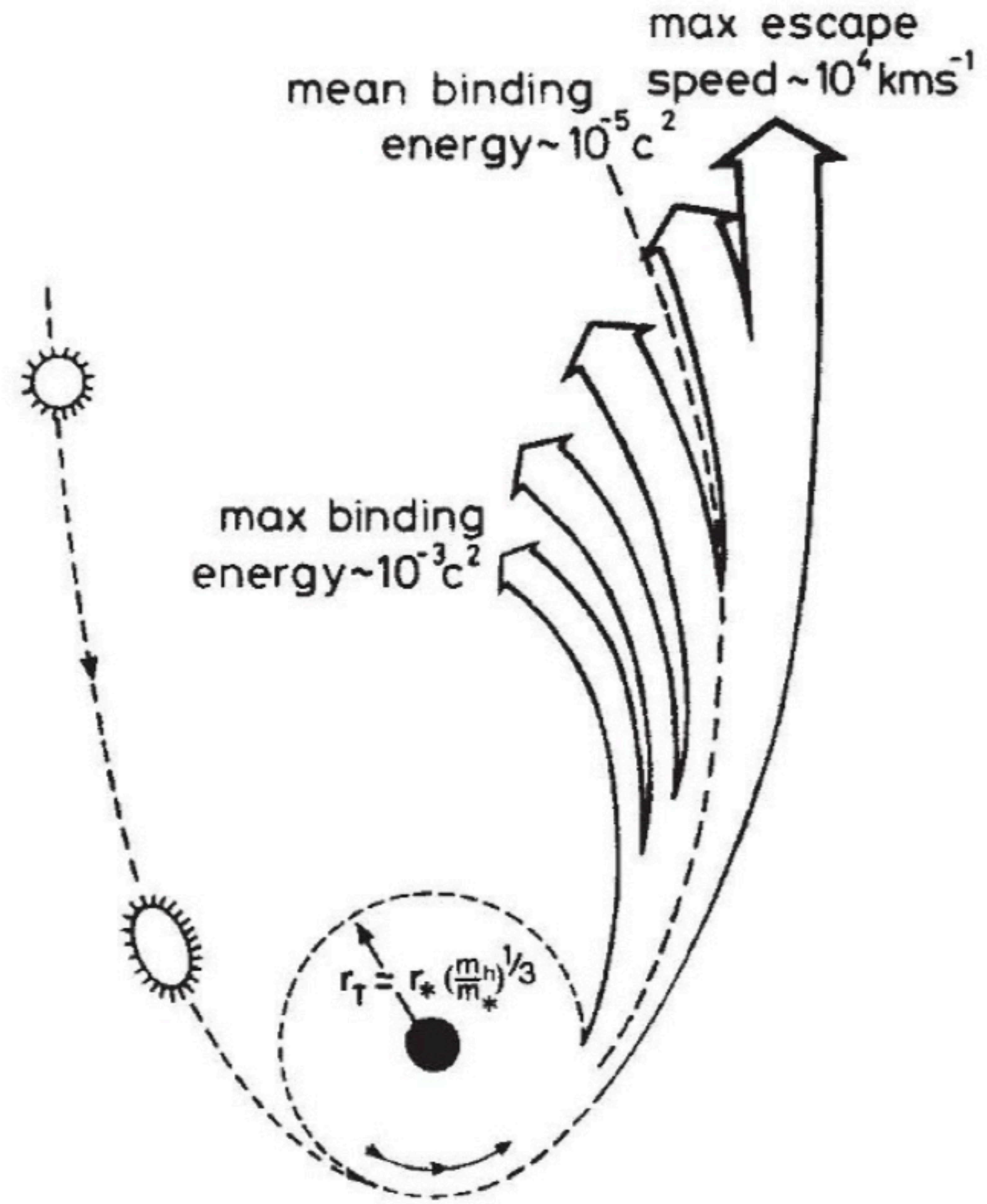
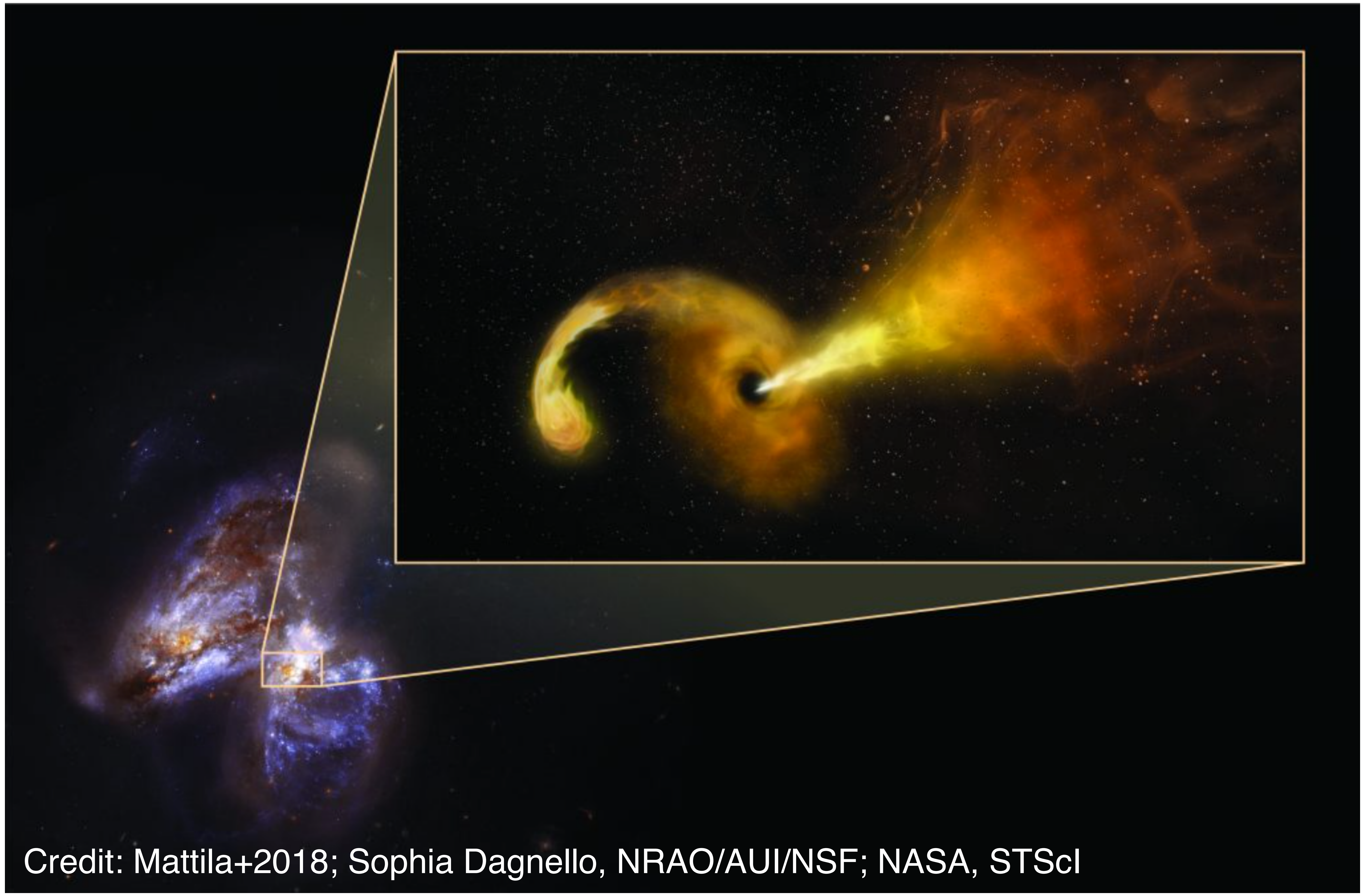
Tidal Disruption Events (TDEs) and Nuclear Transients





Credit: Mattila+2018; Sophia Dagnello, NRAO/AUI/NSF; NASA, STScI

TDEs and Nuclear Transients

SOXS WG10

Seppo Mattila (Univ. of Turku) & Iair Arcavi (Tel Aviv Univ.)

WG members:
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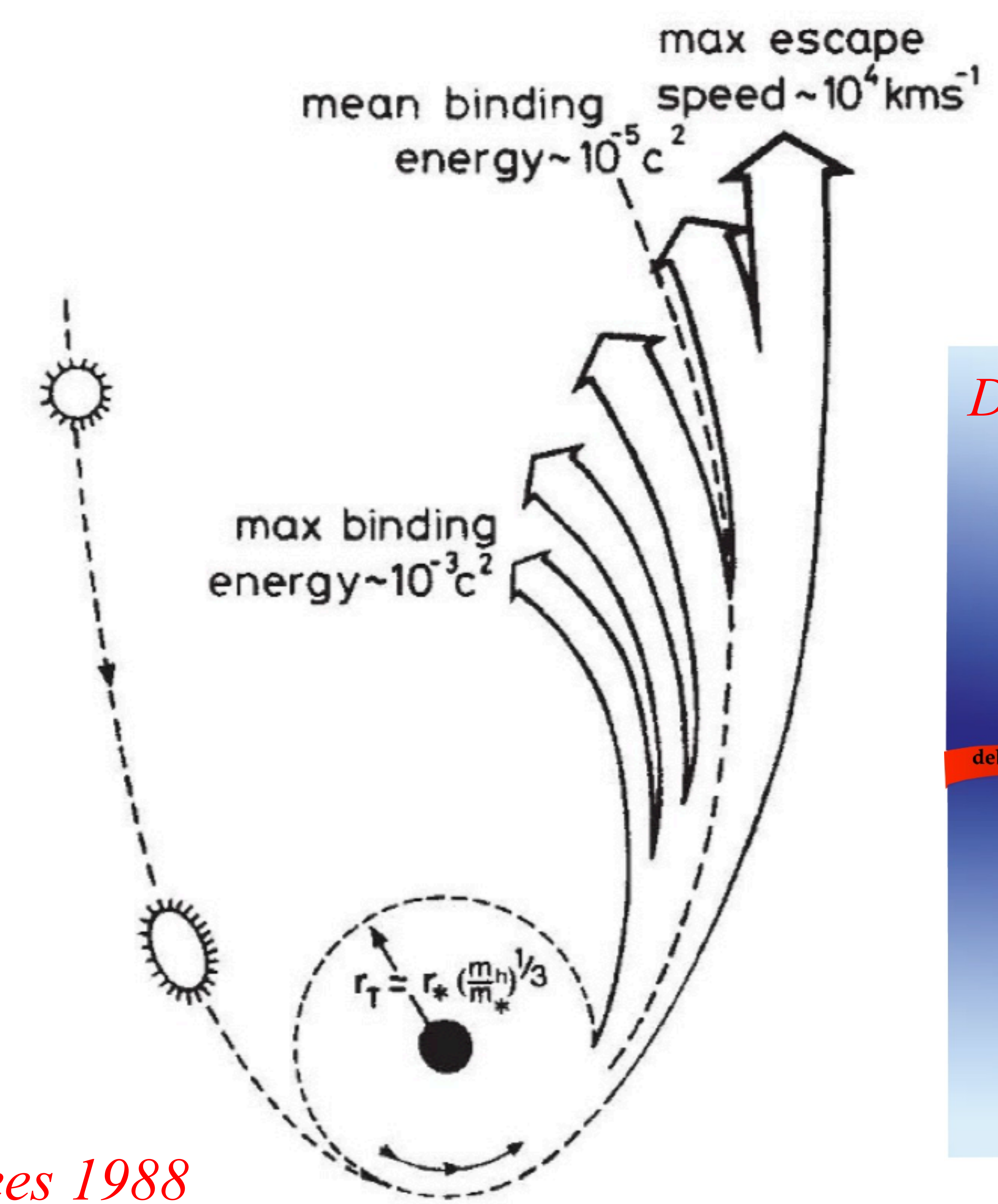
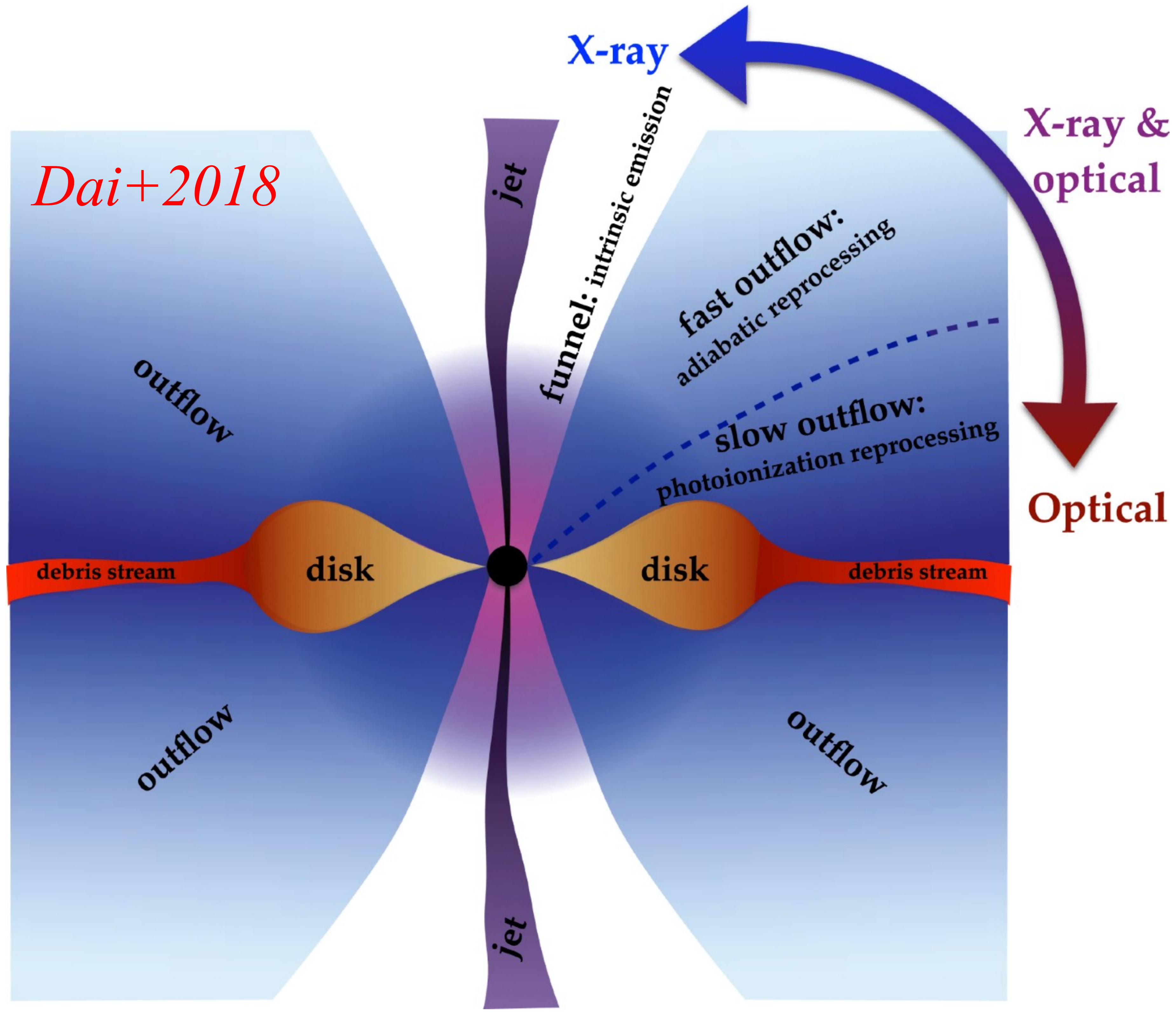
Optical TDE spectra at medium resolution

Origin of the optical/UV emission in TDEs?

