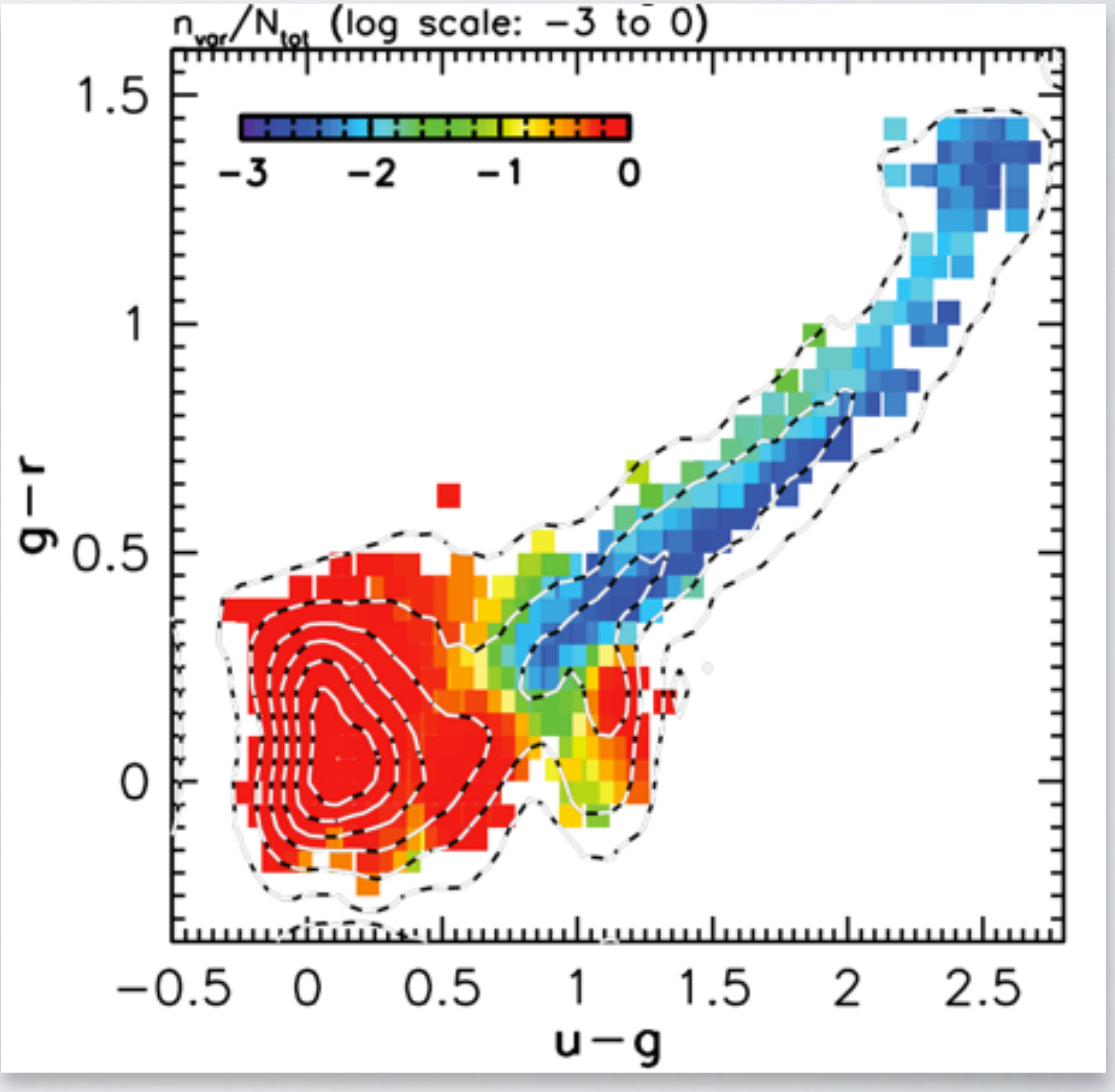
WAVELENGTH-DEPENDENT VARIABILITY OF AGN FROM GALEX AND PAN-STARRS1
+
iPTF16bco (a changing-look quasar)

Tiara Hung (University of Maryland)
with Suvi Gezari (UMD), David Jones (JHU),
Brad Cenko (Goddard), Nadia Blagorodnova (Caltech),Lin Yan (Caltech),
Shri Kulkarni (Caltech), and the iPTF team

MOTIVATION

- Observationally, all unobscured quasars are variable.
- AGN variability in the optical is stochastic, and can be modelled as a damped random walk (DRW) process (Kelly+ 2009; MacLeod+ 2010…etc).
- What mechanisms can produce such a variability?
    - X-ray reprocessing (Shappee+2014, McHardy +2016)
    - disk instabilities
        - thermal fluctuation
        - change in the accretion rate…etc



