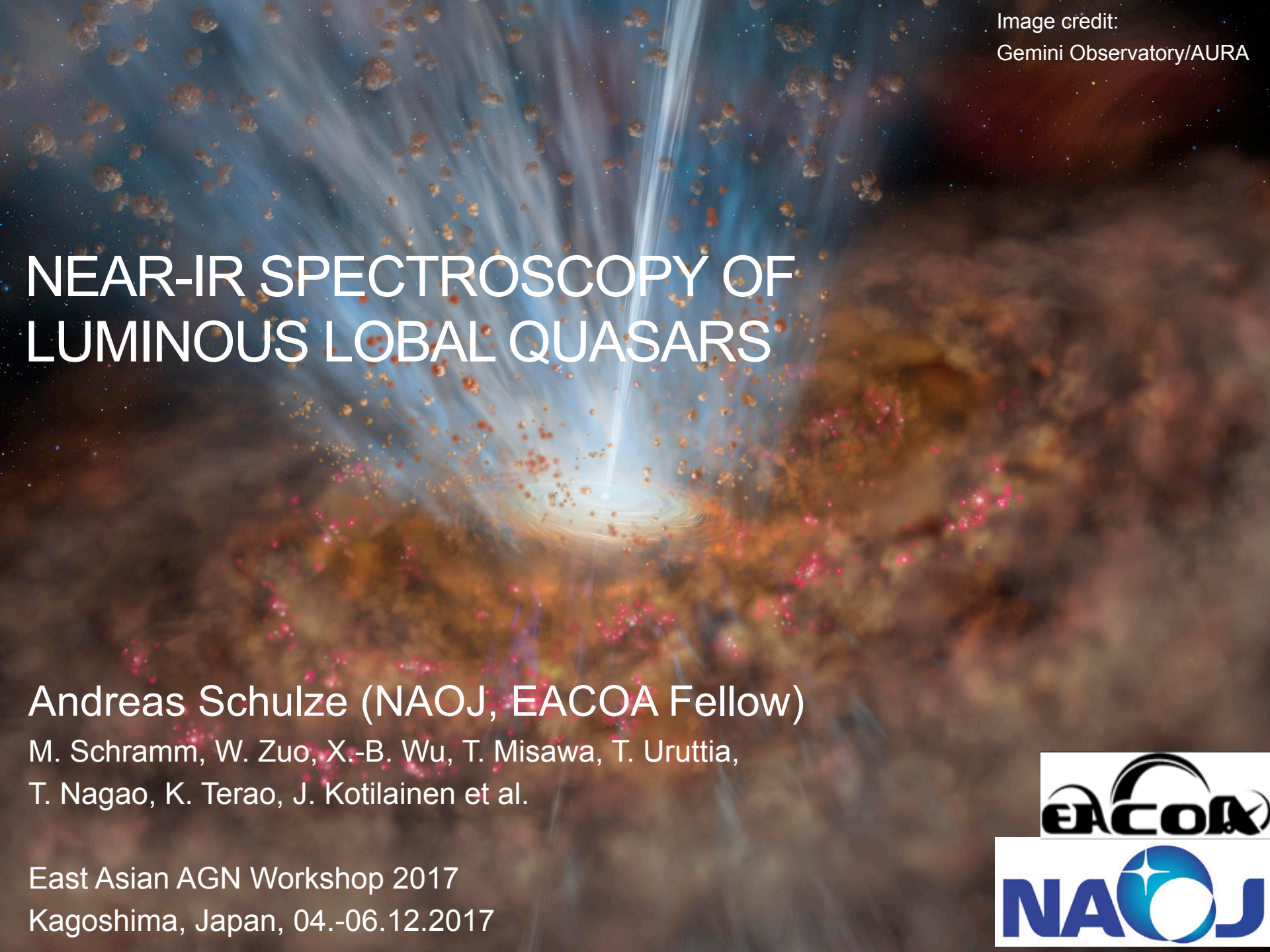


Image credit:
Gemini Observatory/AURA

NEAR-IR SPECTROSCOPY OF LUMINOUS LOBAL QUASARS

Andreas Schulze (NAOJ, EACOA Fellow)

M. Schramm, W. Zuo, X.-B. Wu, T. Misawa, T. Uruttia,
T. Nagao, K. Terao, J. Kotilainen et al.

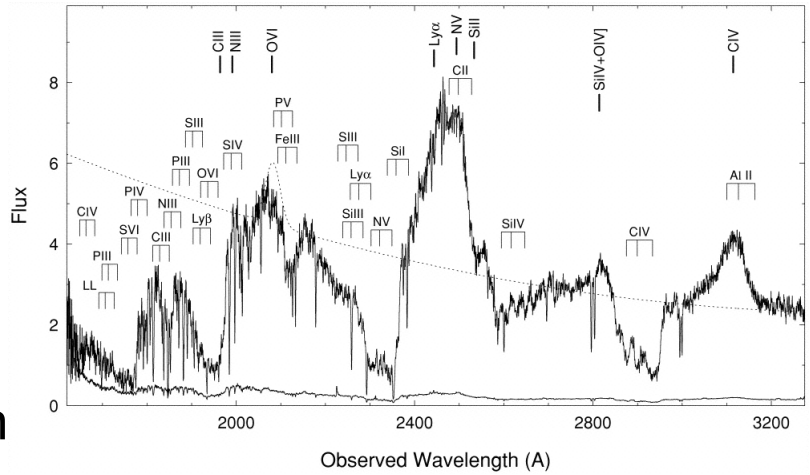
East Asian AGN Workshop 2017
Kagoshima, Japan, 04.-06.12.2017

Broad absorption line QSOs

★ Presence of broad absorption throughs with velocities up to 0.2c

★ Indicative of energetic outflows

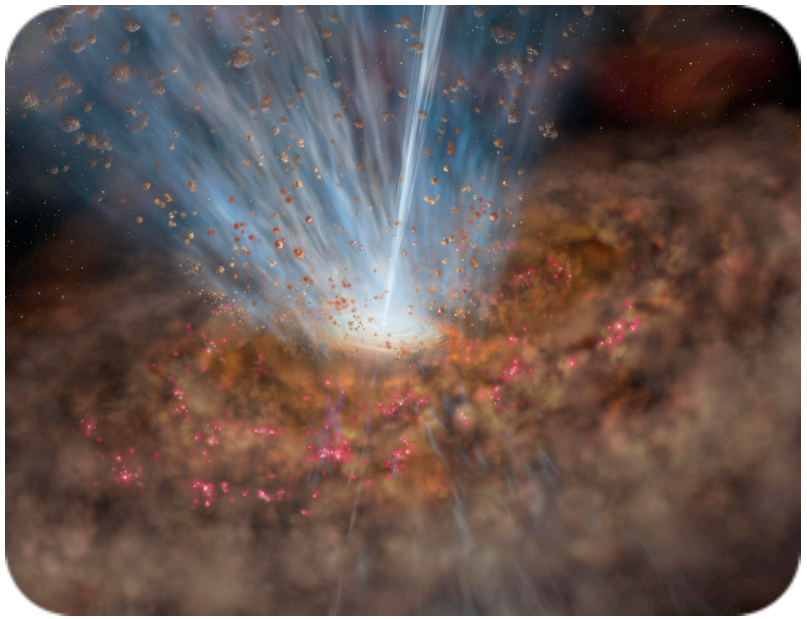
★ Outflows potentially important to regulate BH growth and star formation in host galaxy



Hamann et al. (1998)

★Observed BAL fraction ~15%

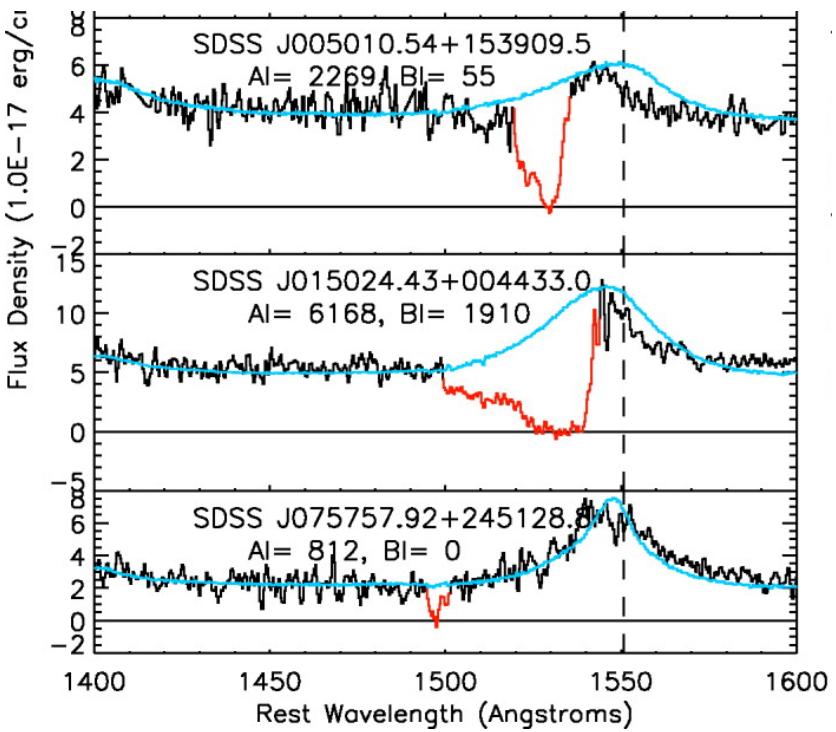
★ Intrinsic fraction higher (up to 40%)

