Swift X-ray to optical SEDs of z~2 quasars

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1: Background:

Quasars emit brightly from the radio to the X-rays and beyond **(Figure 1).** Their ultimate energy source is almost certainly accretion of gas onto a supermassive black hole. However, the detailed structure and physics of the central engine are not well understood.

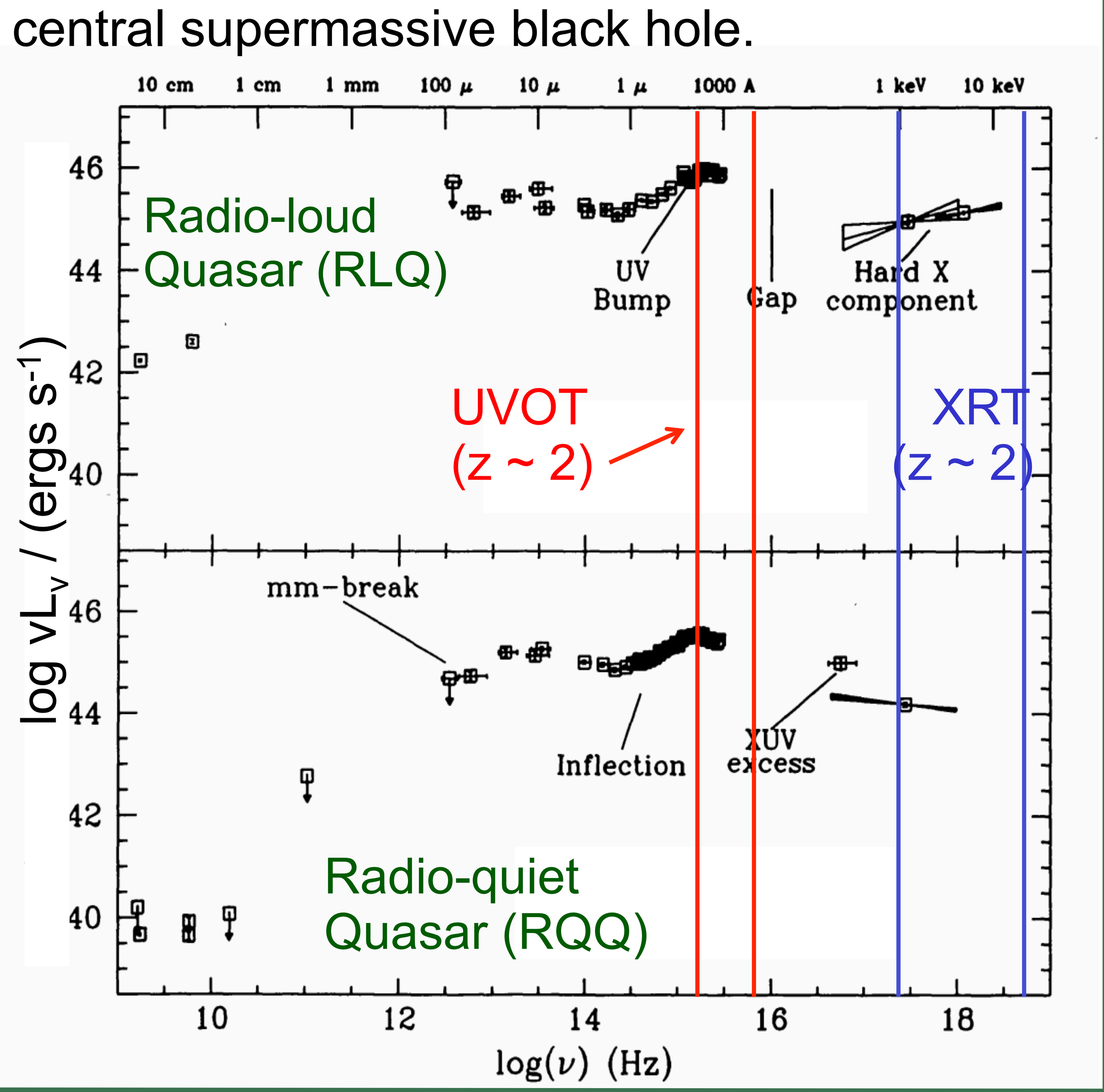
We study the **spectral energy distributions (SEDs)** of ***z* ~ 2 quasars** to learn more about the relationships between the **accretion disk**, the **X-ray emission**, and the UV-optical **broad emission lines**. Our sample has radio-loud and radio quiet objects pair-matched in *z* and absolute V-band magnitude, M_V, and covers the full range of inferred viewing angles for radio-loud quasars. We aim to study effects due to **source** (i.e., jet/disk) **orientation**, **radio loudness**, **X-ray brightness**, and total **accretion luminosity**, and the impacts of disk winds (e.g., Box 5) on emission line shape.

