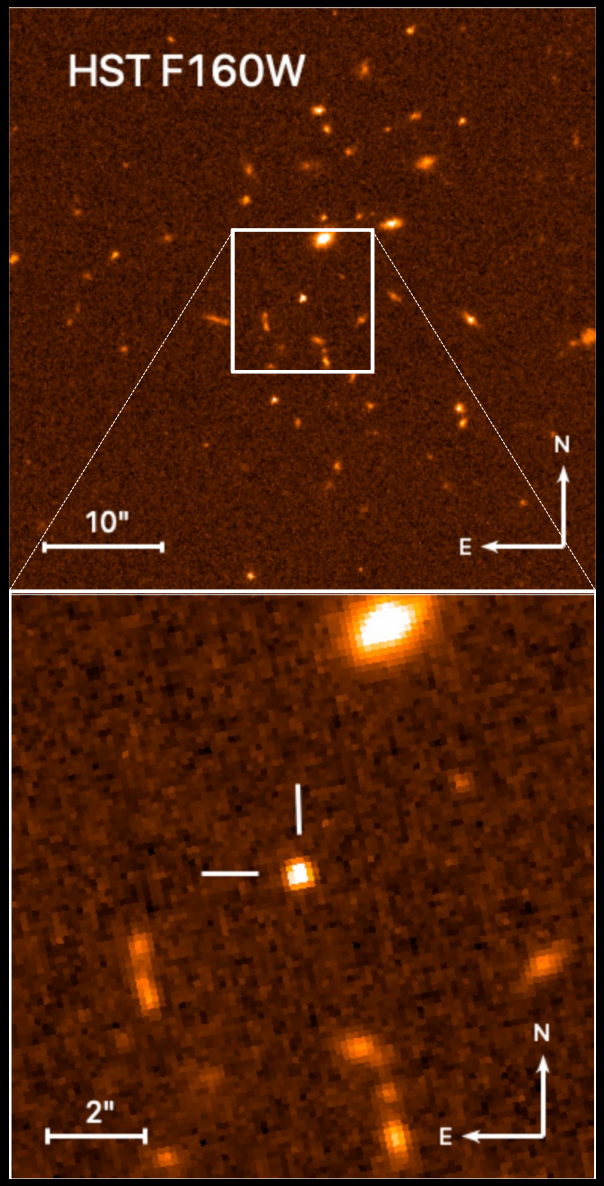


# Day-timescale variability at ~15GHz



# What about the host galaxy?




Using a galaxy bulge – BH mass relation:

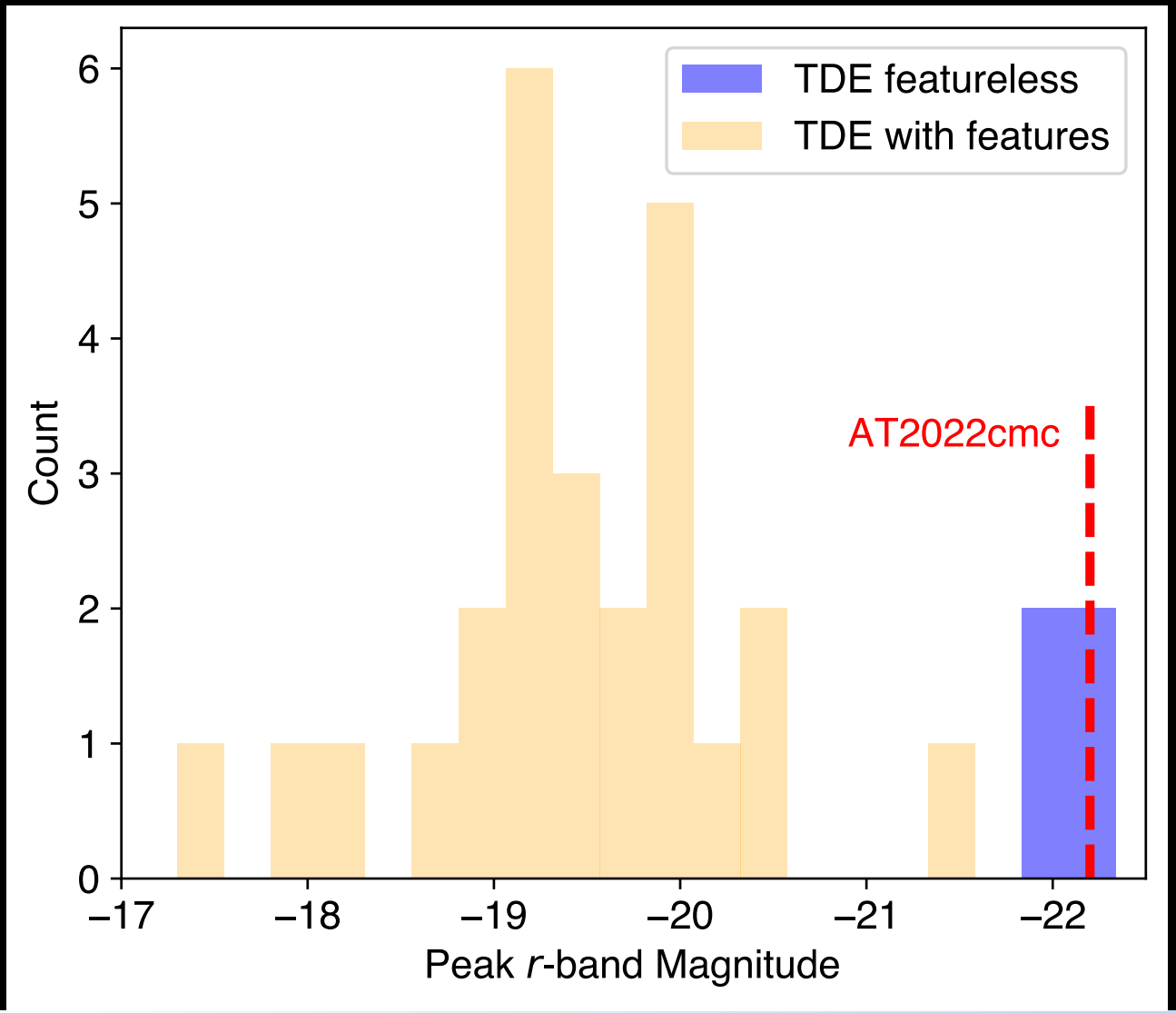
$M_{BH} < 4.7 \times 10^8 M_\odot$

Eddington luminosity: $L_{Edd} < 6 \times 10^{46}$ erg $s^{-1}$

Lorentz factor $\Gamma \sim 10$ (from radio spectrum)

Hubble Space Telescope imaging, PI Cenko,
New observations in Hammerstein et al. in prep

# A connection between featureless luminous TDEs and jetted TDEs?




For Luminous featureless TDEs see also Hammerstein+22

# AT2022cmc: implication for rates

$\text{Rate}_{X} = 0.03^{+0.04}_{-0.02}$ $\text{Gpc}^{-3}\ \text{y}^{-1}$ (Sun+15)

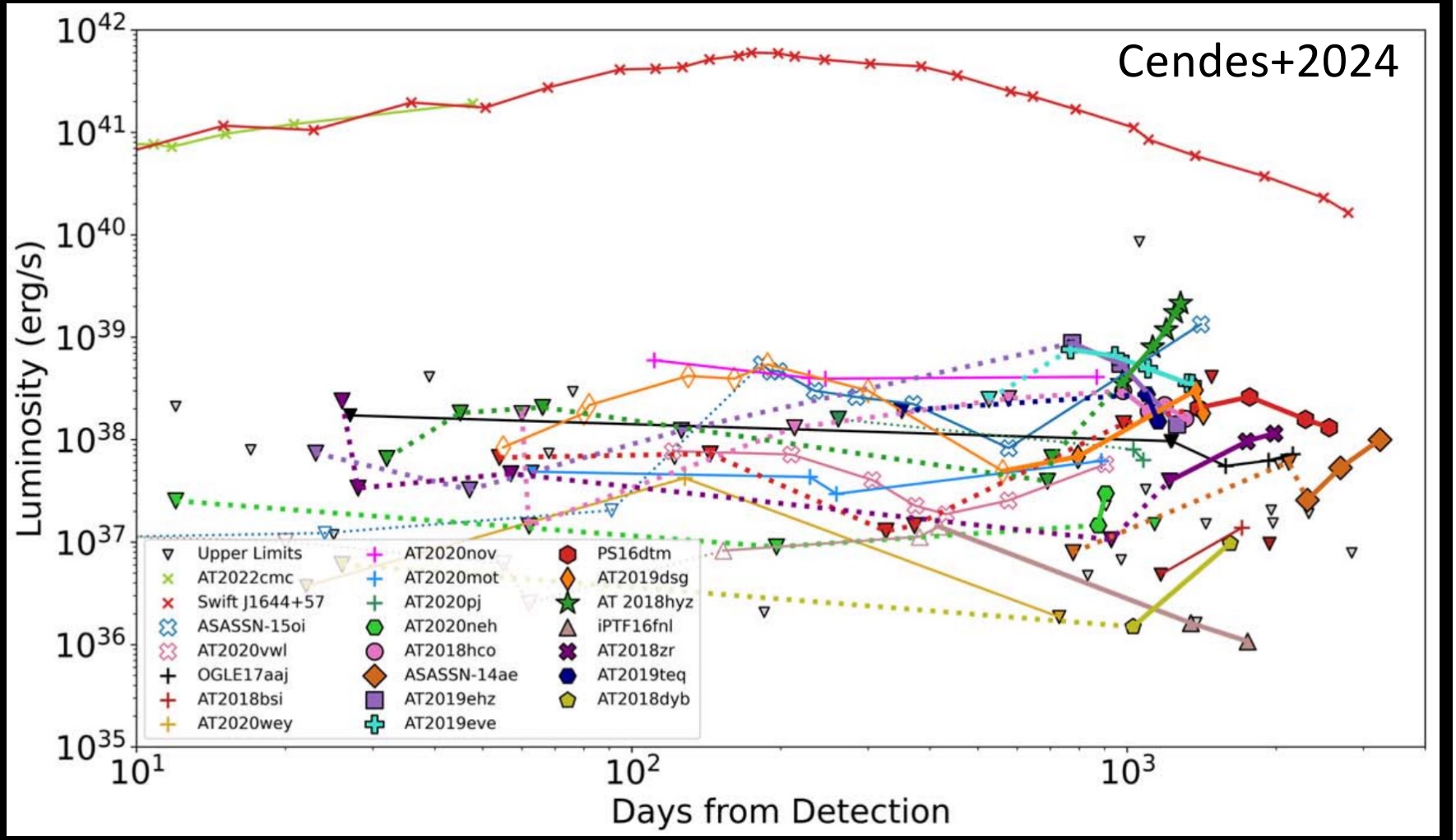
$\text{Rate}_{\text{AT2022cmc}} = 0.02^{+0.04}_{-0.01}$ $\text{Gpc}^{-3}\ \text{y}^{-1}$

Optical and X-ray surveys independently measured consistent rates for jetted TDEs, leading to the conclusion that ~1% of TDEs produce relativistic jets

(however… how many did we miss?)