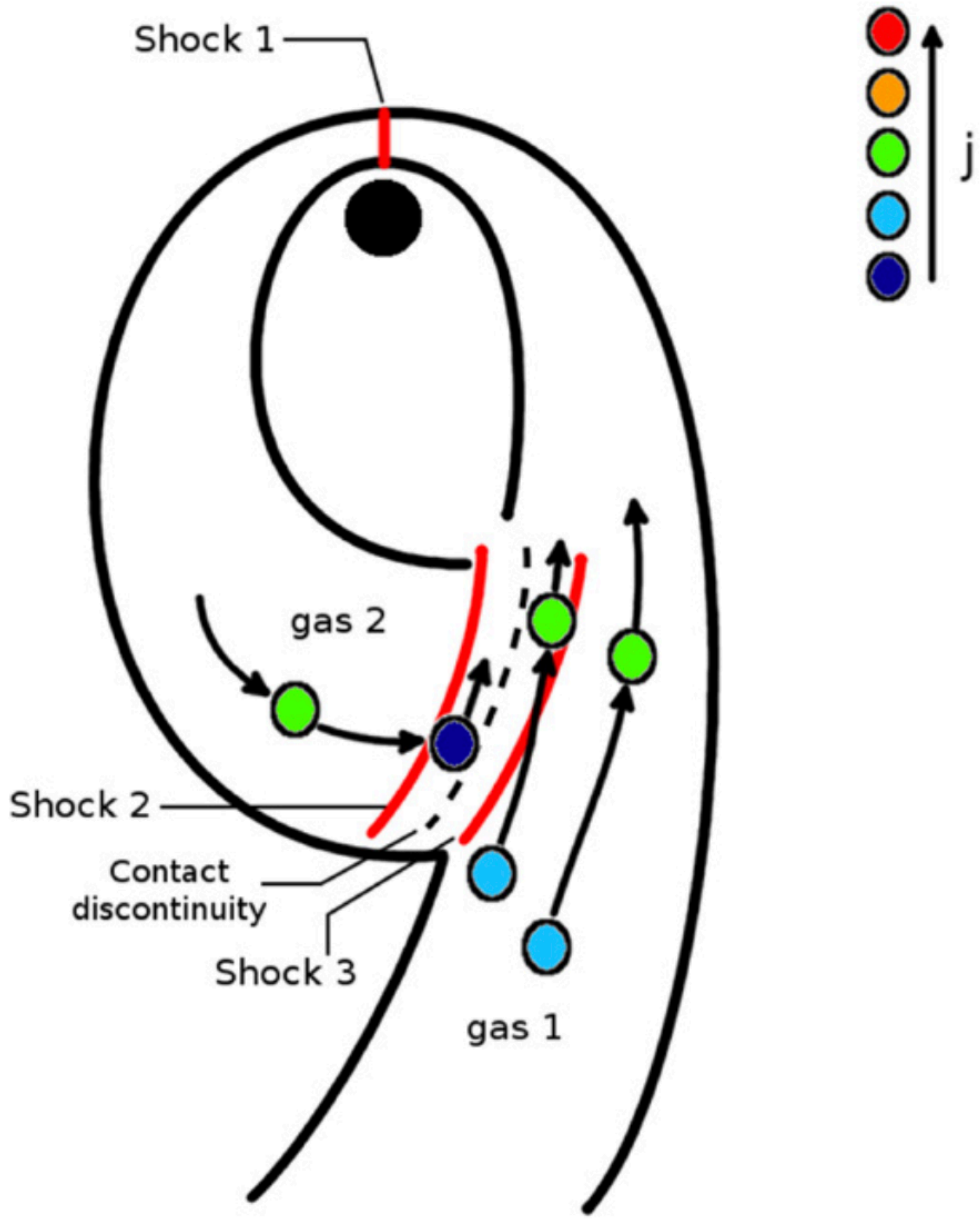


Rees 1988

reprocessing?

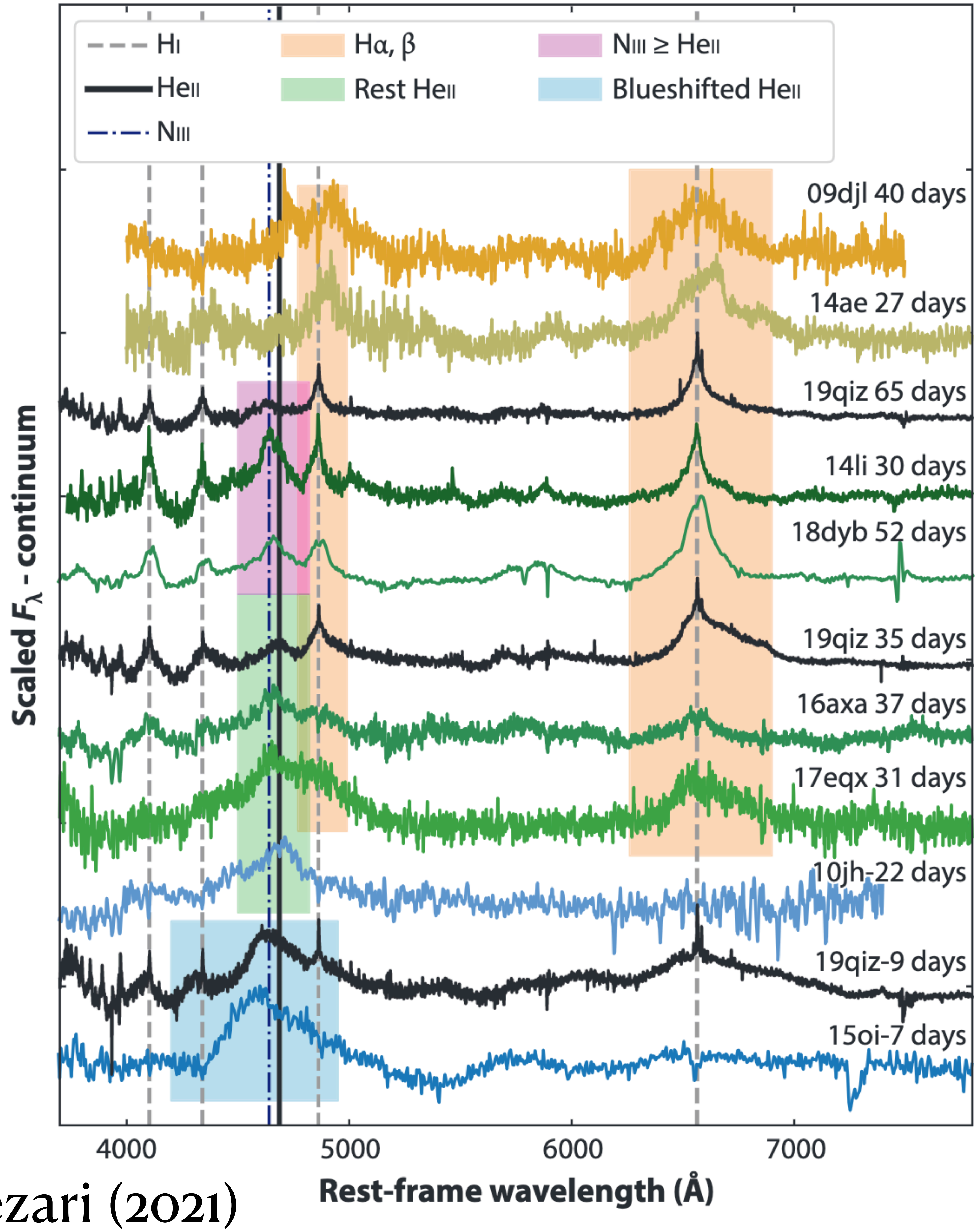


shocks?

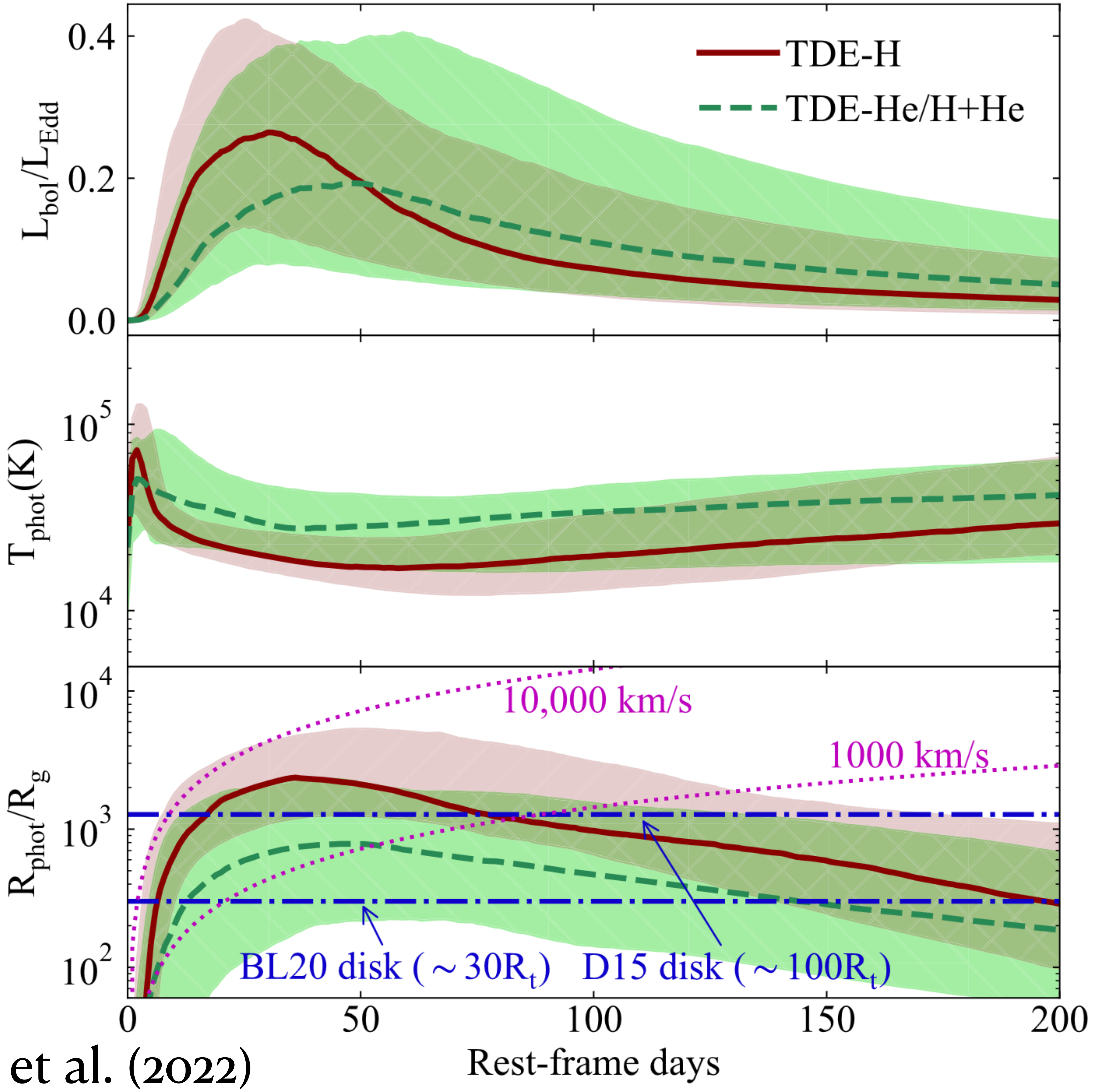


Shiokawa+2015

Mapping spectral types & evolution of TDEs

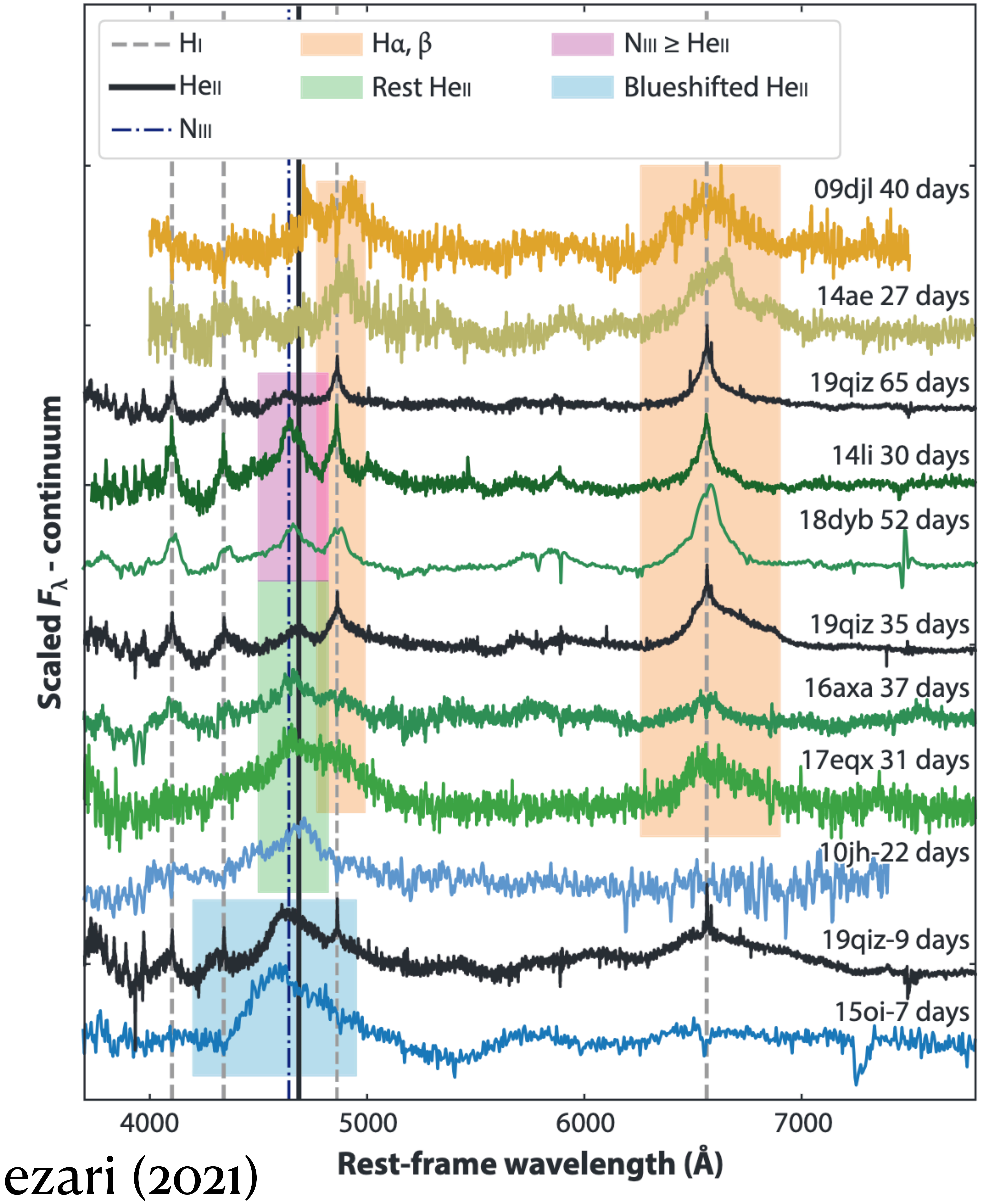


Gezari (2021)

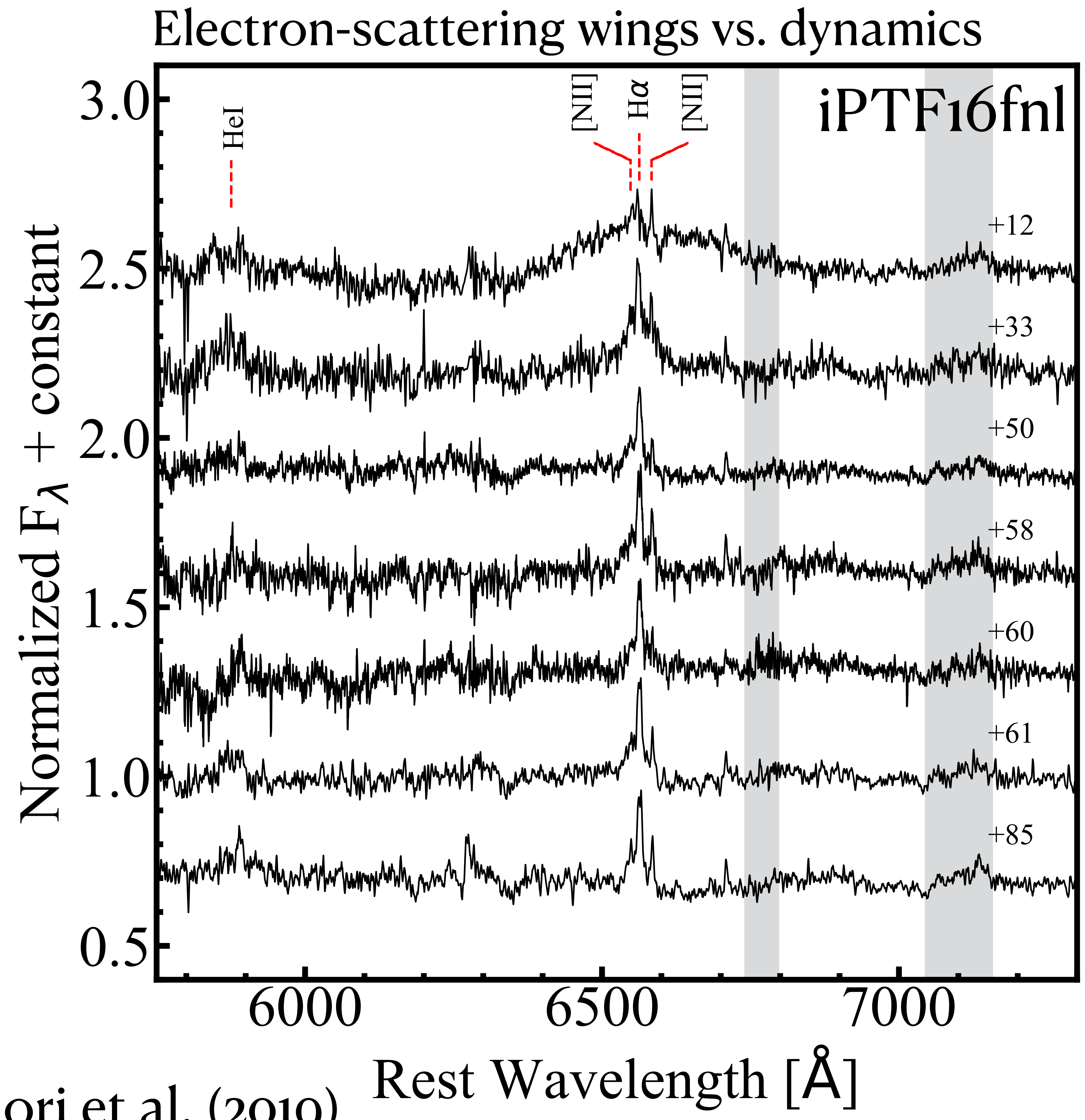


Nicholl et al. (2022)