Sesar+ 2007

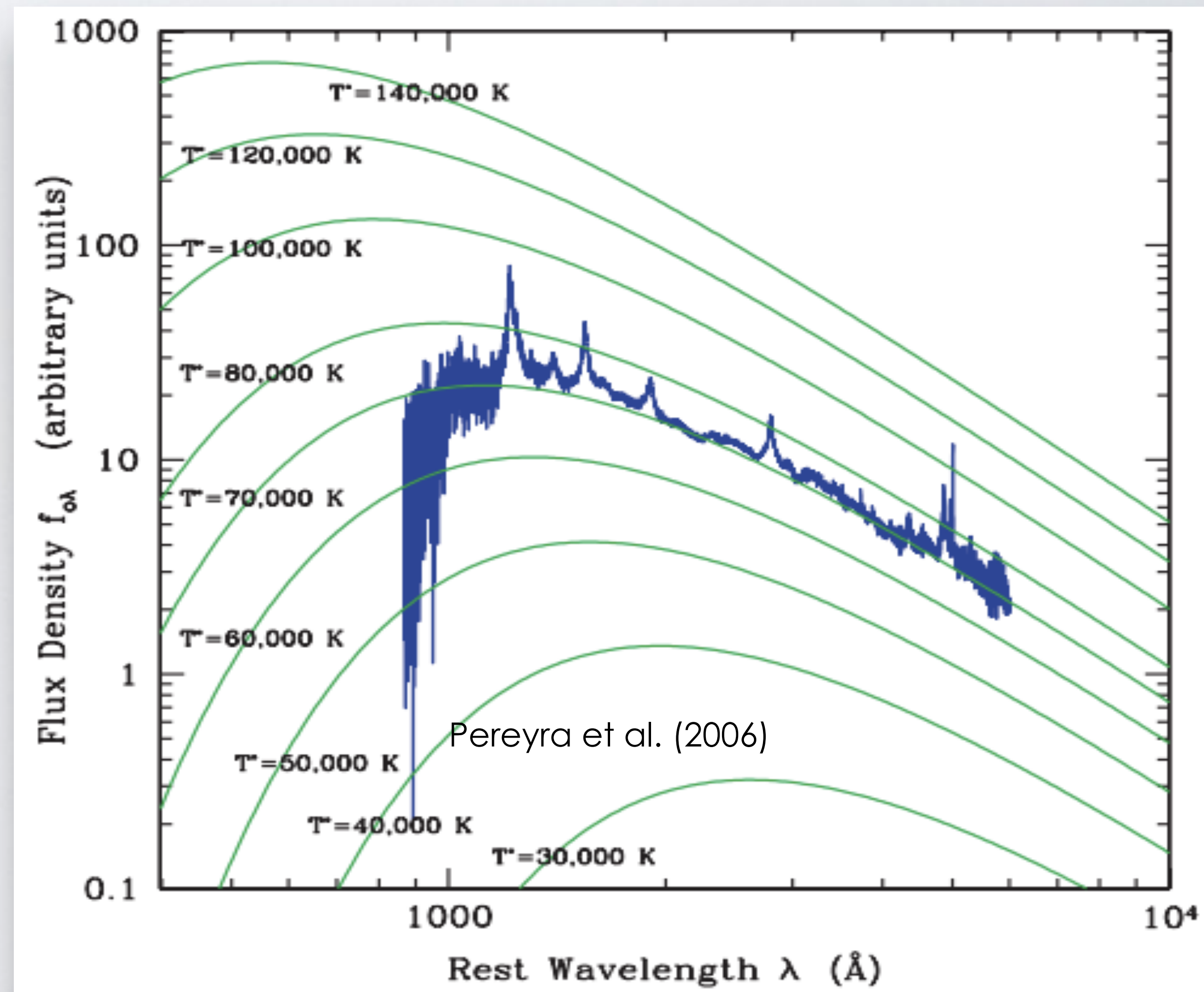
STANDARD THIN DISK MODEL

$$T(r) = T^* \left(\left(\frac{r_i}{r} \right)^3 \left[1 - \left(\frac{r_i}{r} \right)^{1/2} \right] \right)^{1/4}$$

$$T^* = \left(\frac{3GM_{\rm bh}\dot{M}_{\rm accr}}{8\pi r_i^3 \sigma} \right)^{1/4}$$

$$f_\lambda(T^*) = \int_{r_i}^{\infty} \pi \frac{\frac{2hc^2}{\lambda^5}}{\exp\left(\frac{hc}{\lambda k T^* t(r/r_i)}\right) - 1} 4\pi r \, dr$$

The idea: T* (or the accretion rate) in the accretion disk changes at different epochs.



Pereyra+ 2006

STANDARD THIN DISK MODEL

- In reality, the accretion disk model rarely fits real AGN spectra
  - Because of host galaxy contamination at longer wavelengths
  - Solution: assume galaxy light is non-variable!
- We fit the model (disk spectrum@T2 - disk spectrum@T1) to the difference flux SEDs of two selected epochs
- The only parameter in the model is the **average characteristic temperature** of the two epochs. (Due to degeneracy issue, we can not derive T1 and T2 individually.)
- Can explain the bluer-when-brighter trend (Vanden Berk et al. 2004)

SAMPLE

GALEX Time Domain Survey

- 2d cadence over a baseline of 3 years
- NUV variability-selected sources (>5σ; Gezari et al. 2013)
- Overlaps with Pan-STARRS1 MD fields (6 out of 10)
- aperture photometry (m_{lim}~23 mag)

334 sources

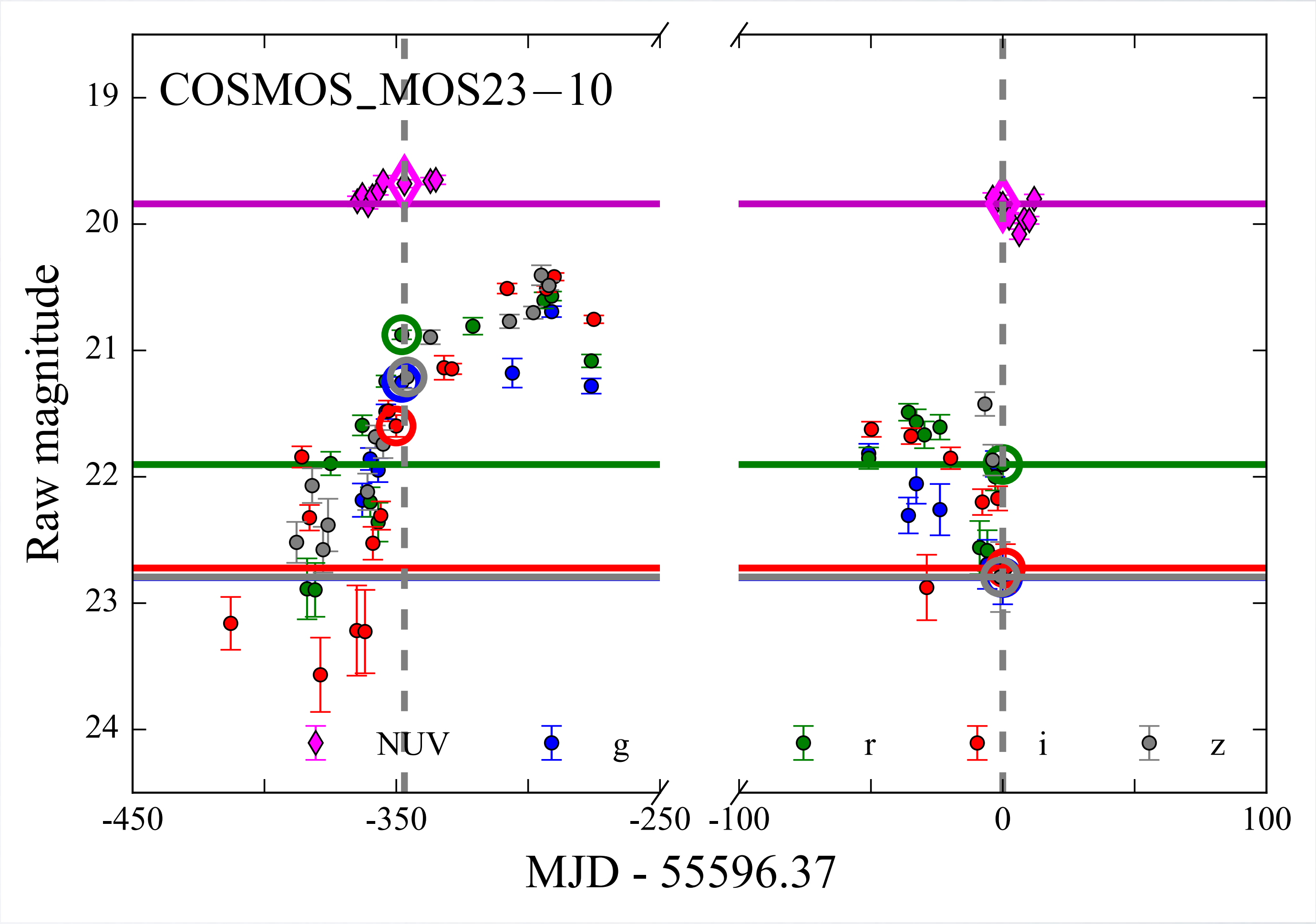
Pan-STARRS1 Medium Deep Survey

- 3d staggered cadence in griz bands (m_{lim}~23 mag)
- optical transients discovered through <u>image differencing</u> (S/N>4)