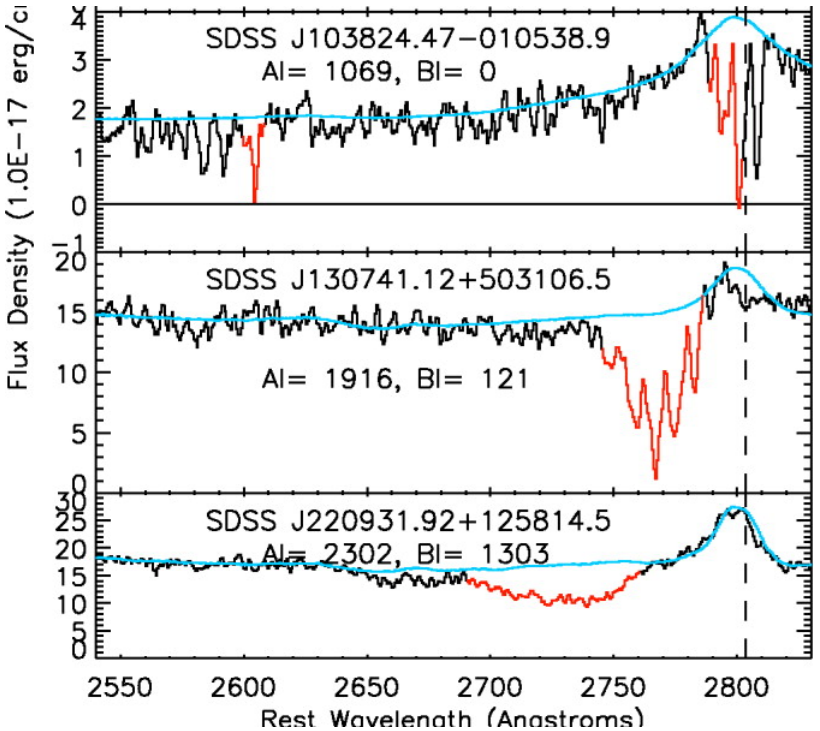


BAL QSOs: two main types

★ High ionization broad absorption line QSOs (HiBAL)
=> absorption in C IV, Si IV, etc

★ Low ionization broad absorption line QSOs (LoBAL)
=> additional absorption in Mg II, Al III



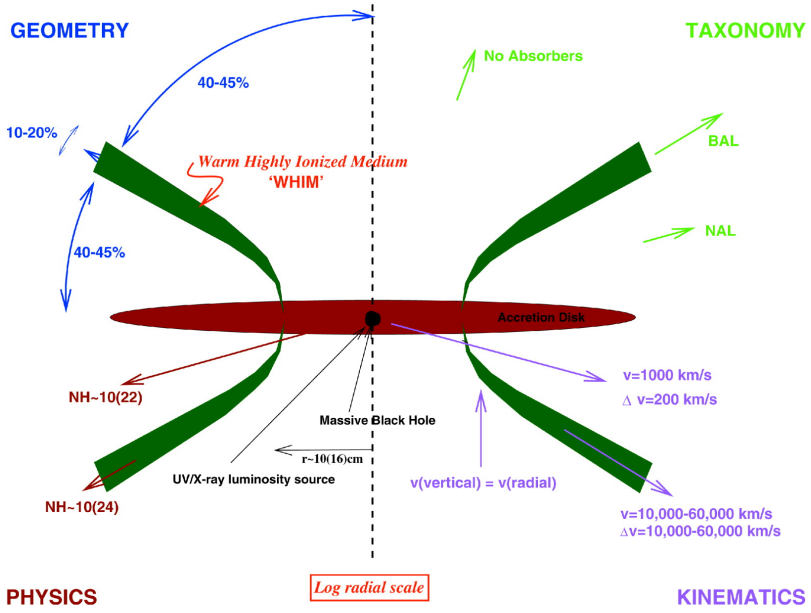


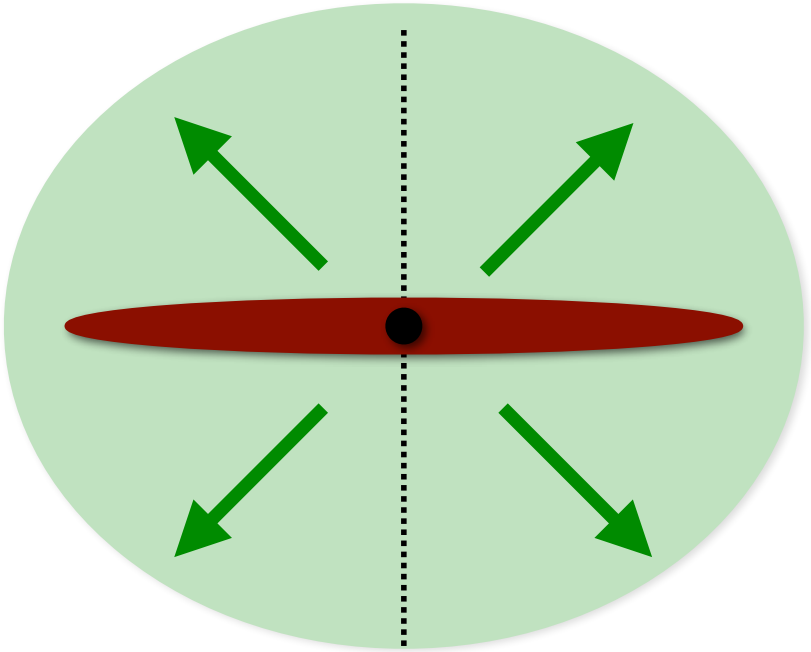
Trump et al. (2006)

BAL QSO scenarios

Orientation -
present in most AGN but low covering fraction

Evolution -
high covering fraction, but only in few AGN



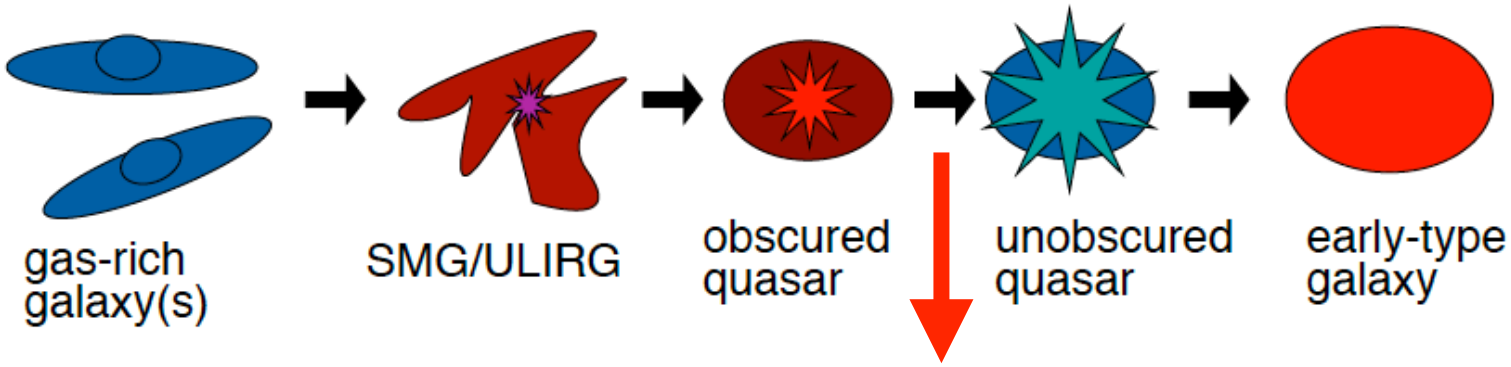


Elvis et al. (2000)

HiBAL

LoBAL???

