

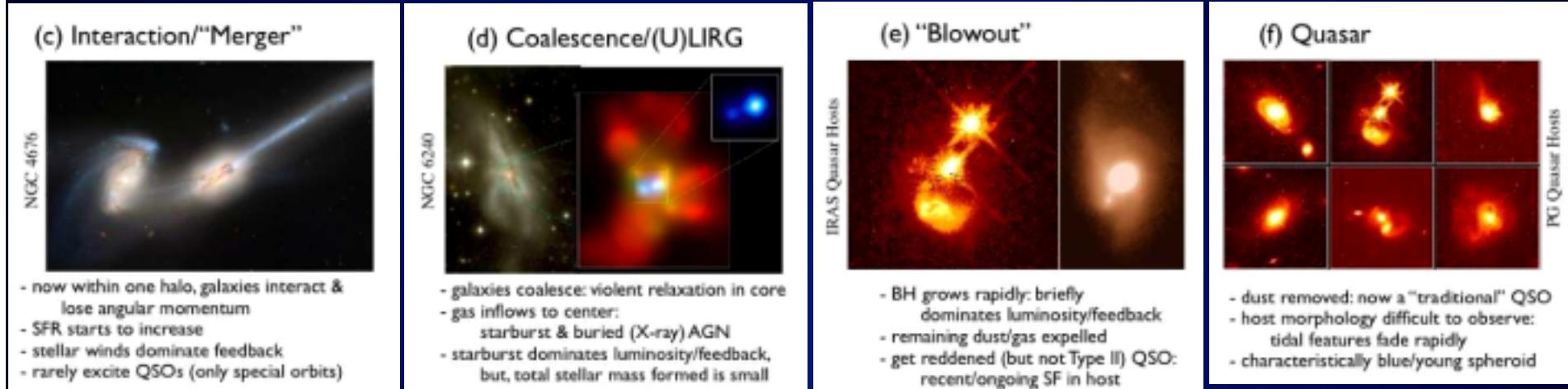
Extremely Red Quasars in BOSS

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Plausible evolution for quasars in massive high-z galaxies



Merger/ triggering event

Starburst ULIRG / SMG

Transition object blowout

Visible Quasar



Signatures of young quasars:

Red colors? Higher accretion rates? More common or more powerful outflows?
Higher star formation rates? Recent merger/interaction? Disturbed ISM/CO kinematics?

Extremely Red Quasars (ERQs) from 2 surveys:

SDSS-III/BOSS:

Sloan Digital Sky Survey-III / Baryon acoustic
Oscillation Spectroscopic Survey

DR12 (fall 2014):

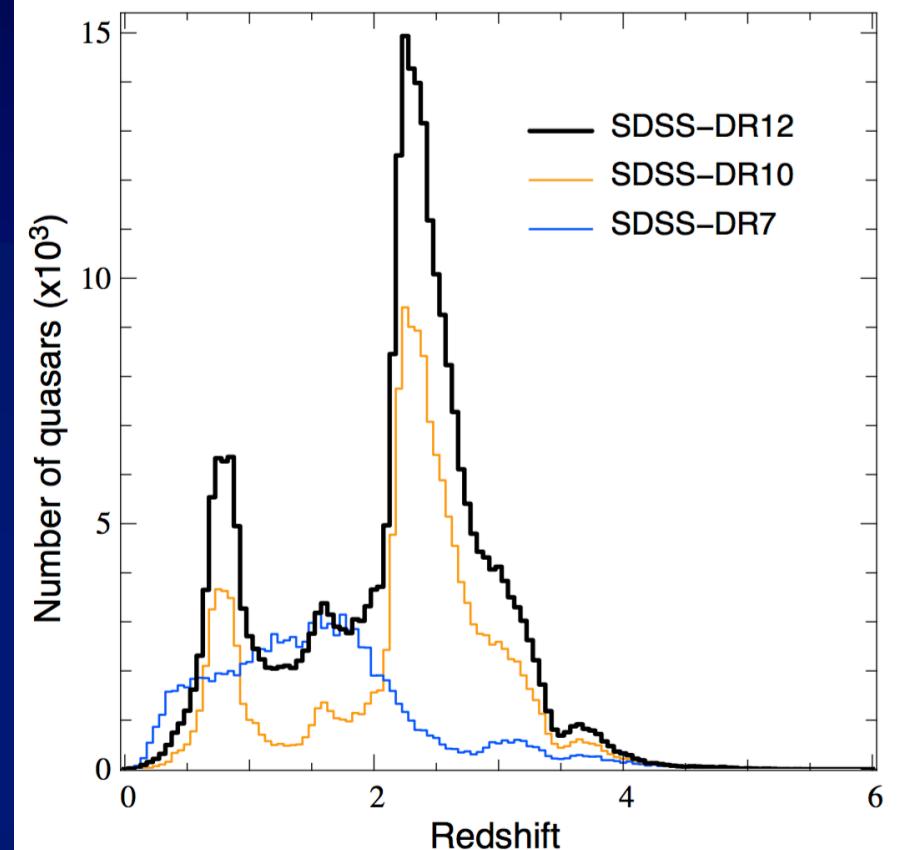
Fainter & redder than SDSS-I/II (DR7)
Spectra of 297,301 quasars at 3600A – 1 μ m
Quasar catalog (Paris+14,16)