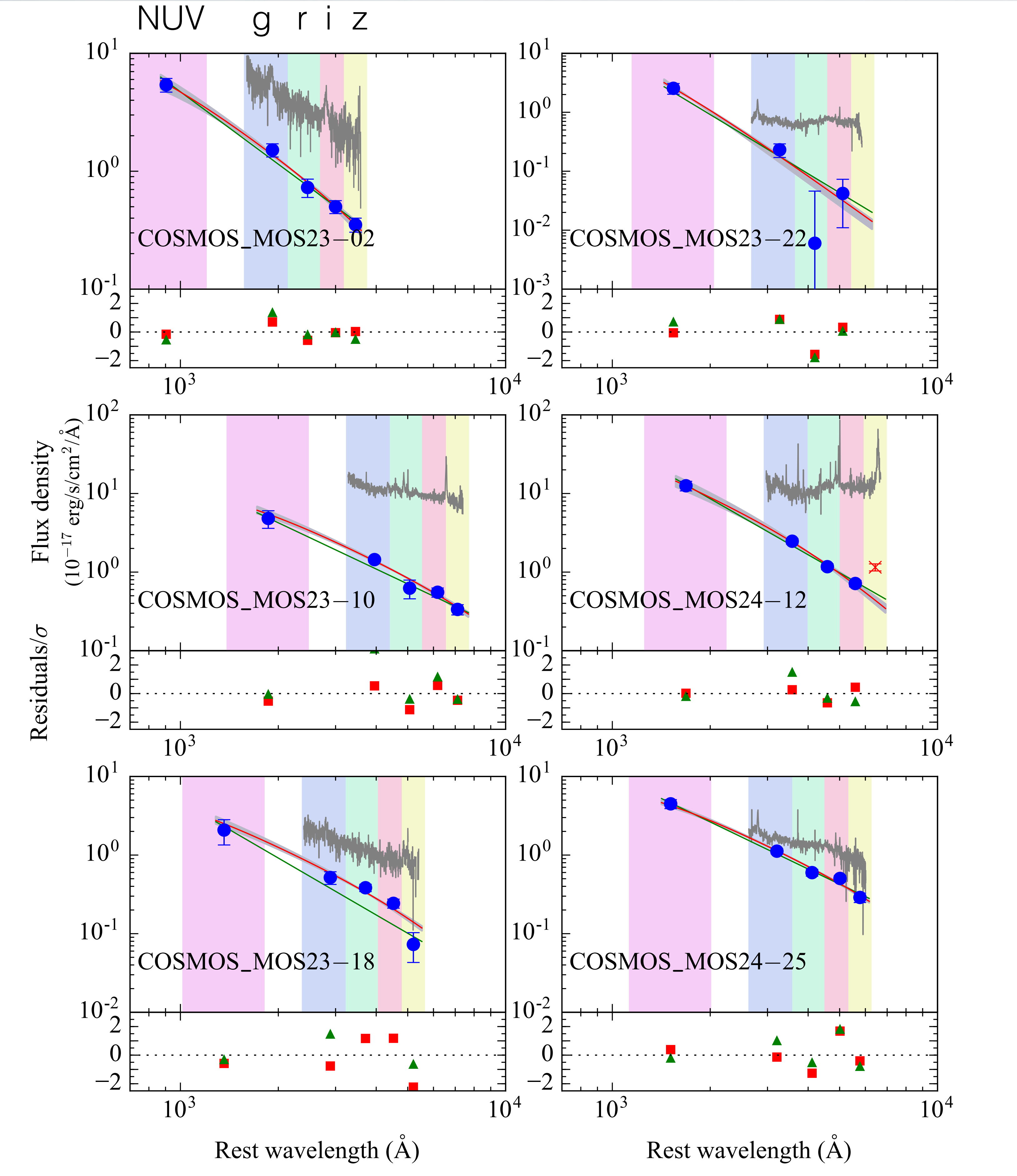
METHOD

- Our final sample consists of 24 targets that have
  - co-temporal observations in GALEX and PS1
  - a large amplitude of optical variability (difference flux (S/N) > 3 in g band)
  - 23 spectroscopically confirmed AGNs. 1 early-type galaxy.
  - The timescale is ~ a year.