LoBAL QSOs as an evolutionary phase



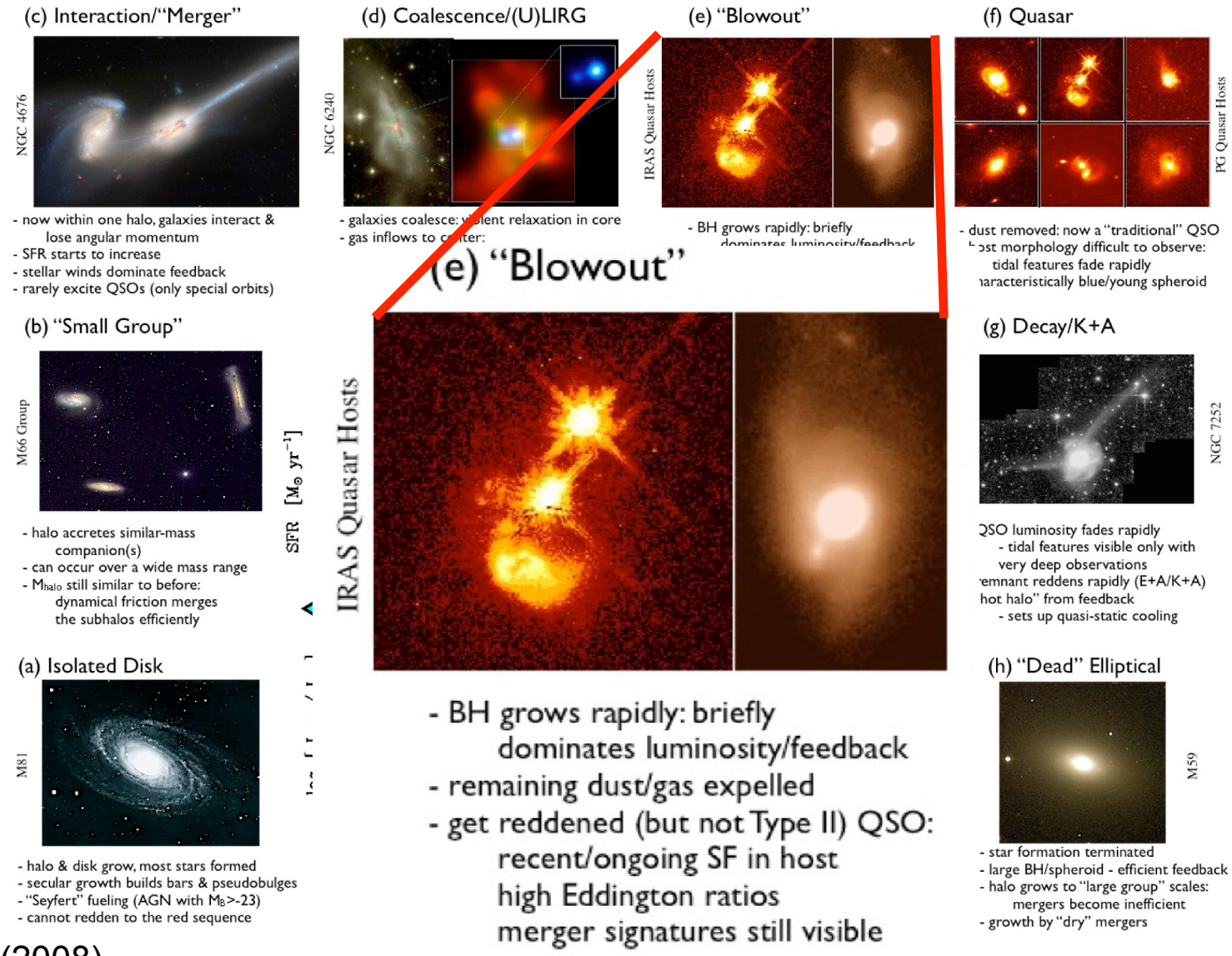
Alexander & Hickox (2013)

★ LoBAL QSOs might represent an early stage of quasar evolution

★ Young AGN in short-lived transition between ULIRG / dust obscured QSO and unobscured QSO

★ Ignited QSO blows off their dusty cocoon by powerful wind
=> “blowout phase

AGN in the blowout phase



Hopkins (2008)

Are LoBALs young QSOs?

Young QSOs should have:

- red colors / dust
- Ongoing (high) star formation
- Merger signatures
- High Eddington ratios

LoBAL QSOs have:

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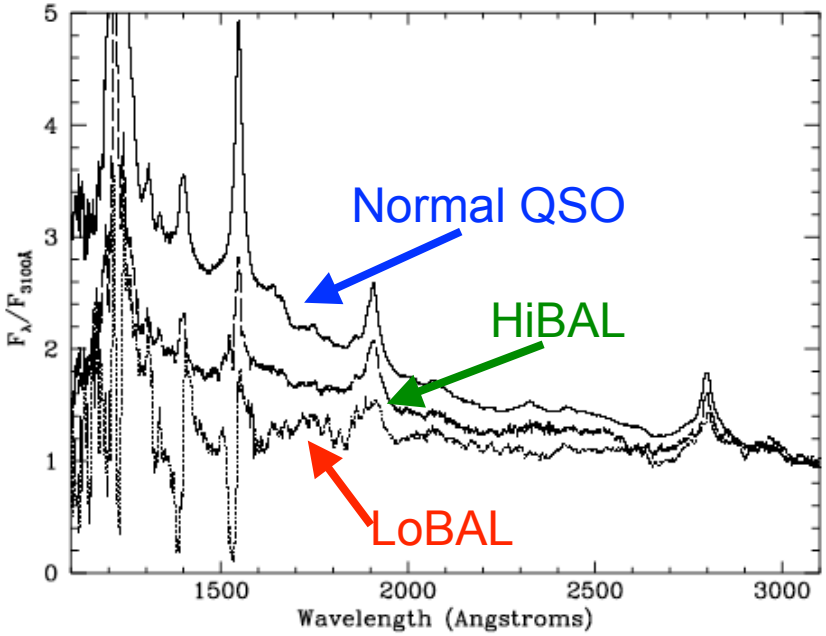
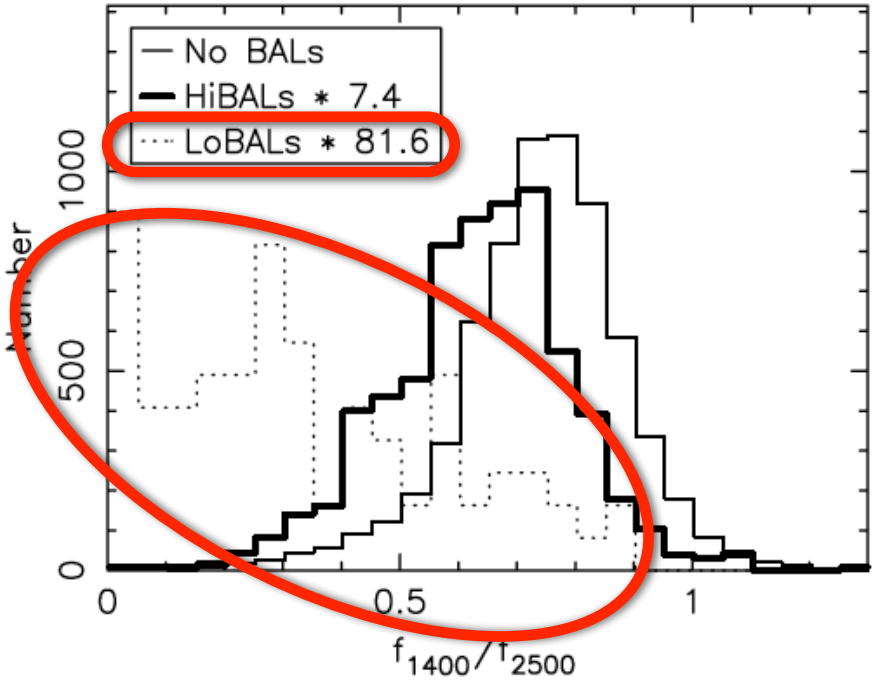


Brotherton et al. (2001)



Gibson et al. (2009)

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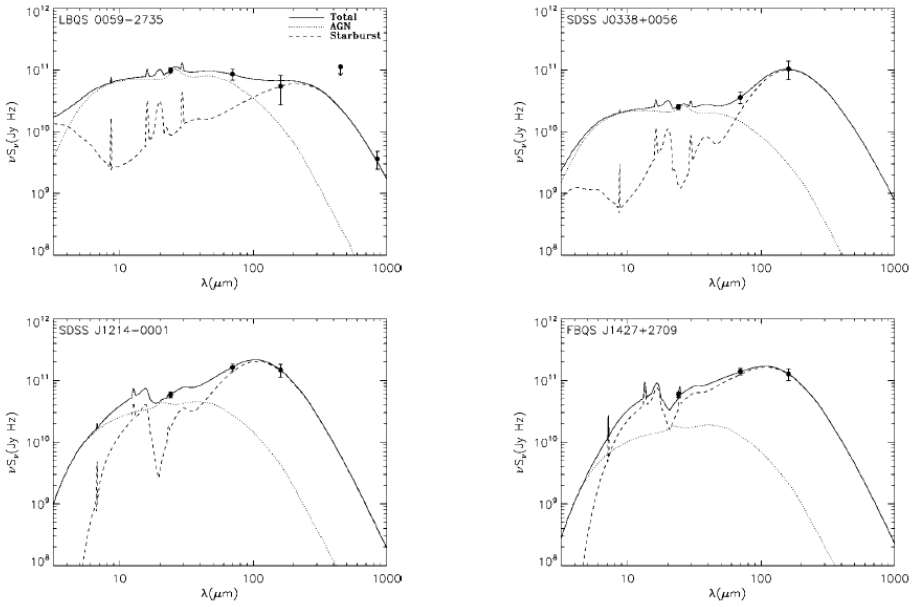
LoBAL QSOs have:

- ✓ red colors / dust
- ✓ Ongoing (high) star formation

High SFRs in (Fe)LoBALs



Farah et al. (2007)