WISE:

Wide-field Infrared Survey Explorer

AllWISE data release (Nov. 2013):

W1, W2, **W3**, W4 at 3.4, 4.6, **12**, and 22 μ m
96,000 detected in **W3** at SNR > 3



Extremely Red Quasars (ERQs)

Ross+15

$r - W4 > 7.4$ (AB)

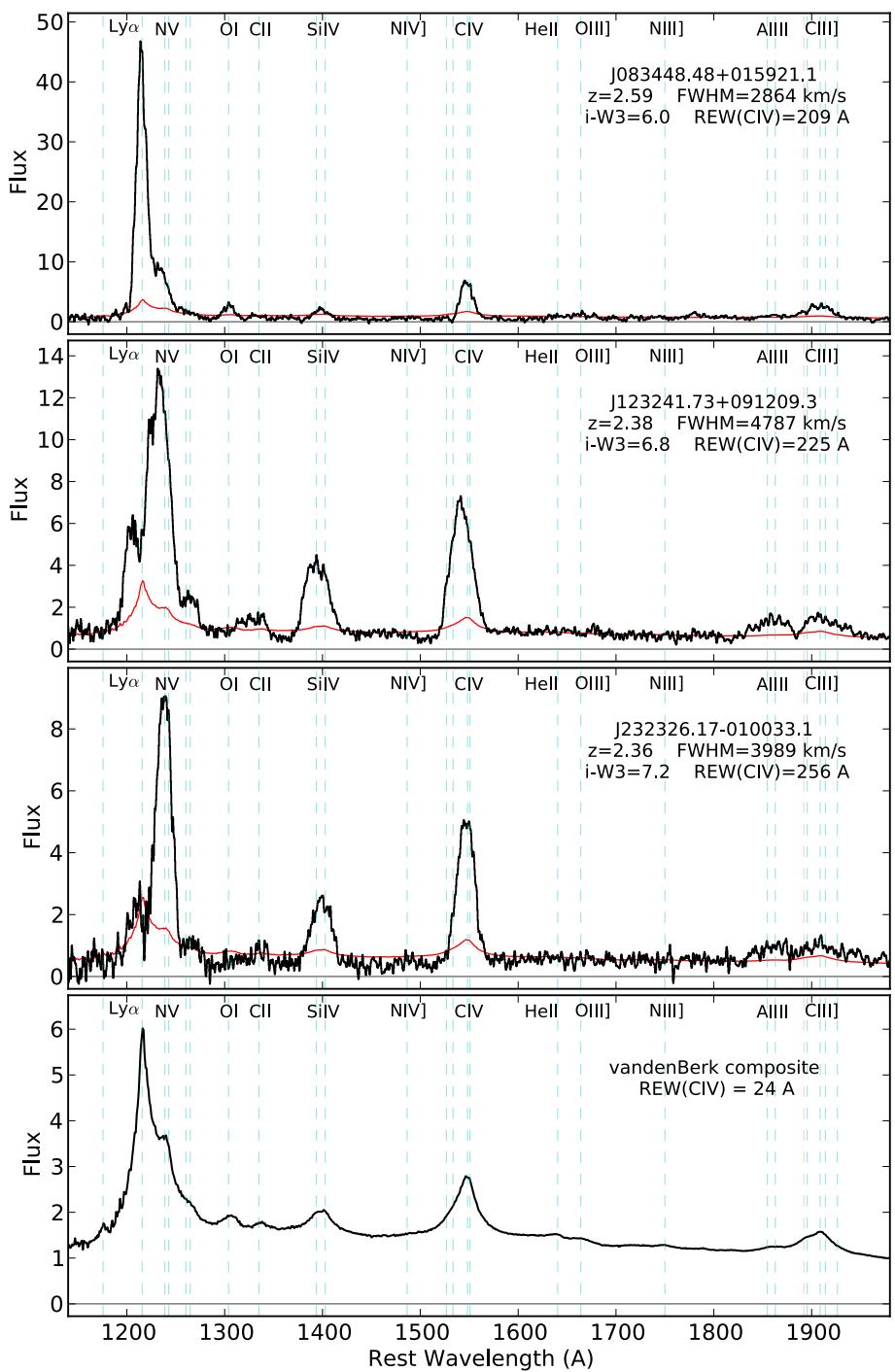
like Dust Obscured Galaxies (Dey+08)