bright faint



Hung et al. 2016



- Difference flux

Disk model

power law

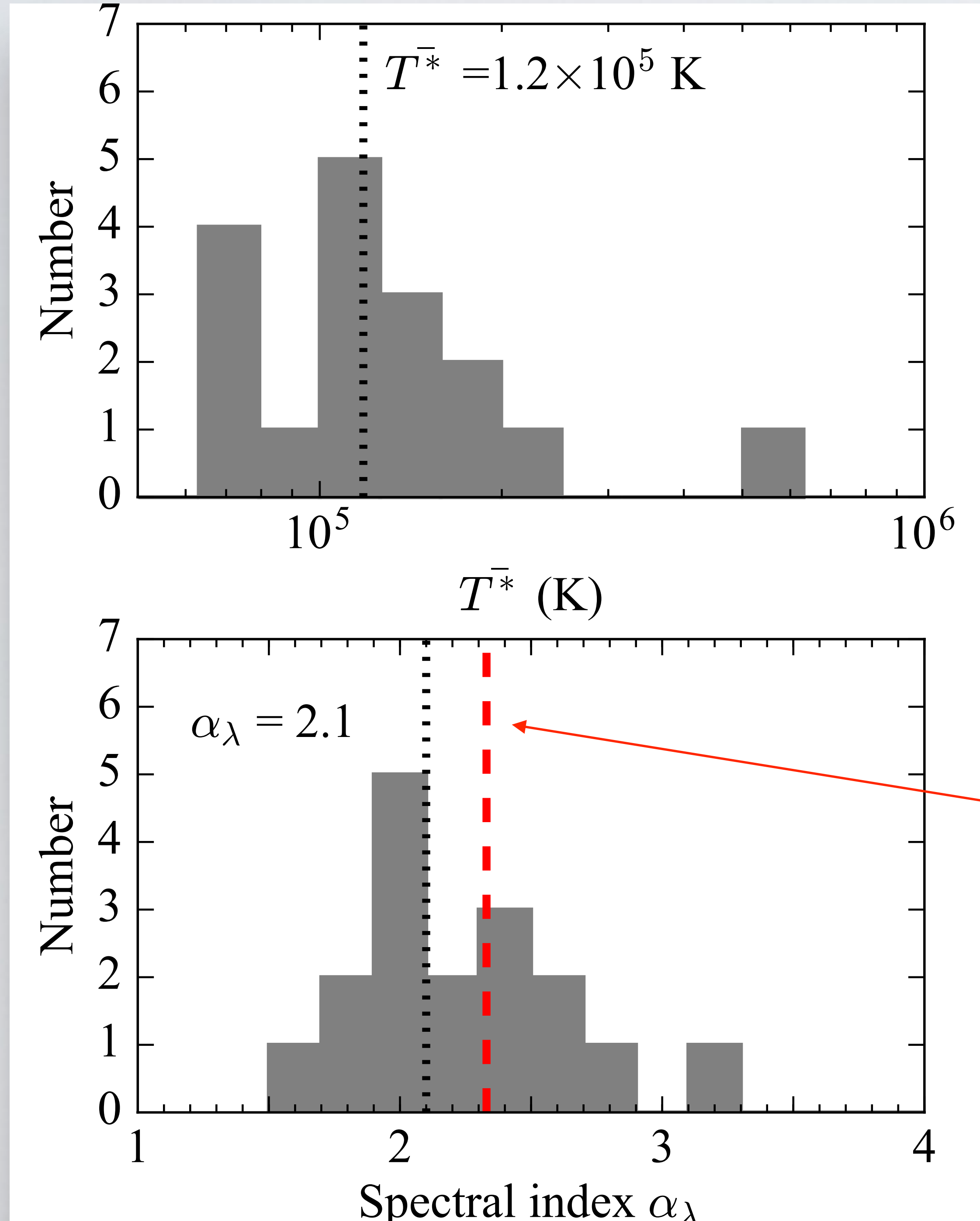
single epoch spectrum

x - masked points

17/23 are well-fitted by the disk model (reduced chi square<3)

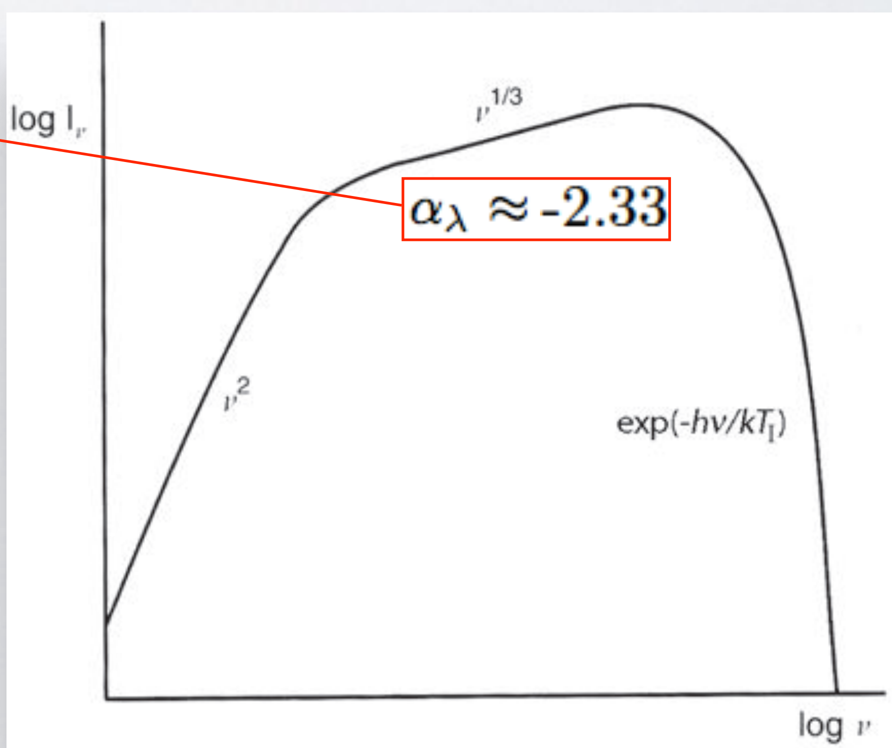
Hung et al. 2016

RESULTS



Hung et al. 2016

- The characteristic temperatures and the power law indices are consistent with what is expected for a thin disk.



DISCUSSION

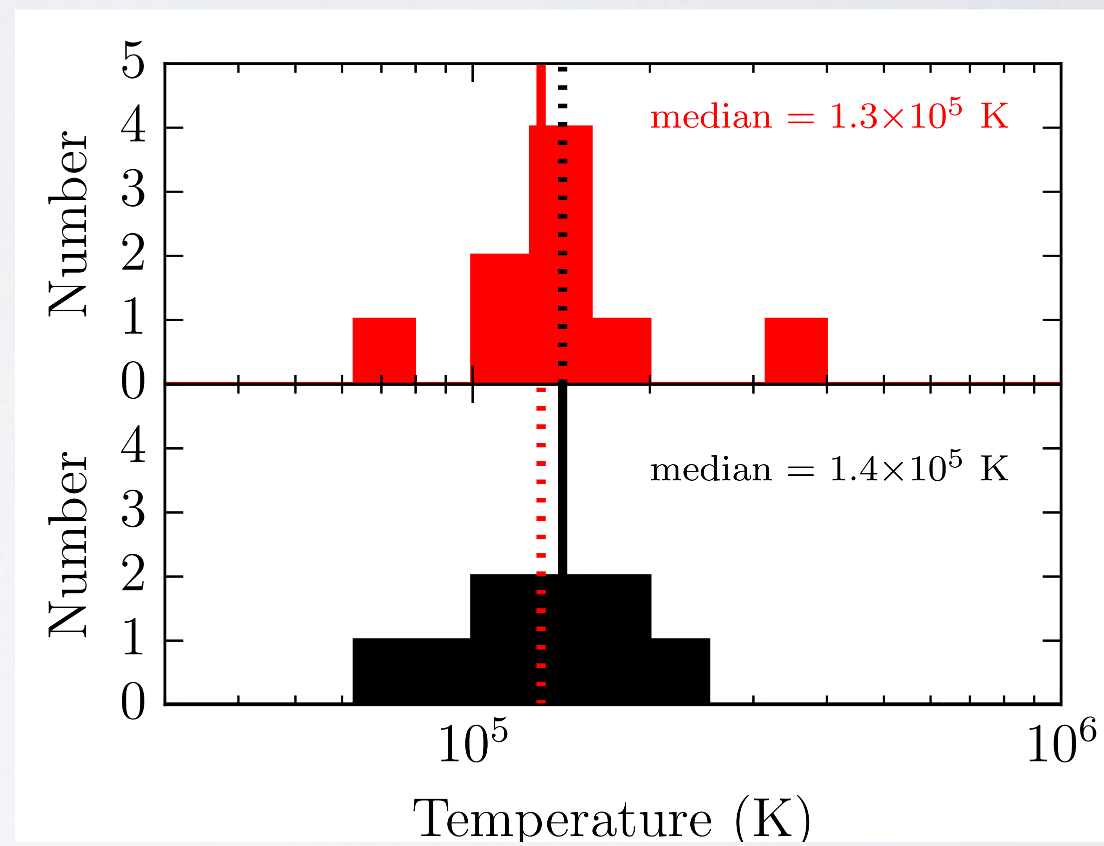
$$T^* = \left(\frac{3GM_{bh}\dot{M}_{accr}}{8\pi r_i^3 \sigma}\right)^{1/4}$$