Through this study we also aim to **identify which line components are virialized**. This will improve the accuracy of linewidth-based mass estimates of the central supermassive black hole.

Figure 1: Sample radio to X-ray observed quasar SEDs.

Vertical lines mark the spectral coverage of *Swift* UVOT (red) and XRT (blue) for z~2 quasars

Adapted from Elvis et al. (1994).



2: Our sample:

143 quasars: 76 RLQs, 67 RQQs

We obtained 'accretion SED' with simultaneous *Swift* UVOT and XRT observations during 2013-2018 (Danish Program and GO Programs).

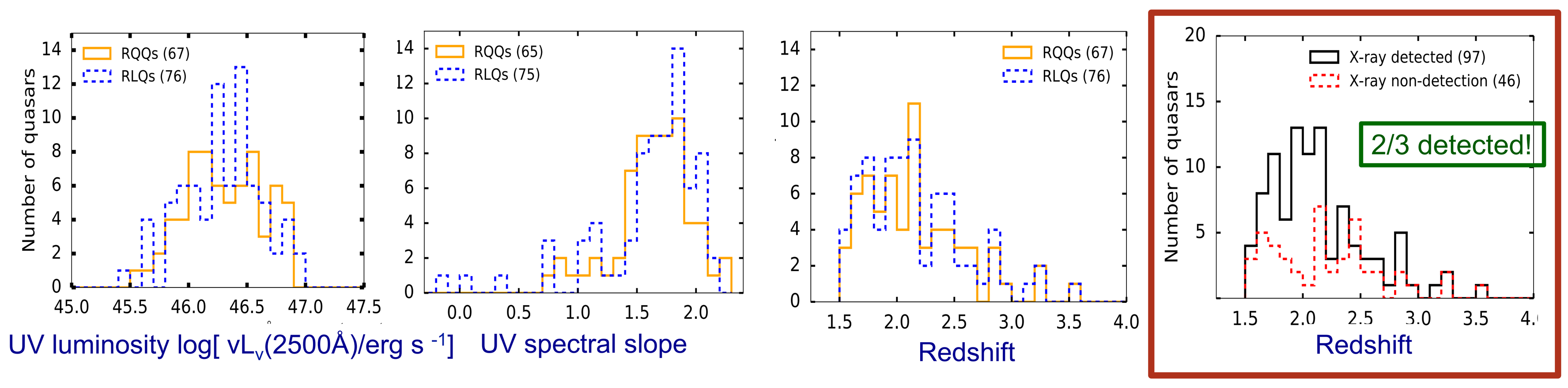


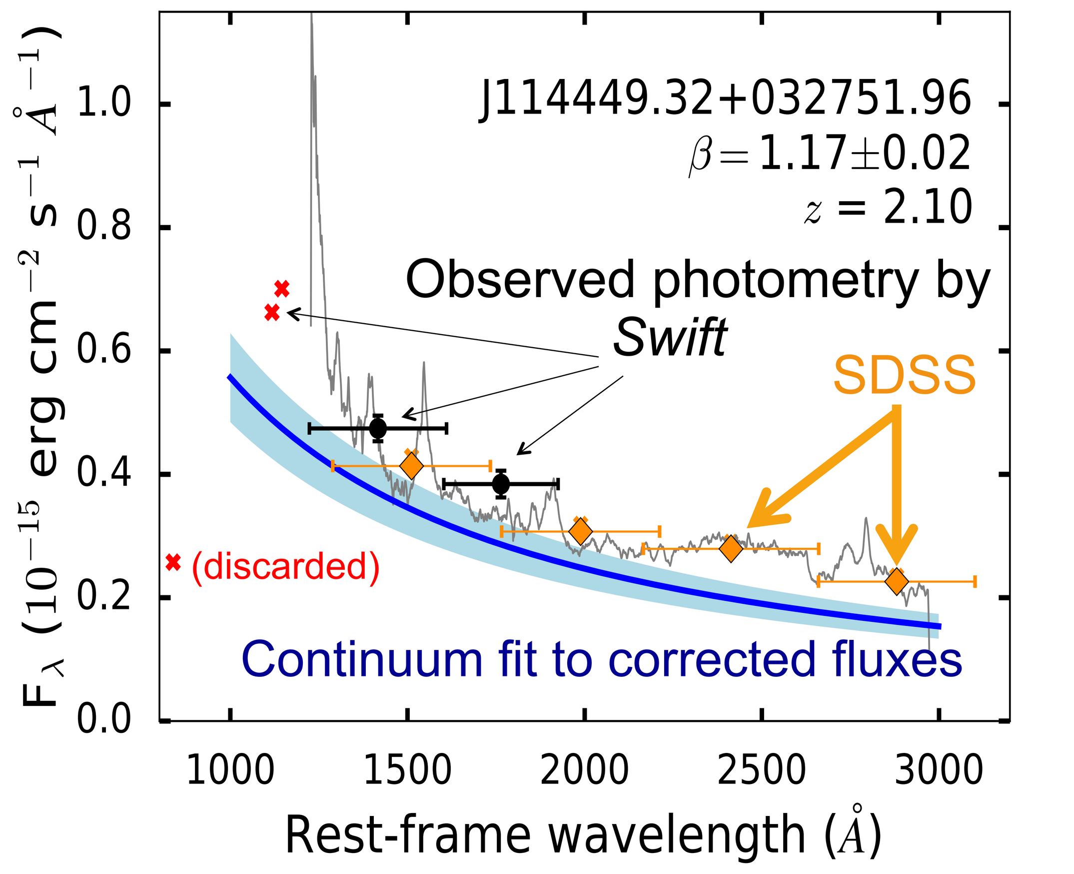
Figure 2 Properties: typical of z~2 quasars, yet they are not the brightest or the faintest (M_V: –26.5 to –29.5 mag). *Swift* is not powerful enough to detect all objects

3: Correcting for emission line contribution

To isolate the accretion disk emission and make use of all available photometry, **we use quasar template spectra** (Selsing+ 2016; Vanden Berk 2001) to determine the emission line contribution in each UV-optical band-pass.

We model the continuum with a power-law function based on the corrected broad-band fluxes.

Figure 3



4: Spectral Energy Distributions and Accretion Luminosity

- Rescaling of SDSS photometry ➔ **'Pseudo-simultaneous'** SEDs between rest-frame ~ 3000 Å and ~ 25 keV.
- α_{OX}: the X-ray to optical-UV **spectral index** between 2500Å and 2 keV

