Swift, ASAS-SN and "AGN"

- Normal AGN Variability
- (Repeating) Tidal Disruption Events
- ANTs and ENTs
- Changing Look AGN

ASAS-SN and co-conspirators, including (but not limited to) K. Stanek, B. Shappee, J.-L. Prieto, S. Dong, J. Hinkle, M. Tucker, J. Neustadt, A. Payne, W. Hoogendam, P. Pandey……

All-Sky Automated Survey for Supernovae – ASAS-SN

- 20 14cm telescopes located in South Africa, Chile, Texas, Hawaii
- Started collecting data in 2014
- In good conditions, images the entire visible sky to g~18 mag every ~20 hours
- Data immediately publicly available – continuously updated light curves for ~100 million sources, you can get a light curve for any position on sky
- General purpose – transients (SN, TDEs, flares ……), AGN, variable stars,…….

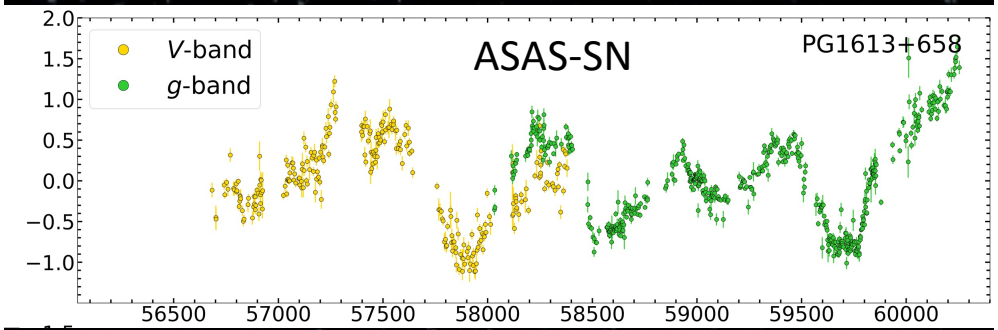
Since 2014, ~10% of Swift papers also reference ASAS-SN
Probably 100s of Swift TOOs

Not unique to ASAS-SN – almost certainly true of ZTF and ATLAS as well

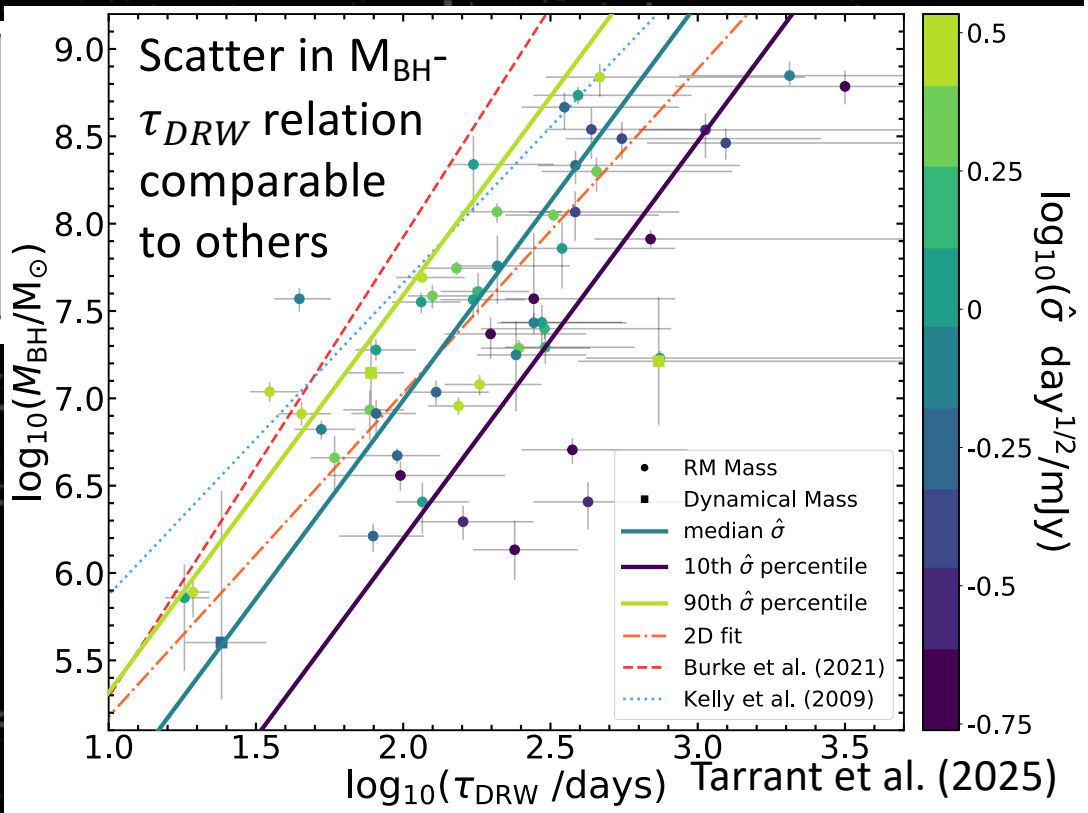
Normal AGN Variability

Reasonably (but not perfectly) modeled as a Damped Random Walk Gaussian process - two parameters - time scale τ_{DRW} and amplitude

Parameters correlated with rest wavelength, black hole mass

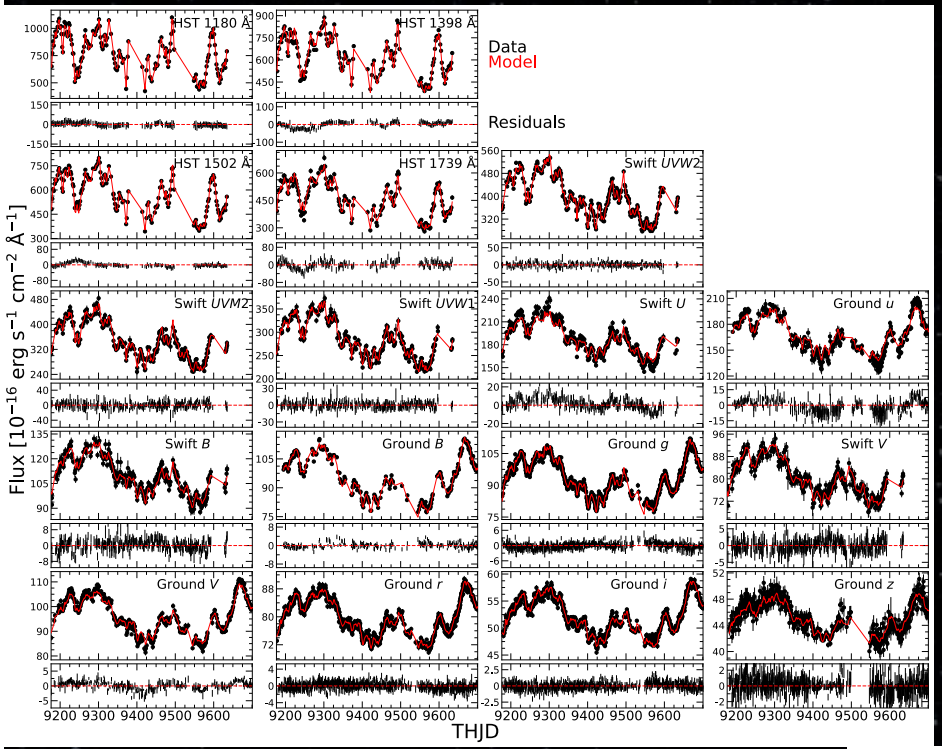


Measuring τ_{drw} is hard – light curve must be much longer than time scale (e.g. Kozlowski 2017), signal-to-noise must be OK → waiting for Rubin for ”normal” QSOs



e.g., Kelly et al. (2009), Kozlowski et al. (2010), MacLeod et al. (2010, 2012), Burke et a. (2021), Tang et al. (2023), Tarrant et al. (2025)