Mapping spectral types & evolution of TDEs

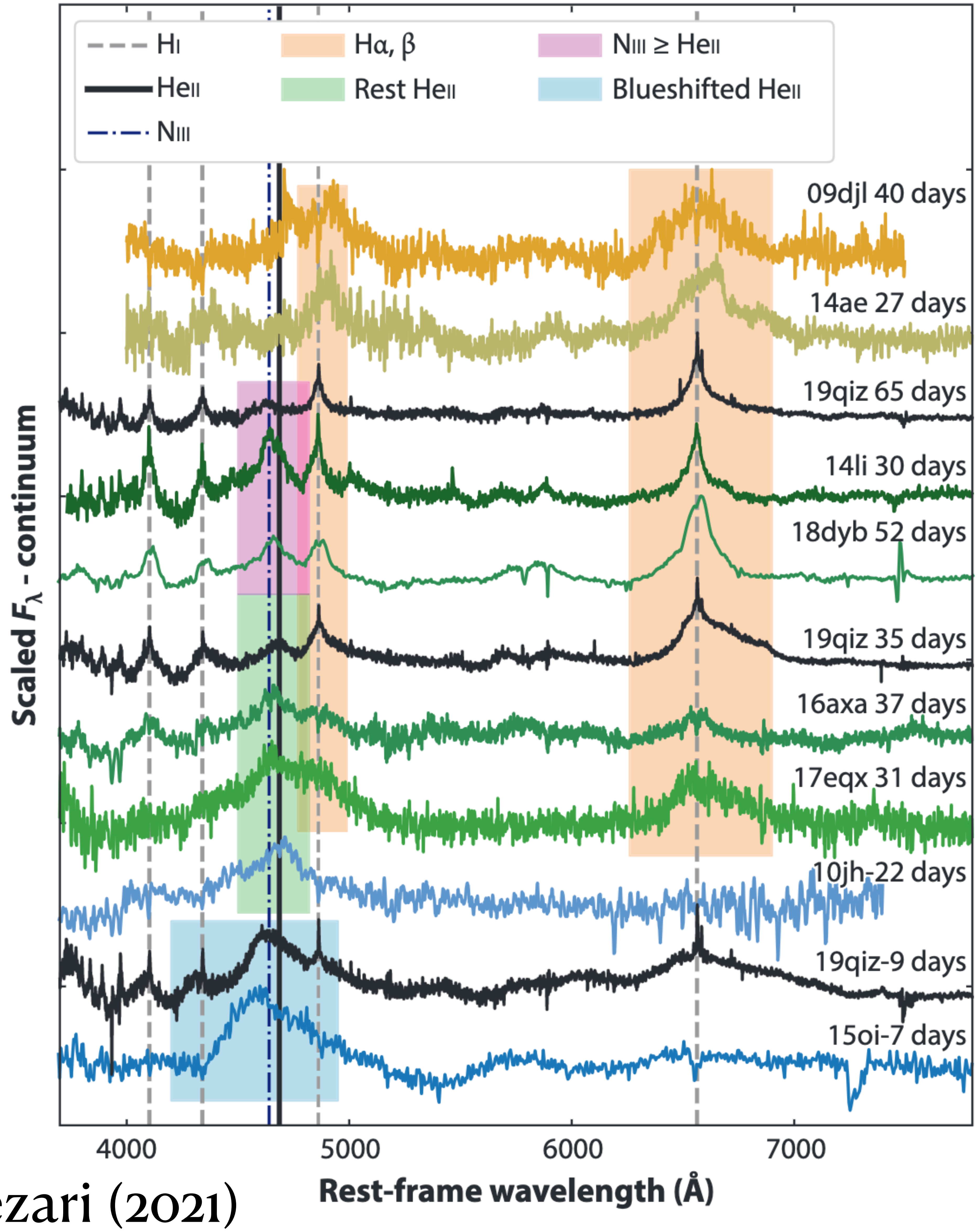


Gezari (2021)



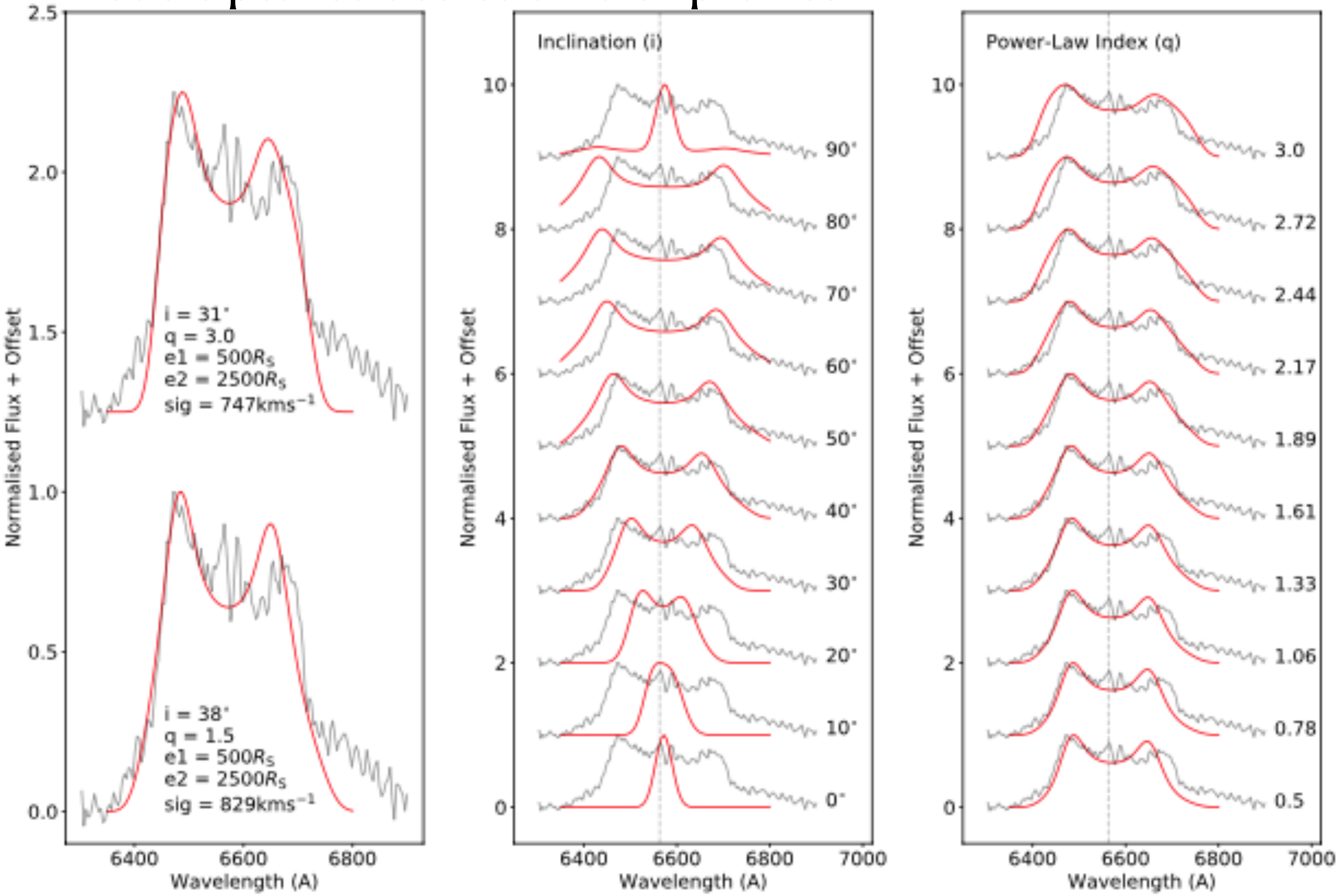
Onori et al. (2019)

Mapping spectral types & evolution of TDEs



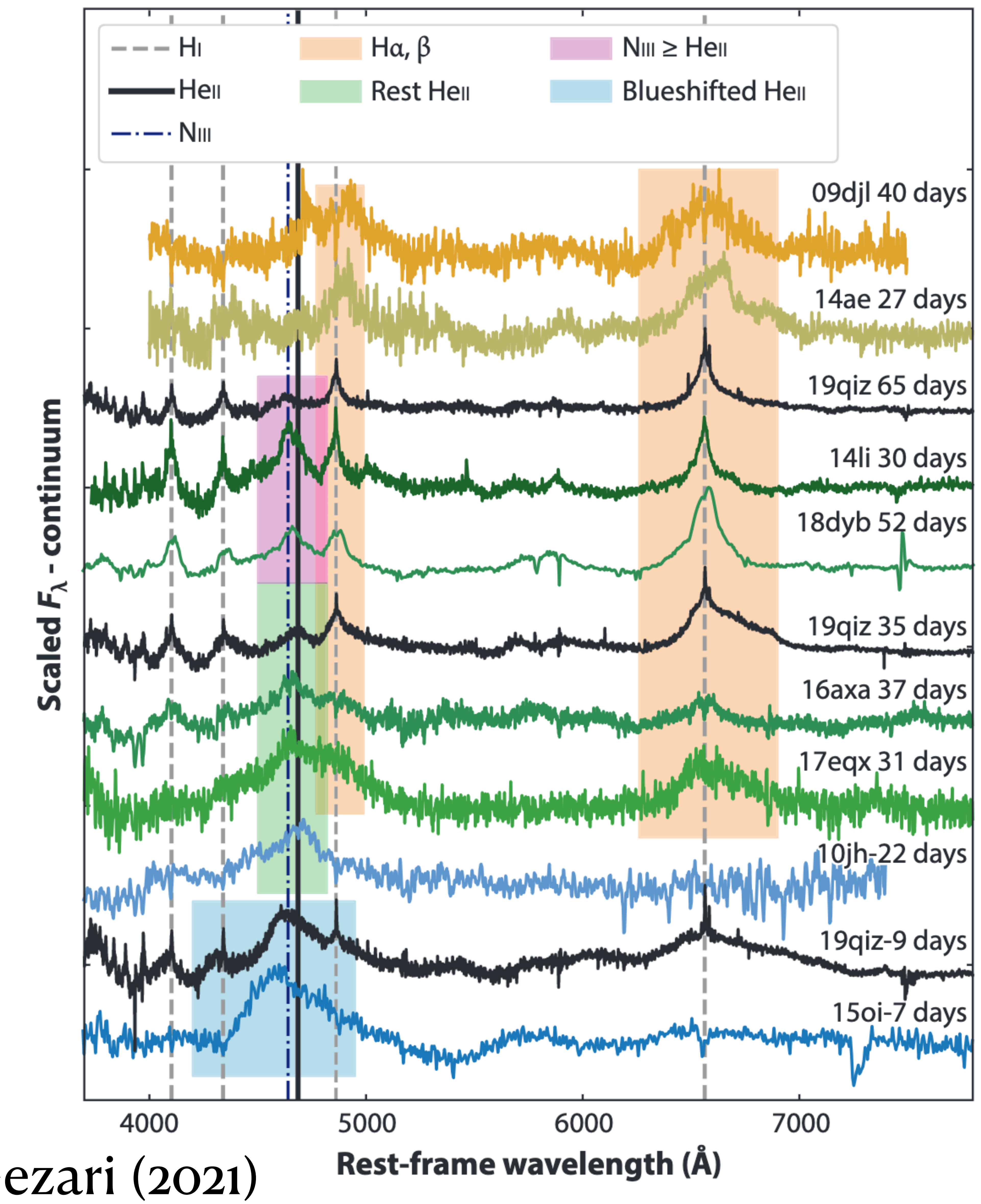
Gezari (2021)

Double peaked accretion-disk profiles

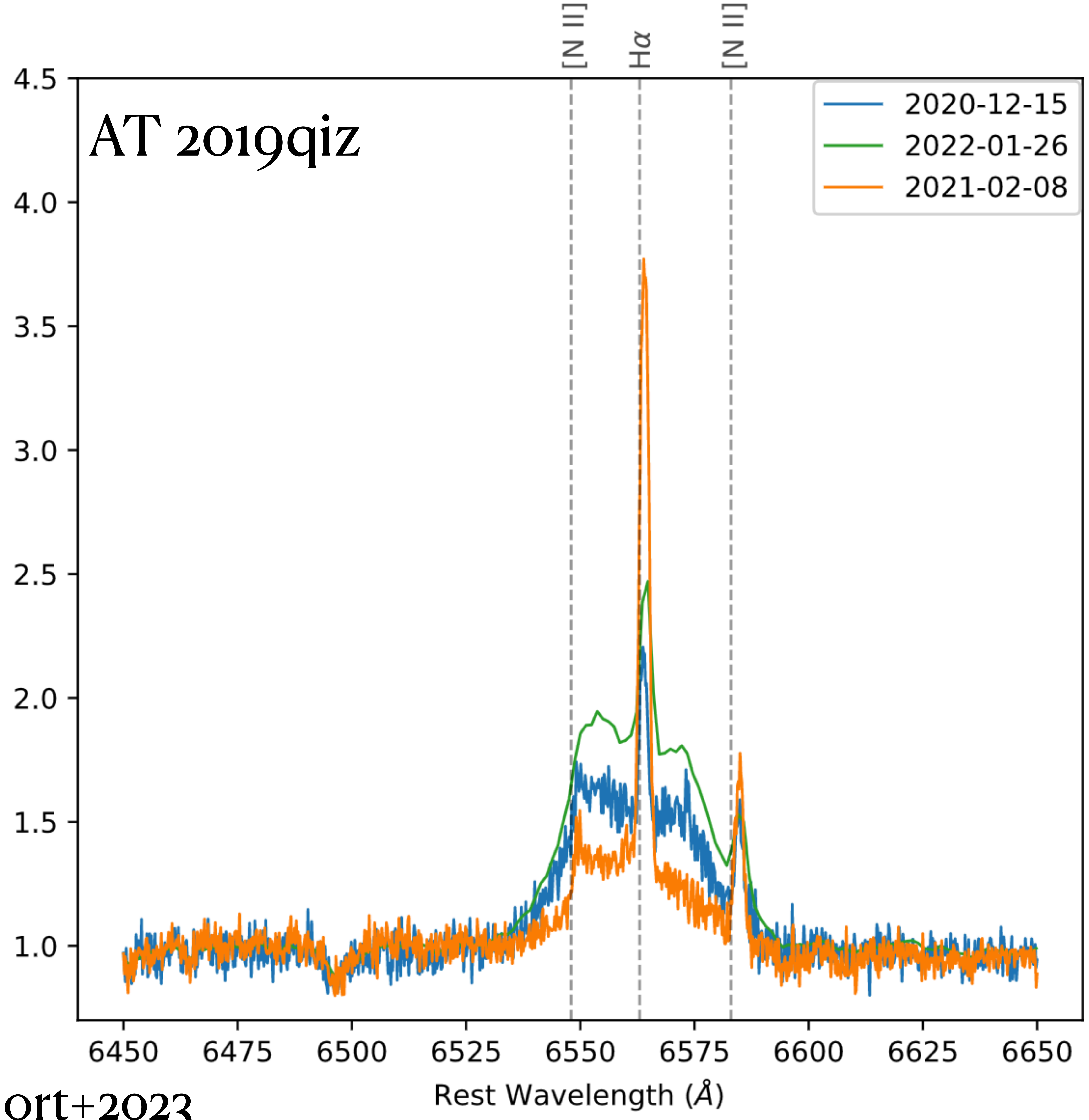


Short et al. (2020), see also Hung et al. (2020)