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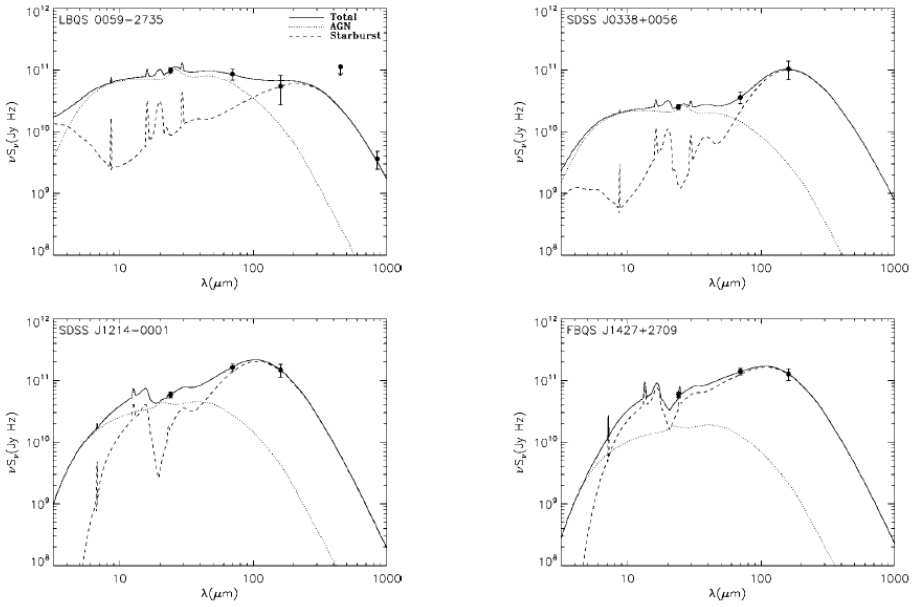
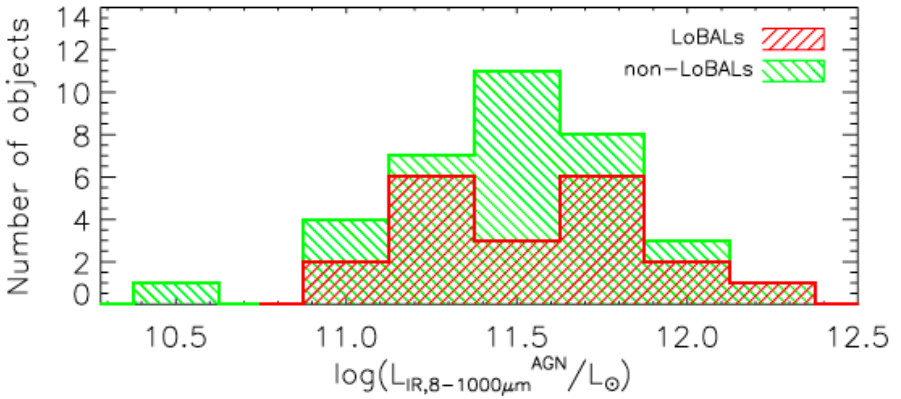


Farah et al. (2007)

No difference in LIR between LoBALs and non-LoBALs



Lazarova et al. (2012)

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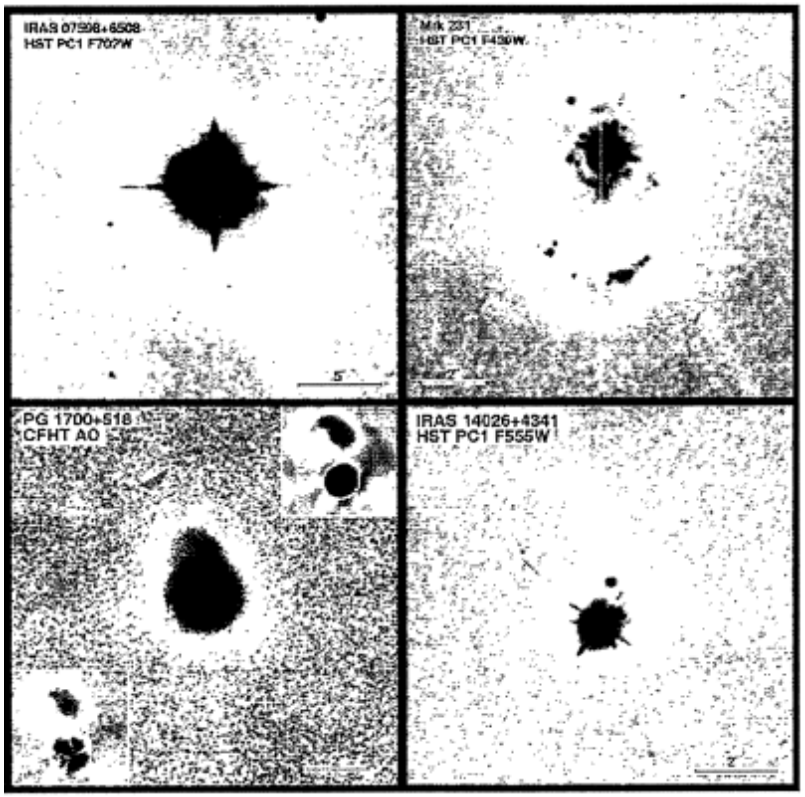

Canalizo & Stockton (2002)

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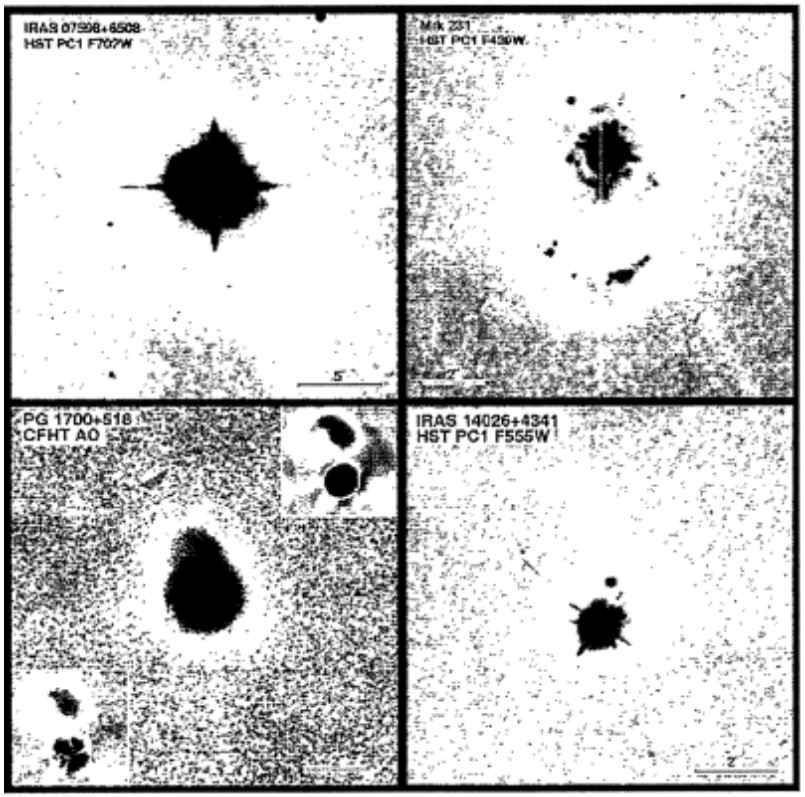

But only based on 4 low-z LoBAL QSOs

Larger sample (at higher z) needed

Canalizo & Stockton (2002)

Are LoBALs young QSOs?

Young QSOs should have:

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- Merger signatures
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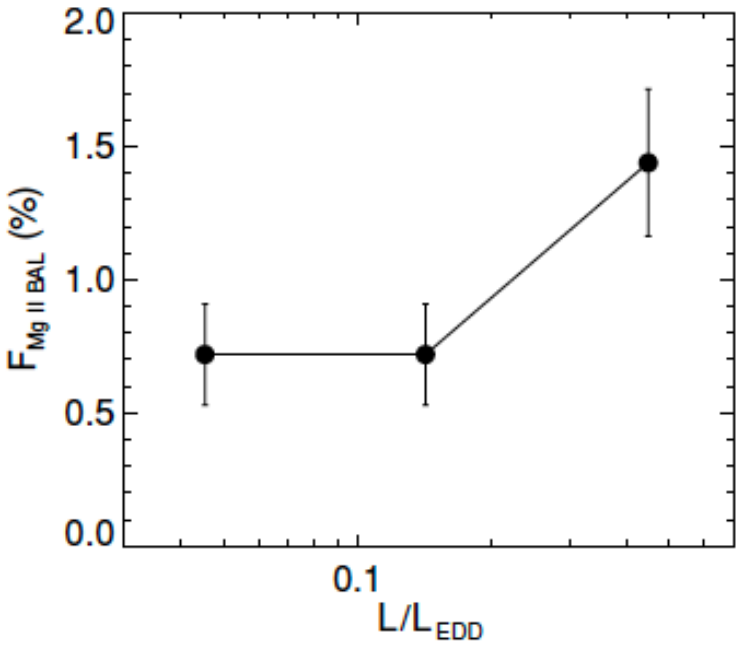
LoBAL QSOs have:

✓ red colors / dust
- Ongoing (high) star formation
? Merger signatures
? High Eddington ratios

=> evidence for higher LoBAL fraction at higher Eddington ratio



Zhang et al. (2010)