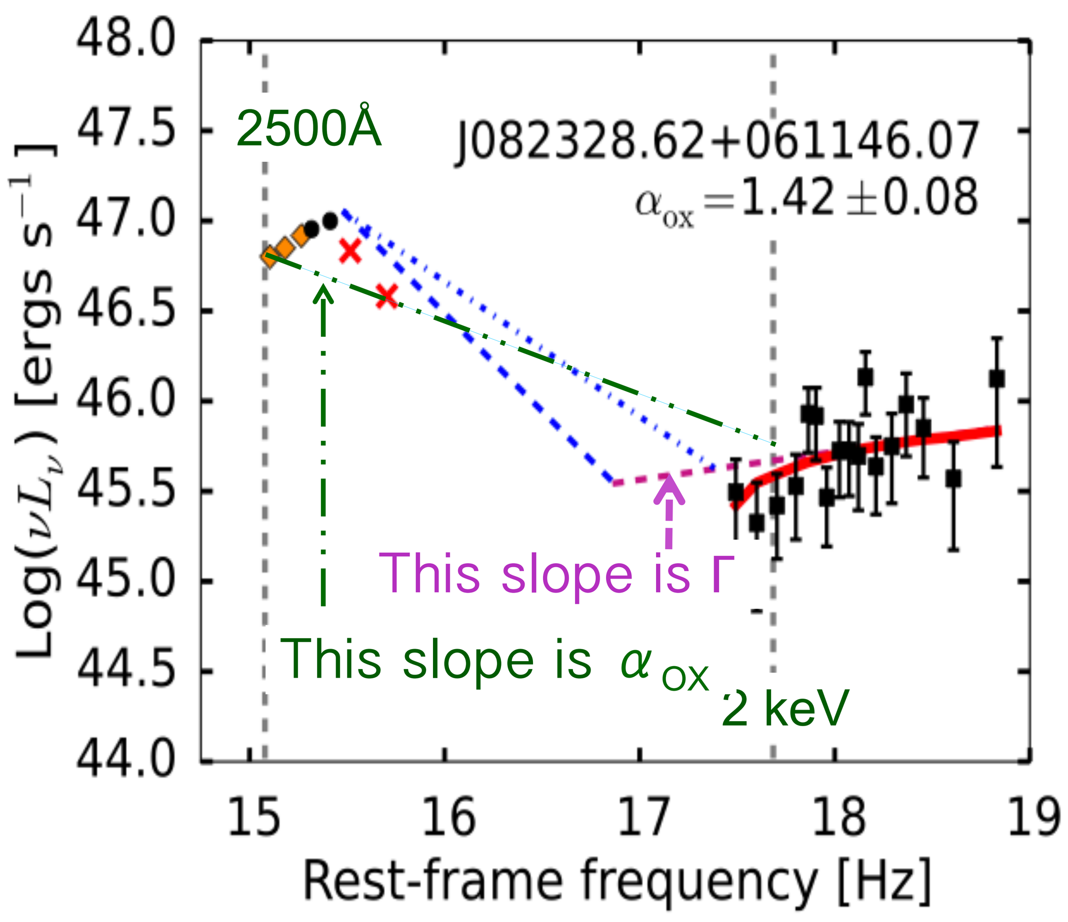


Figure 4: Sample quasar X-ray-UV-optical SED.

- Power-law extrapolation across the unobservable extreme-UV band (blue)
- Guideline estimate of total **accretion luminosity**
- Consistent with physically motivated SED modeling (Kilerci-Eser & Vestergaard 2017)