- Measured T* from single epoch spectroscopy
  - Mbh measured from MgII or Hb line FWHM assuming virialized motion

  - Mass accretion rate derived from NUV and optical photometry assuming an empirical mean quasar SED and the efficiency of a Schwarzschild BH

Hung et al. 2016

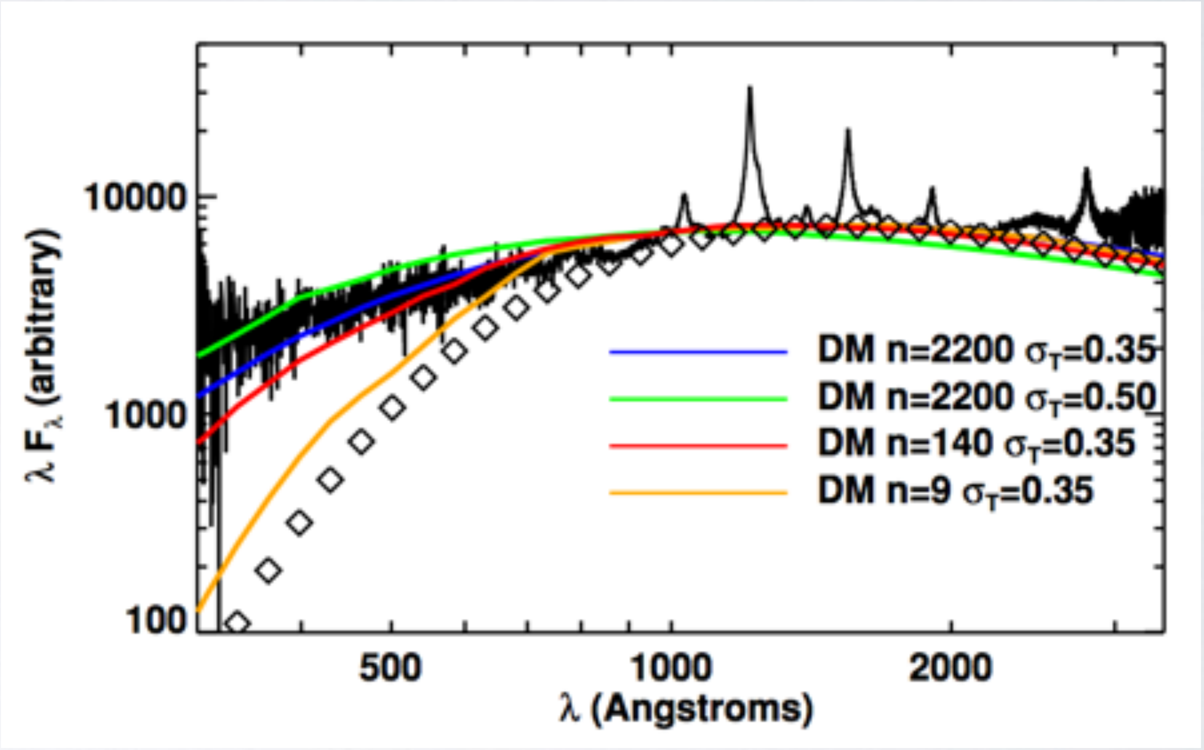
From spectroscopy



From fitting difference flux SEDs

DISCUSSION

- Accretion disk timescales
  - Light crossing time
    - t ~ a few days (e.g. X-ray reprocessing)
  - Thermal/dynamical timescale
    - ~100 days (found in DRW fit of SDSS quasars)
    - localised thermal fluctuations in the disk (Dexter & Agol 2011, Ruan+ 2014, Cai+ 2016)
  - Viscous timescale (for global changes in accretion rate)
    - ~1000 years