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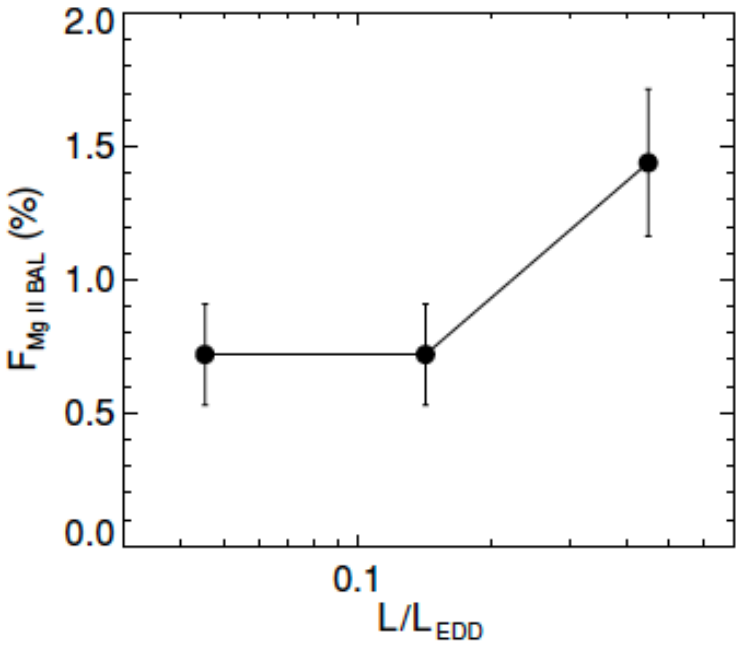
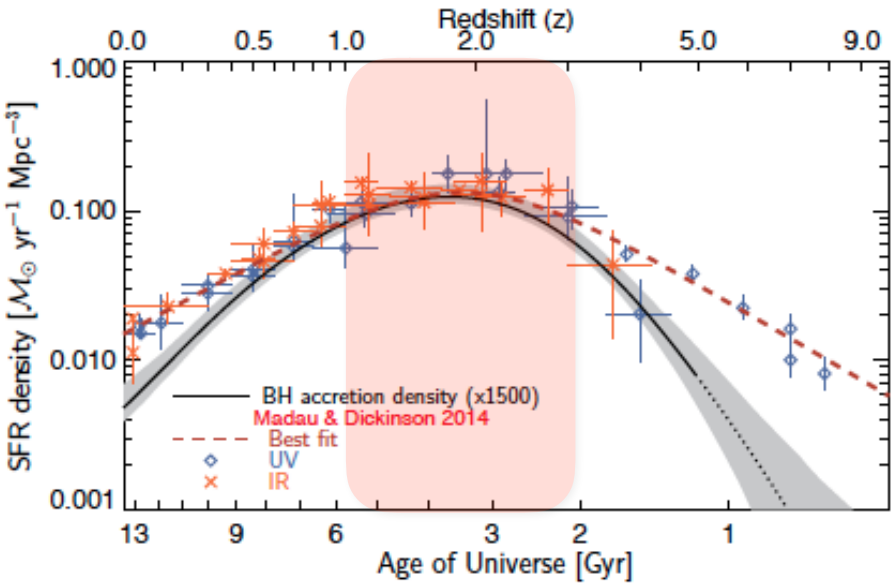


Zhang et al. (2010)

Probing LoBALs at z>1

★ QSO epoch at 1<z<3 (peak in space density)

★ but BH masses, Eddington ratios and rest-frame optical properties of LoBAL QSOs poorly known



Aird et al. (2015)

differ LoBAL QSOs (at z>1) from normal QSOs in their

- Eddington ratios and BH masses?
- mid-IR properties?
- Rest-frame optical properties?

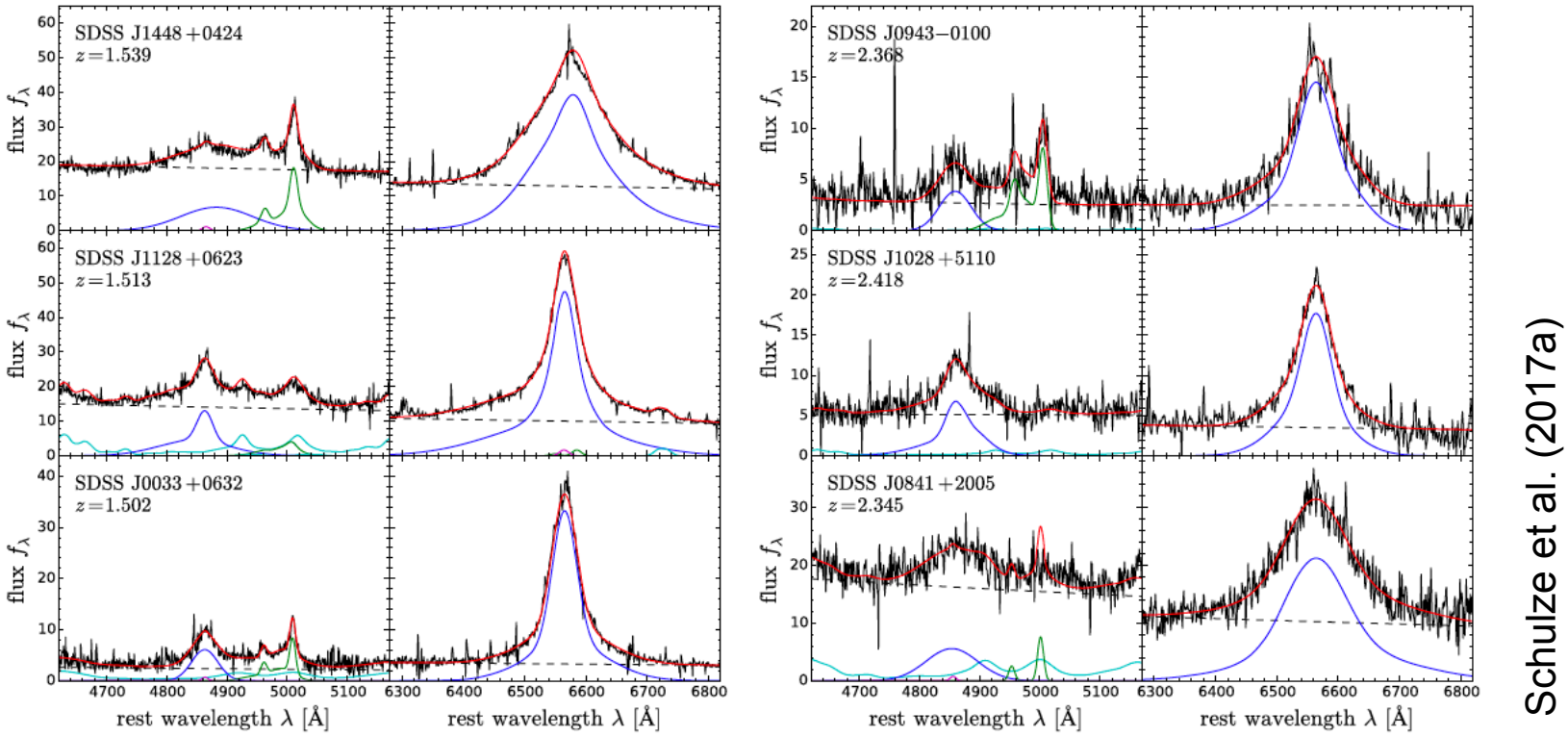
=> requires near-IR spectroscopy

Sample

- ★ Select LoBALs from SDSS QSOs with BI>0 from Allen et al. (2011)
- ★ 12 LoBALs @ 1.3<z<1.6 with BI(MgII)>0
- ★ 10 LoBALs @ 2.2<z<2.5 with BI(AlIII)>0

=> near-IR spectra from Triplespec (Palomar), NOTCAM (NOT), ISLE (OAO)

- ★ Complemented by 34 LoBALs @ 0.4<z<0.9 wit BI(MgII)>0 (SDSS spectra)



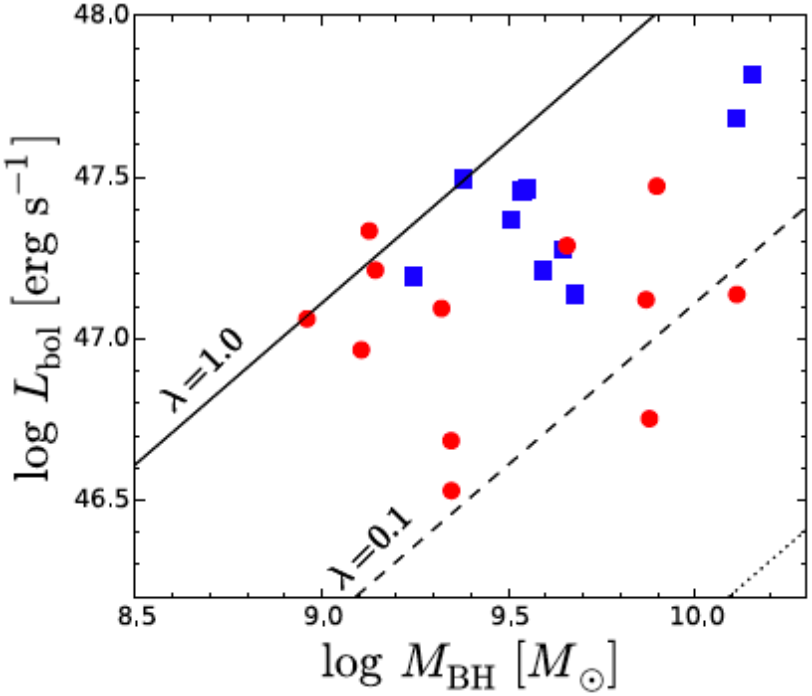
Schulze et al. (2017a)