Mapping spectral types & evolution of TDEs

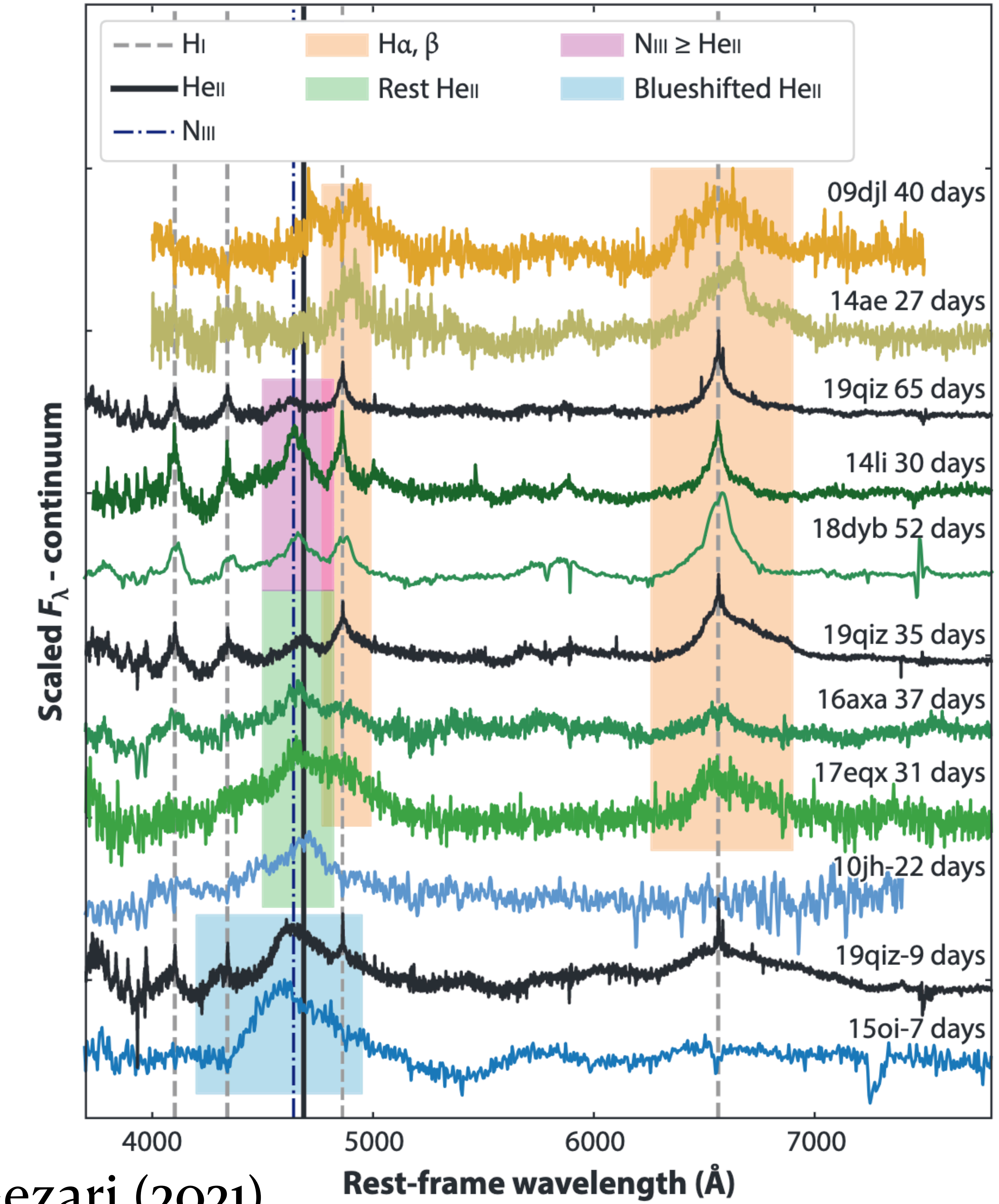


Gezari (2021)

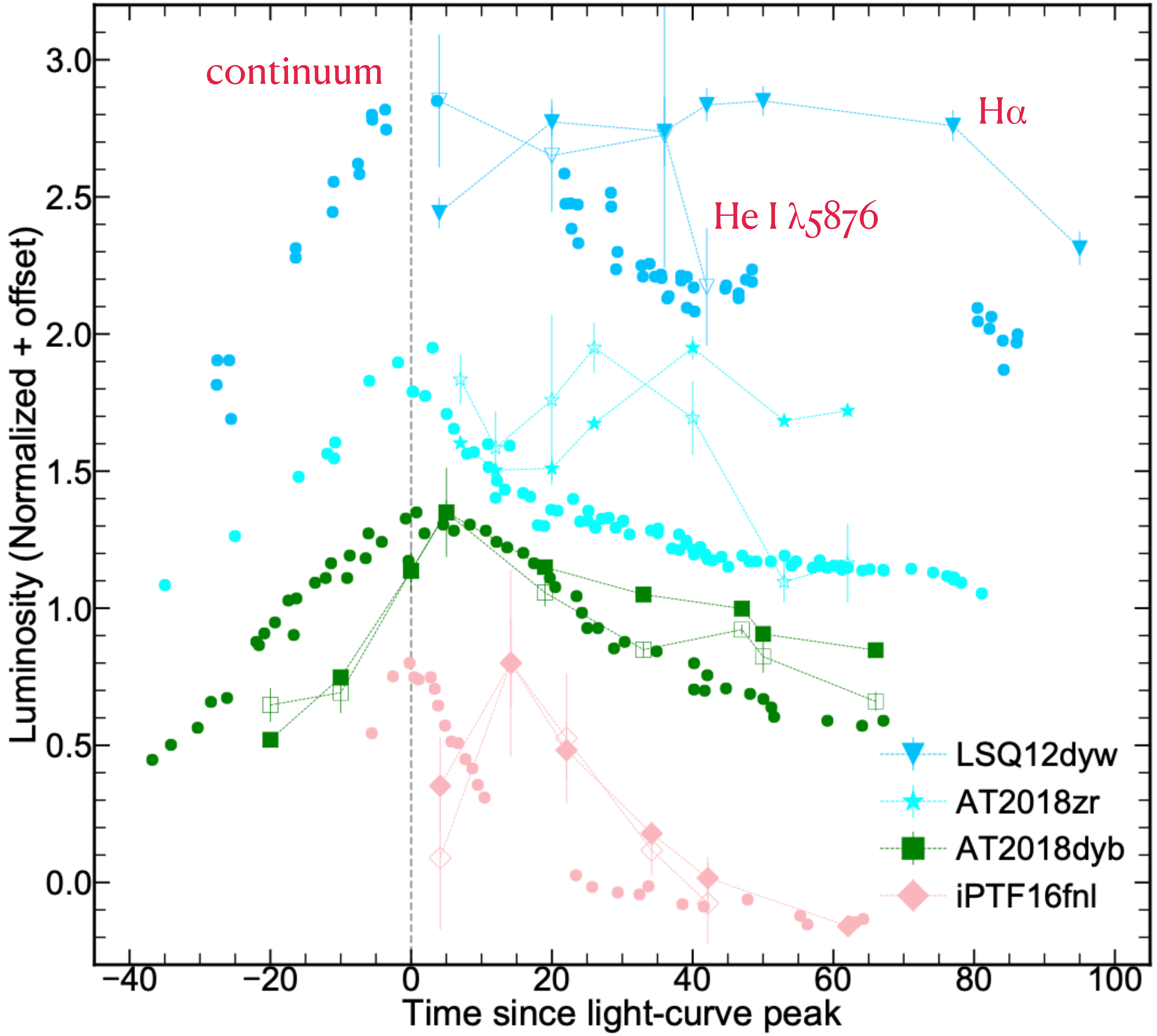


Short+2023

Mapping spectral types & evolution of TDEs

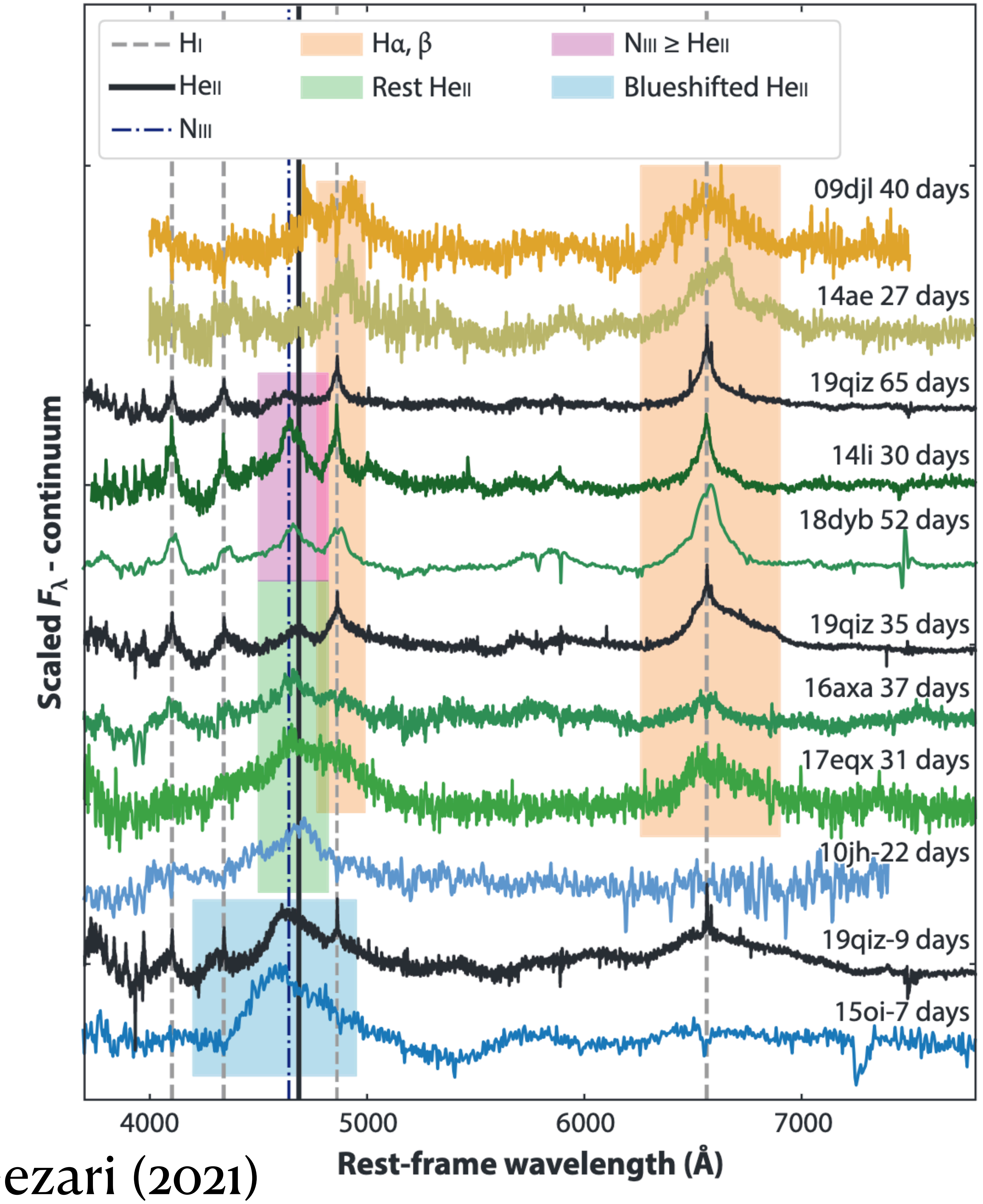


Gezari (2021)

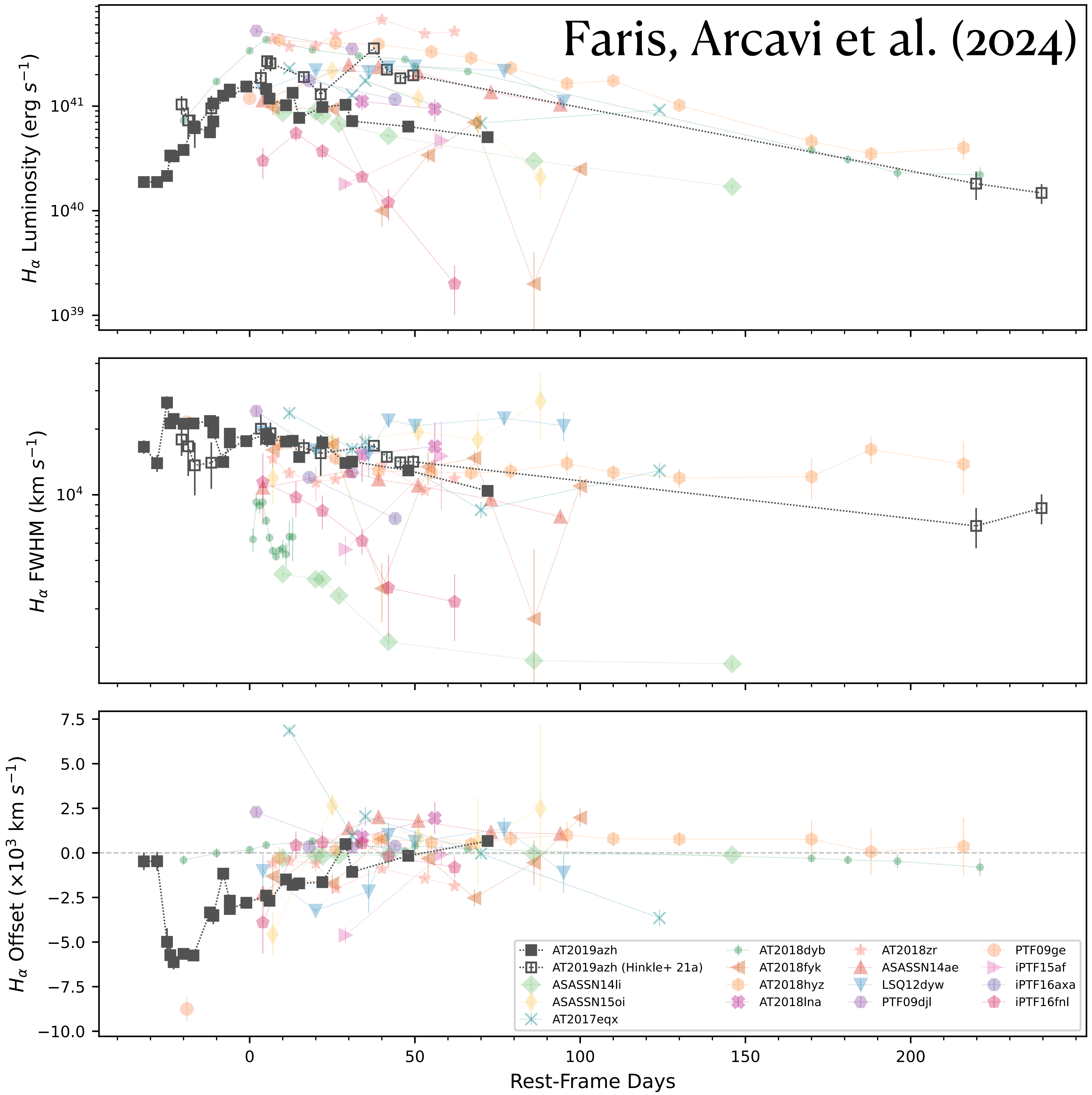


Charalampopoulos et al. (2022)

