Weak Emission Line Quasars:

Confronting New Challenges in Understanding the Broad Emission Line Region

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The Inner Regions of Quasars, UT Austin, September 13, 2014

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Outline

- Weak emission line quasars (WLQs): history and mystery
- Insights from multiwavelength observations
- What are WLQs telling us about the BELR and SED?
- Summary of key questions

Weak Emission Line Quasars (WLQs): History and Mystery

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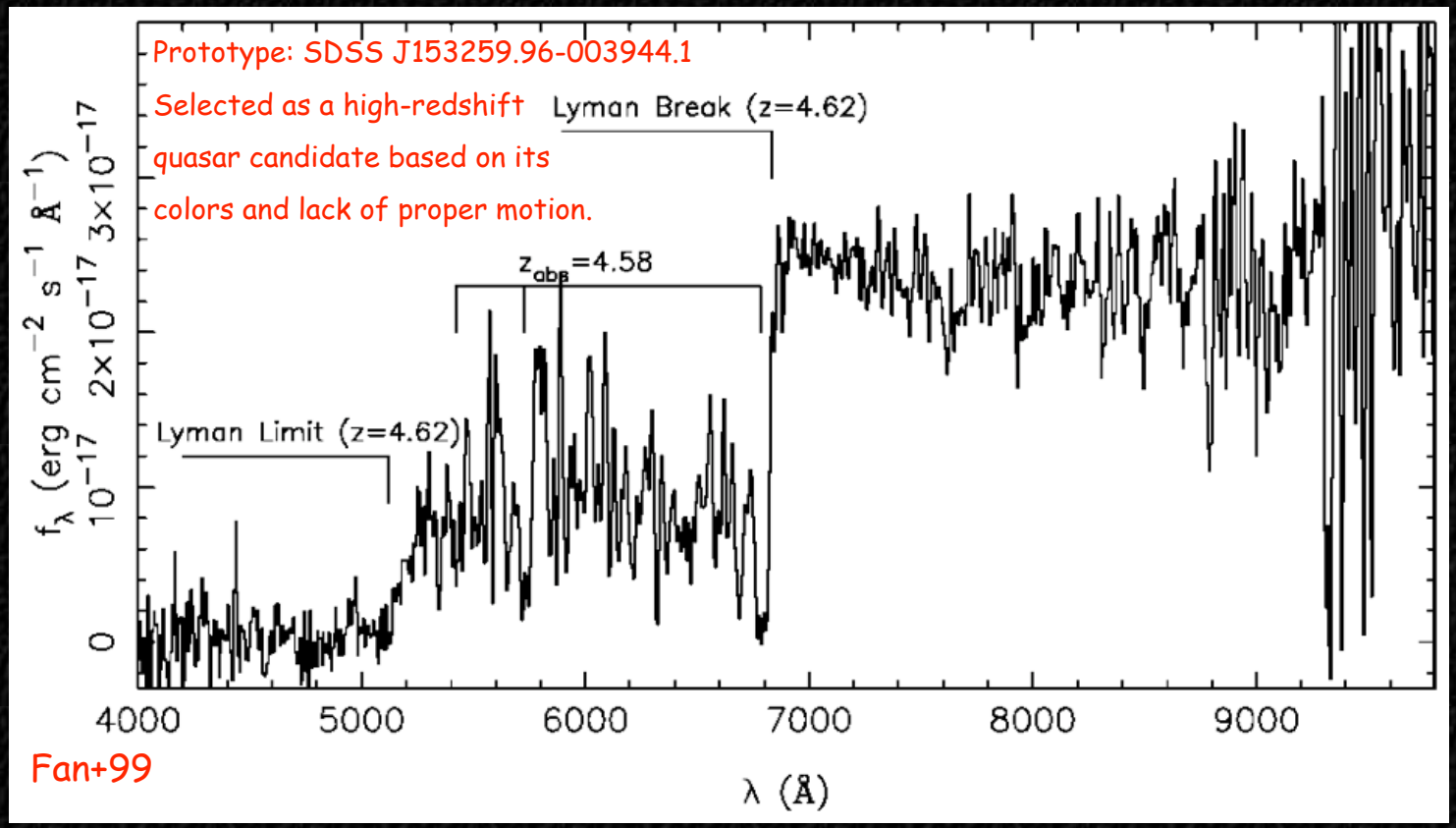
WLQs: History and Mystery

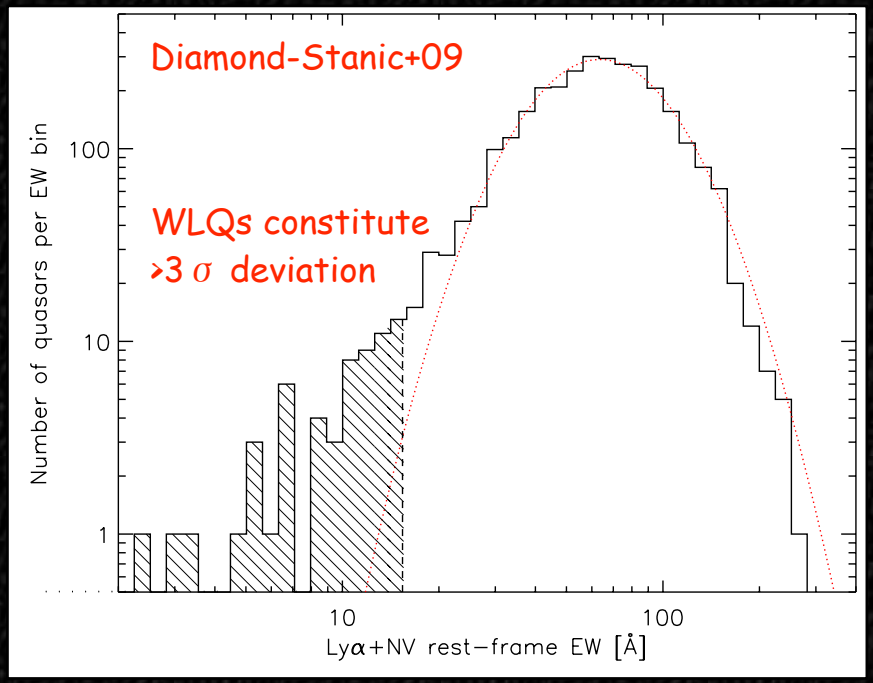
~100 SDSS sources, mainly at high redshift, with quasar-like continua but extremely weak or undetectable emission lines in their UV spectra.

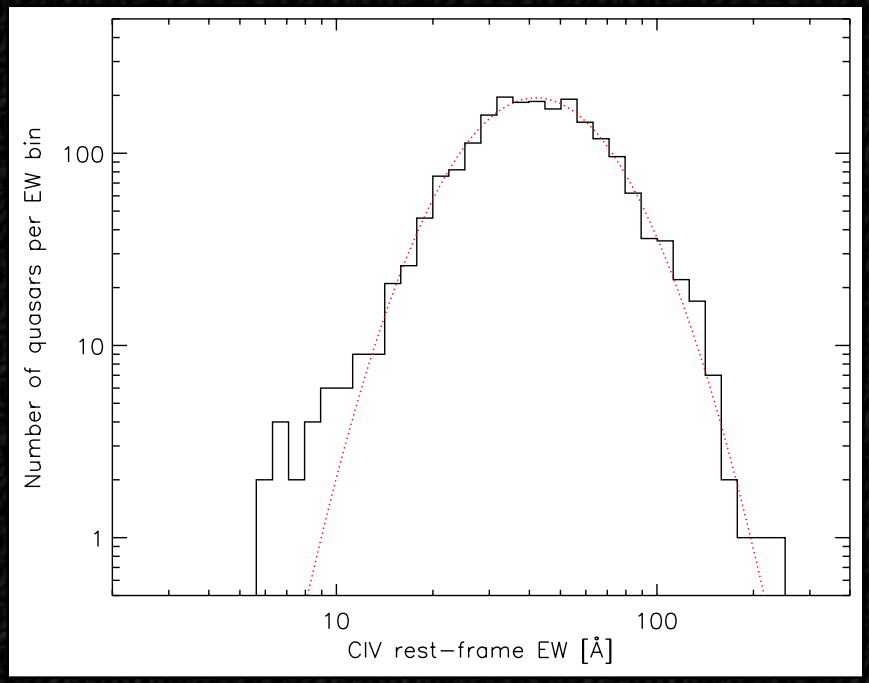


Have we found the long-sought BL Lacs at high redshift?