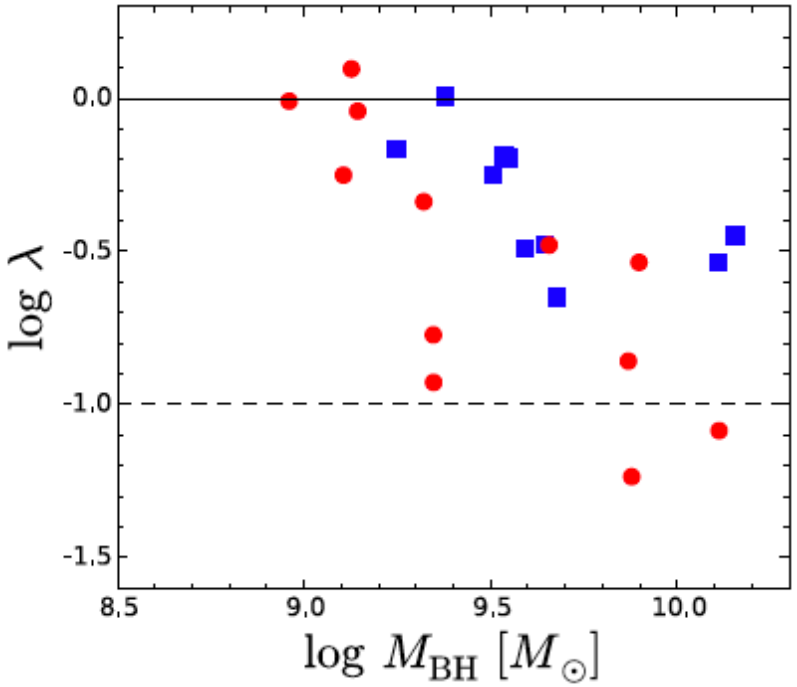
Black hole masses and Eddington ratios

Estimate BH mass from broad Halpha via:

$$M_{\rm BH}({\rm H}\alpha) = 10^{6.711}\left(\frac{L_{\rm H\alpha}}{10^{42}\ {\rm erg\ s^{-1}}}\right)^{0.48}\left(\frac{\rm FWHM}{3000\ {\rm km\ s^{-1}}}\right)^{2.12} M_\odot.$$

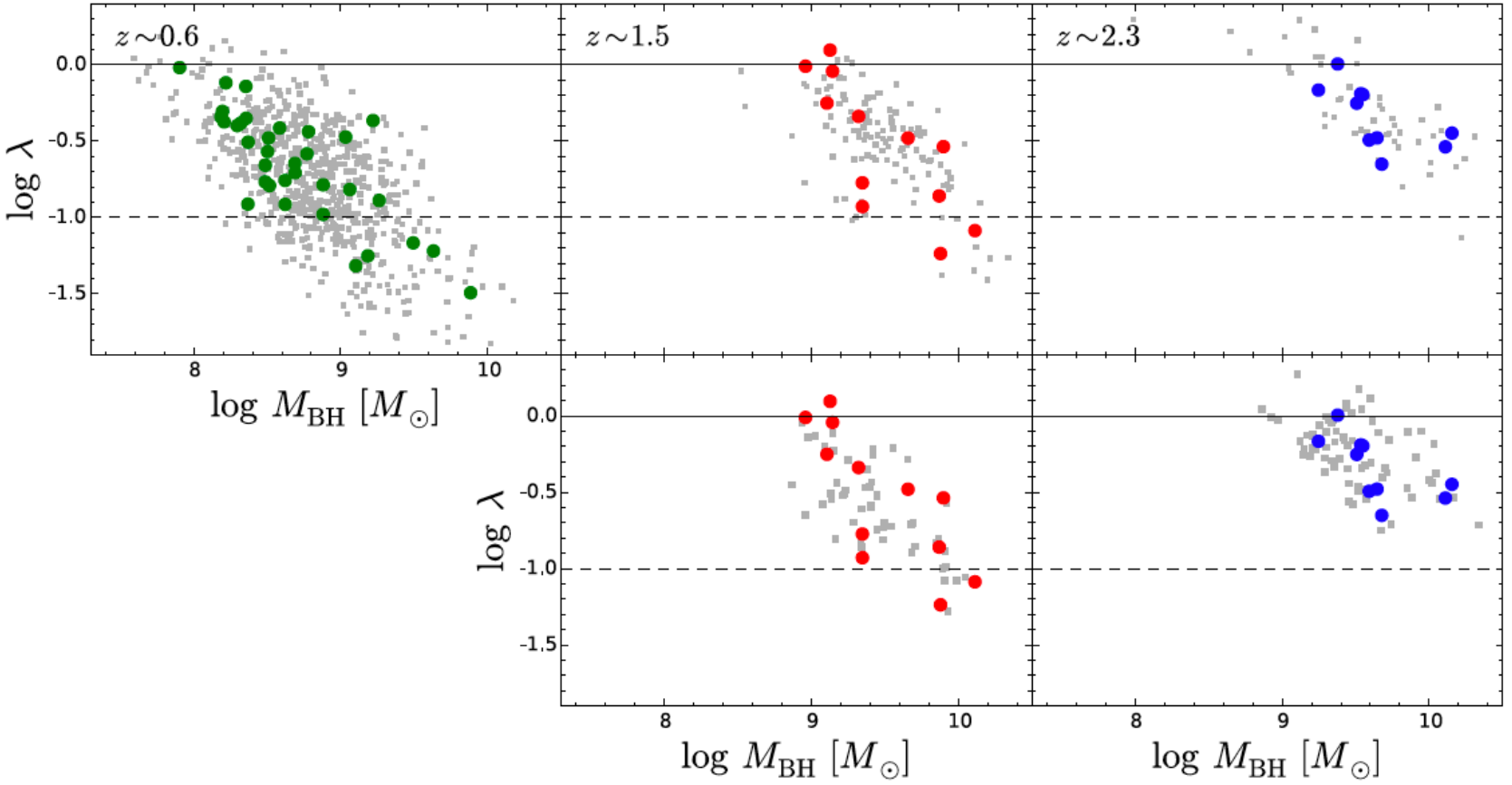
=> High BH masses and high Eddington ratios, but broad range for both





Are LoBALs in Eddington-limited accretion phase?

Compare M_{BH} and Eddington ratio distribution with matched sample of normal QSOs (matched in L5100)



=> no statistically significant difference of LoBALs to non-BAL QSOs

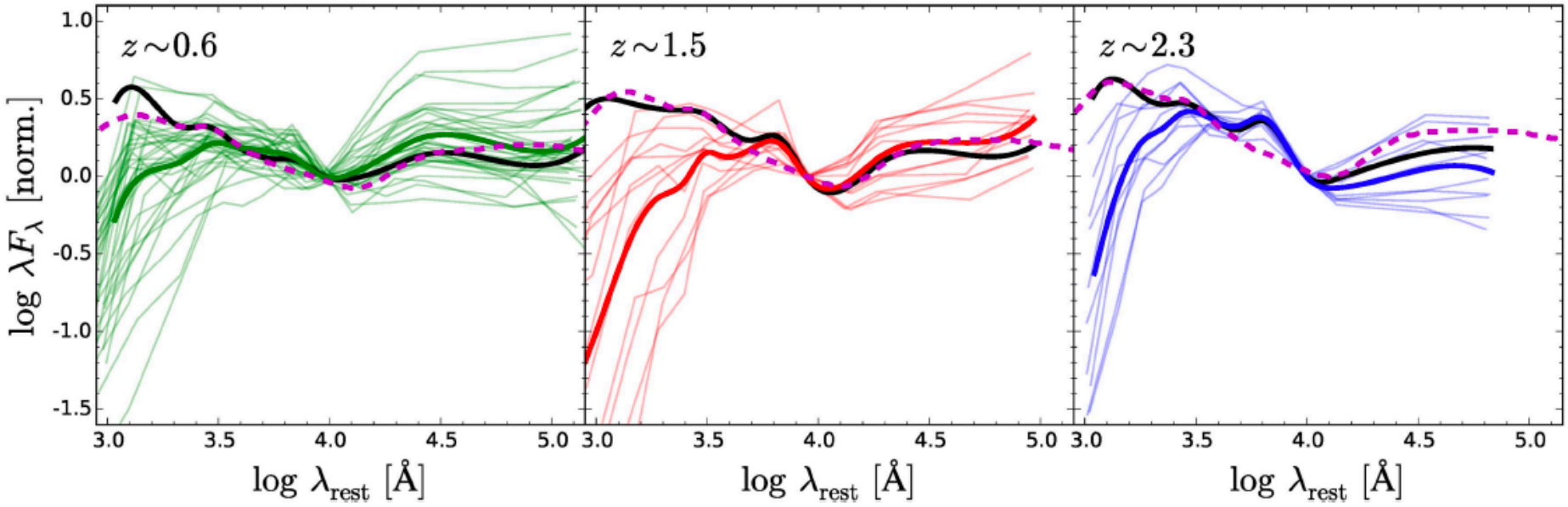
LoBAL spectral energy distribution

★ Construct LoBAL SED in comparison to non-BAL match and QSO SED from Richards et al. (2006)