Swift has contributed beautiful AGN light curves



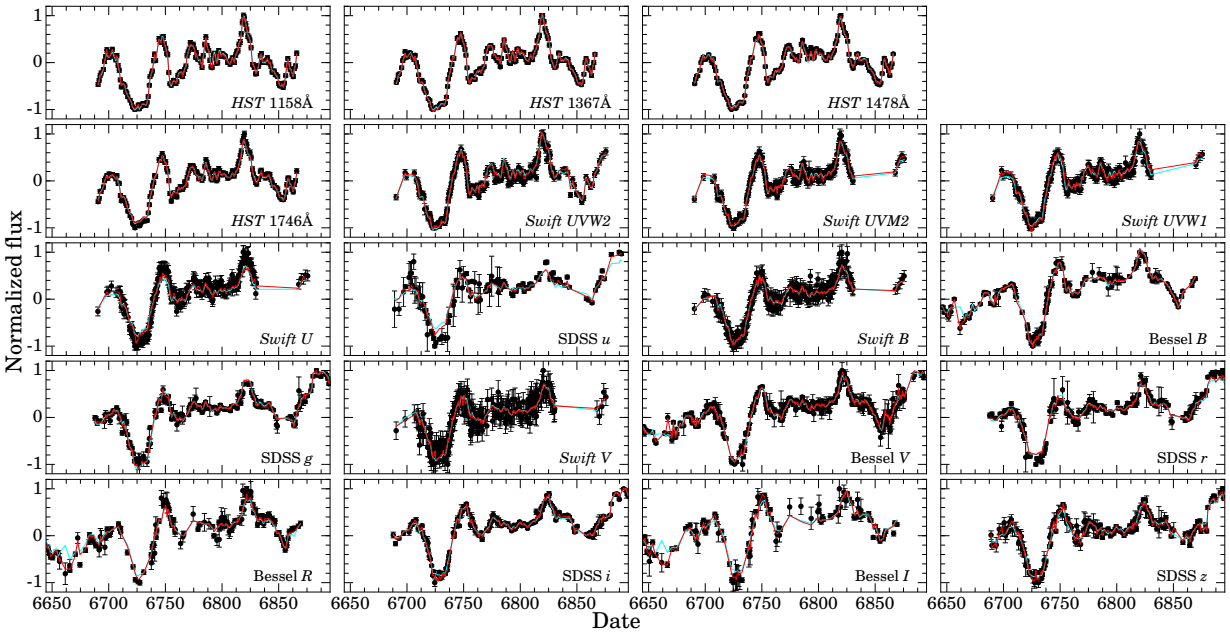
AGN STORM1 – NGC5548

De Rosa et al. (2015), Edelson et al. (2015), Fausnaugh et al. (2016)

AGN STORM2 – Mrk 817

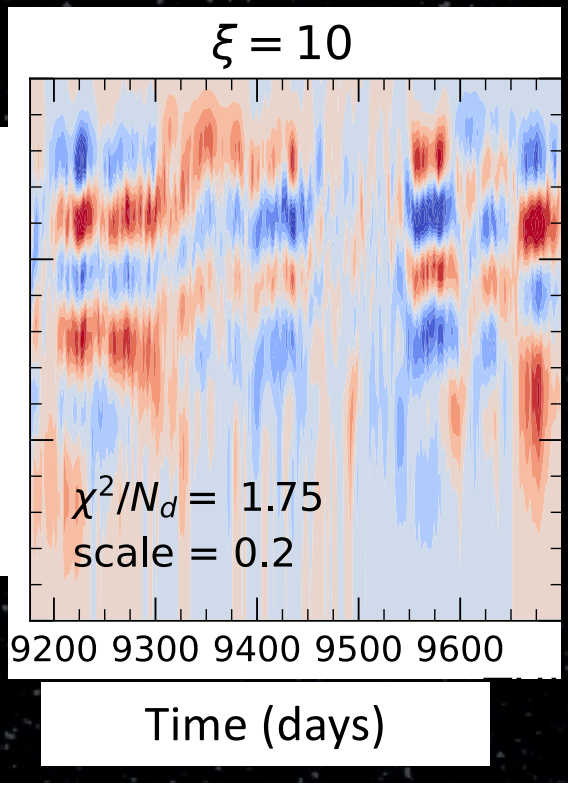
Kara et al. (2021), Homayouni et al. (2023), Cackett et al. (2023), Montero et al. (in prep)

Also Fairall 9 (Hernandez-Santiseban et al. 2020, Edelson et al. 2024), Mrk 152 (Cackett 2020), Mrk 110 (Vincentelli et al. 2021), NGC 4151, NGC4593, Mrk 509, PGC1302-102 (Edelson et al.),



What is “Normal” AGN Variability?

- Short time scales seem to be driven by “reverberation” – variations in brightness close to BH drive thermal fluctuations in disk on light travel times (a.k.a., the ``lamppost” model, talk by Cackett)
- Theory and general expectations say disks must also be intrinsically variable
- Likely reverberation on shorter time scales and other variability on longer times scales (Neustadt et al 2022, 2024)
- Reconstruct time varying disk temperature profiles needed to explain light curves



Red=hotter, blue=colder

Nearly vertical patterns – reverberation signal moving out through disk at the speed of light

More horizontal patterns – more slowly moving temperature fluctuations moving both inward and outward

On long time scales, slower fluctuations should increasingly dominated variability

The First Anomalous Source of AGN Variability
Tidal Disruption Events (TDEs)

- Predicted early – first ~correct by Lacy, Townes and Hollenbach (1982) – then Rees (1988), Phinney (1989), Evans & Kochanek (1989)

- First, arguments for archival X-ray detections (e.g. Bade, Komossa & Dahlem 1996, Saxton et al. 2007)

- Optical/UV claims start – e.g., -- van Velzen et al. (archival, 2011), Cenko et al. (2012, Swift!), Gezari et al. (2012) – retrospectively clear that optical surveys were avoiding the centers of galaxies (see, Holoien et al. 2016, 2017) -- now definitely fixed!