WLQs: History and Mystery

Distributions of broad emission line equivalent widths (EWs) in SDSS quasars at z>3

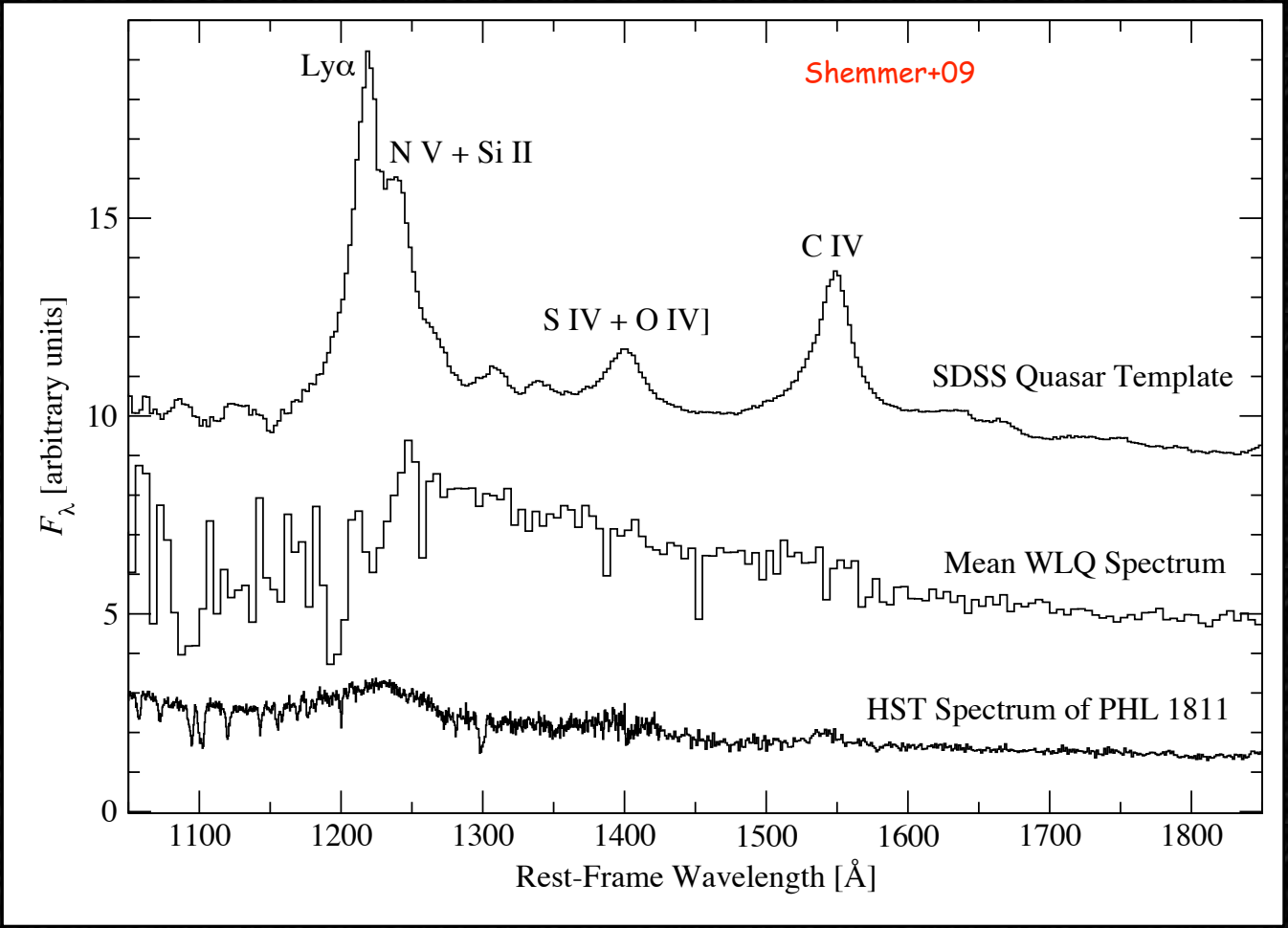




WLQs were originally defined as quasars having EW ≤ 15.4 Å for the Lyα+N V emission-line complex (EW ≤ 10 Å for C IV).

Q1: What determines the shape of the line EW distributions?

WLQs: History and Mystery



Why are the UV emission lines in WLQs so weak or absent?

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WLQs: History and Mystery

Following Bev's footsteps...

- ✳ Orientation?
- ✳ Obscuration?
- ✳ Polarization?
- ✳ Radio loudness?
- ✳ X-ray weakness?
- ⋮

Insights from Multiwavelength Observations

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Insights from Multiwavelength Observations

UV - optical

Clues from the UV - optical band

(e.g., Diamond-Stanic+09):

- quasar luminosities (L_{Bol} ~10^{47}-10^{48} erg s^{-1}).
- typical (blue) quasar continua.
- no broad absorption lines.
- no significant variability.
- no significant polarization.
- no detection of multiple images (not lensed).

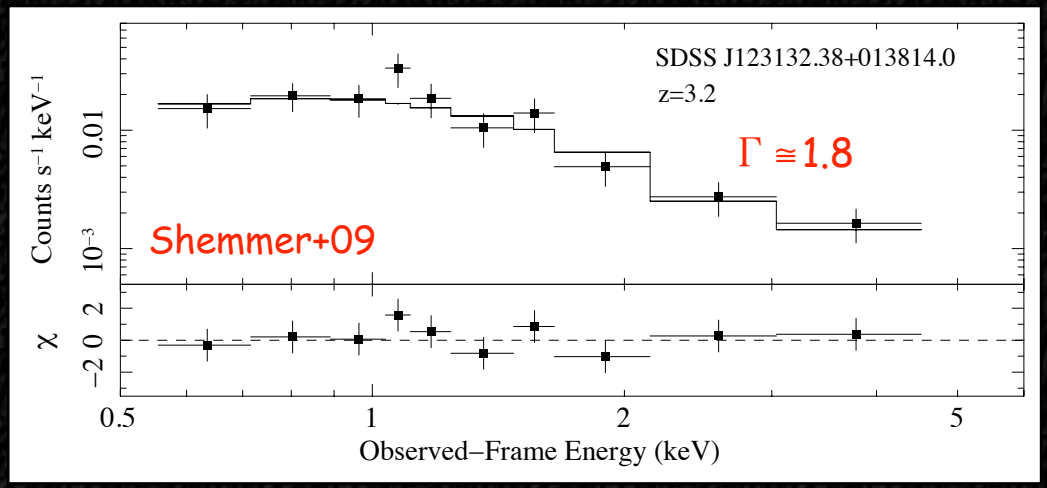
Insights from Multiwavelength Observations

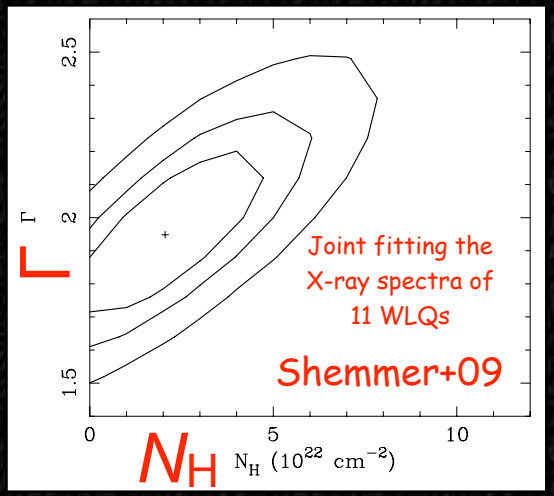
X-ray

X-ray clues:

- ✳ no sign of significant absorption.
- ✳ typical quasar power-law spectra.