★ Reddened SED in rest-frame UV

★ No difference in near-IR to mid-IR

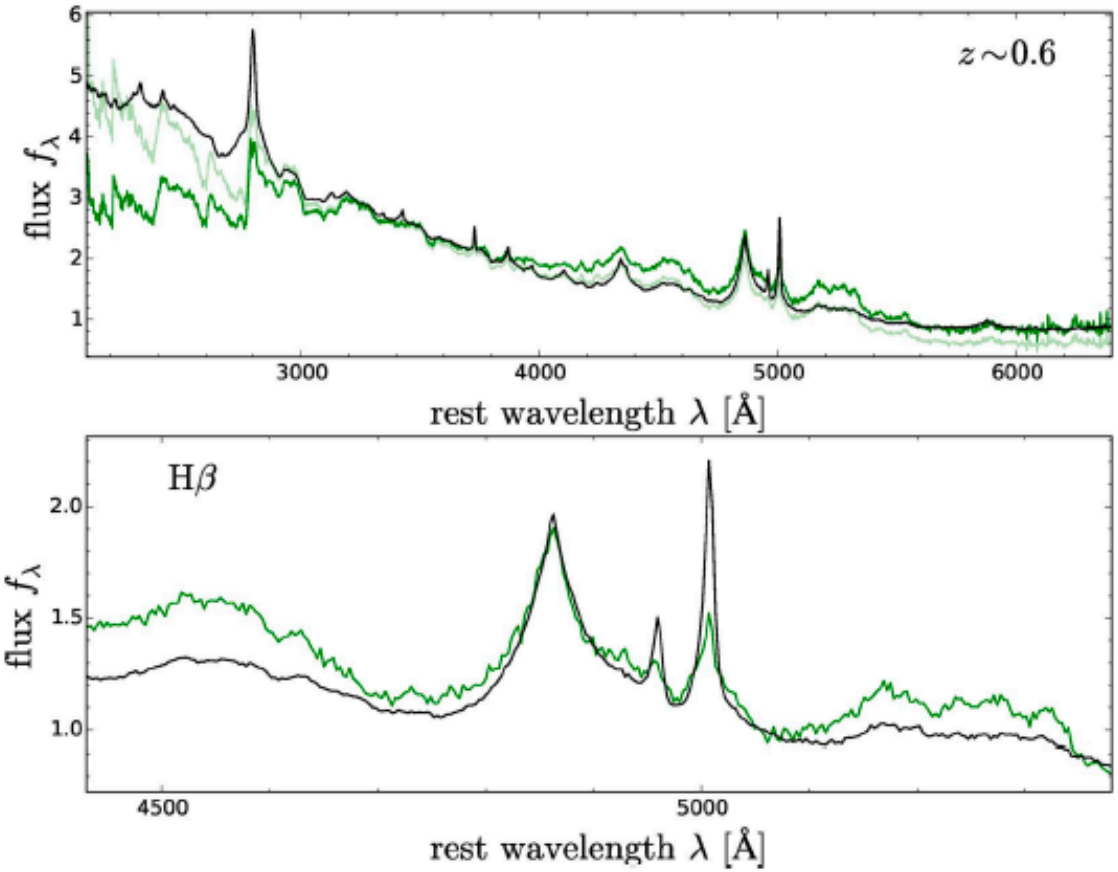
=> does not support large dust covering fraction as predicted in evolution scenario



Stacked spectra

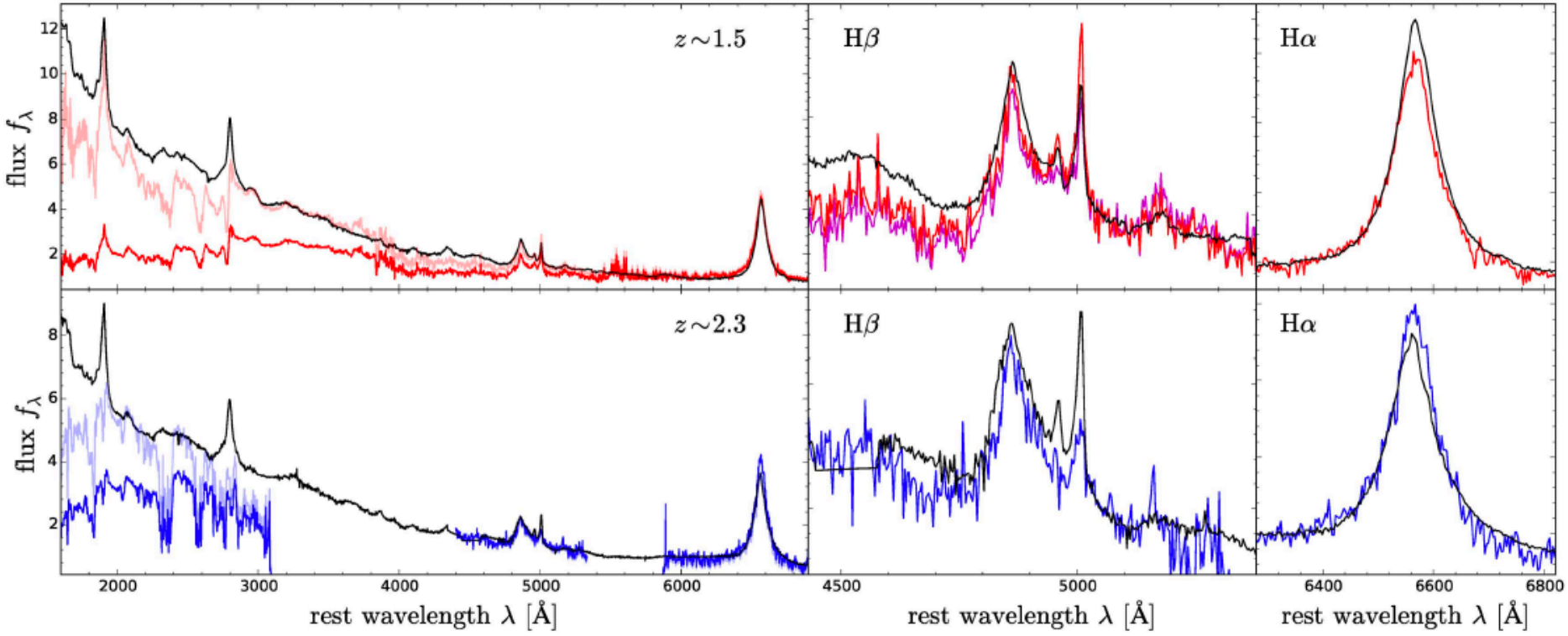
★ LoBALs at low-z tend to show weaker [OIII] emission and strong FeII
(Boroson & Meyers (1992), Canalizo & Stockton (2001), Zhang+ (2010))

★ Confirmed in stacked spectrum of z~0.6 sample



Stacked spectra

- ★ Significant reddening in LoBAL QSOs
- ★ Consistent broad Balmer lines
- ★ No stronger iron emission for z>1 samples
- ★ z~1.5: consistent [OIII] emission line | z~2.5: weaker [OIII] line
- ★ No evidence for stronger outflows in LoBAL sample based on [OIII]



Summary: LoBAL properties

Are LoBAL QSOs a short evolution stage in the blowout phase?

✓ have red colors / dust

-/? controversial results on star formation rates

? merger signatures only for very small sample without control sample

- show Eddington ratios and black hole masses consistent with non-BALs

- no mid-IR excess as would be expected for large covering fraction

- inconclusive results on [OIII] and FeII strengths
  (no excess for z~1.5 sample, no strong FeII at z>1)

- no enhanced prominence of strong ionized outflows

=> properties of z>1 LoBALs do not support evolution scenario

Balmer absorption line LoBAL QSOs

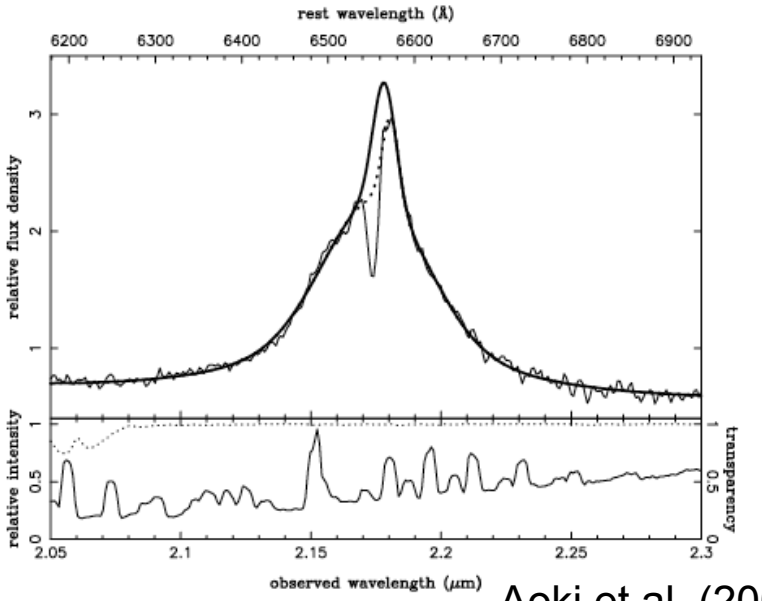
=> We discovered two new cases of Balmer absorption QSOs in our near-IR LoBAL sample