Mapping spectral types & evolution of TDEs

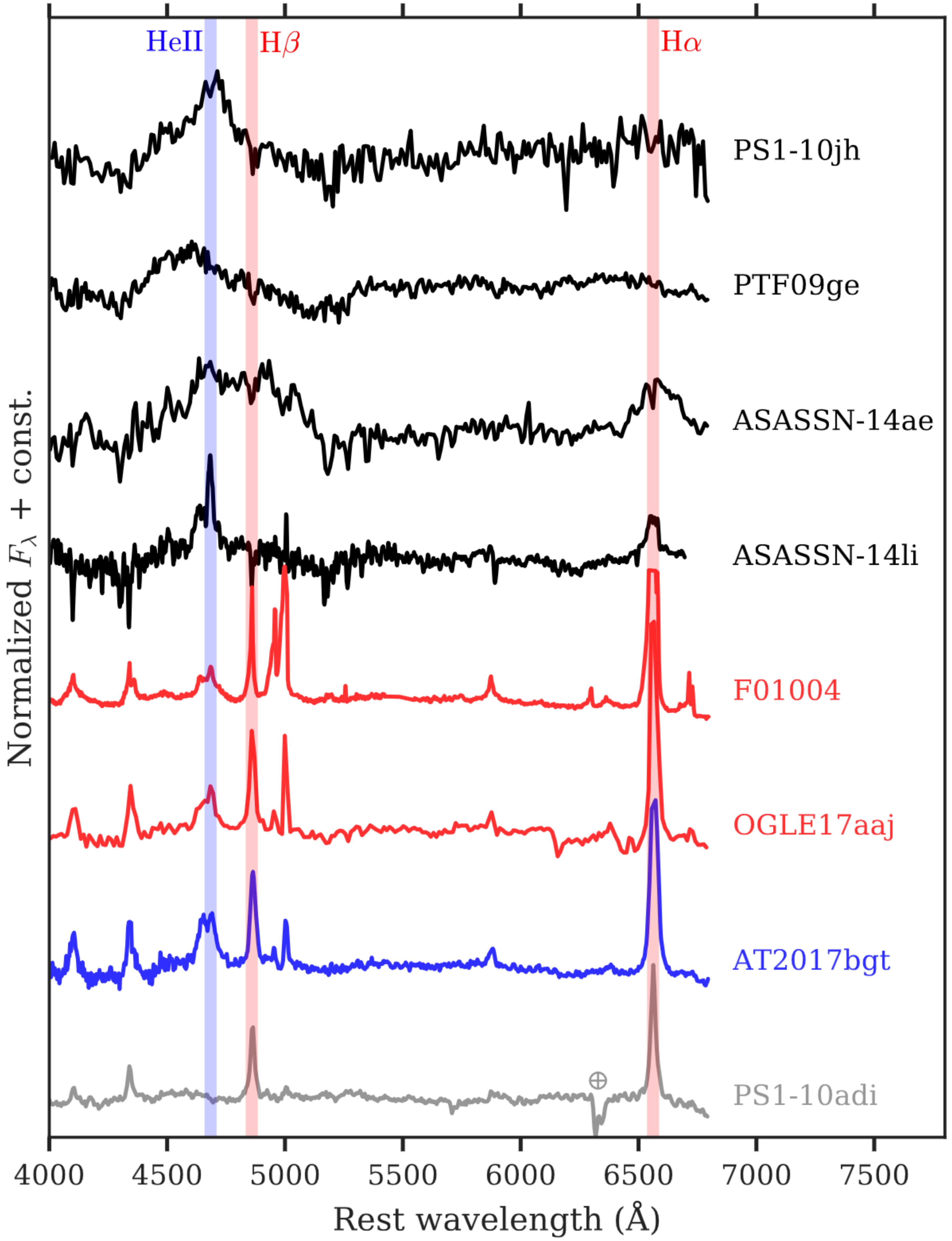


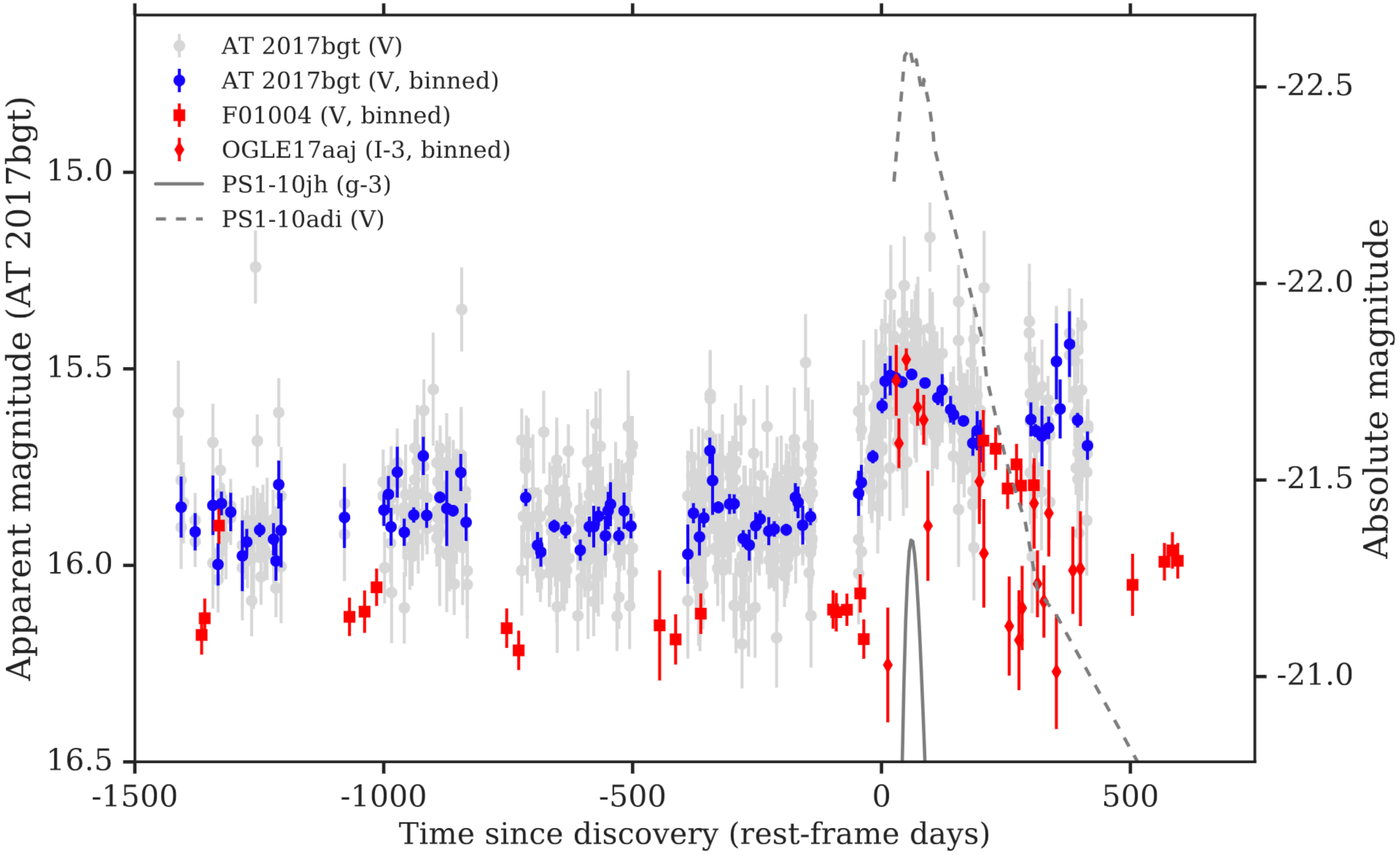
Gezari (2021)



Diversity of nuclear transients

Bowen Fluorescence Flares (BFFs)

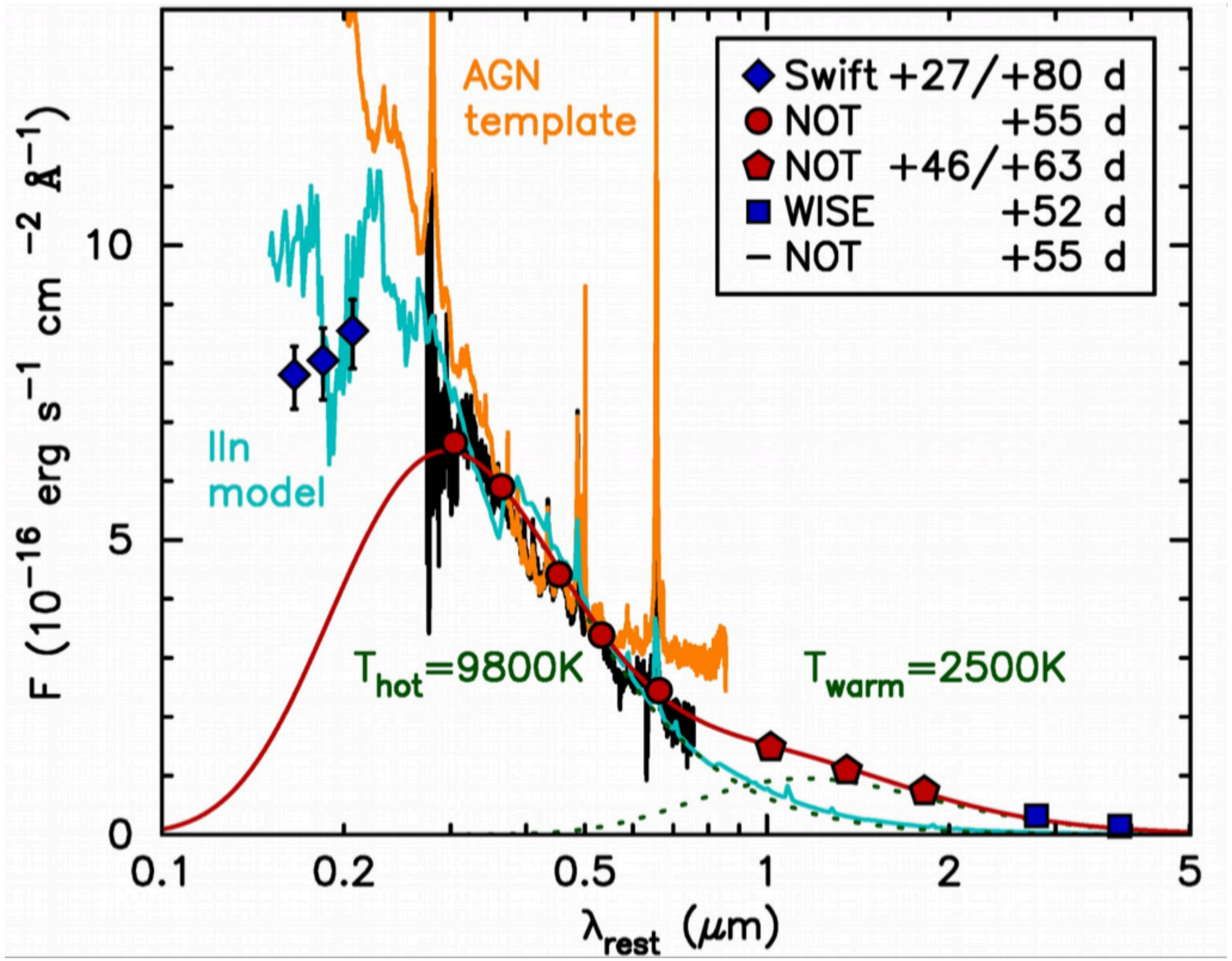


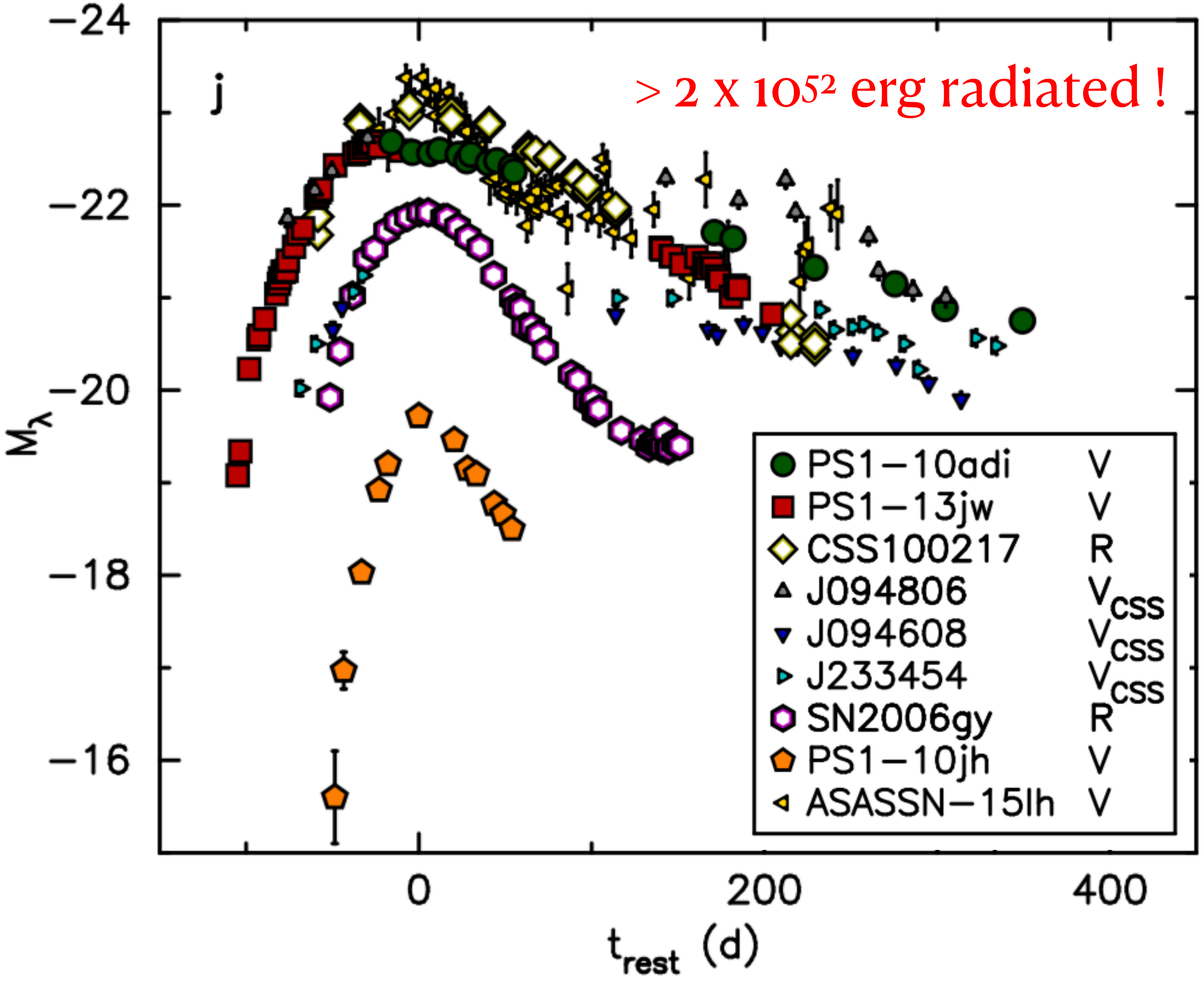


Trakhtenbrot, Arcavi et al. (2019)

Extremely energetic nuclear transients

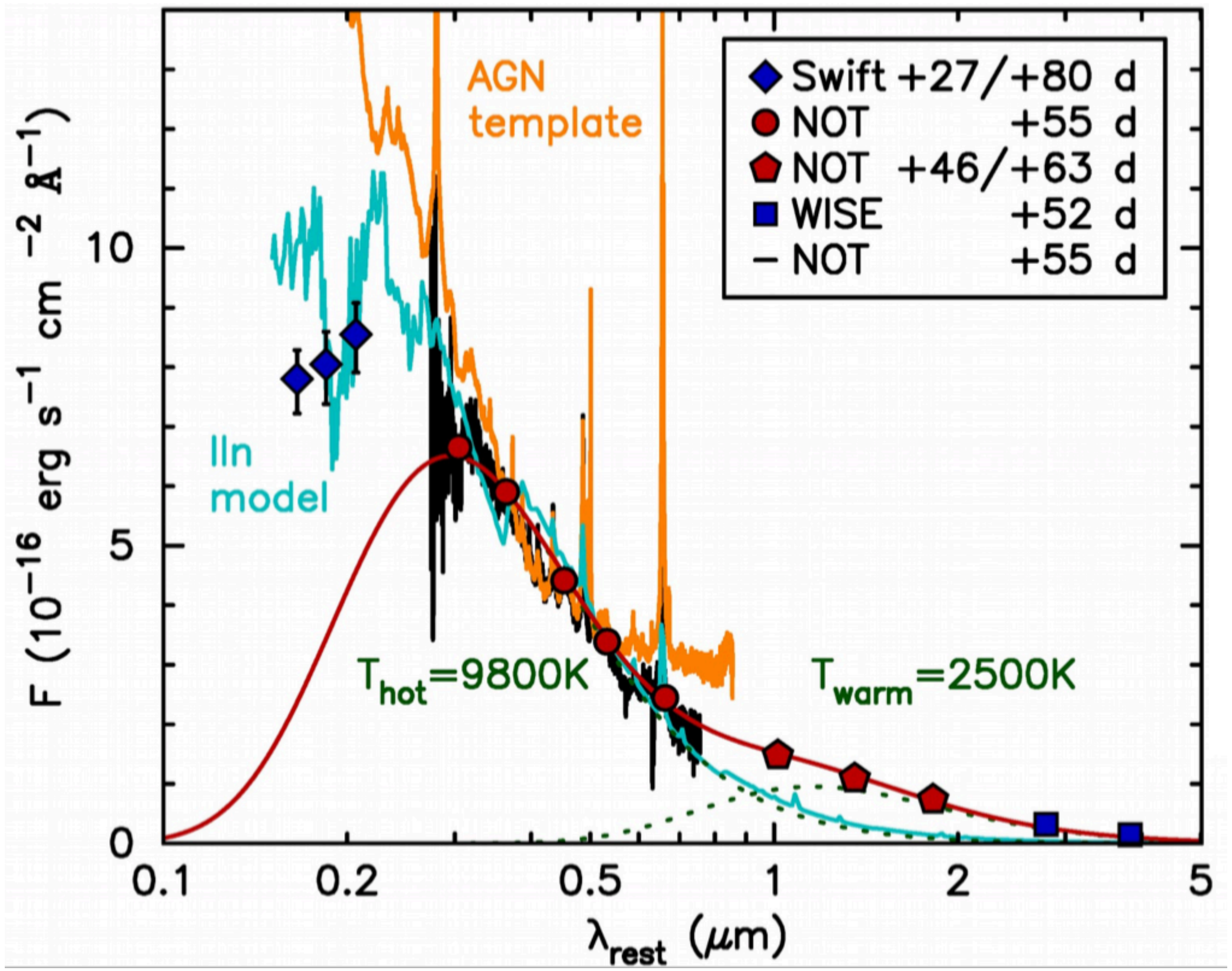
PS1-10adi: Kankare et al. (2017)