See also e.g.: Bloom+11, Burrows+11, Zauderer+11, Cenko+12, Pasham+15, Brown+15, Mattila+18

# Delayed radio flares: indication of a jet? (probably not, but…)



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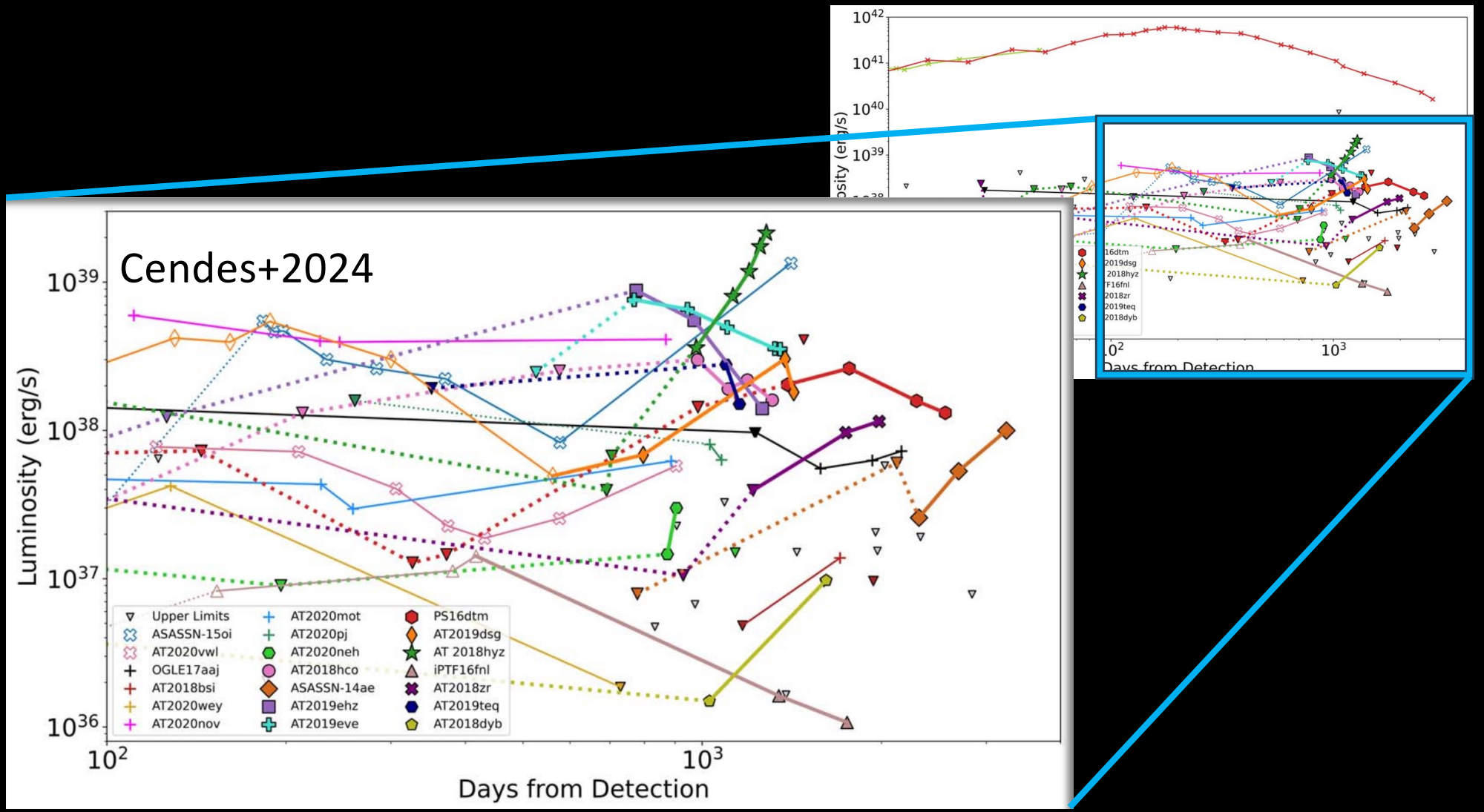