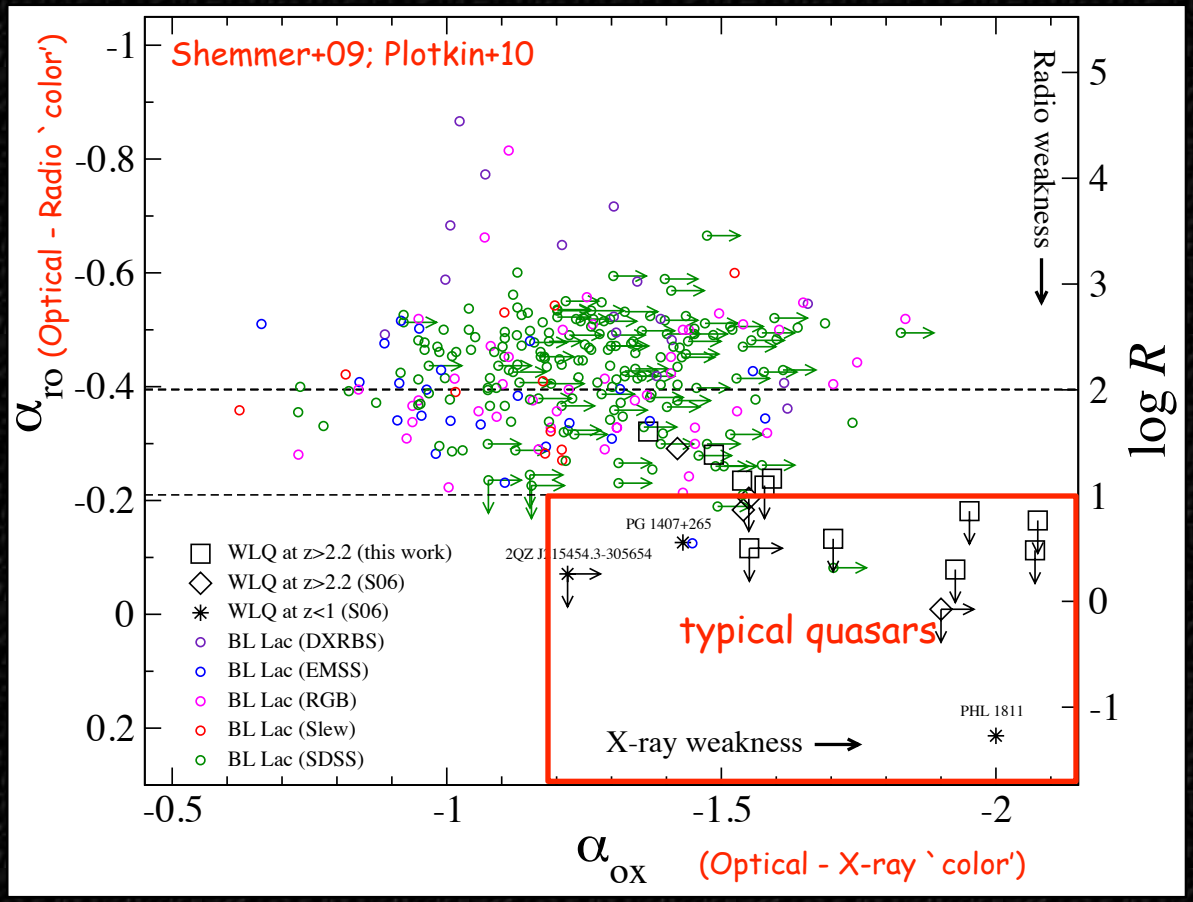
(However, so far, results are tentative: based mostly on shallow *Chandra* observations.)





Insights from Multiwavelength Observations

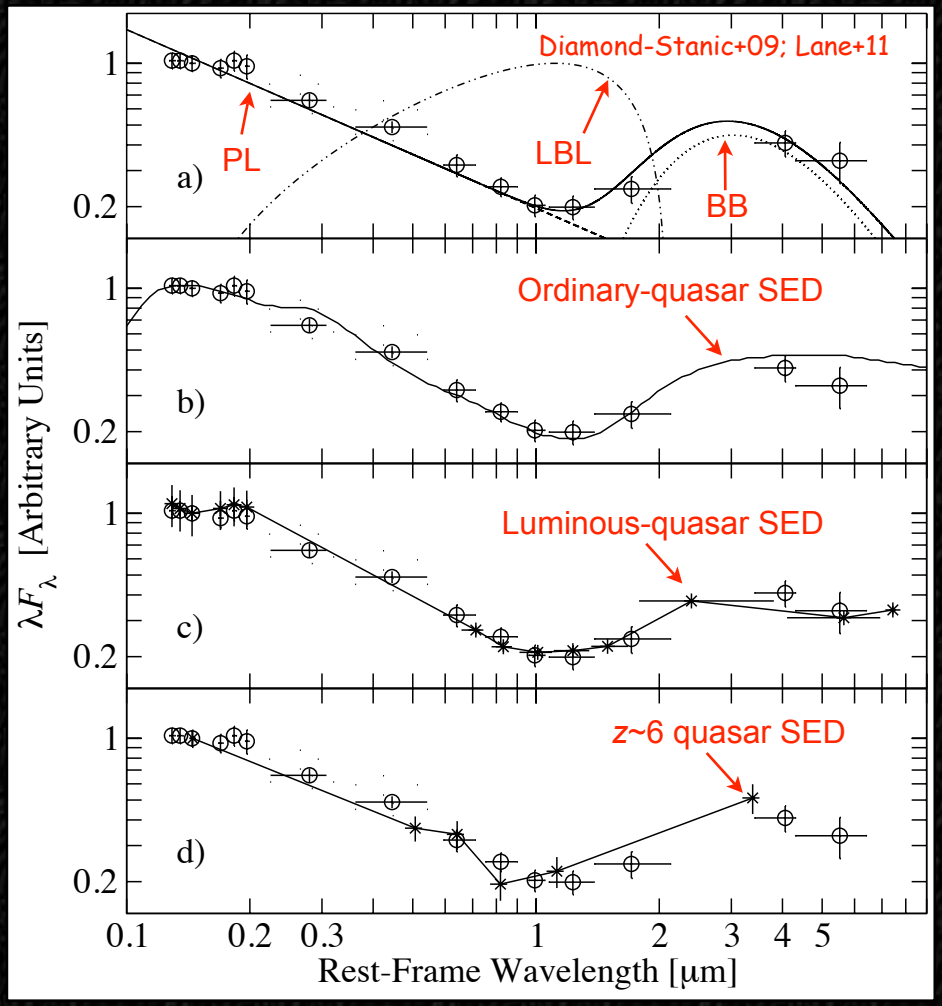
radio - optical - X-ray



If WLQs are high-redshift BL Lacs, then where is the 'parent' population of X-ray and radio bright weak-lined sources at such redshifts?