★ intrinsic absorption in Balmer lines is very rare, only 11 cases known

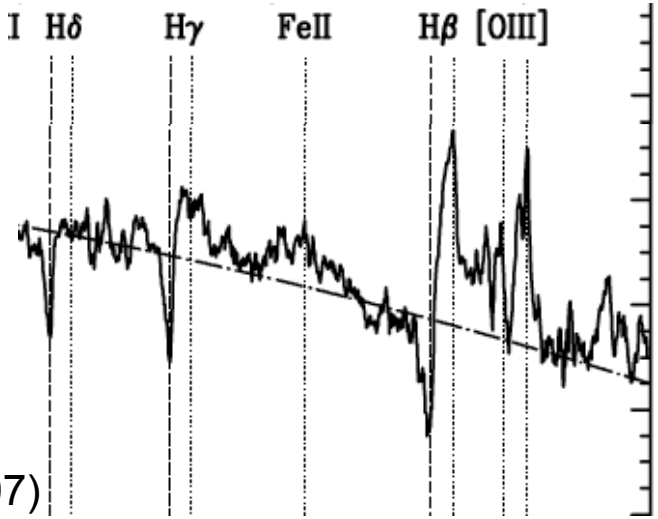
★ only two known at z>1

★ rare physical conditions, possibly Lyalpha pumping (Hall 2007)

★ serve as probes of AGN structure and outflows



Aoki et al. (2006)



Hall (2007)

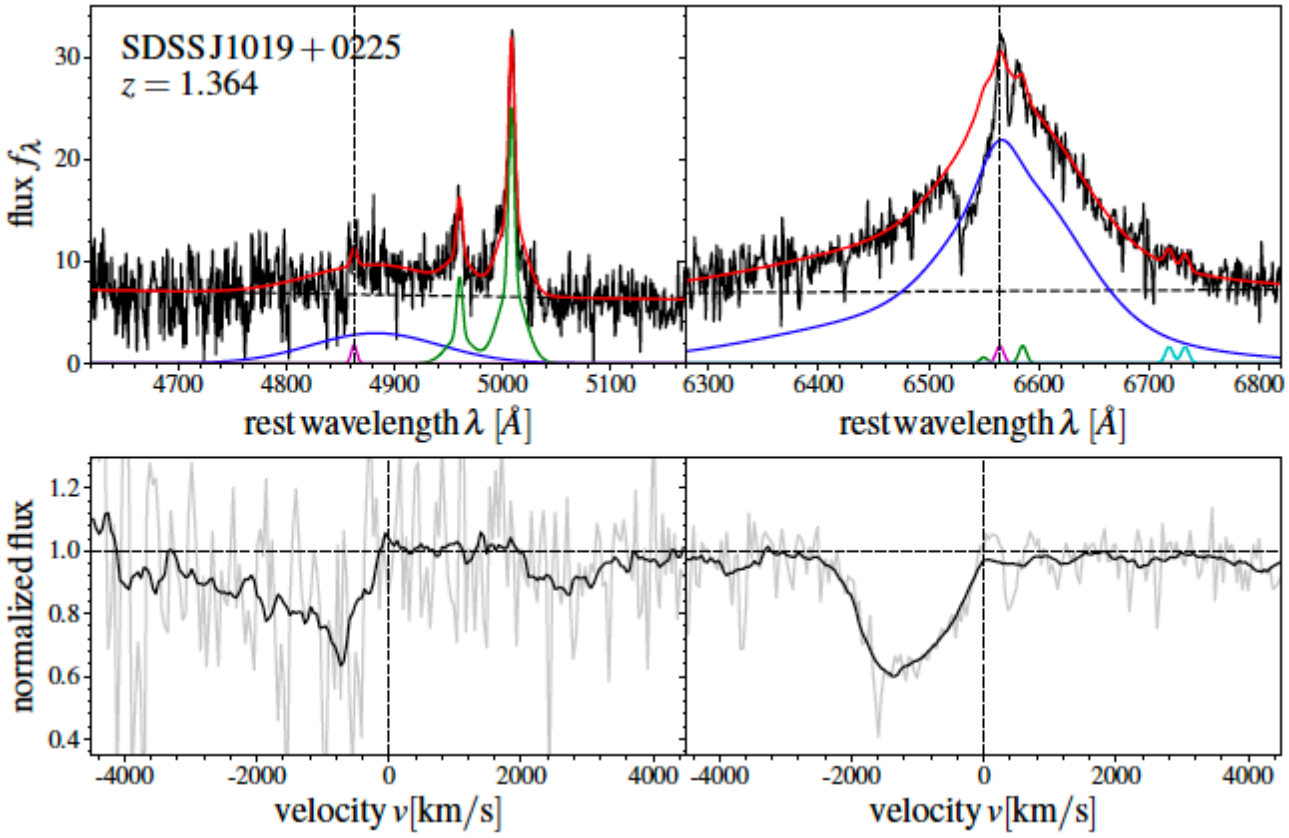
SDSS J1019+0225

★ z=1.36, log M_{BH}= 9.9, log λ=-0.9, radio-loud (R=129)

★ presence of blue shifted asymmetric absorption profile with FWHM=1460 km/s and V=-1390 km/s

★depth ratio of Hα to Hβ troughs indicates that absorption is saturated

★ estimated hydrogen column density N_H~1.7x10^{18} cm^{-2}



Schulze et al. (2017c)

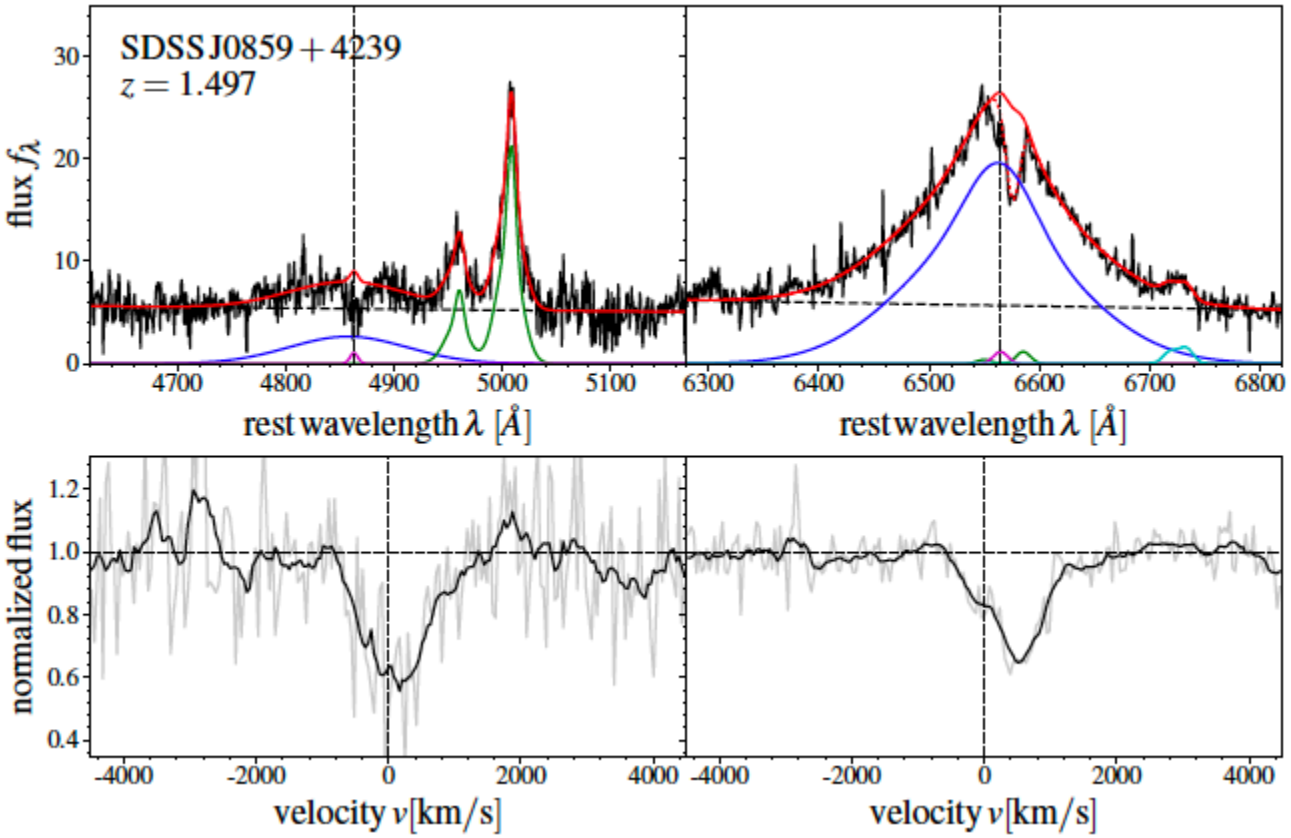
SDSS J0859+4239

★ z=1.50, log M_{BH}= 10.1, log λ=-1.1, radio-loud (R=15)

★ presence of redshifted absorption profile with FWHM=780 km/s and V=500 km/s

★ candidate for gas inflow onto SMBH

★ estimated hydrogen column density N_H~1.2x10^{18} cm^{-2}



Schulze et al. (2017c)

Conclusions

=> our observations of 1.0<z<2.5 LoBALs do not support evolution scenario:

Consistent M_{BH} and λ, mid-IR luminosity, rest-frame optical properties, ionized outflow strength

=> discovered interesting rare population of z>1 LoBALs with strong intrinsic absorption in Balmer lines,

Estimated hydrogen column densities $N_H \sim 10^{18}$ cm^{-2}

Schulze et al., 2017, ApJ, 848, 104
Schulze et al., 2017, arXiv:1710.08563