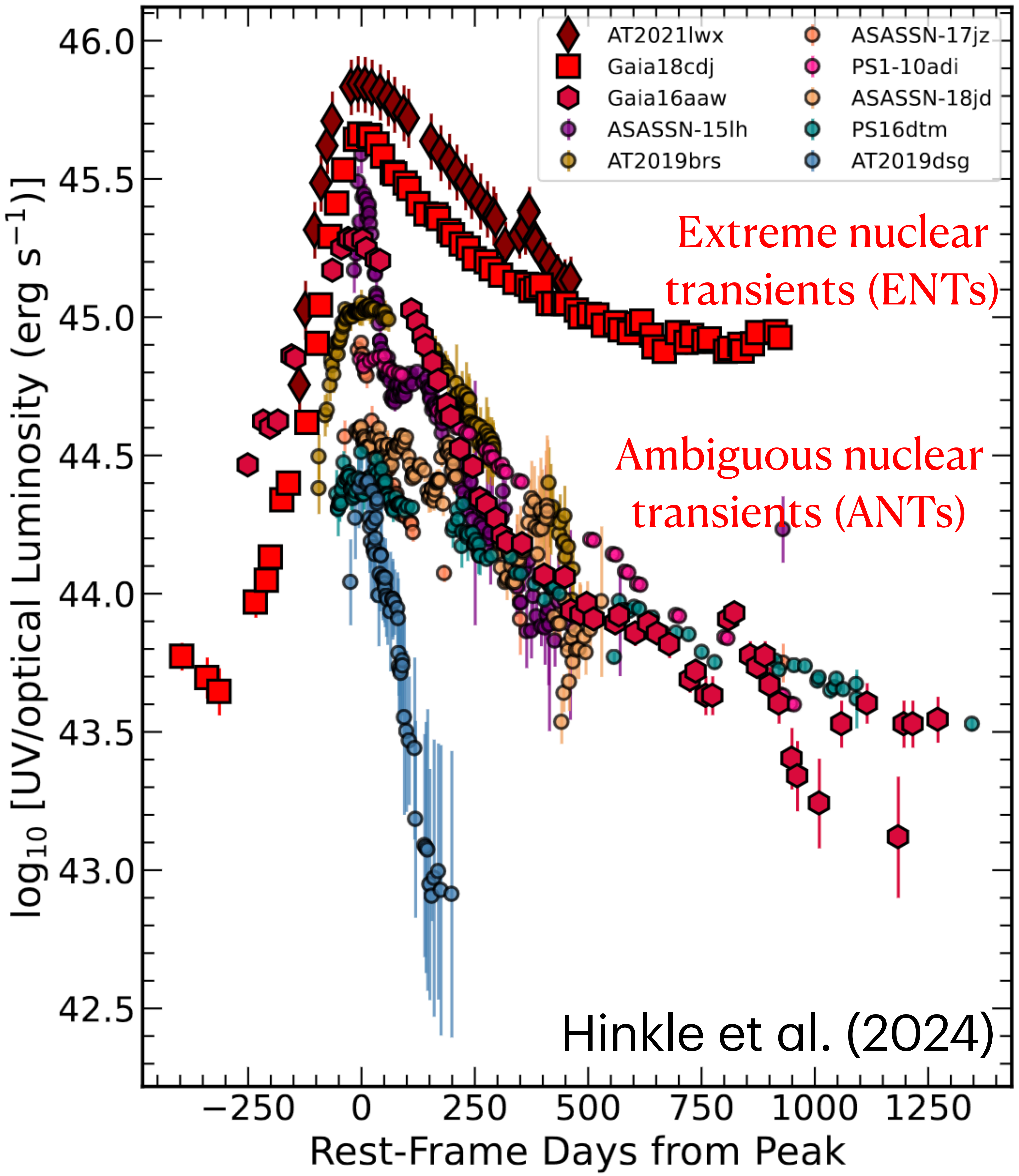




Extremely energetic nuclear transients

PS1-10adi: Kankare et al. (2017)

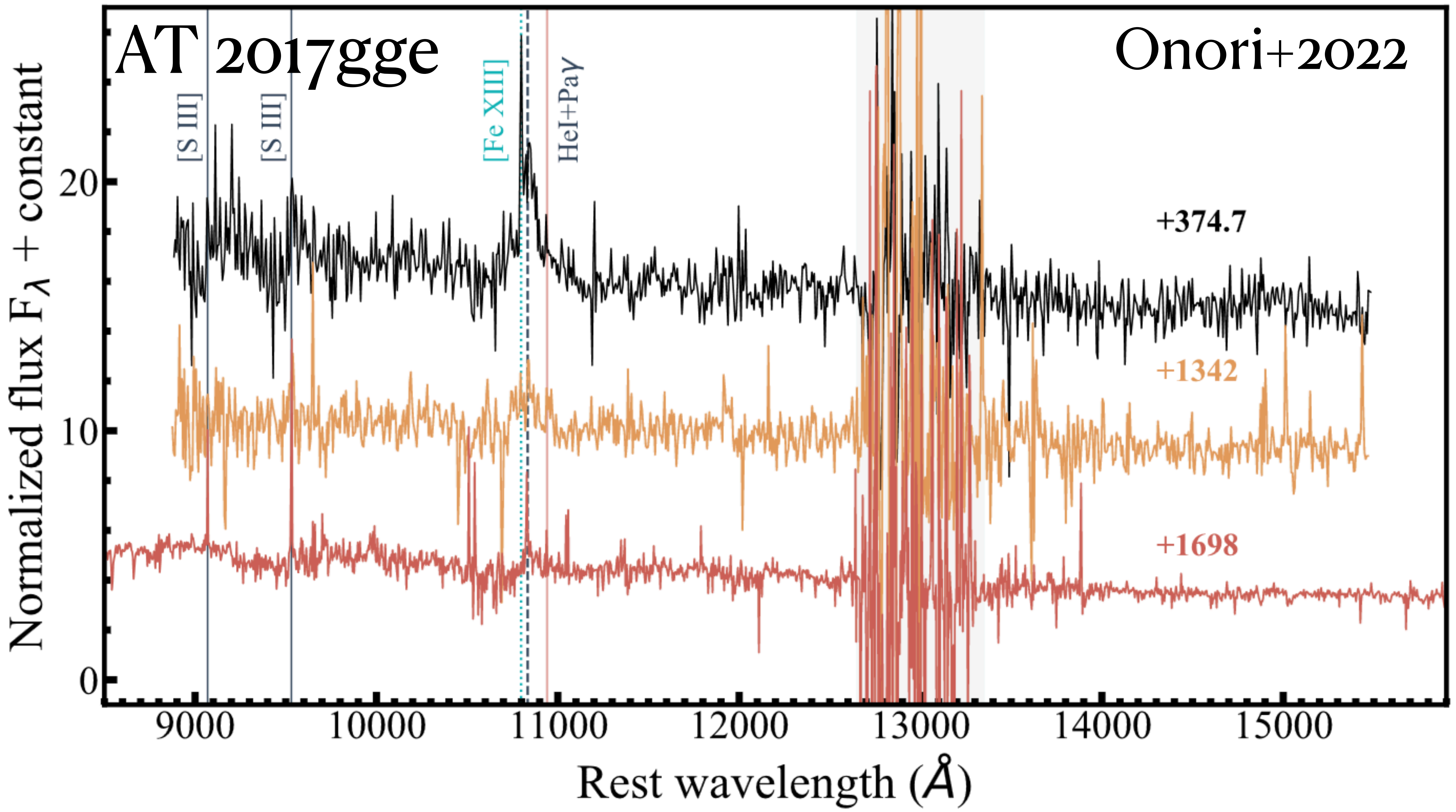


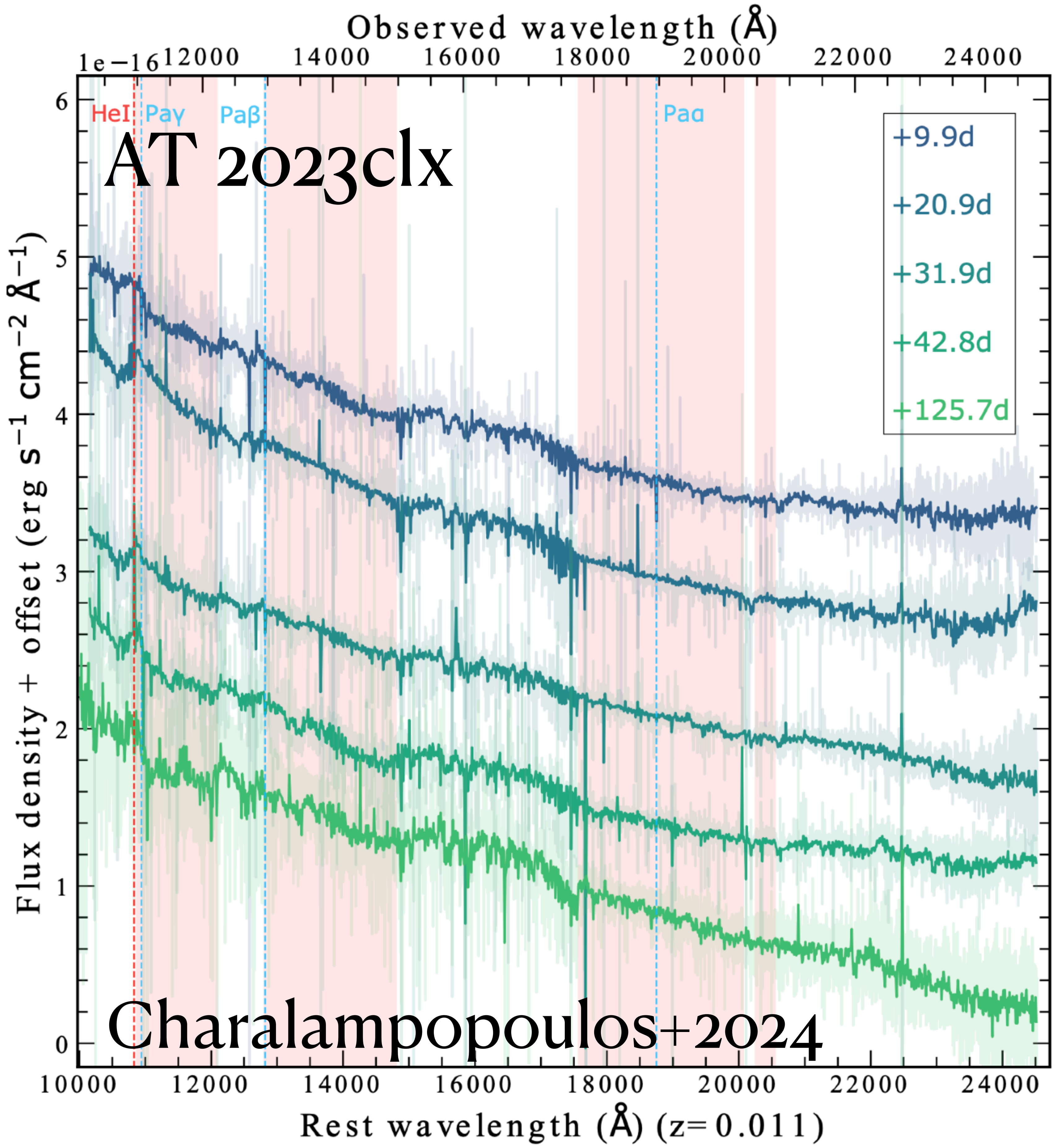


Near-IR coverage

Near-IR spectroscopy of TDEs

- Near-IR spectra of TDEs from NTT/SofI and VLT/X-Shooter
- Broad He I λ10830 detected but no H Paschen or Brackett lines …
- Narrow [Fe XIII] detected in AT 2017gge at 375 days !