Insights from Multiwavelength Observations

UV - optical - mid-IR



Stacking SEDs of 18 WLQs using data from SDSS+NIR+*Spitzer* (Lane+11). WLQ SED is consistent with an ordinary-quasar SED.

WLQs are **unbeamed** quasars. The UV emission lines are **intrinsically** weak. Can be selected *only* via spectroscopic surveys.

What are WLQs Telling Us About the BELR and SED?

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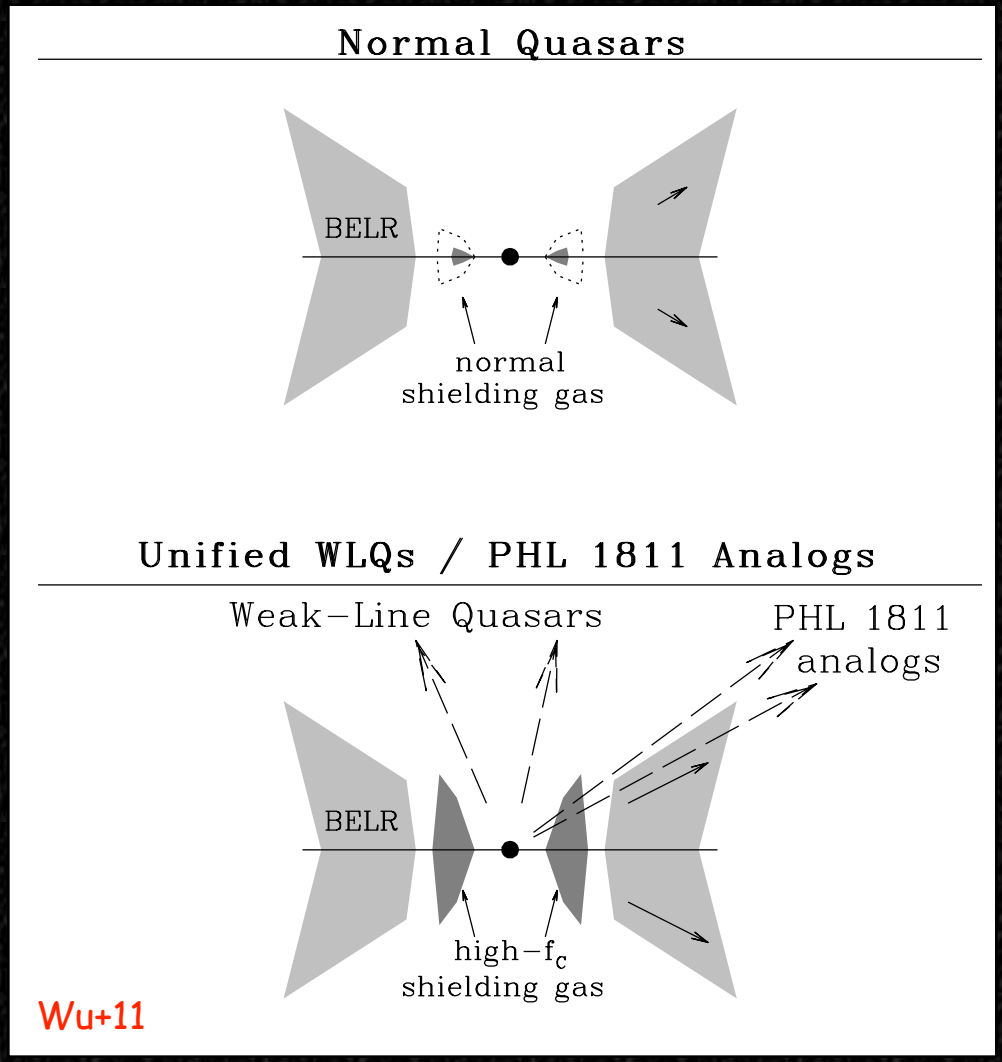
What are WLQs Telling Us About the BELR and SED?

Orientation? (see Niel Brandt's talk for more details)



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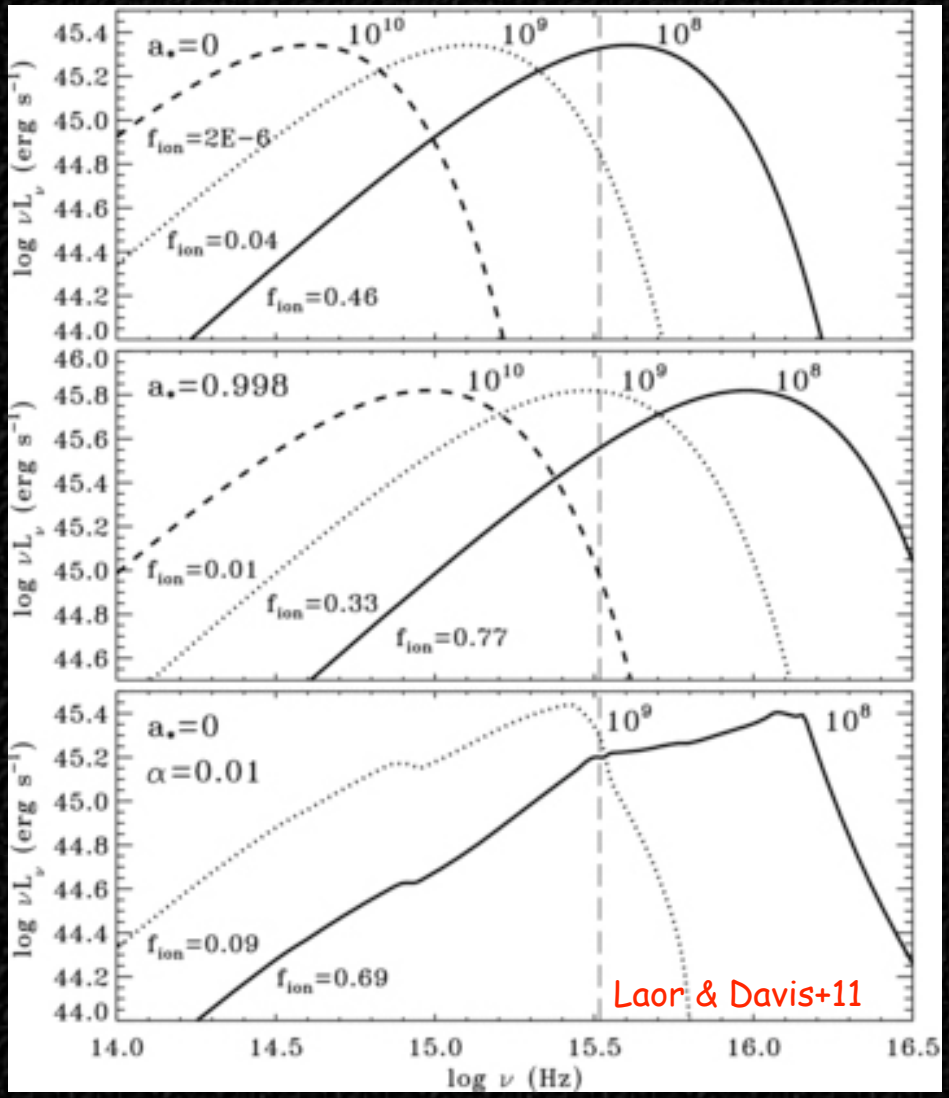


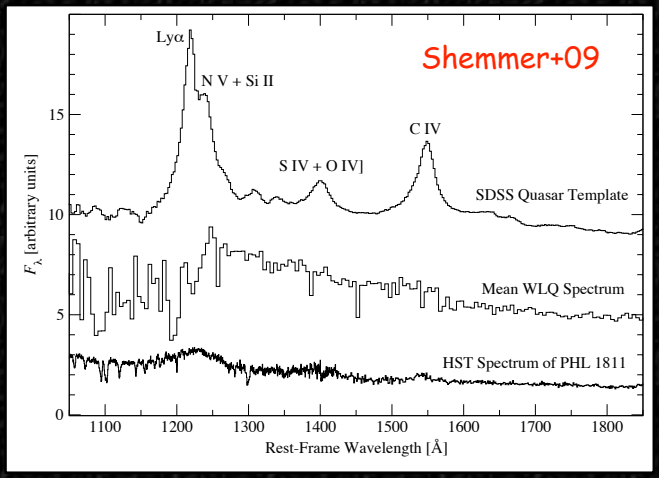
`Cold' accretion disk?