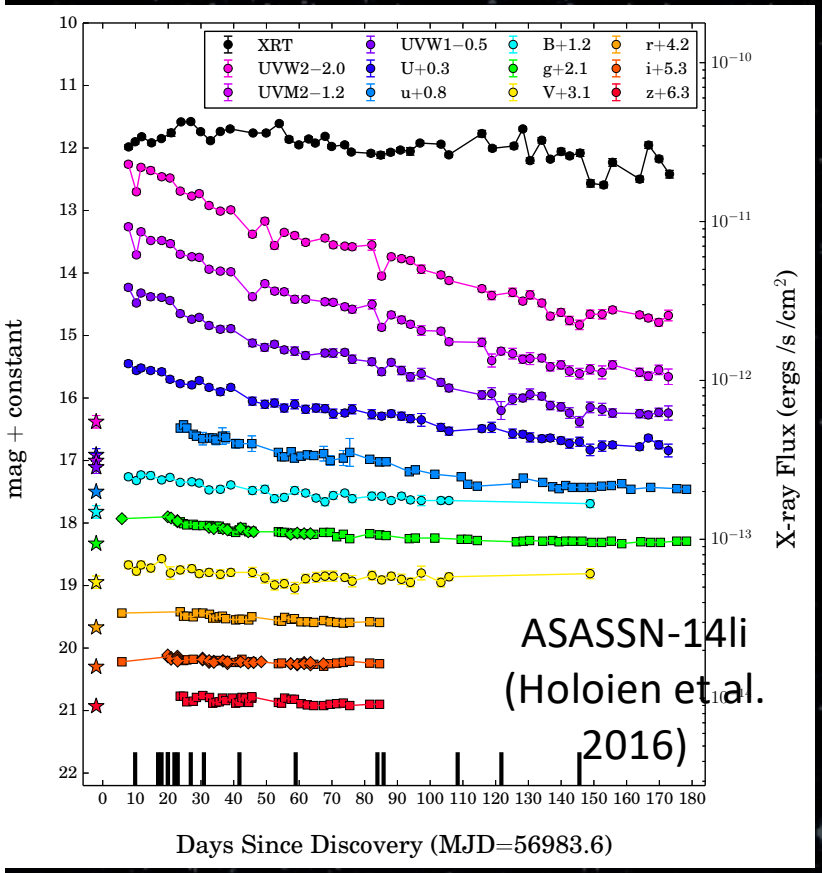
- At ASAS-SN's 16 arcsec resolution, had no choice but to include the centers of galaxies – quickly found a series of optically bright, easy to study TDEs