5: Results I – Sample properties

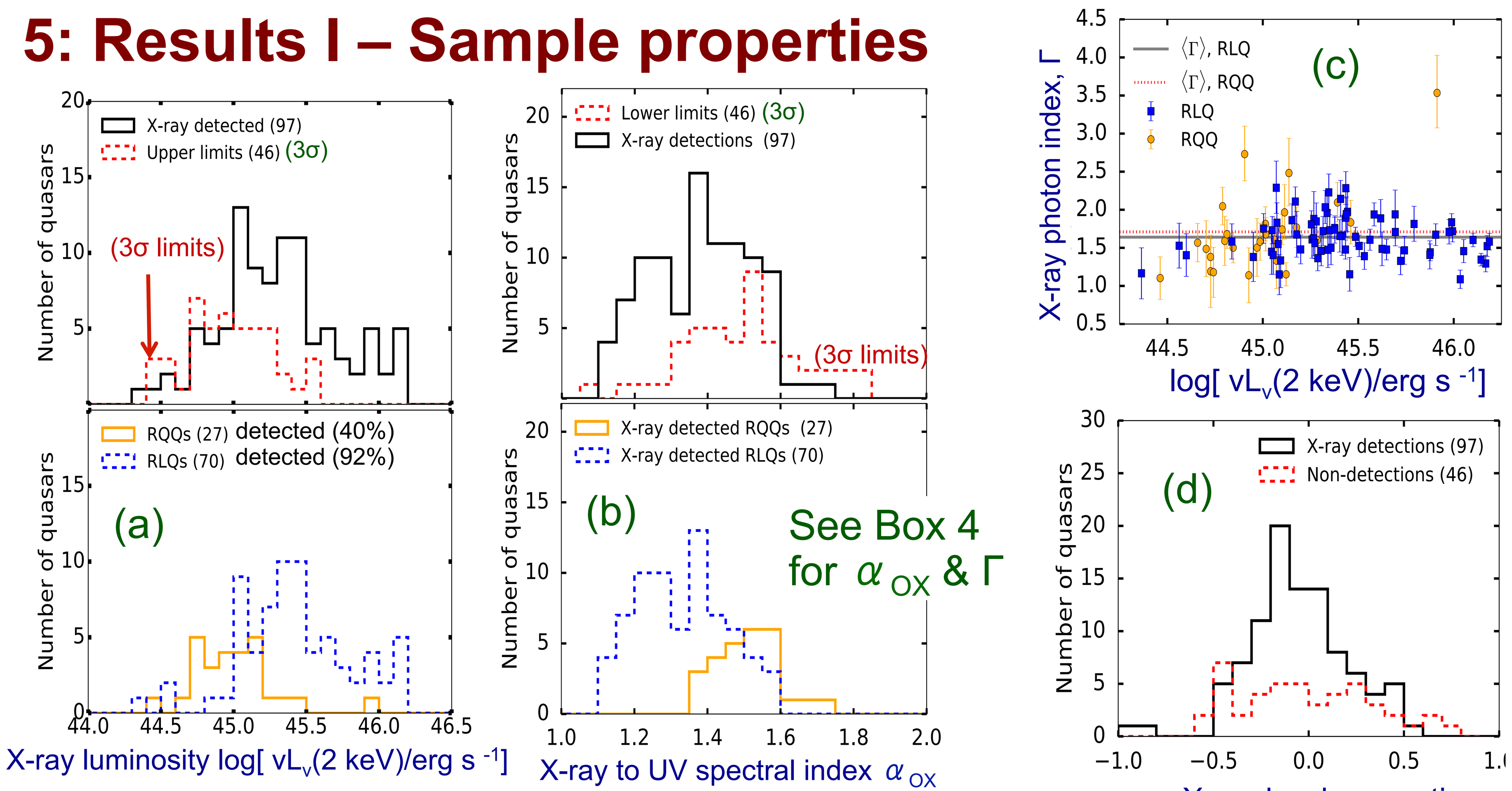


Figure 5 Sample X-ray and UV properties.