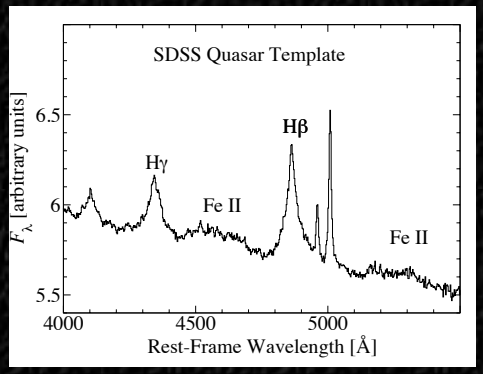
Disk SED peak frequency decreases as black-hole mass increases. Fewer energetic photons are available for ionizing the BELR. Currently investigating new *HST* UV spectra of WLQs - searching for a predicted continuum drop below 1000Å (Plotkin et al., in prep.).

What are WLQs Telling Us About the BELR and SED?

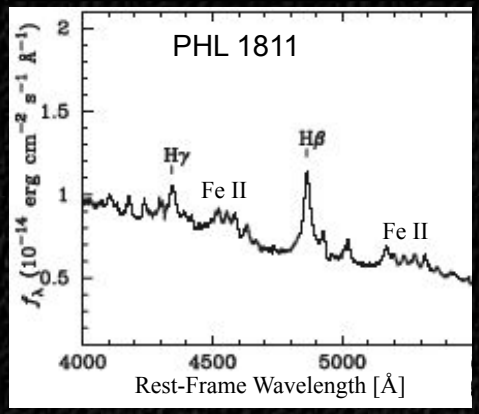
Extremely high accretion rates?

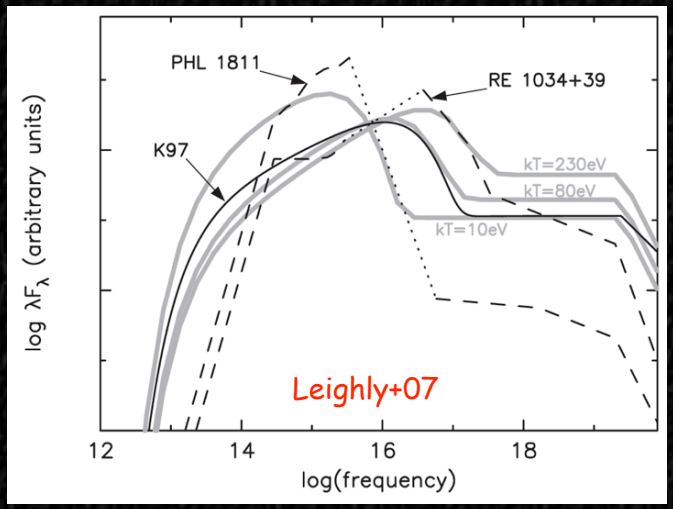
Clues from low redshift





WLQ ?



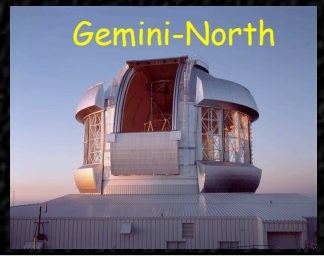


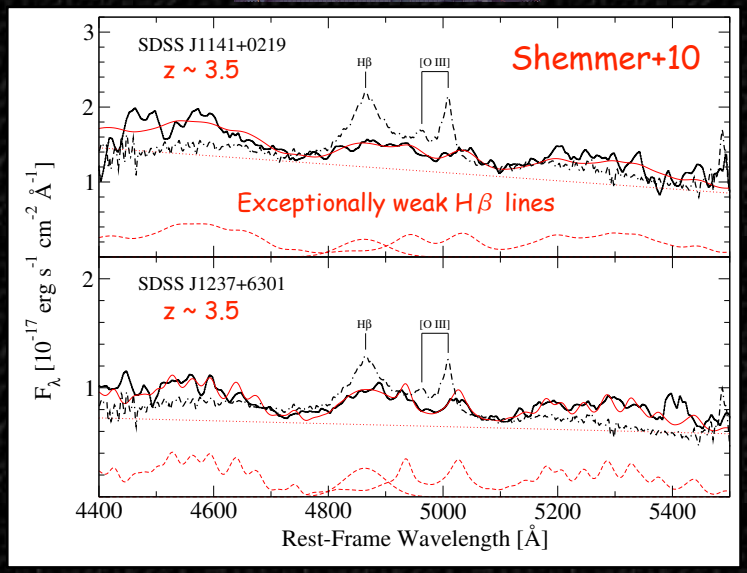
Are there low-redshift analogs to high-redshift WLQs?

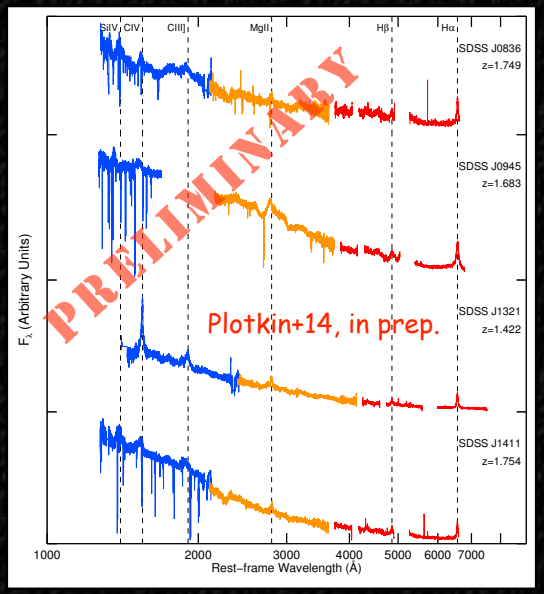
Soft SED responsible for weak high-ionization BELR lines in WLQs?

What are WLQs Telling Us About the BELR and SED?

Determining low-ionization emission line EWs and Eddington ratios [$L/L_{Edd} \propto \nu L_\nu(5100\text{Å})^{0.5}\,\mathrm{FWHM(H\beta)}^{-2}$]. Requires NIR spectroscopy.







Are the BELRs in WLQs unusually gas deficient or subject to exotic ionization conditions?