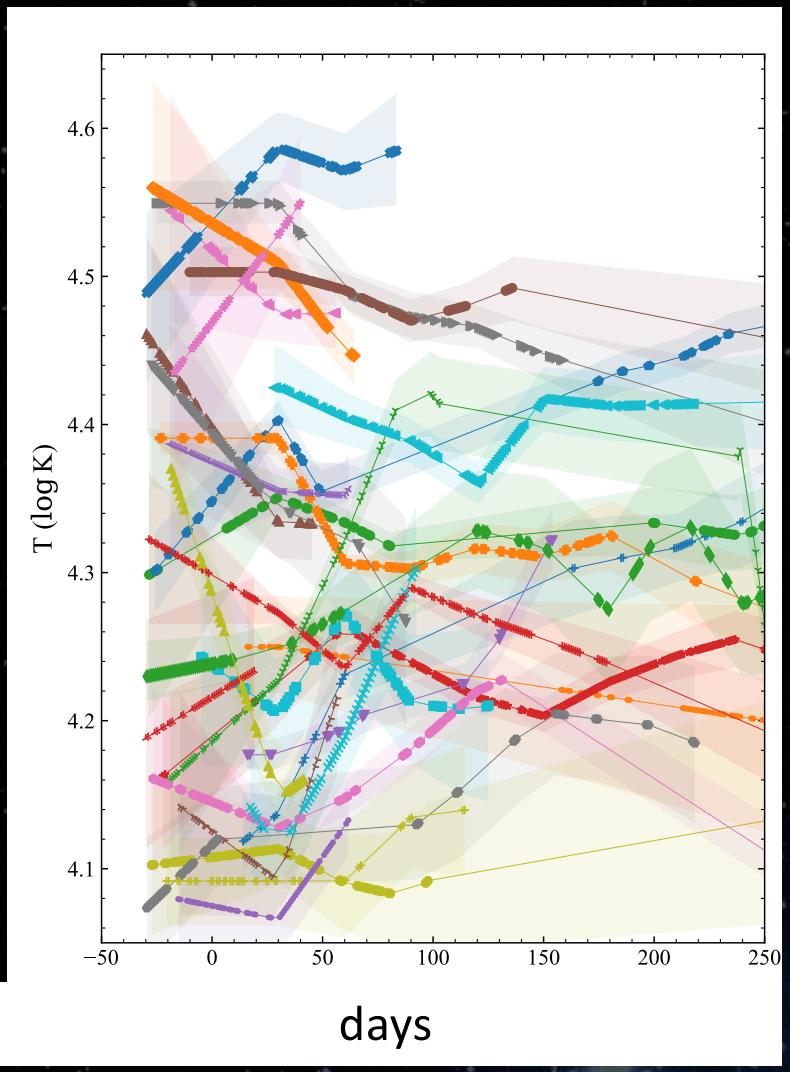
- Now more than 100 optically-selected

In particular, easy to study with Swift

Talks by Yao, Horesh, Eyles-Ferris, Pasham, Hammerstein

TDEs are creatures of the Ultraviolet

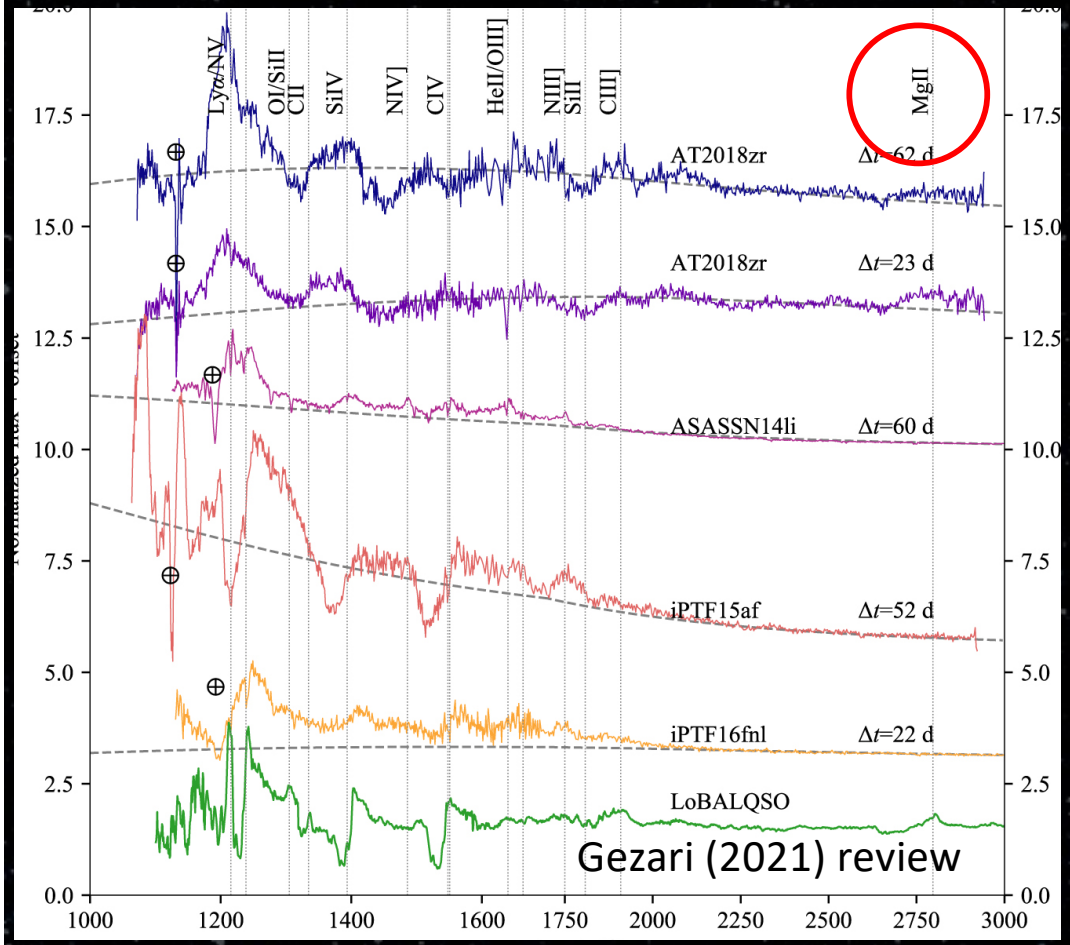




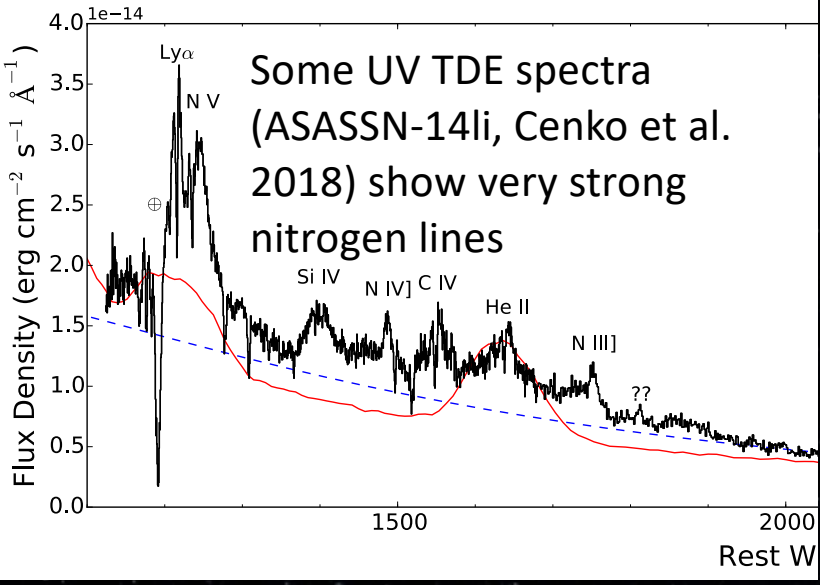
- SED typically a ~30,000K black body – UV-optical slope definitely not AGN-like
- Emission (recombination) lines usually imply an ionizing UV excess over the black body
- UV emission continues at late (many year) times (e.g. van Velzen et al. 2019)

Hammerstein et al. (2023)

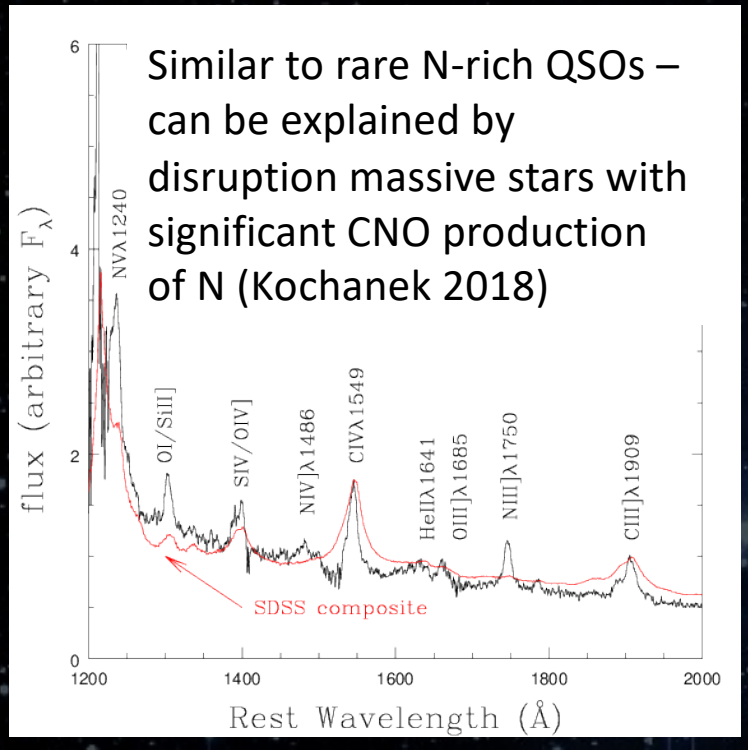
UV Spectroscopic Peculiarities



Seem to generically lack the MgII line – different from other standard AGN lines in that it requires the presence of a significant partially ionized zone



Some UV TDE spectra (ASASSN-14li, Cenko et al. 2018) show very strong nitrogen lines