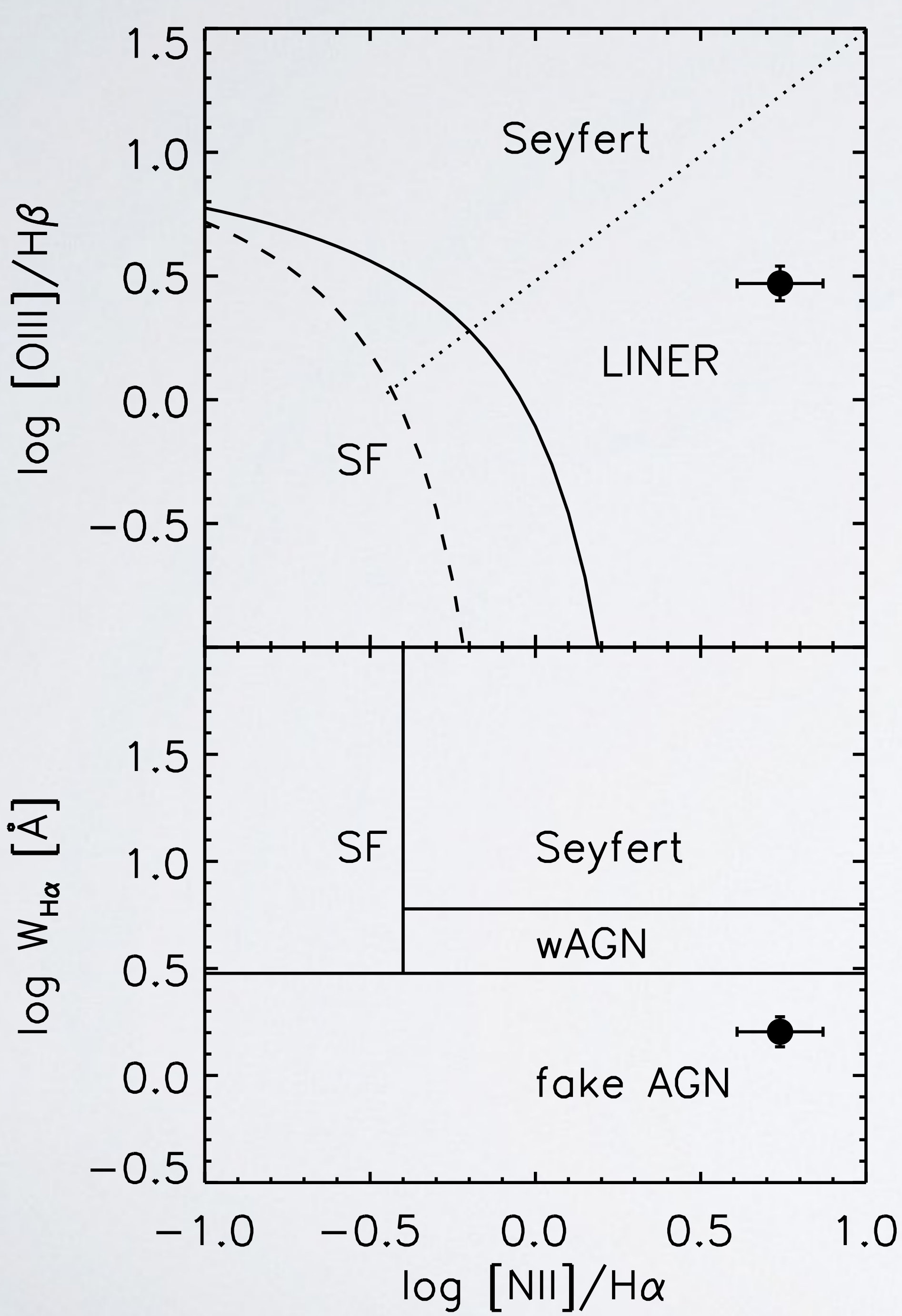


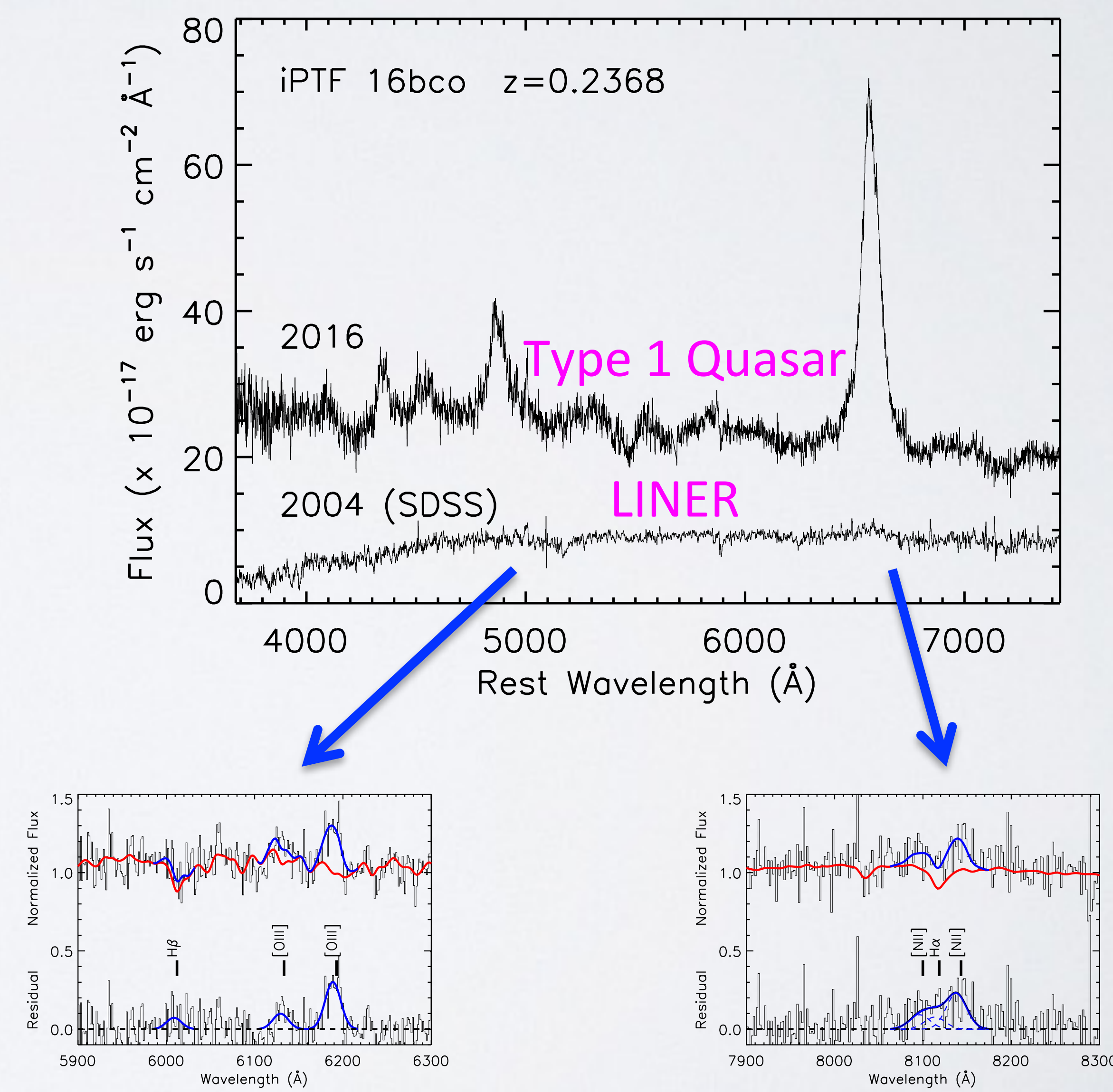
Dexter & Argol 2011

iPTF16bco

Gezari+ 2017

Jun 1: Changing-look quasar at z=0.237