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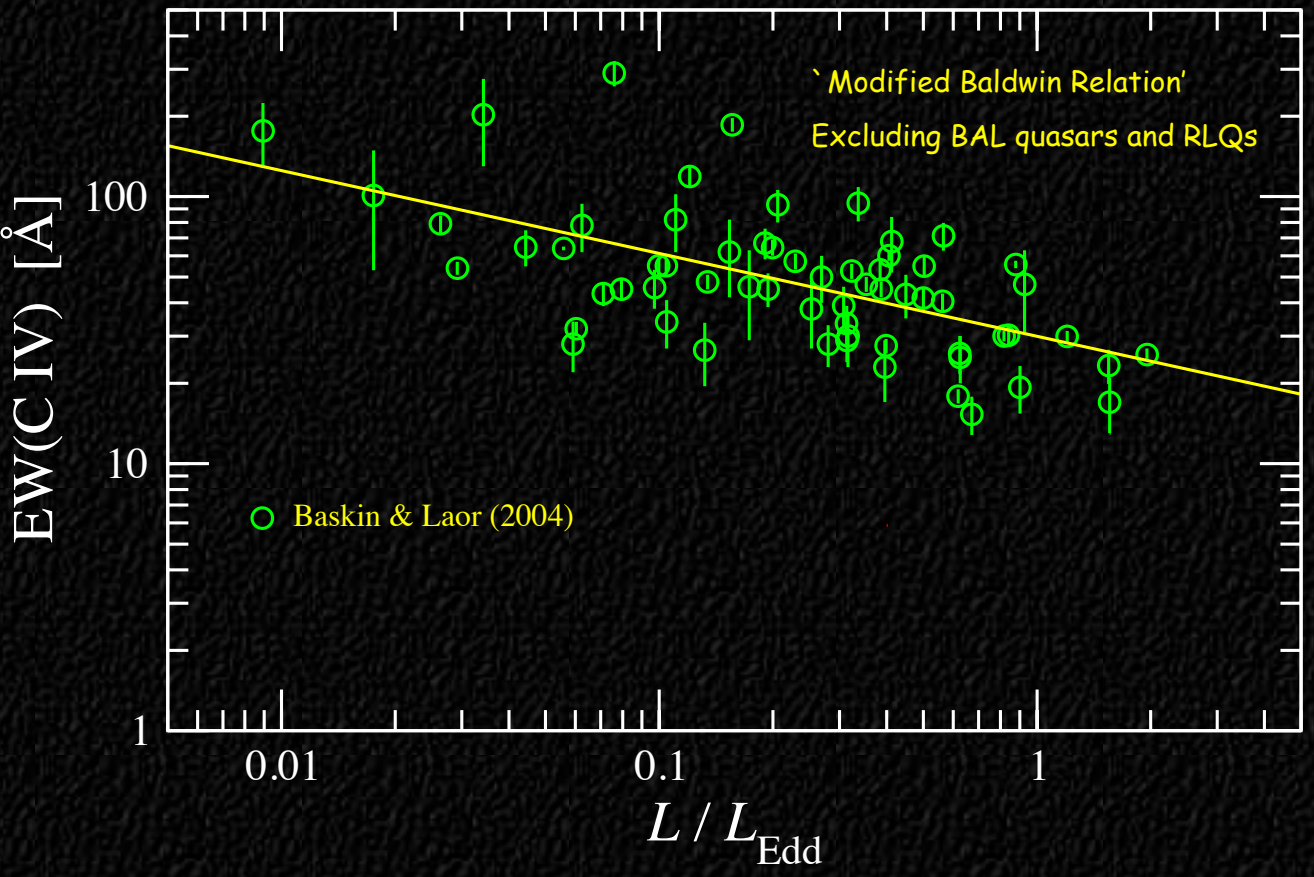
What are WLQs Telling Us About the BELR and SED?

Extremely high accretion rates or anemic BELRs?



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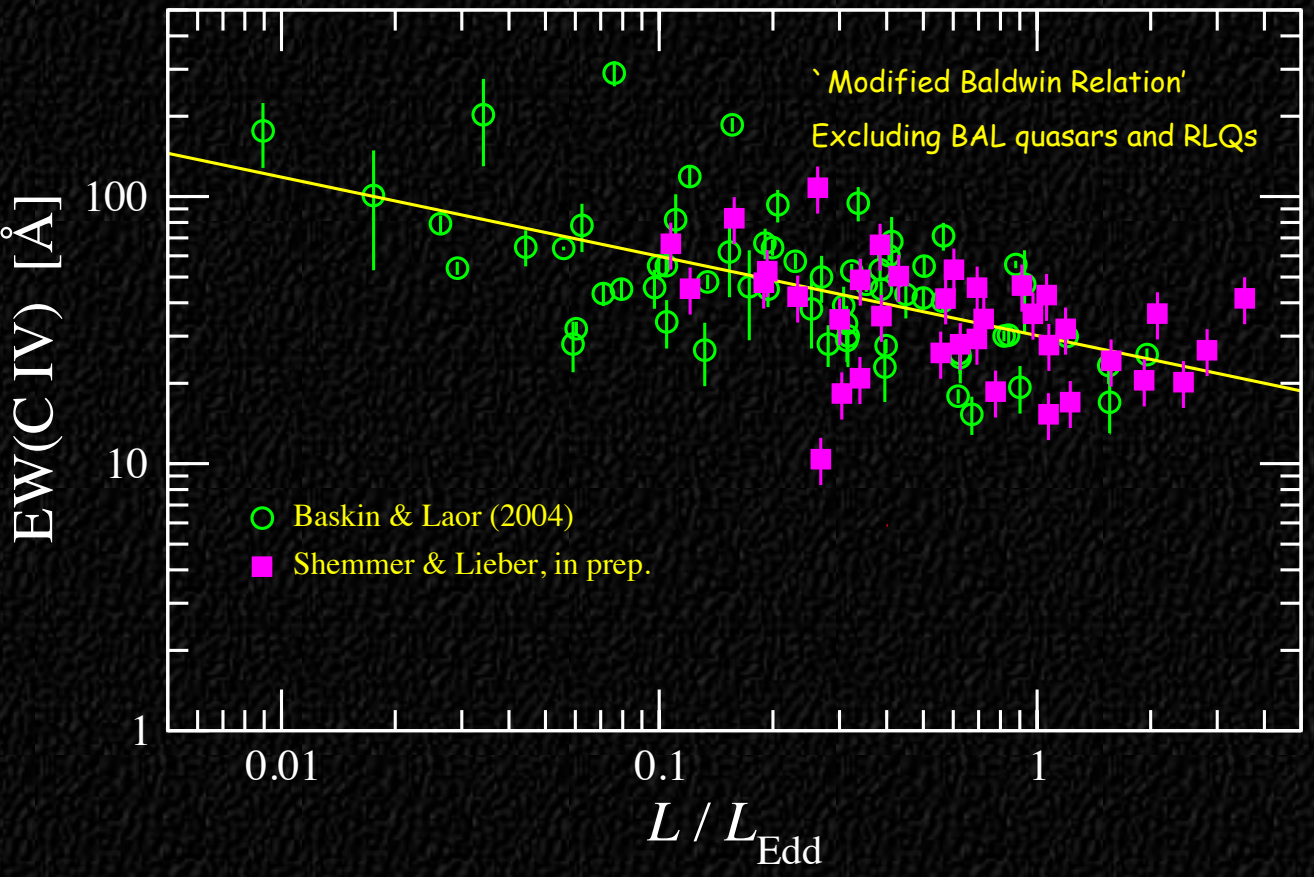