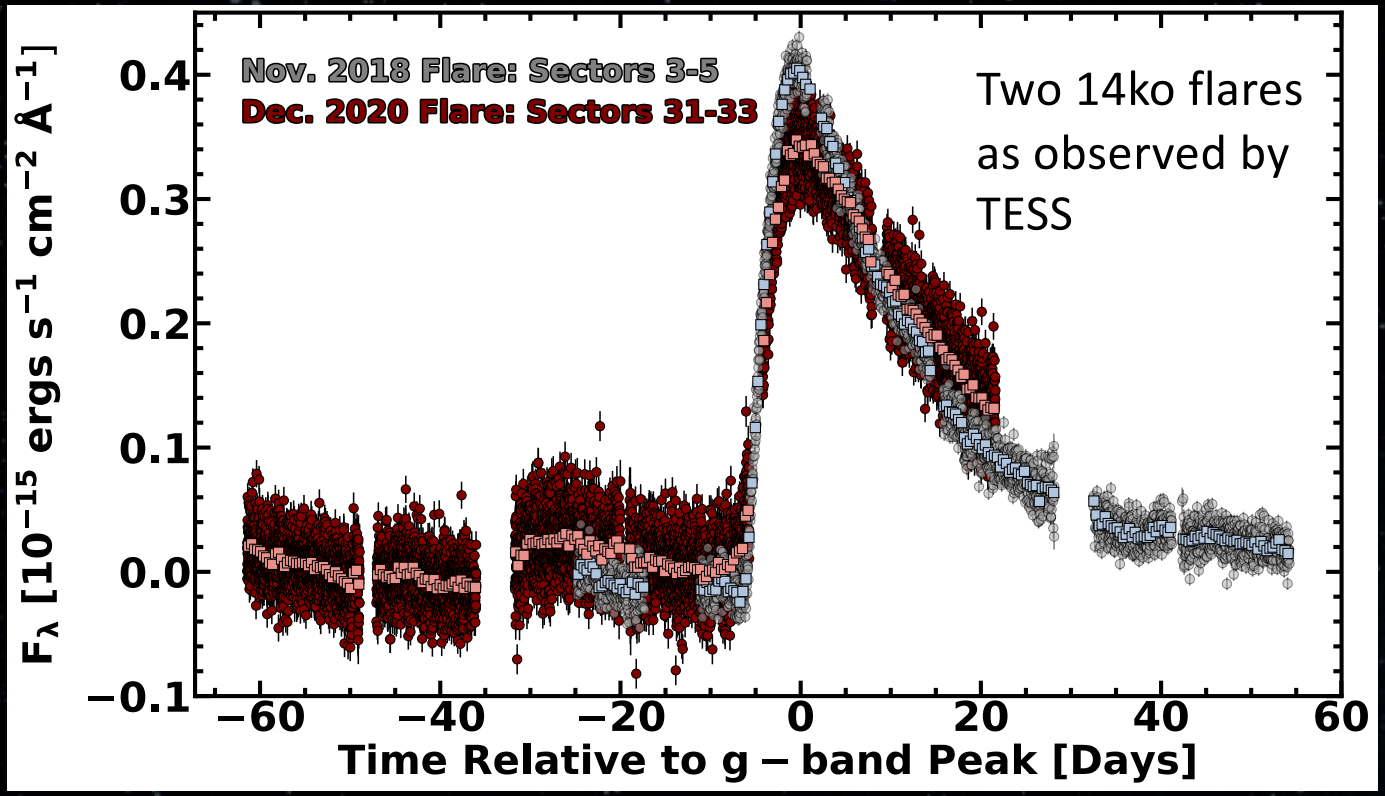


Similar to rare N-rich QSOs – can be explained by disruption massive stars with significant CNO production of N (Kochanek 2018)

Repeating TDEs – the Chance for Detailed Study

TDEs of red giants can repeat – slowly stripping the envelope – repetitions are (quasi)periodic, so you can just schedule detailed observations of subsequent flares (e.g. ASASSN-2014ko, AT2018fyk, Wevers et al. 2023, AT2022dbl, Lin et al. 2022)

Most famous at present is ASASSN-14ko with 21 flares as of Payne et al. (2023) – period of 115 days with a relatively well-determined, shrinking, period derivative

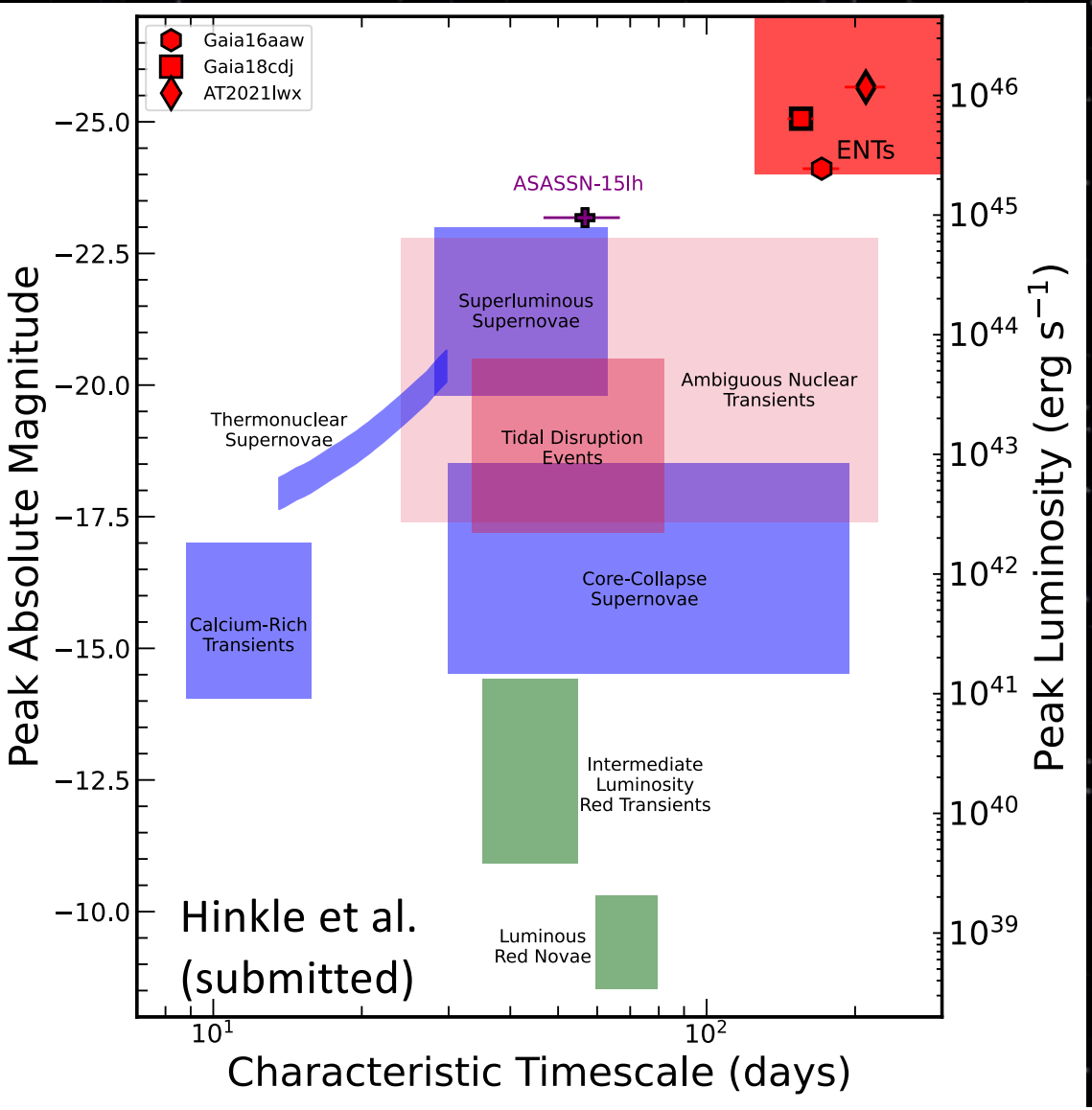


ASASSN-14ko: Payne et al. 2021, 2022, 2023; Tucker et al. 2020

ANTs & ENTs

Anomalous and Extreme Nuclear Transients

(e.g., Trakhtenbrot et al. 2019, Neustadt et al. 2020, Frederick et al. 2021, Holoien et al. 2021, Wiseman et al. 2025)