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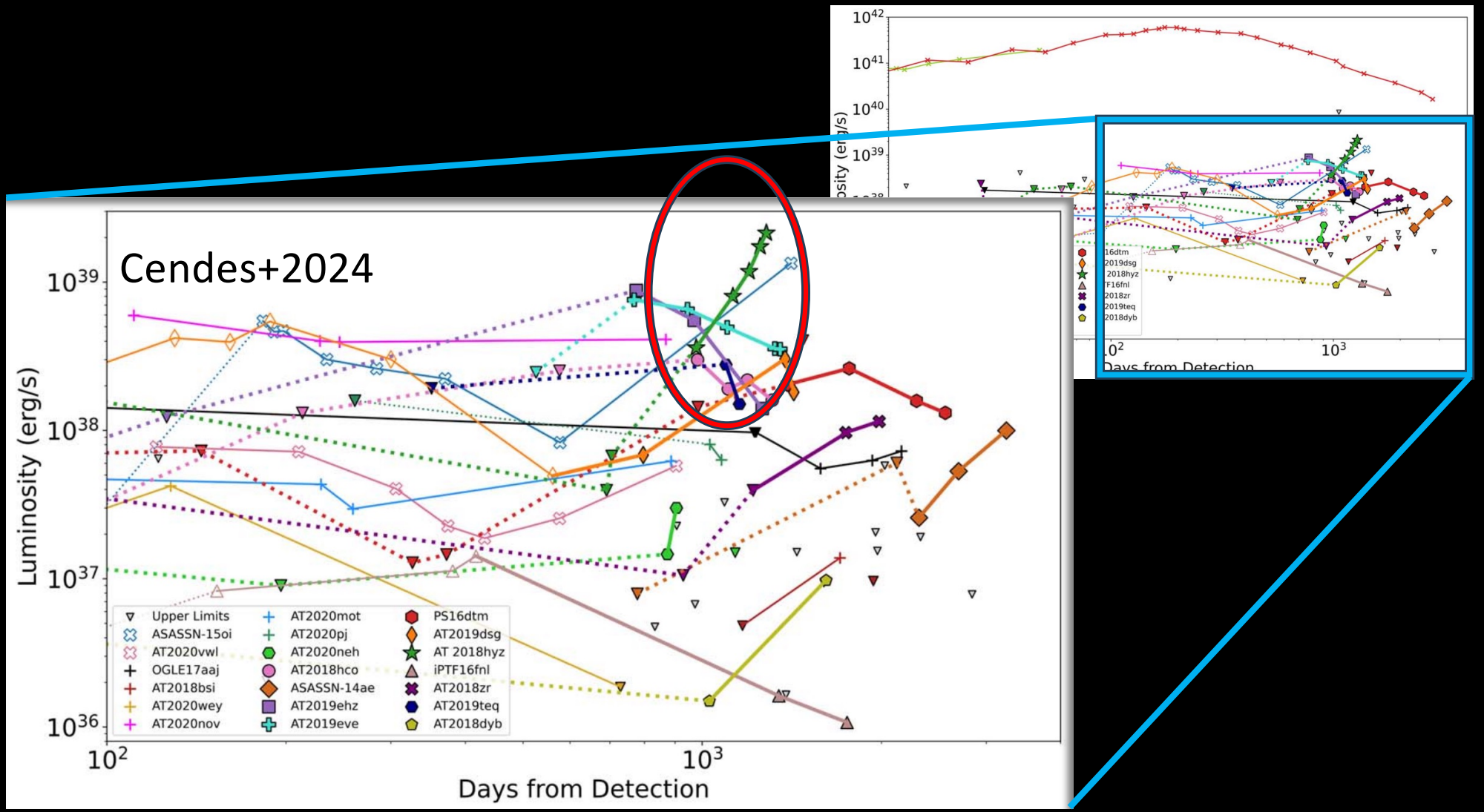