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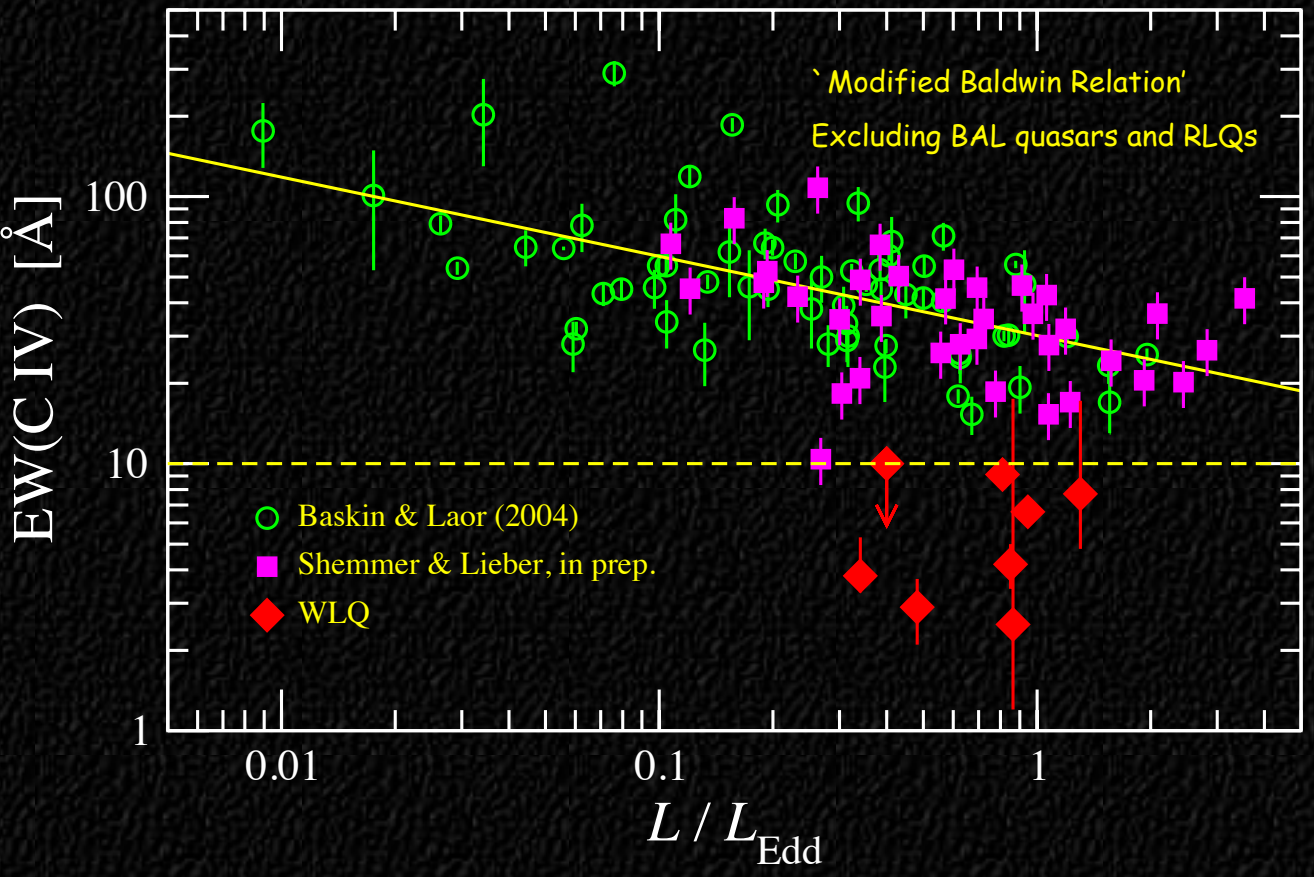

Q2: Can we determine the Eddington ratio for *all* quasars?

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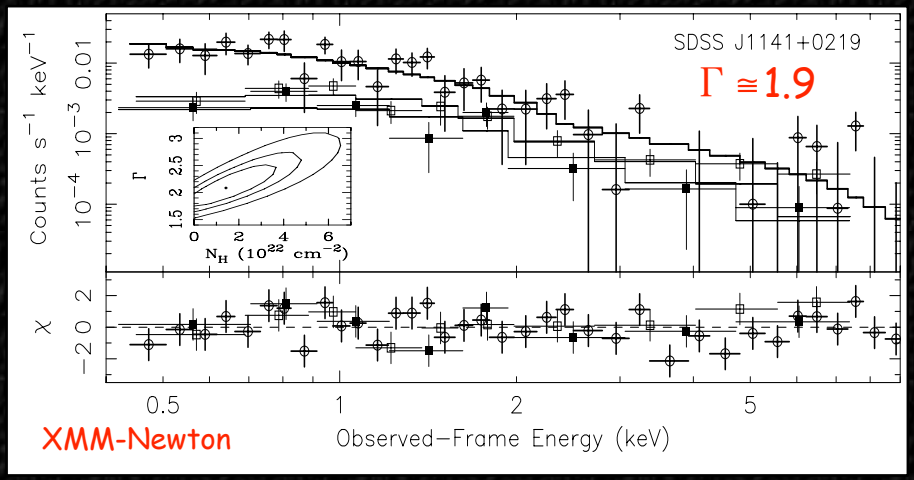
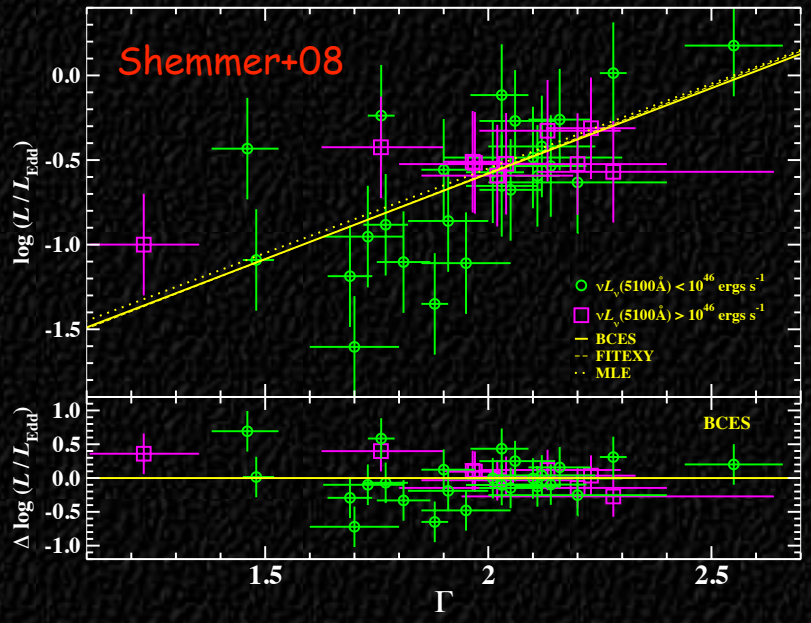
Extremely high accretion rates or anemic BELRs?





$$\log(L/L_{\rm Edd}) = (1.0 \pm 0.3)\Gamma - (2.5 \pm 0.5)$$

XMM-Newton observations of WLQs to cross-check $L/L_{\rm Edd}$ determinations: utilizing the hard-X-ray power-law photon index as an accretion-rate indicator (Stein+14, in prep.).