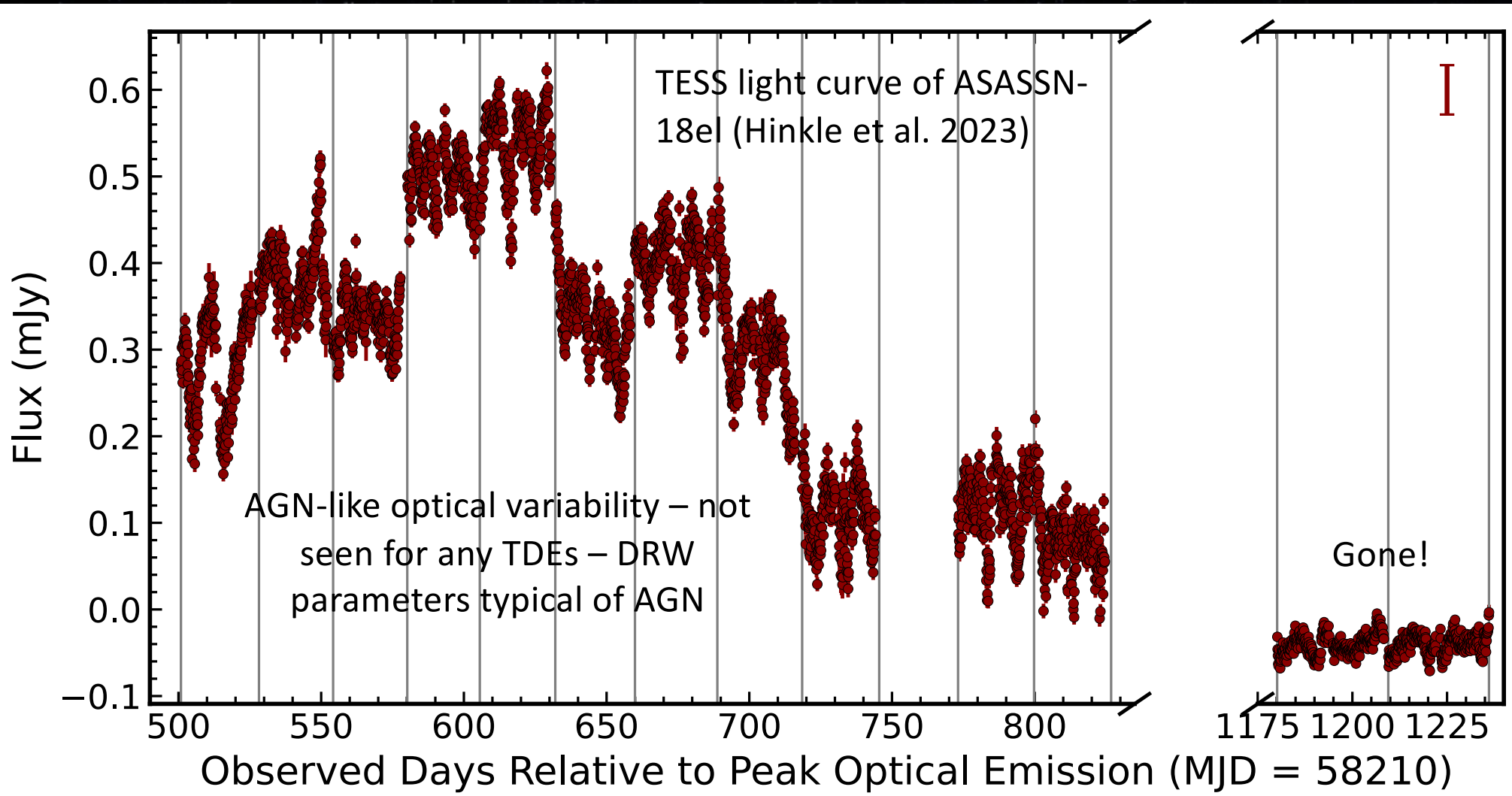
"Isolated" nuclear Optical/UV flares – so not normal AGN variability

Typically decay more slowly that "normal" TDEs

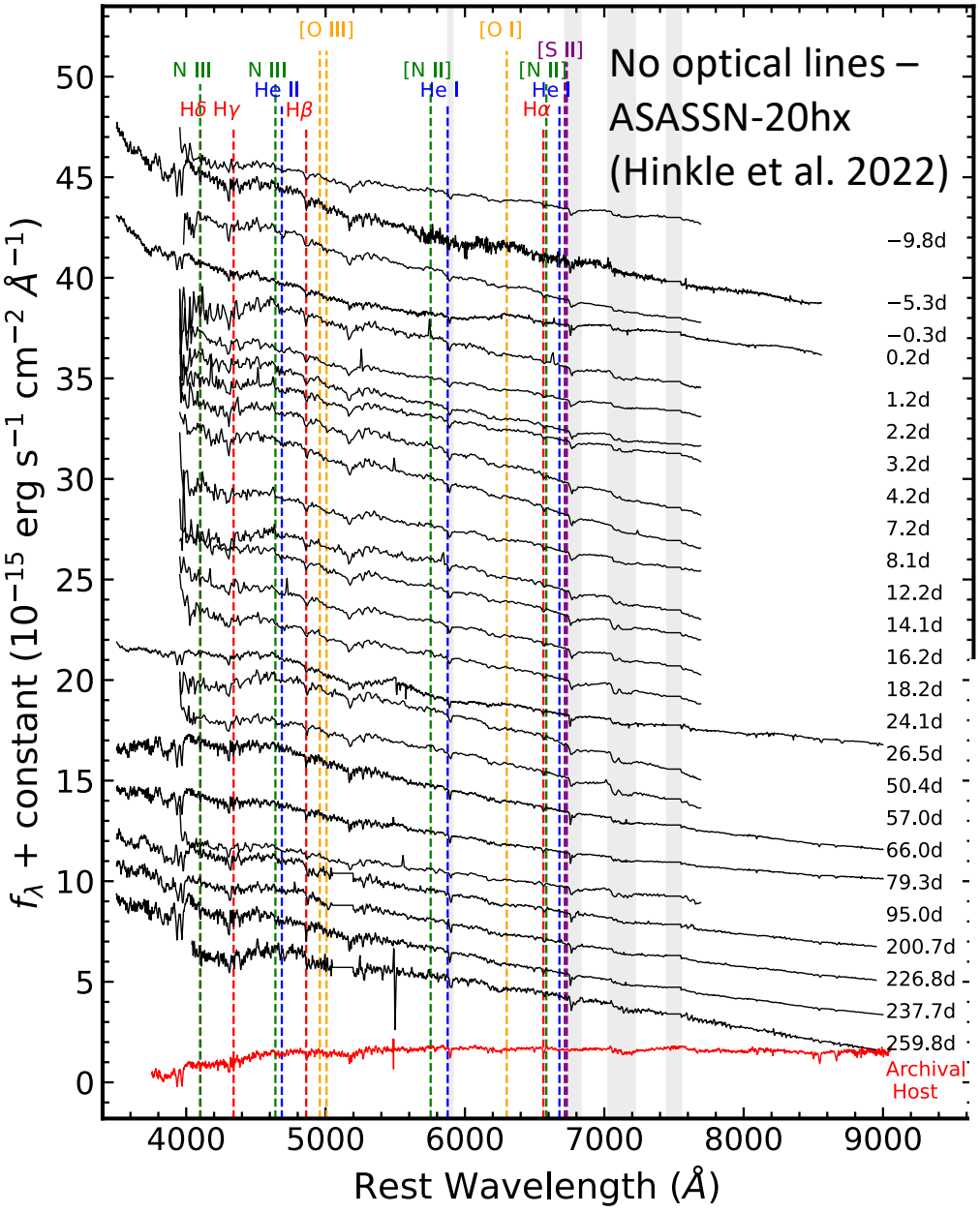
If UV/optical SED black body-ish, parameter evolution is generally non-TDE-like (more like supernovae)