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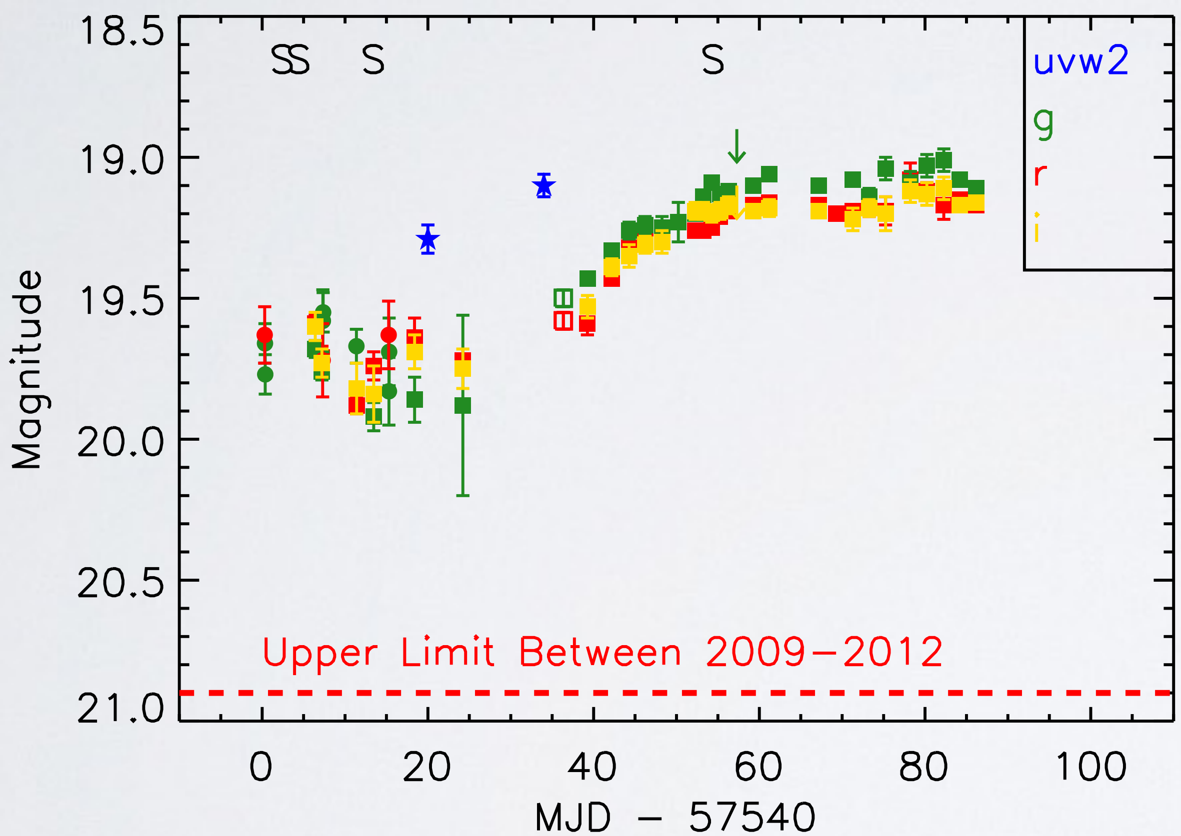
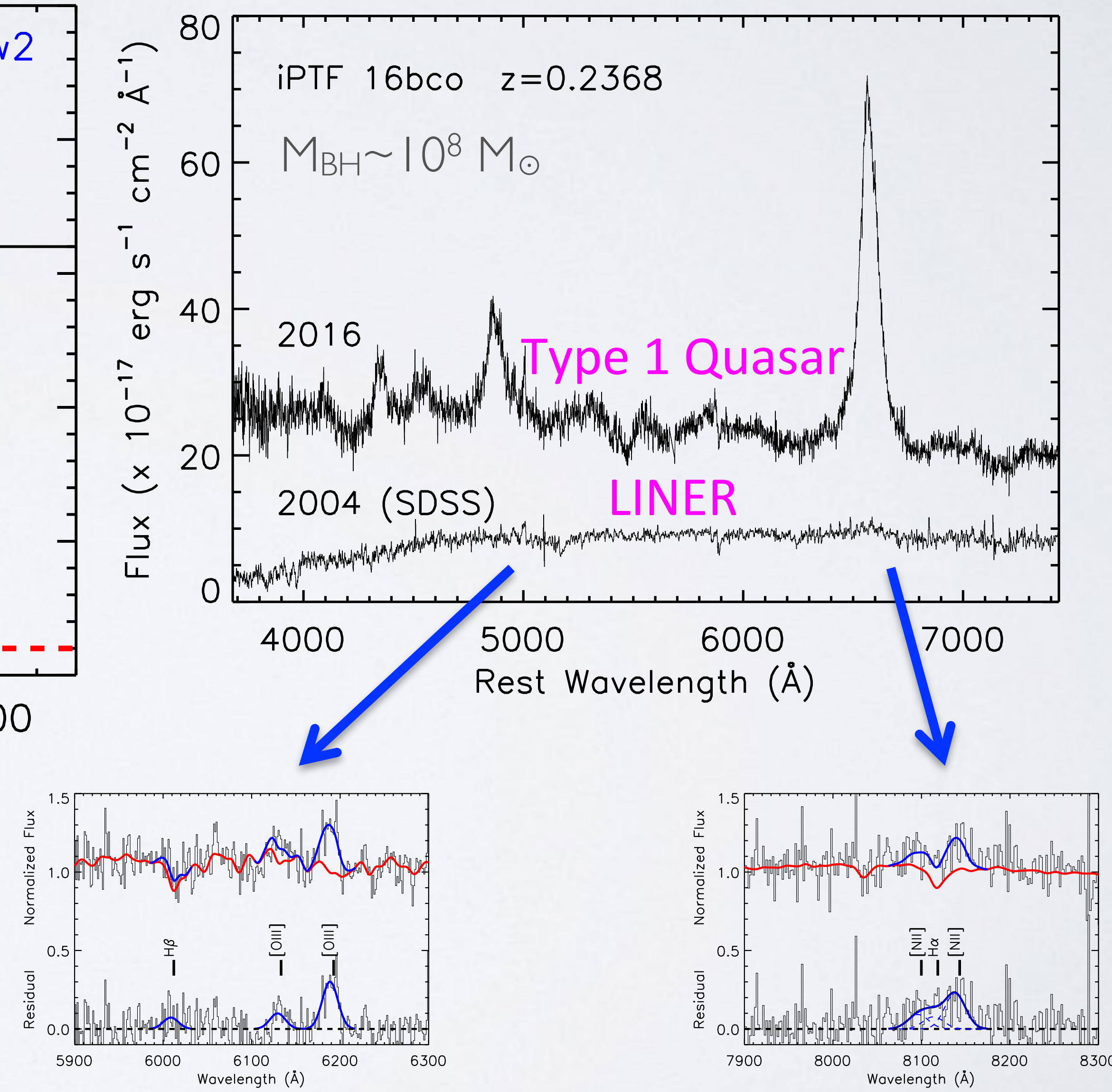
Gezari+ 2017