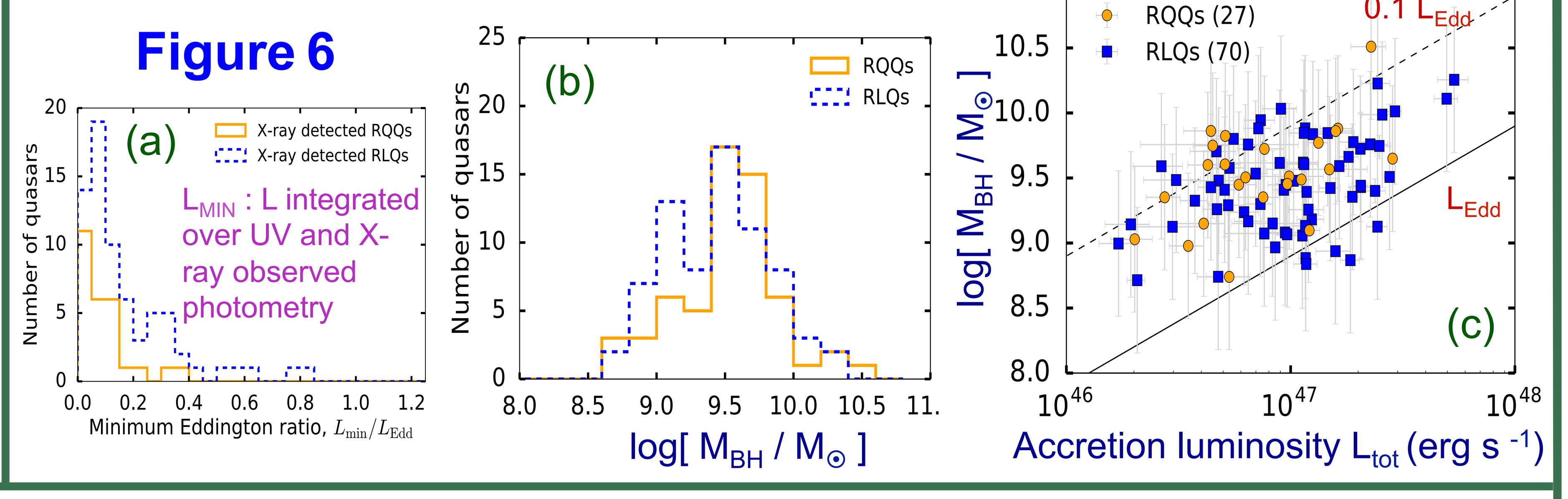
- Properties are typical of RLQs & RQQs at *z*~2. RLQs & RQQs similar, except:
- RQQs are X-ray weaker (panel a) and have softer SEDs (higher α_{OX}; panel b).

★NB! Objects with softer SEDs are more prone to have disk winds (Murray+ 1995)★

6: Black hole masses and accretion rates are typical!

- **Black hole masses** from C IV linewidth and continuum luminosity (Vestergaard+Peterson 2006) – typical of *z*~2 quasars! (Fig. 6, panel b)
- Sample median M_{BH} : $3.9\times10^9\ M_\odot$ (panel b) ✓
- Integrated UV – X-ray luminosity (L_{tot}) and M_{BH} ➔ L_{tot}/L_{Edd} (panel a,c) & **a crude accretion rate estimate** (Raimundo+ 2012): 3.3 $M_\odot$ yr^{-1} (median)
- Our quasars accrete at similar rates to *z* < 2 Palomar-Green quasars with comparable black-hole masses ✓

Figure 6



7: Results II

- High-rate accreters (L_{tot}/L_{Edd} > 0.3) cannot have a thin accretion disk (Shakura+ Sunyaev 1973). The disk will thicken ('slim disk') – advanced modeling is needed.
- Attempts to model the data with Novikov+Thorne (1973) theoretical accretion disk models show that too many parameters are unconstrained. Better black hole masses and inclination measures are needed. Work is in progress (Koay+ in prep.; Vestergaard+, in prep.)

Next step

- ***Verified (!!!):*** Sample is typical of RLQ and RQQ at *z* ~ 2. ✓
- Next step: Analyze X-ray – UVOT *Swift* catalog along with UV-optical-IR spectral properties to address the issues outlined in Box 1. For example, do RQQ UV-optical line profiles show signatures of outflowing disk winds (Boxes 1 & 5)?

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REFERENCES: Elvis+ 1994 ApjS, 95, 1 – Kilerci-Eser & Vestergaard 2018, MNRAS, 474, 1590 – Murray+ 1995, ApJ, 451, 498 – Novikov & Thorne 1973, in Astrophysics of Black Holes, eds. Dewitt & Dewitt – Raimundo+ 2012 MNRAS, 419, 2529 – Selsing+ 2016 A&A, 585, A87 – Shakura & Sunyaev 1973 A&A, 24, 337 – Strateva+ 2005 AJ, 130, 387 – Vanden Berk+ 2001, AJ, 122, 549 – Vestergaard & Peterson 2006, ApJ 641, 689