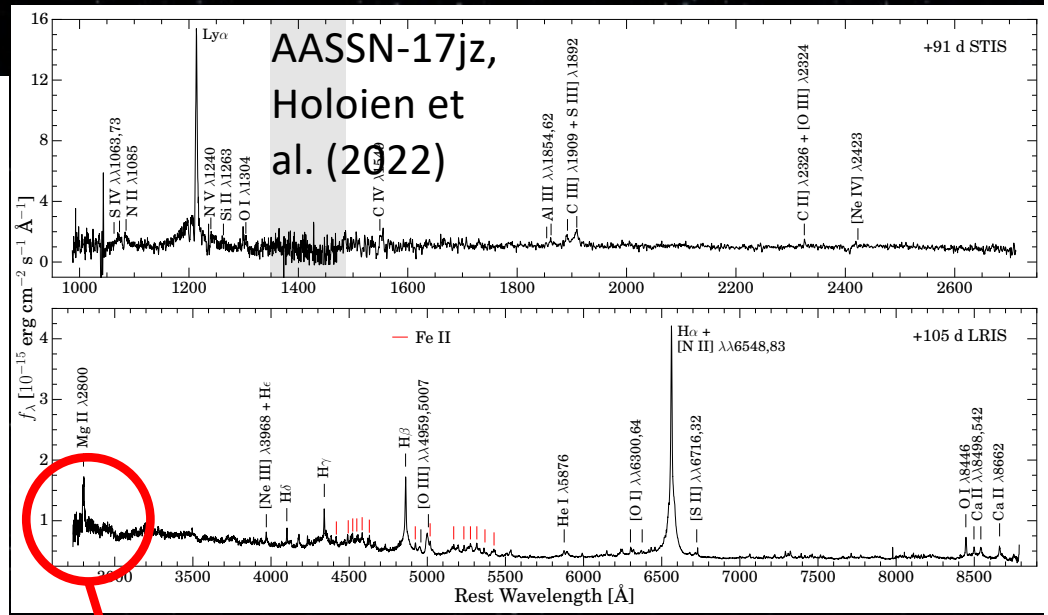
SED not always black body-ish – e.g. ADP2020adpi flatter and more AGN-like (Pandey et al. in prep)

One Shows AGN-like variability – for a while

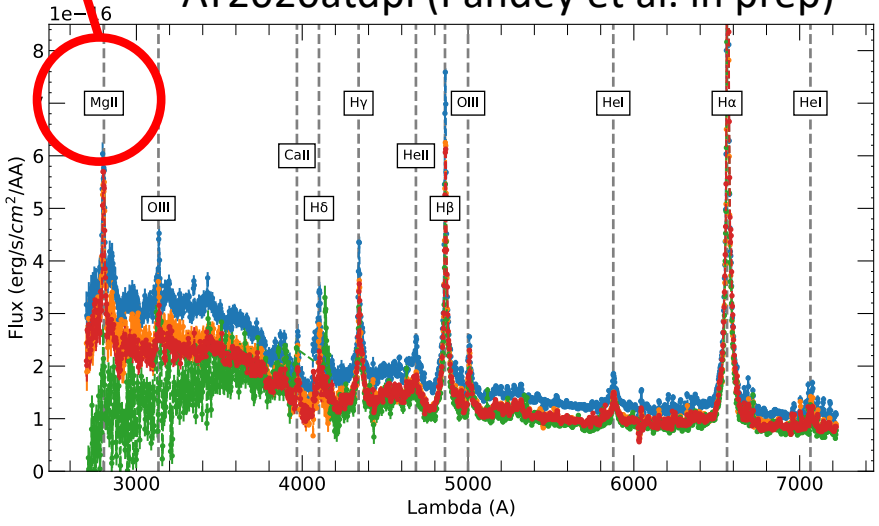


Spectral Oddities





Many have MgII emission

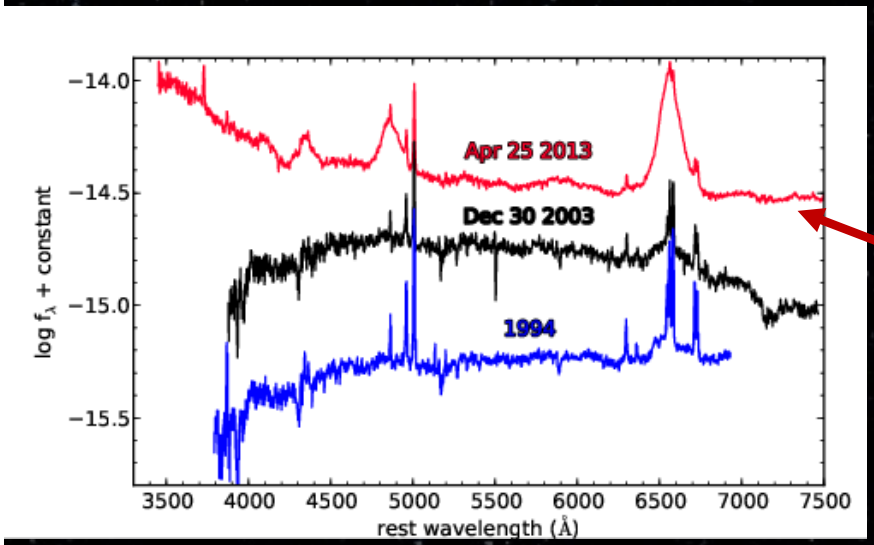


Changing Look AGN*: Type I ↔Type II

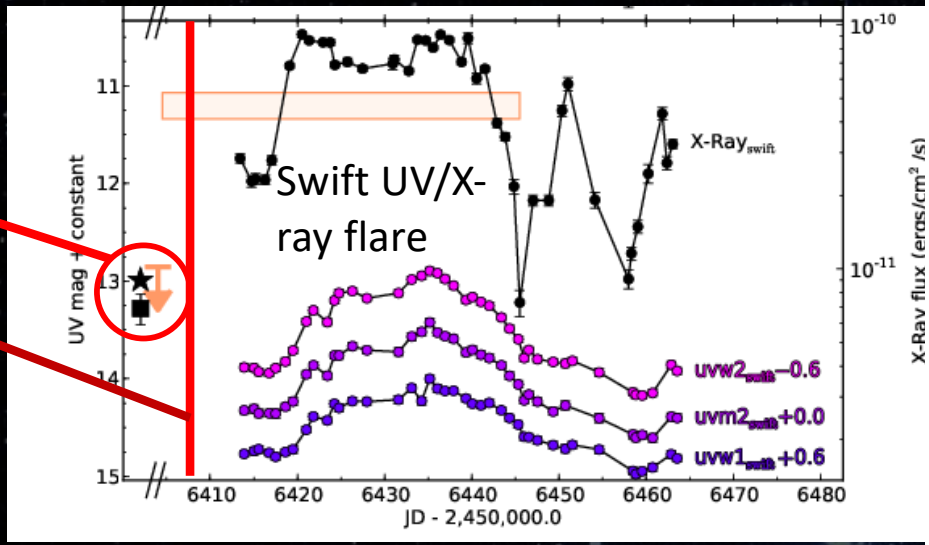
Type I (with broad lines)/Type II (no broad lines)
AGN Unificatiaon model → dichotomy is due to absence/presence of absorbing (dust) "torus" along the line of sight (e.g. Urry & Padovani 1995)