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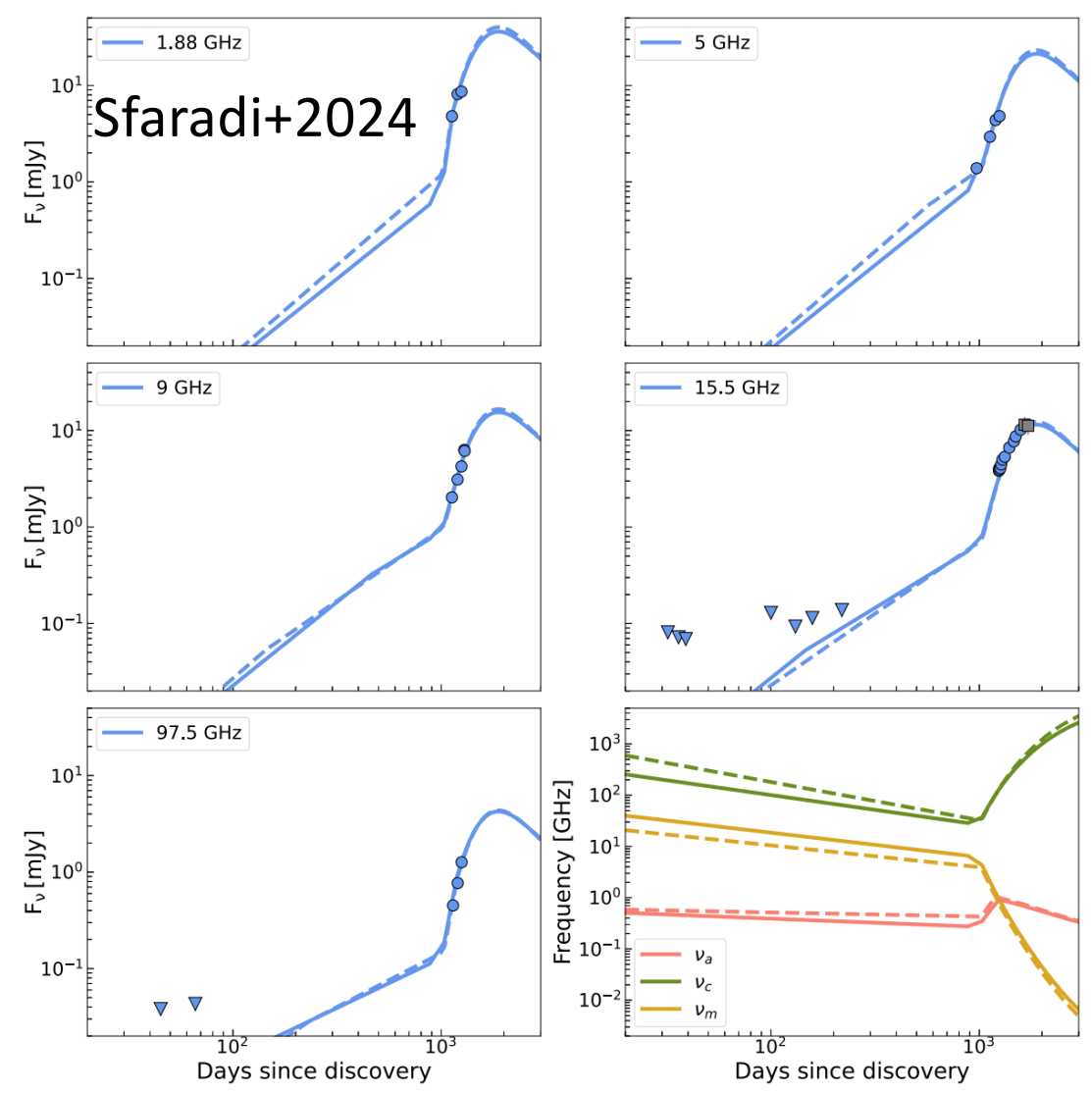
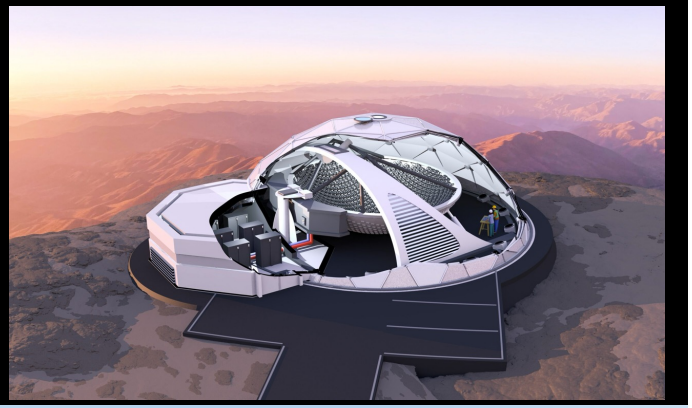


# A new spring for jets in optical surveys


Relativistic afterglows in ZTF
(22 so far, see Perley's talk)
Ho+2020, 2021, 2022
Andreoni+2020, 2021, 2022
Lipunov+23, Perley+2024
Li+2024

Vera Rubin Observatory
10M

Argus Array @UNC
2-5M
+50M photometric points
(Corbett, private comm.)



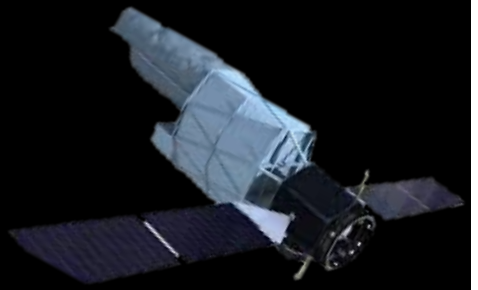
# A new spring for jets in optical surveys