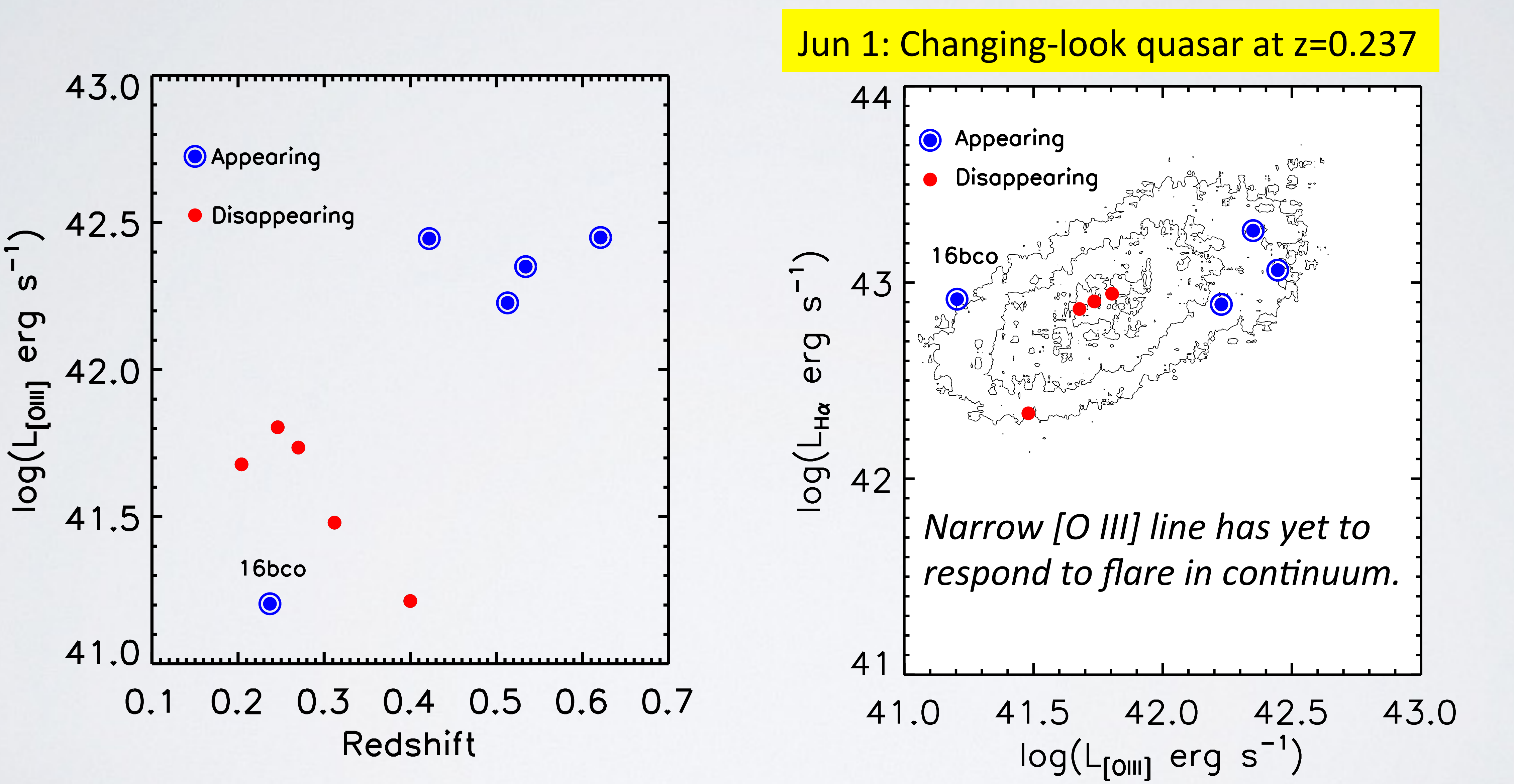




Flare in X-ray/UV/optical continuum occurred < 1 yr ago!

Gezari+ 2017

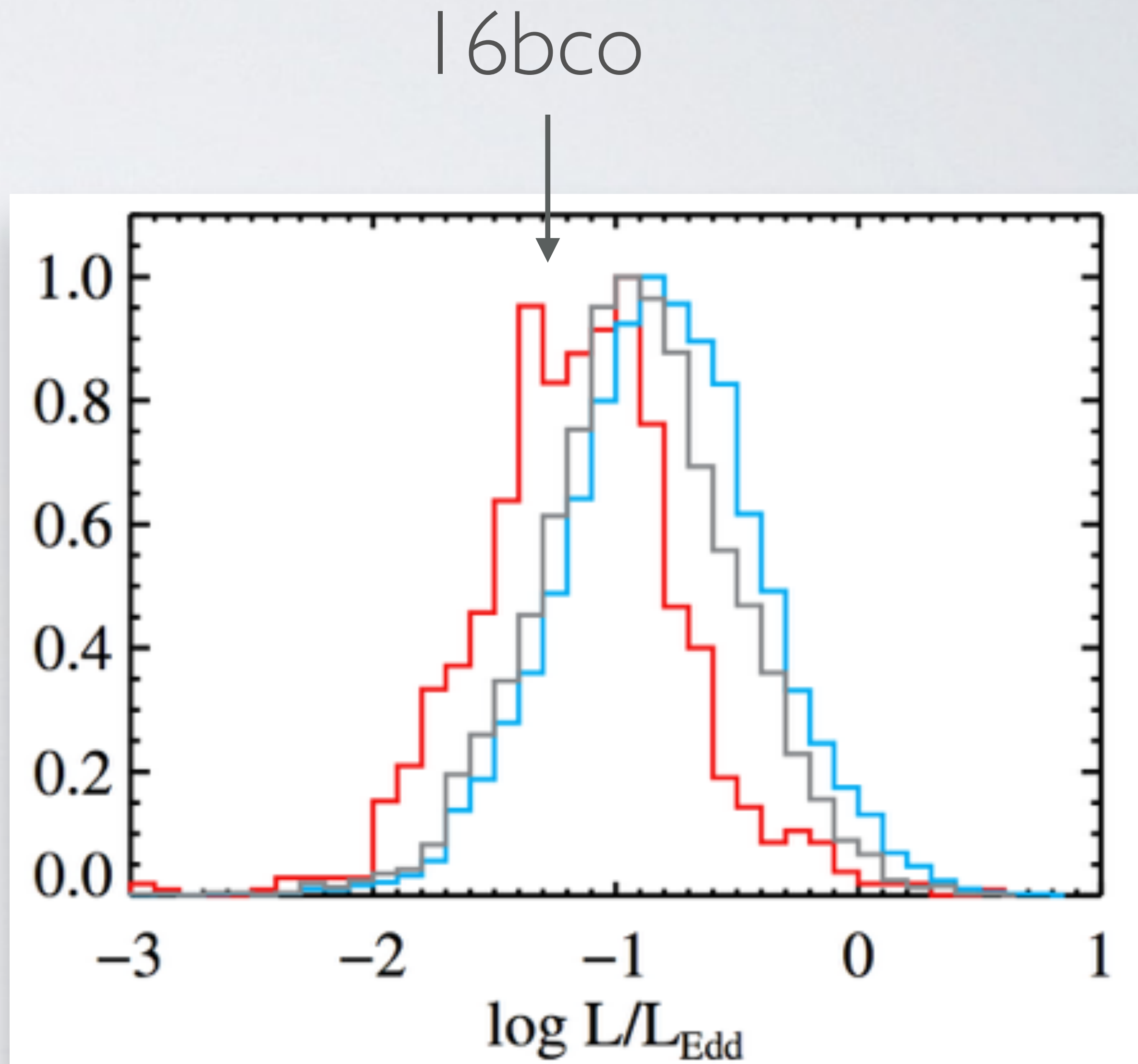
iPTF16bco



Gezari+ 2017

SUMMARY

- The most plausible explanation of the variability seem in 16bco is a changing accretion rate.
- requires a disk instability that can develop around a ~10^8 $M_\odot$ black hole on timescales less than a year
- With the transient pipeline of ZTF, more CLQs will be discovered routinely, especially the ones 'turning on'.



RUMBAUGH+ 2017