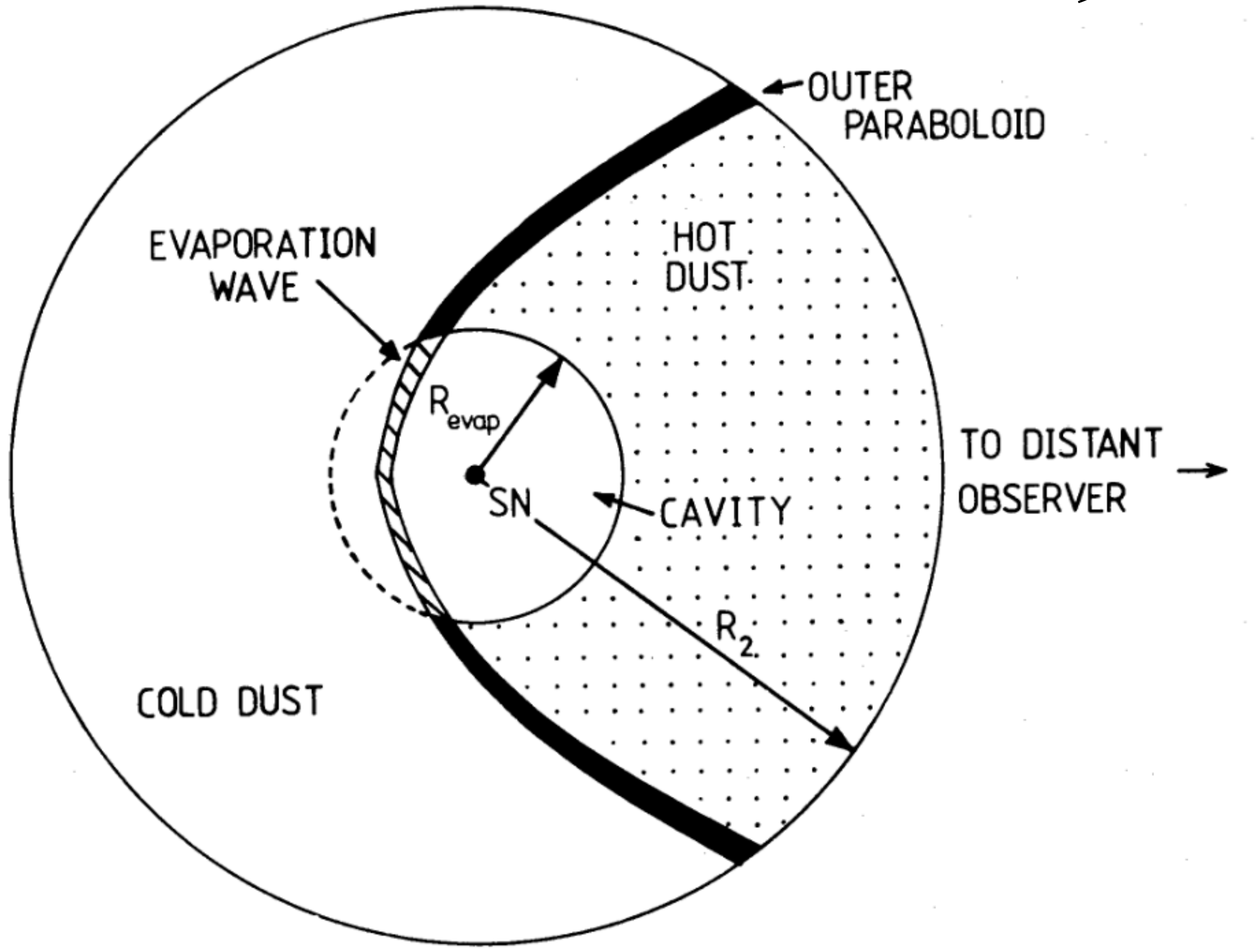


Near-IR spectroscopy of dust obscured transients

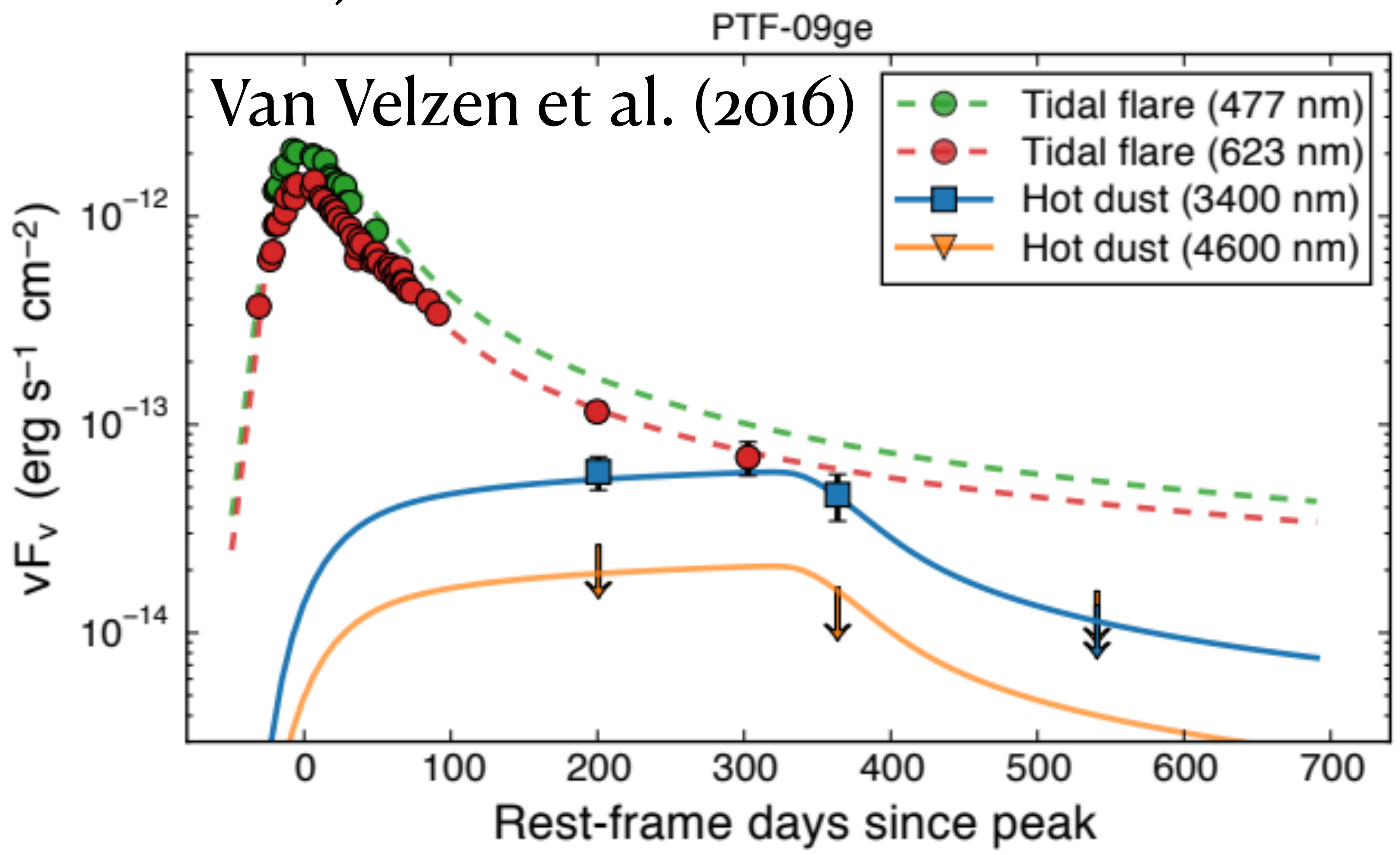
AT2017gbl: Kool et al. (2020)

IR echoes from TDEs

Graham & Meikle (1986)



- Dust exists close to the SMBH even in quiesecent galaxies, AGN have dusty torii
- TDE's radiation can evaporate dust up to a radius determined by TDE's UV/optical luminosity
- Dust outside this absorbs and re-radiates in IR (similar to SNe)
- Delay time (opt - IR) from light travel time effects constrain the evap. radius => TDE's luminosity
- Integrated IR luminosity constrain total rad. energy
- IR echo can act as a TDE bolometer + provide info on the properties and geometry of surrounding dust

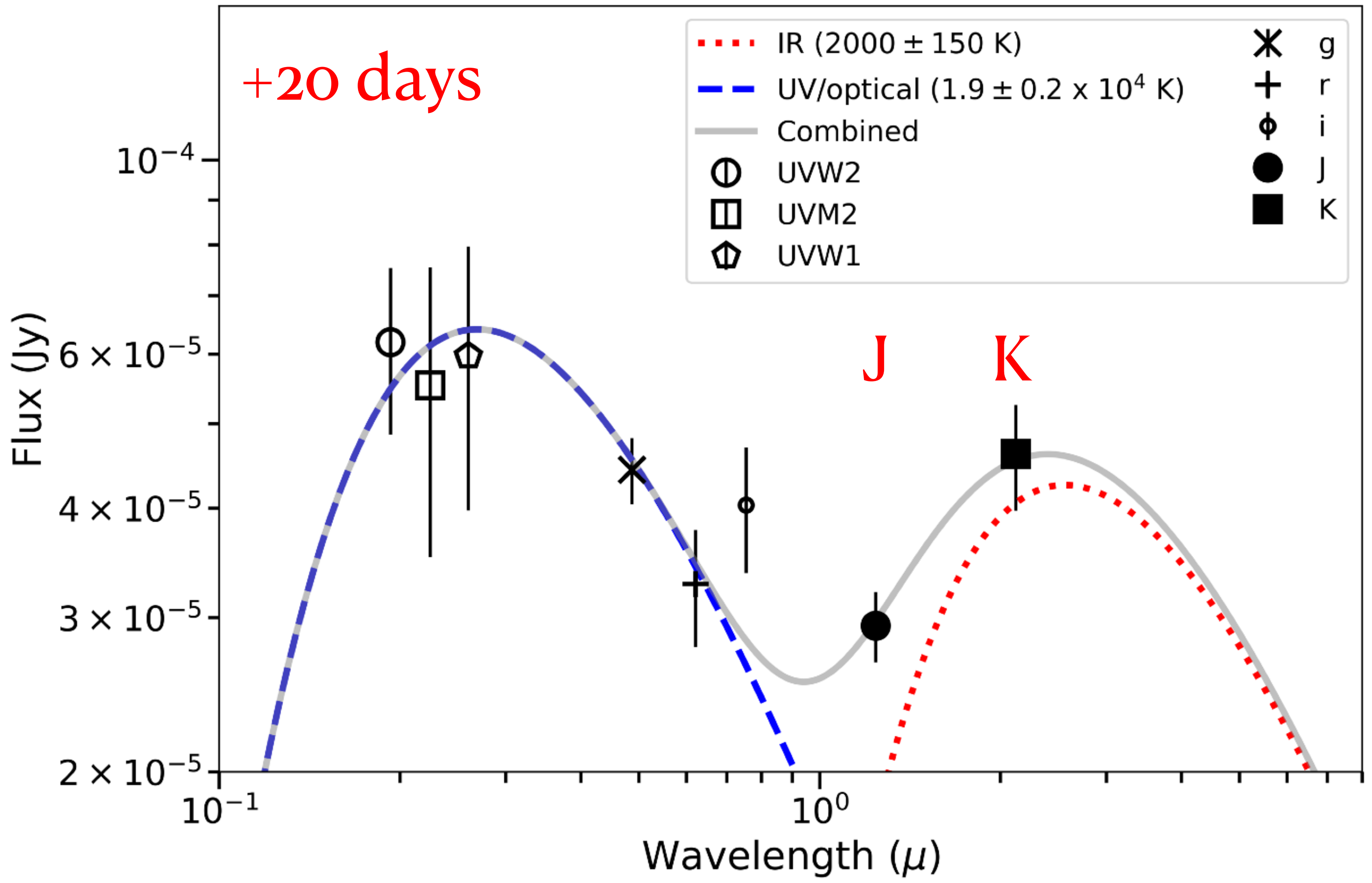


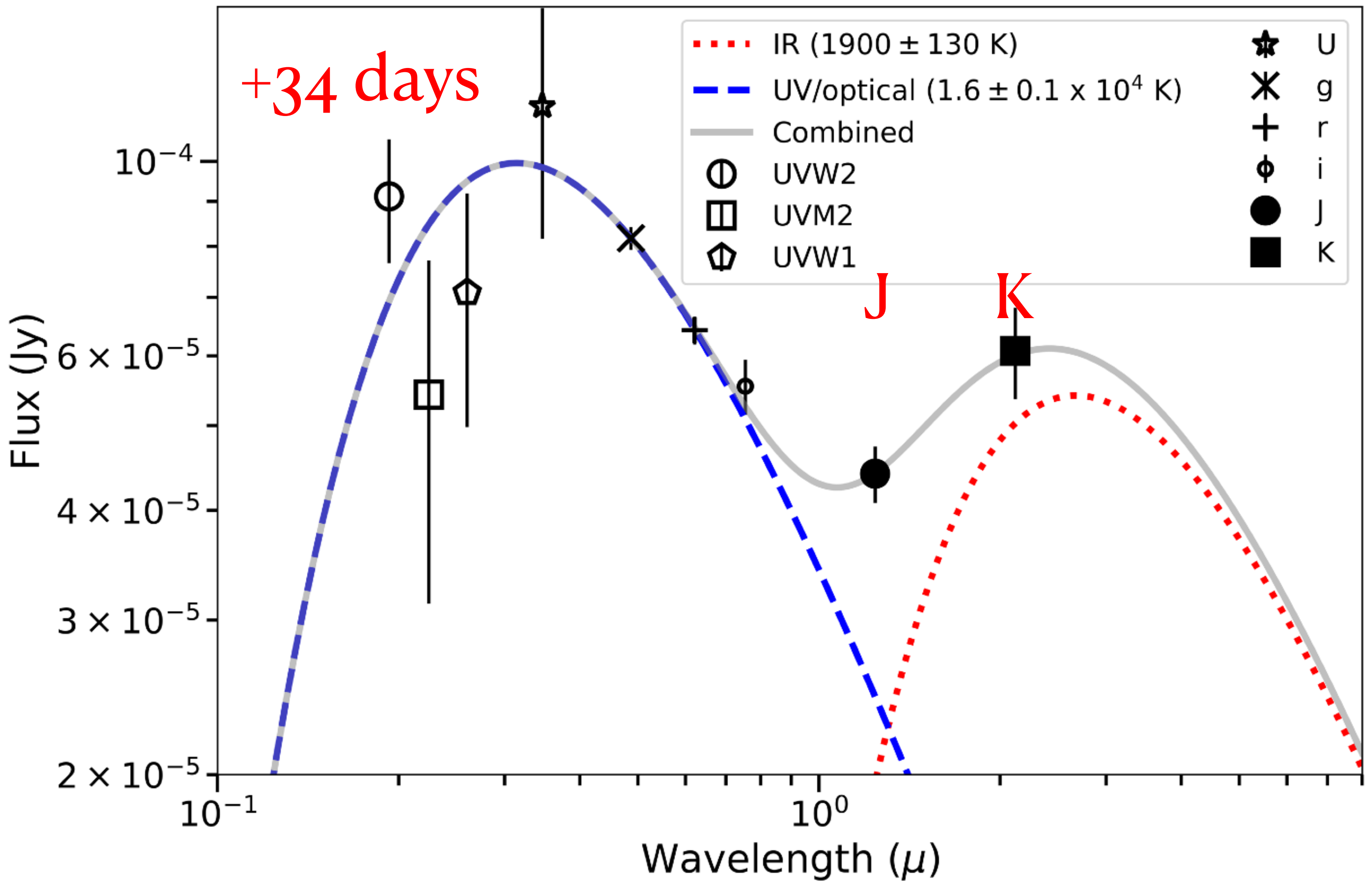
also Newsome, Arcavi et al. (2024)

IR emission from the TDE AT 2021sdu

Kool, Reynolds et al. in prep.

- Simultaneous fit of a "hot" blackbody to describe the UV+optical TDE emission and a "warm" blackbody to describe the IR re-radiation by dust
- Early time NOTCam observations show a clear near-IR excess consistent with re-radiation by dust close to the evaporation temperature (T ~ 2000K)
- Rapid near-IR evolution over 2 weeks showing that ~weekly cadence can be useful!

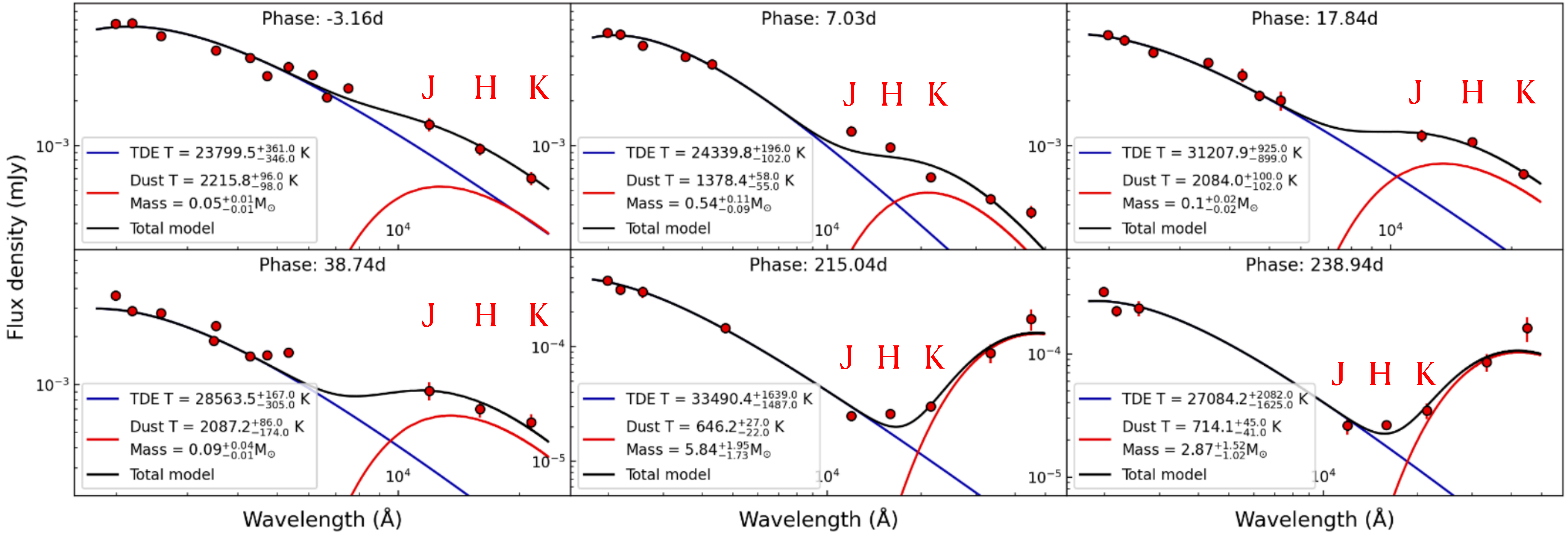




IR emission from the TDE AT 2019azh

Reynolds, Mattila, Nagao et al. in prep.