Einstein Probe

SVOM

ULTRASAT

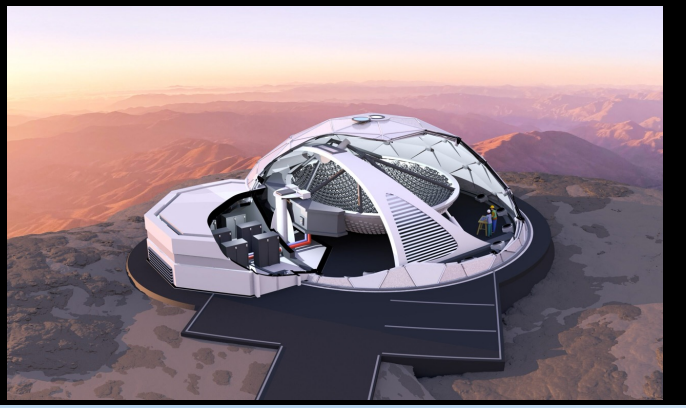
UVEX



ZTF
300k

Vera Rubin Observatory
10M

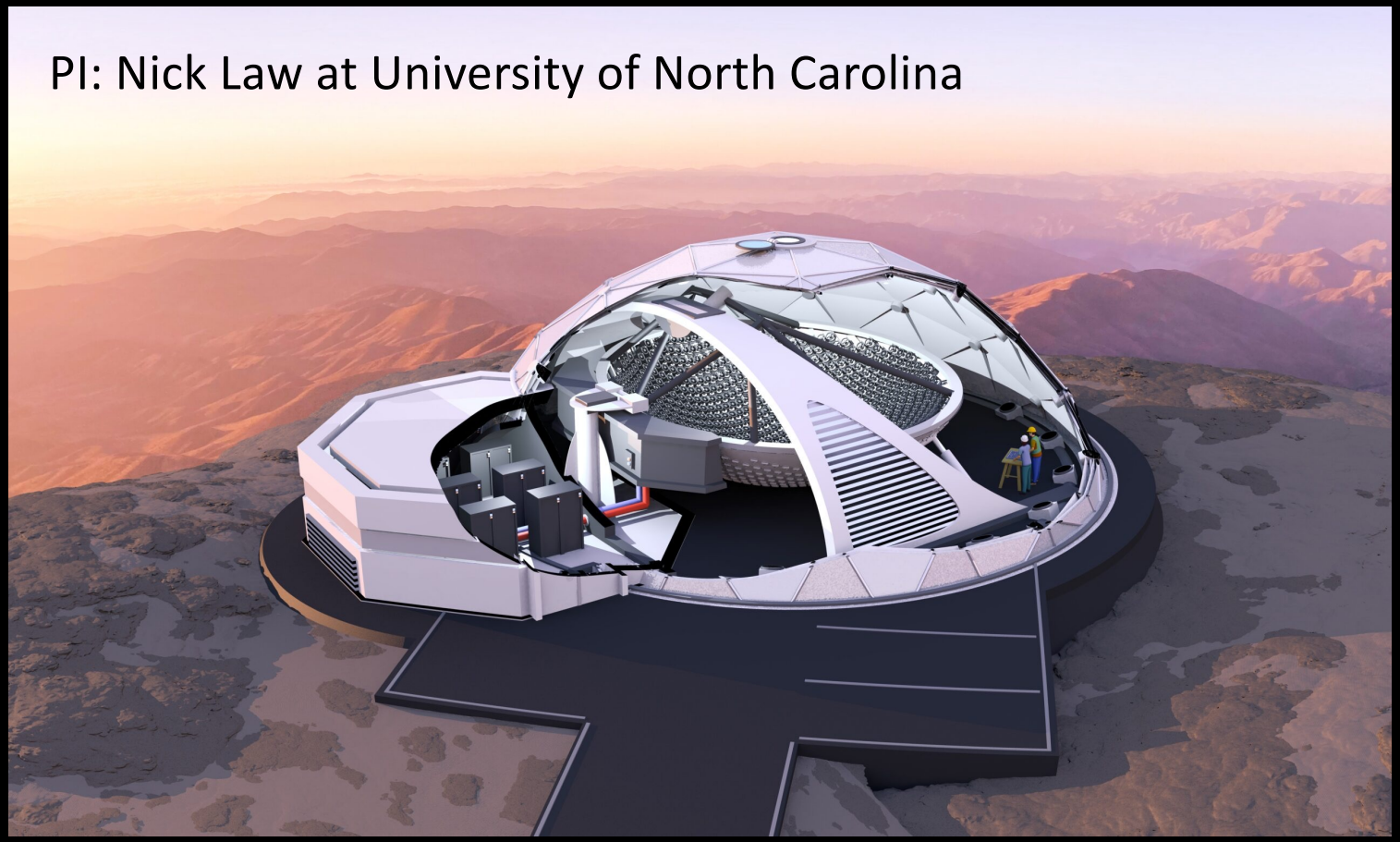
Argus Array @UNC
2-5M
+50M photometric points
(Corbett, private comm.)



Square Kilometre Array

DSA-2000
5B sources!!

# Argus Array (~2027)




Preliminary

- 900 telescopes, 1.5 arcsec resolution
- Continuous 1s-1min observations (16.1-19.6 mag), FoV ~8000 deg$^2$
- Full available sky at ~24 mag in 2 filters every 5 nights via stacking

# Summary

Systematic, high-cadence optical observations and follow-up enabled the discovery of a transient class never identified before in the optical

Rapid follow-up can reveal an association with luminous multi-wavelength counterparts, prompting more observations