Major surveys for AGN changing spectral type recently – now many examples (e.g. MacLeod et al. 2016, 2019; Yang et al. 2018, Green et al. 2022, Hon et al. 2022)

In fact, the "original" ASAS-SN paper, Shappee et al. (2014), is really an analysis of a changing look AGN NGC2617 – used as the "survey" paper because no one had the energy to write a "survey paper"



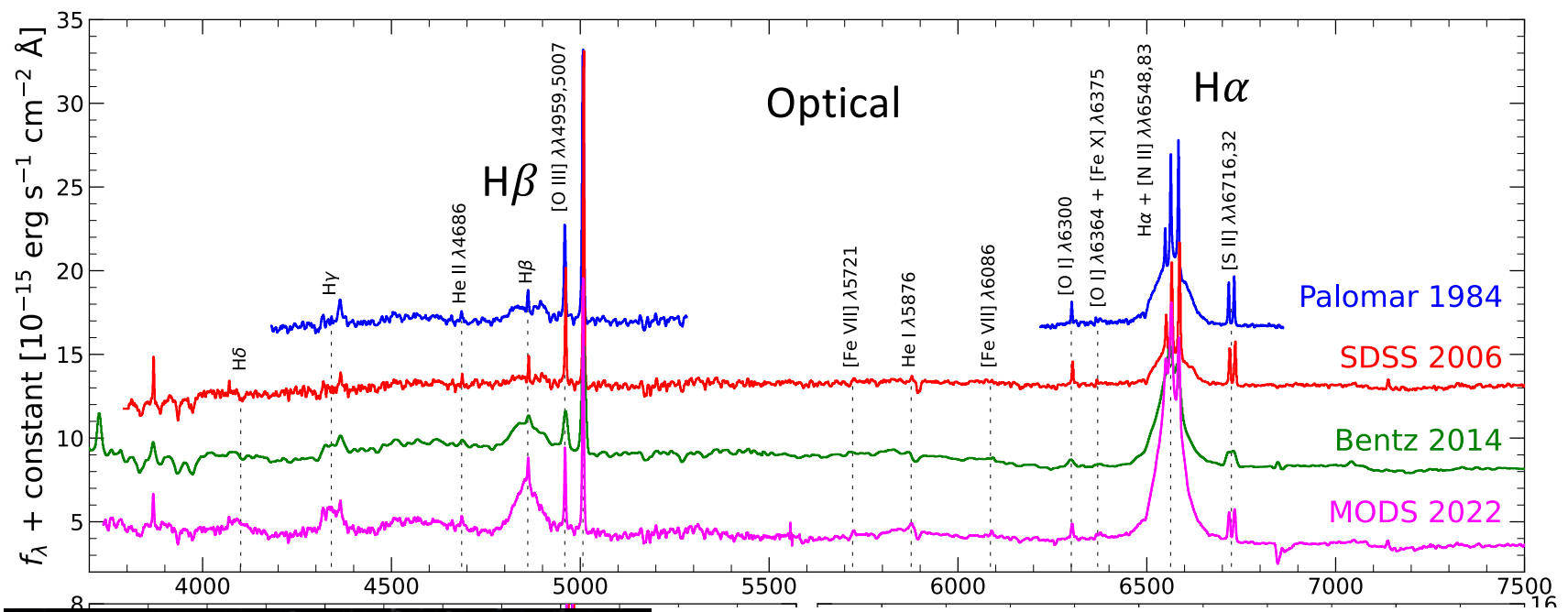
XMM in 2007



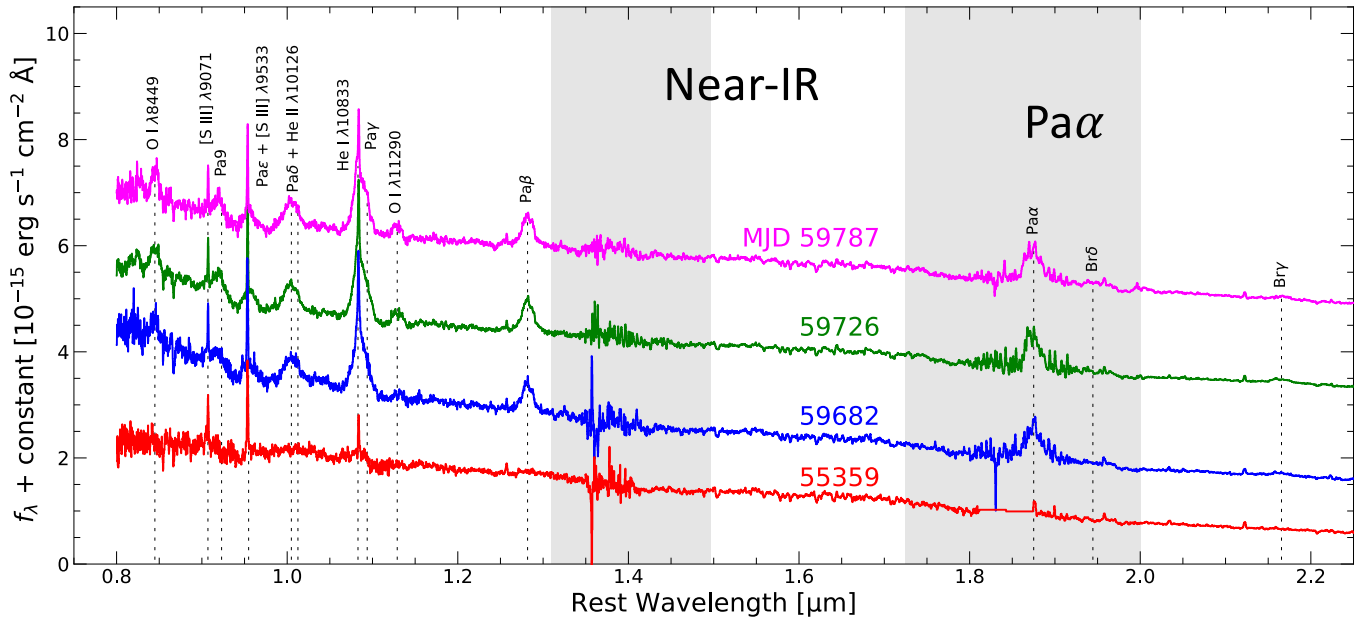
*X-ray folks have a different meaning of "changing look AGN"

Perhaps Cleanest Case for Not a Change in Dust

Changing look NGC5237 (which also has a Swift UV flare) – Neustadt et al. (2023)



Broad Hα is always visible, while Paα, Hβ and Paβ weaken/vanish



Summary

- AGN science has expanded greatly with the help of Swift
  - New studies of "classic AGN"
  - Studies of predicted but "unobserved" AGN activity – TDEs
  - New types of AGN activity – ANTs/ENTs and changing looks

- Ground based surveys needed to provide optical light curves and to trigger spaced based UV and X-ray studies – not just ASAS-SN – ZTF and ATLAS today, Rubin shortly

- There is a lot of AGN physics in the UV, both photometric (Swift) and spectroscopic (HST)

- Similar synergies exist for many other areas of transient science (supernovae, stellar transients, stellar flares……)