- AT 2019azh one of the best observed (in UV and optical) H+He TDEs
- Simultaneous fit of a “hot” blackbody to describe the UV+optical TDE emission and a “warm” modified blackbody to describe the IR re-radiation by dust
- In early epochs our 2 blackbody models can’t explain both near- and mid-IR data

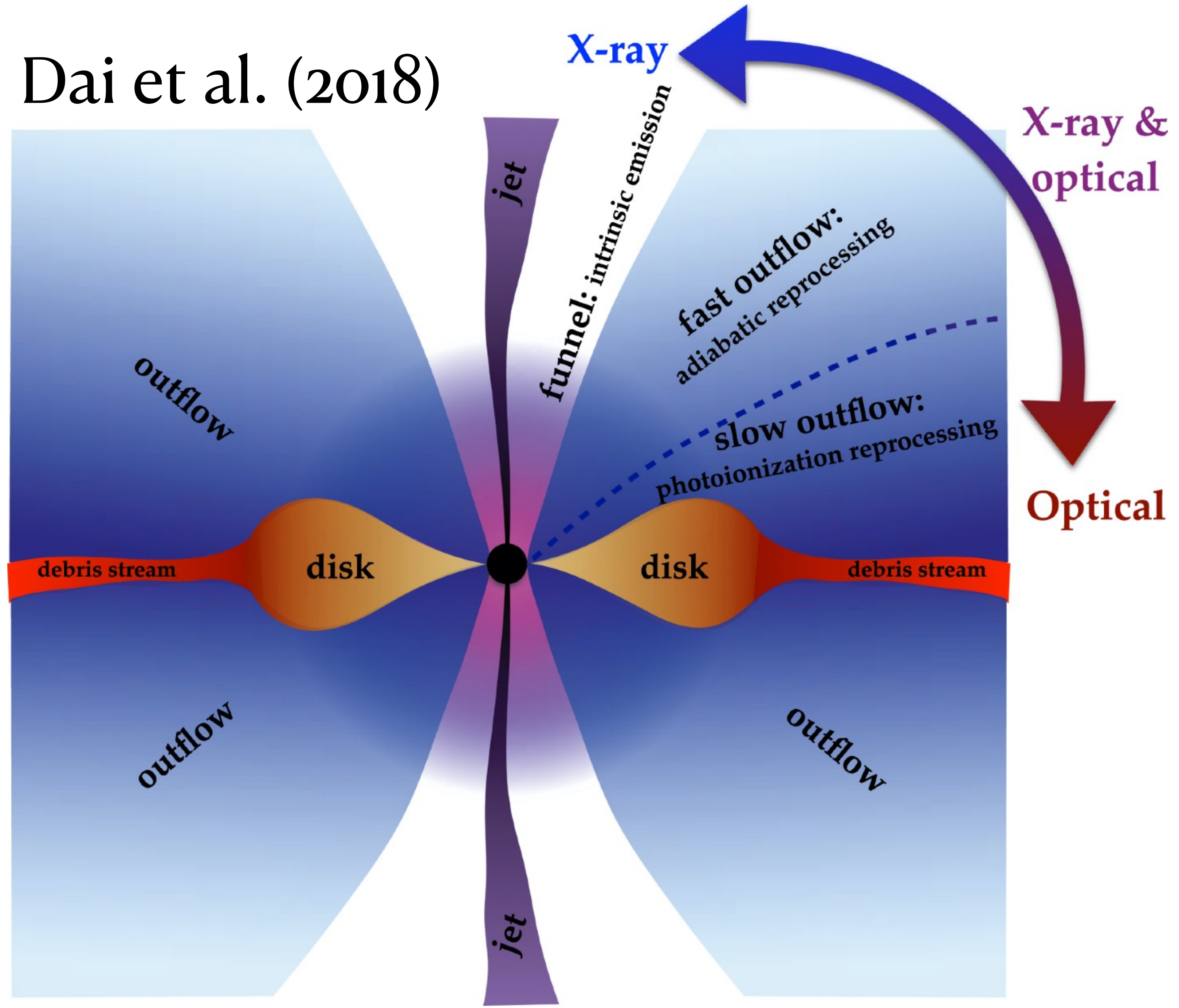


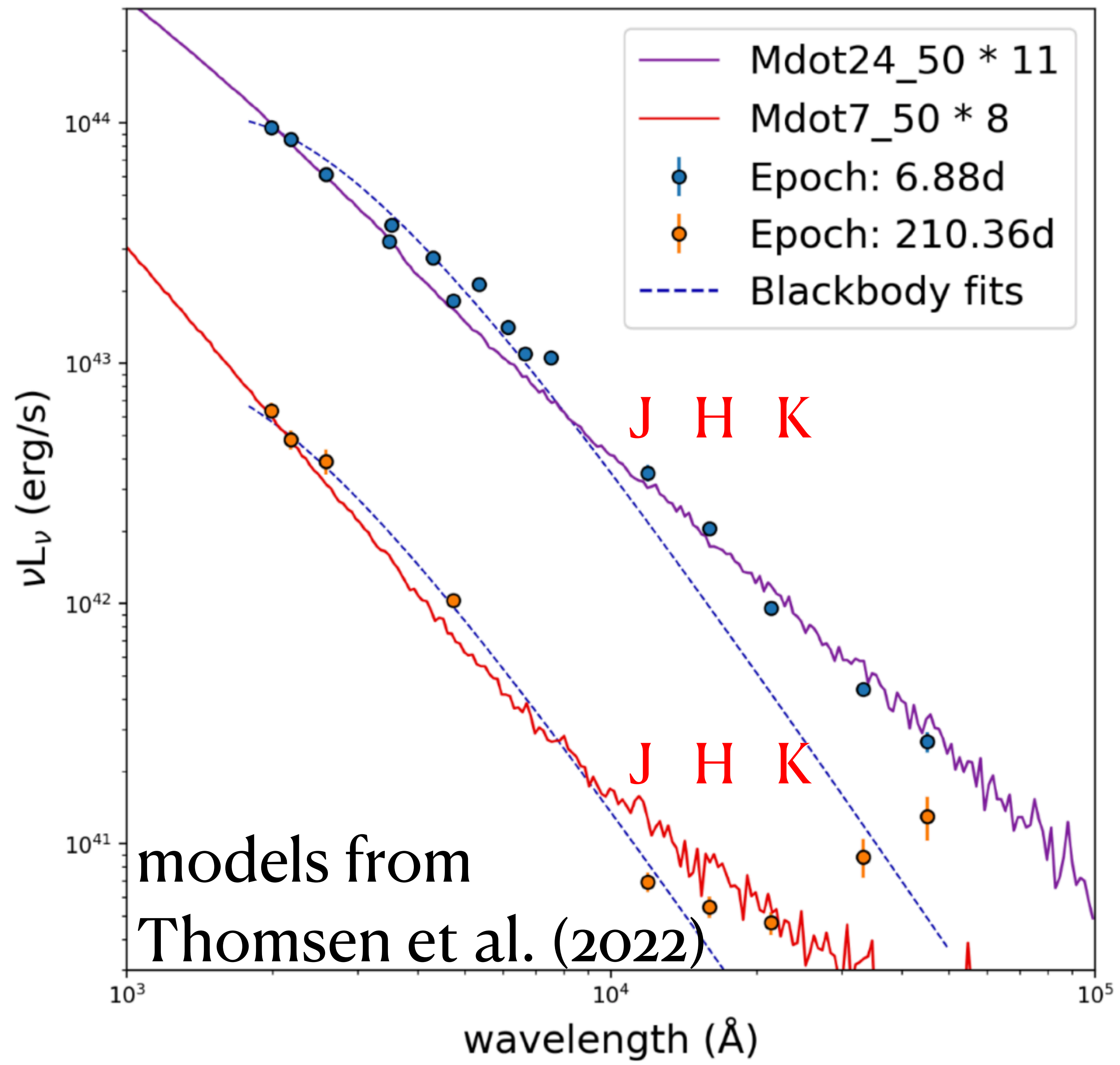
IR emission from the TDE AT 2019azh

Reynolds, Mattila, Nagao et al. in prep.

- Thomsen et al. (2022) calculated reprocessed TDE spectra following the unified model for TDEs that deviate from the simple blackbody approximation
- Explains both near- and mid-IR data at early epochs and near-IR data at late epochs, re-radiation by dust needed for late mid-IR

Dai et al. (2018)





Look forwards

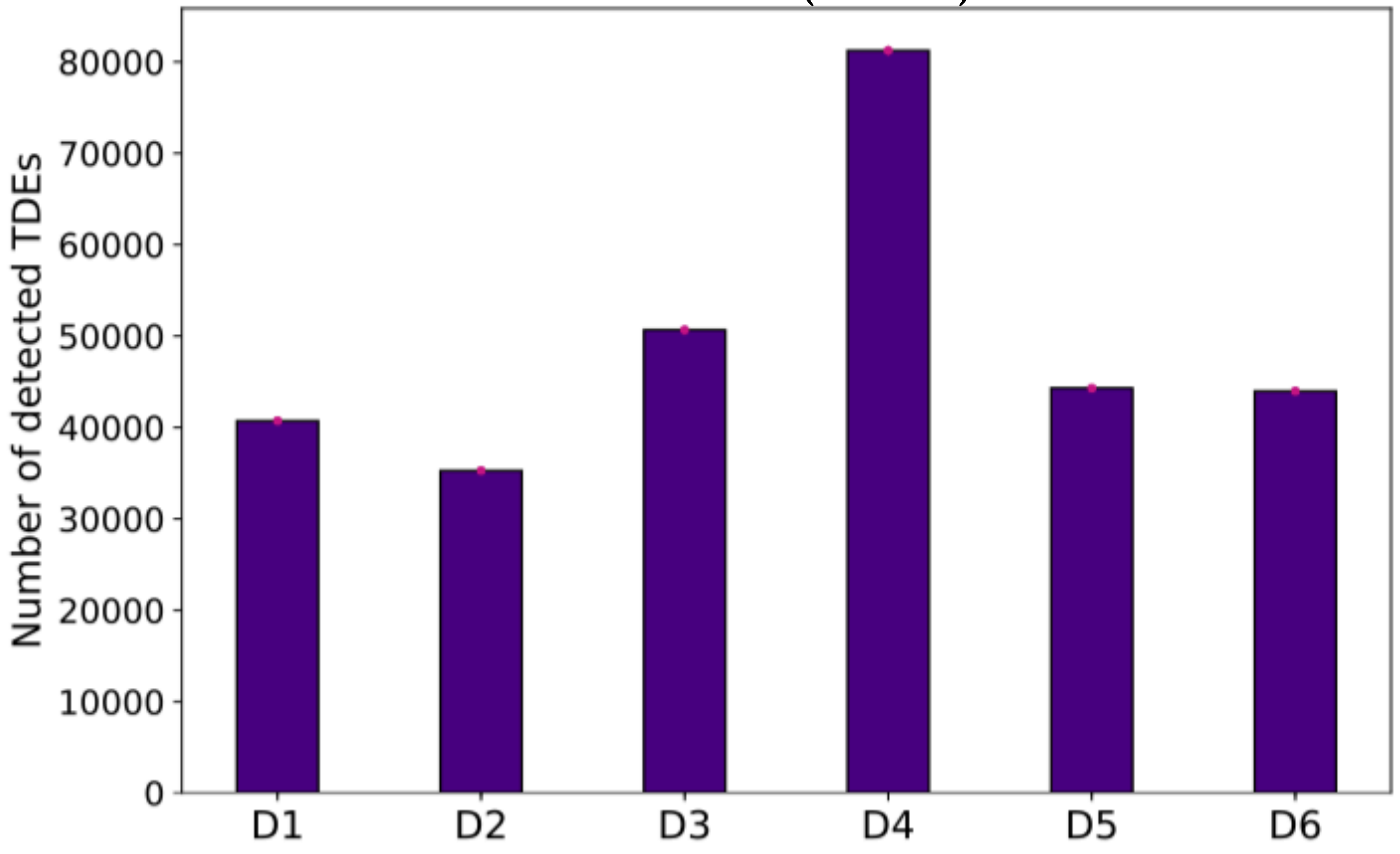
Why use SoXS for TDEs and nuclear transients?

- Spectral resolution R ~ 4500 (< 100 km/s) not typically available in previous studies
  - More accurate removal of underlying nuclear background (especially in AGN)
  - Studies of line profiles and possible narrow line components in the spectra
- Near-IR spectra of TDEs currently lacking: SOXS will cover these wavelengths systematically in all observed events - spectral lines and thermal (dust) continuum
  - Useful mainly for the most nearby/luminous events and/or dust obscured events
- Whole dataset obtained in a controlled way with a single instrument will allow more accurate host galaxy subtraction using template spectra
  - ADC will allow to use a fixed position angle for the slit
- Time available over 5 yrs will allow systematic follow-up of long-lasting events

How many TDEs are in the reach of SoXS?

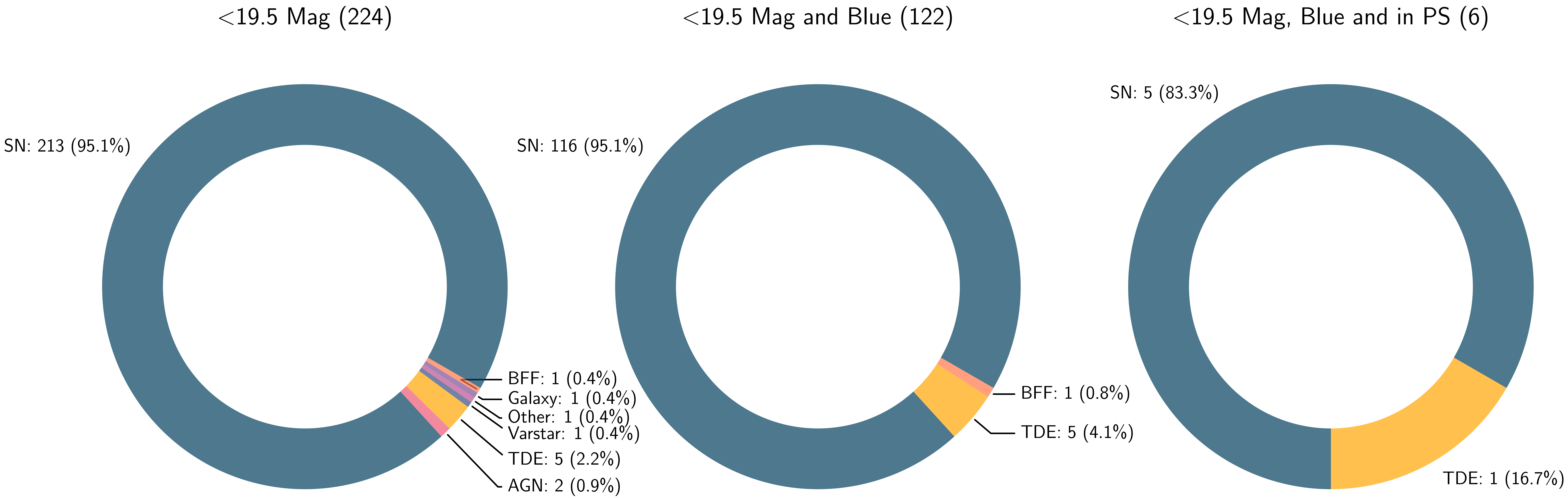
- Expect ~35 000 - 80 000 TDEs detected by LSST over 10 yrs
- Assuming M(peak)~ -19 to -20, this implies a volume within z~0.15-0.2 for mag<20
- ~3500 - 8000 TDE within z < 0.2 i.e. ~350 - 800 TDE yr^{-1}
- Let's assume rates are overestimated and we may not be able to identify all of these, so say 100 TDE yr^{-1}
- Before LSST numbers will be much lower !

Bricman & Gomboc (2020)



Needle in a haystack …

- Examined 224 spectroscopically classified nuclear transients from ZTF public alerts with no history of previous activity



Dgany, Arcavi et al. (2023)

Nuclear transients science for SoXS
(from the SoXS science meeting in 2020)

- Complete sample of TDE within 100 Mpc for legacy purposes
- Spectral evolution with emphasis on spectra before the peak
- Dense spectroscopic monitoring on early stages to constrain the mass of the disrupted star
- One spectrum near the peak for every TDE within z ~ 0.2 for demographics of TDE types and hosts
- Extremely energetic (~10^{52} erg) nuclear transients (e.g. PS1-10adi) and energetic nuclear transients in dust obscured environments
- Luminous nuclear transients in AGN hosts

SoXS WG10 look forward

- Prepare one internal proposal including all the nuclear transients topics?
- Total request of SOXS time **~150 hours per year** to be divided between the national/partner GTO shares
- Overlap with the AGN WG9 on nuclear transients in AGN: agreed on collaboration on case by case bases
- Possibility of observe a significant number of nearby TDE candidates (1 spectrum per event) in the classification WG13 for demographics of TDE types and hosts
- Anyone not yet included in WG10 and interested in these topics please contact Seppo and Iair !
- **WG meeting over the lunch to start discussions in prep. for the internal proposal(s) !**

extra slides for discussion session

Which are our triggering criteria

- **Classification**
  - E+A hosts, blue colour, slow rise (need to get rid of SNe Ia) …
  - But also need to control biases (dust extinction, biases against certain host galaxy types etc.)
  - How much classification do we want / need ?
  - Where will these come from and how much from us vs. others?

Which are our triggering criteria

- **Follow-up**
  - TDEs above some threshold brightness at peak that we can follow into the tail phase, obtain sufficient S/N also in the near-IR (IR excess and lines incl. high ionisation narrow coronal lines)
  - TDEs discovered before peak to study the early evolution (not many early studies exist, clues regarding the line forming location and physics)
  - Repeating TDEs?
  - Very nearby events to have multi-wavelength (incl. polarimetry / radio / mid-IR / X-ray) coverage
  - Extremely energetic nuclear transients (above some absolute magnitude threshold) with unclear origin
  - Relativistic TDEs - optical/near-IR follow-up
  - What to do in GTO vs. normal proposal(s)?

Access to feeder surveys and other observing facilities

- feeders: LSST, BlackGEM, ZTF?, GOTO, ATLAS, LS4, 4MOST, Gaia Alerts, ULTRASAT (2027)
- optical photometry: LCO, REM + ??
- near-IR photometry: GROND, TAO (through collaboration) + ??
- mid-IR observations: JWST, TAO (through collaboration), NGRST (2026)
- radio: though collaborations: ATCA, VLA, MeerKAT, ASKAP, VLA sky survey …
- X-ray: XMM, Chandra, Swift
- UV: HST, ULTRASAT (2027)

Special requirements for the observations and data reductions?

- Requirement for accurate host galaxy subtraction using template spectra
  - Use a fixed slit position angle (use ADC to compensate for differential atmospheric refraction)?
  - Accurate centering of the slit in all the observations
  - Minimise the effects of seeing?
- Best ways to carry-out the subtraction
  - 1D vs. 2D ?
  - Rectified 2D spectra vs. curved spectra?