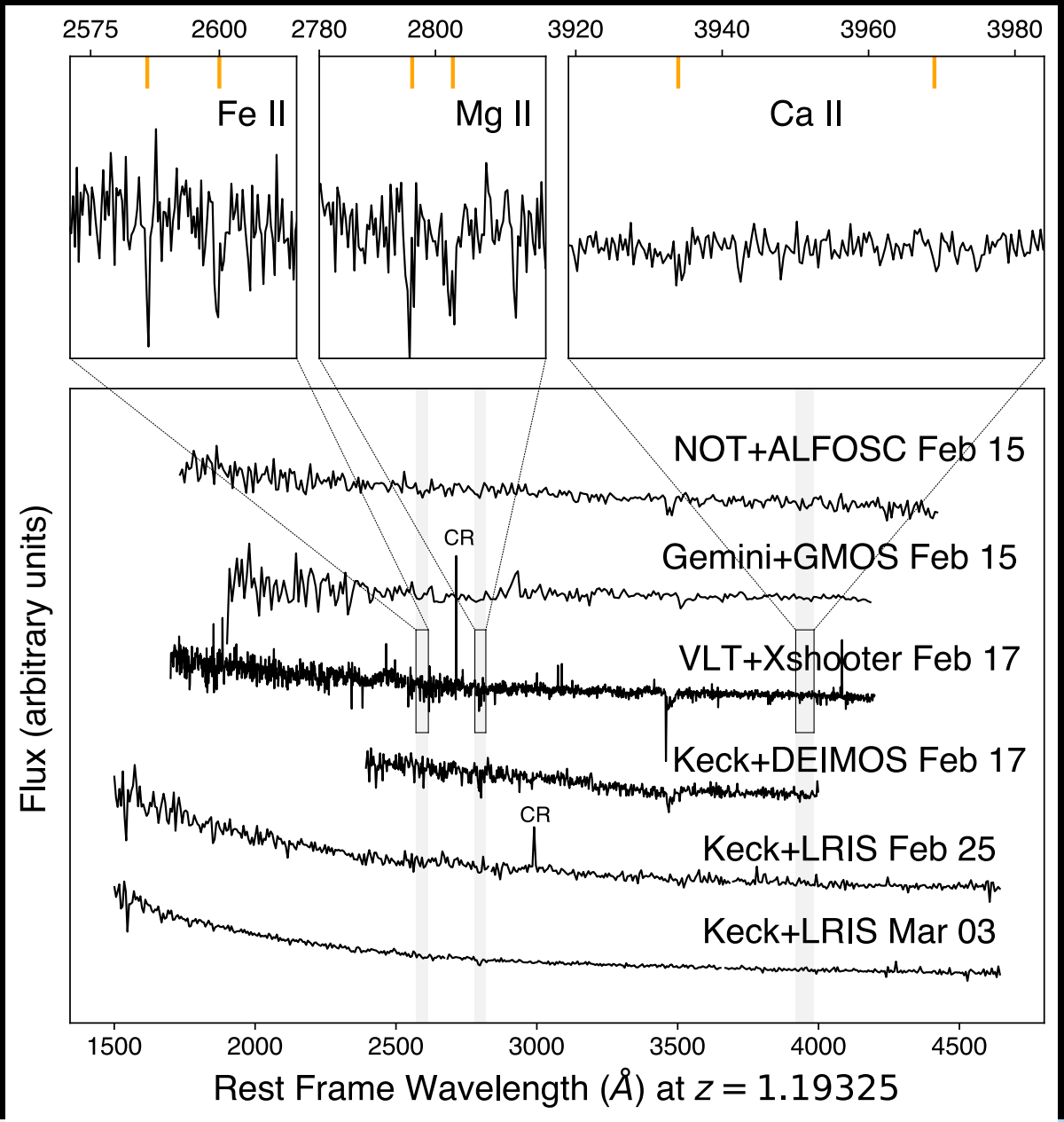
We interpreted AT2022cmc as a jetted TDE
Likely launched by a rapidly spinning black hole,
strong magnetic fields, but other models are viable

Only ~1% of TDEs produce relativistic jets. Connection with the class of luminous featureless TDEs?

What is the mechanism powering jetted TDEs?
Are some delayed radio flares also jetted TDEs, how many in radio surveys?
How many will be found by Rubin Observatory and Argus Array?