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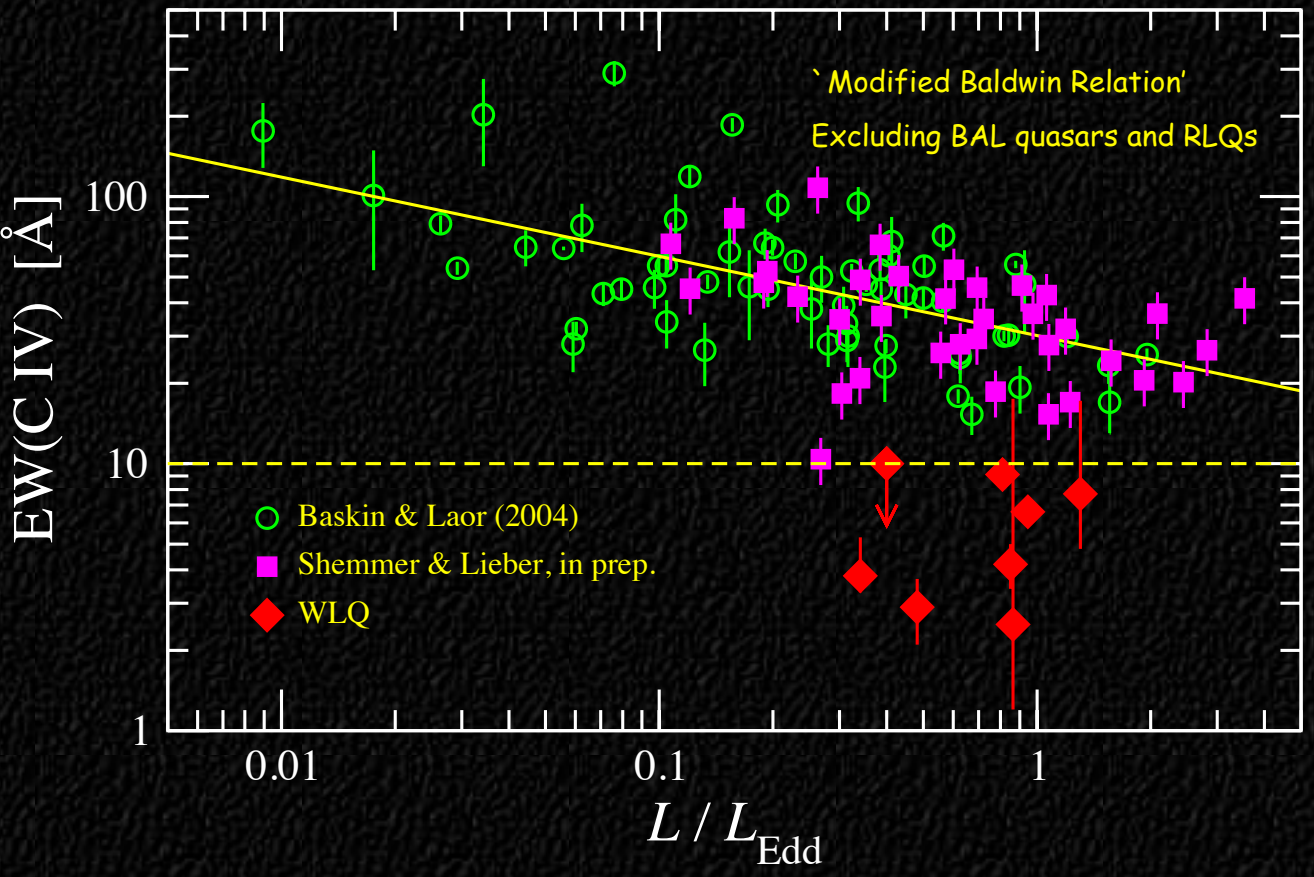

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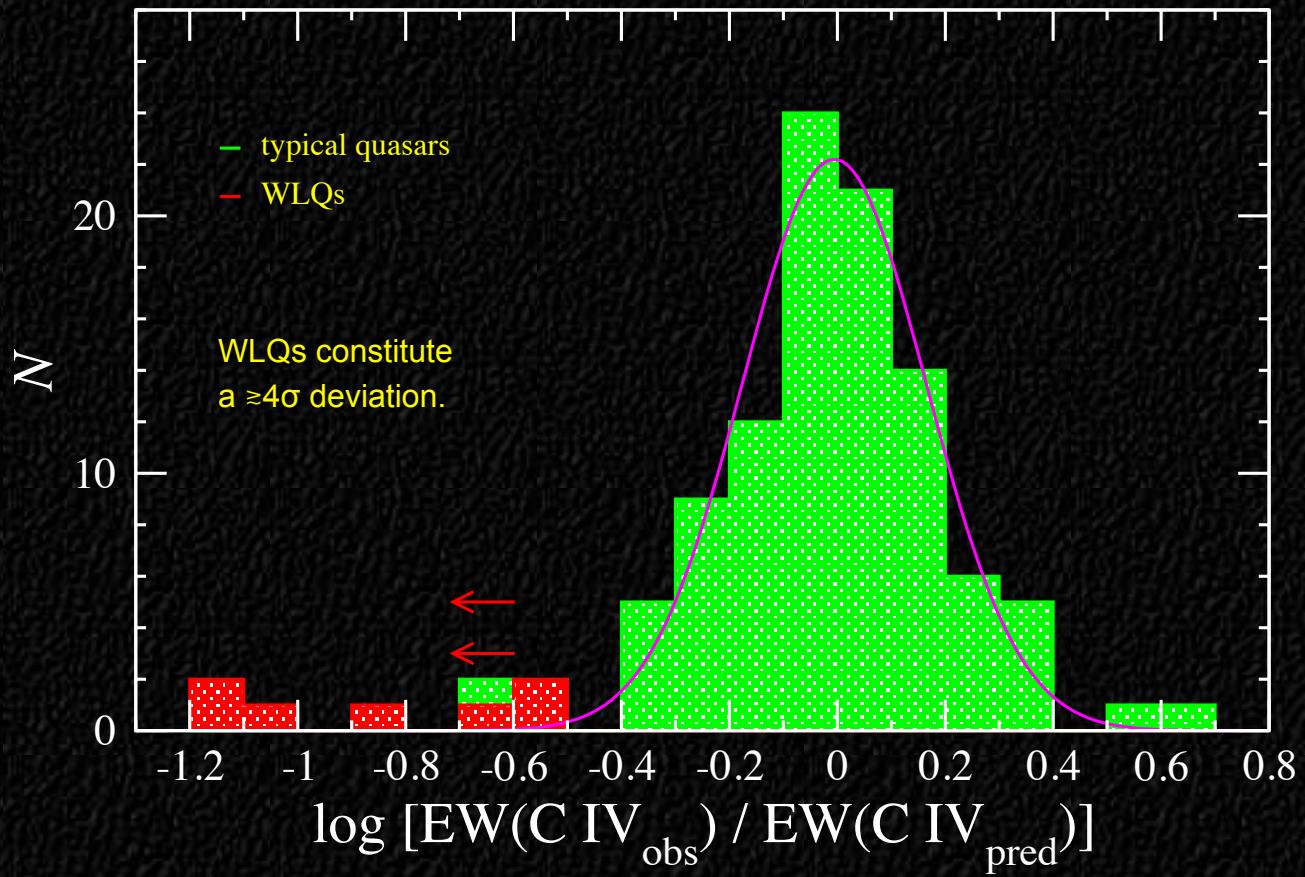
Do WLQs mark a brief evolutionary phase that all quasars go through (e.g., Hryniewicz+10)?



Q3: How long does it take the BELR to form?

What are WLQs Telling Us About the BELR and SED?

On the To Do List:

- Obtain additional NIR and X-ray spectra of WLQs.
- Analyze available *HST*/STIS spectra of six WLQs.
- Measure the relative strengths of low- and high-ionization emission lines in WLQs and compare with ordinary quasars.
- Check the dependence of relative line strengths on C IV blueshift.
- Ultimate goal: in conjunction with photoionization modeling, understand the roles that L, M_{BH}, L/L_{Edd}, the SED, density, and covering factor, play in determining the relative strengths of the BELR lines.

Summary of Key Questions

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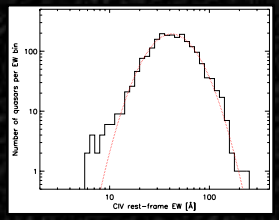
Q1: What determines the shape of the line EW distributions?



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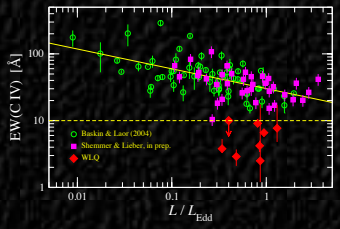

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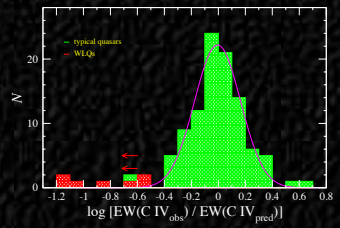

Feedback Welcome!

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