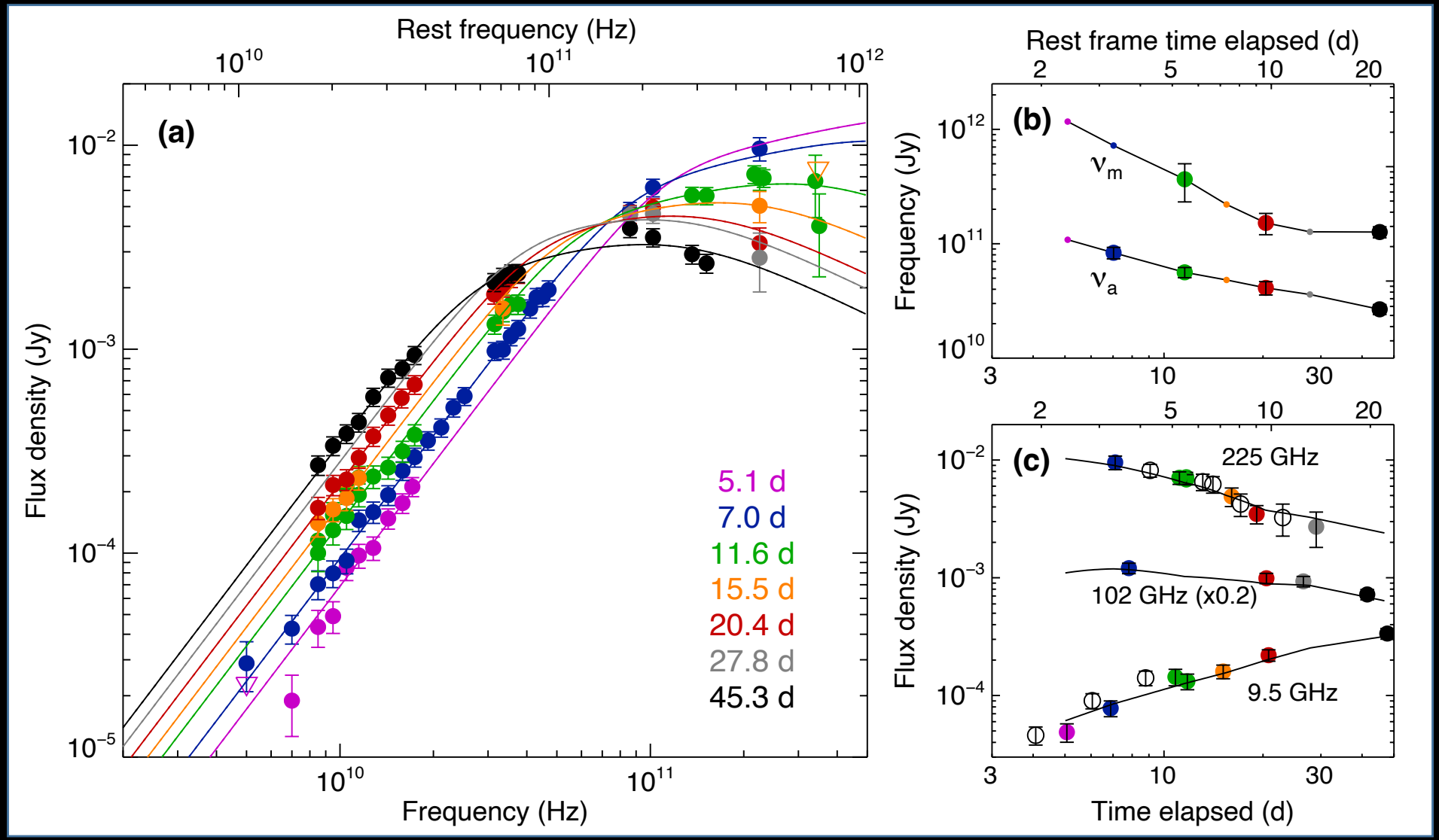
# Extra slides

# Redshift z = 1.1935, featureless

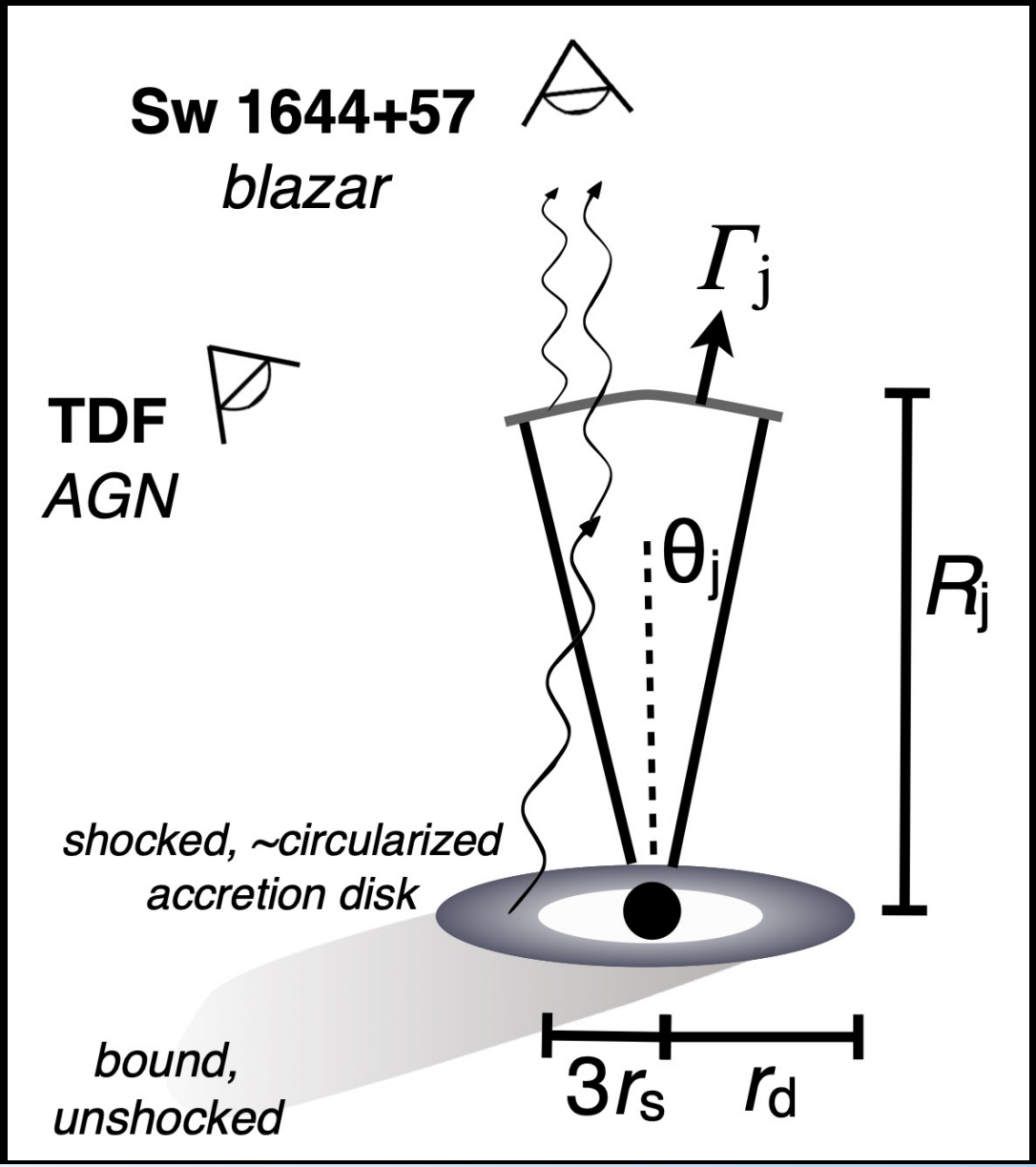



Andreoni & Coughlin+2022

# AT2022cmc: Radio/mm



# Blazar analogy for jetted TDEs




Bloom+11