At $z > 2$, particular odd line properties:

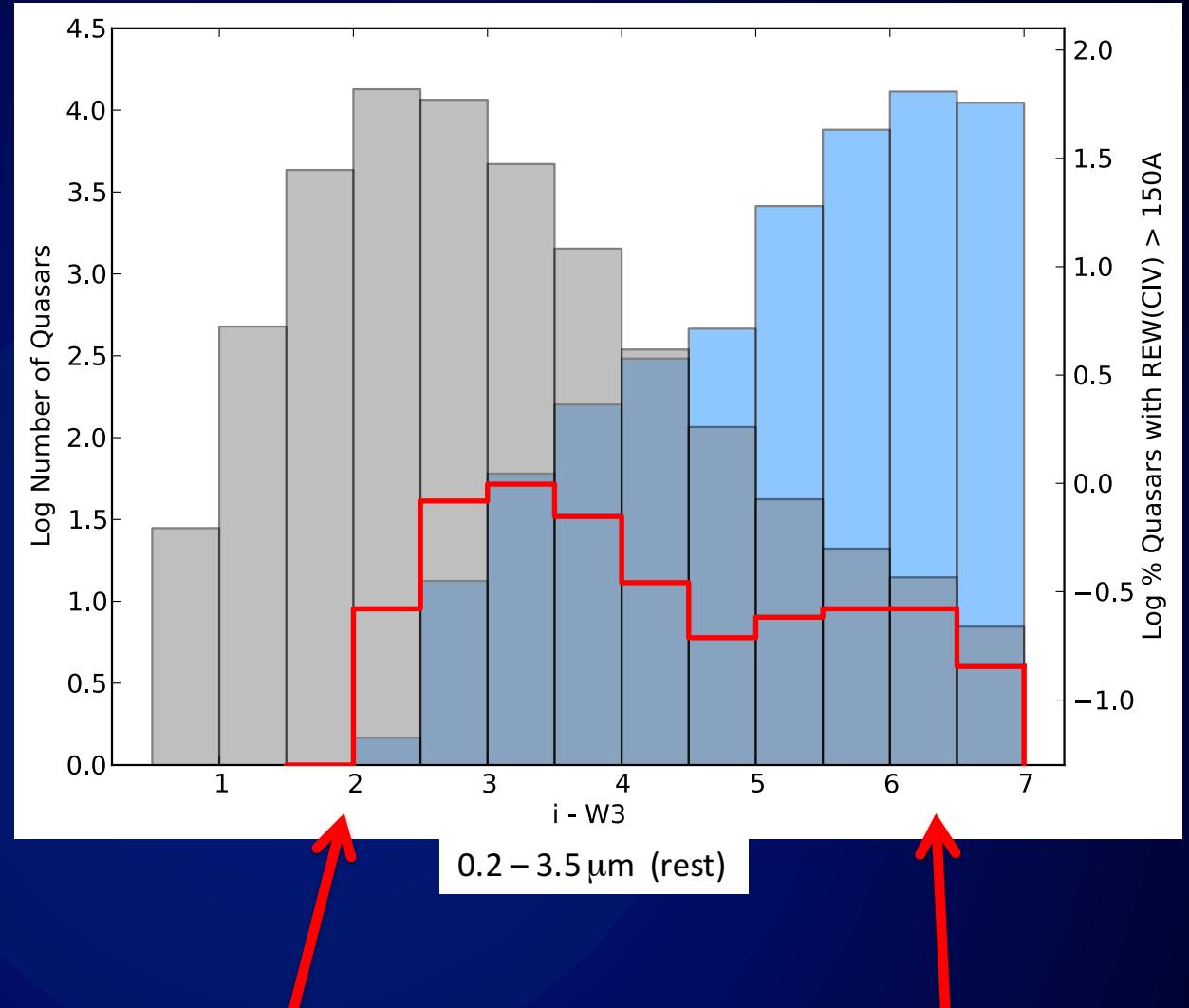
- 1) Very large emission-line REWs
- 2) Unusual “wingless” line profiles
- 3) Unusual line ratios

Hamann+16 (submitted):

- Fit CIV, NV emission lines in BOSS quasars
- Redshifts: 2.0 to 3.4
- Trends vs color (and L) across all of BOSS
- Find larger, more uniform ERQ samples

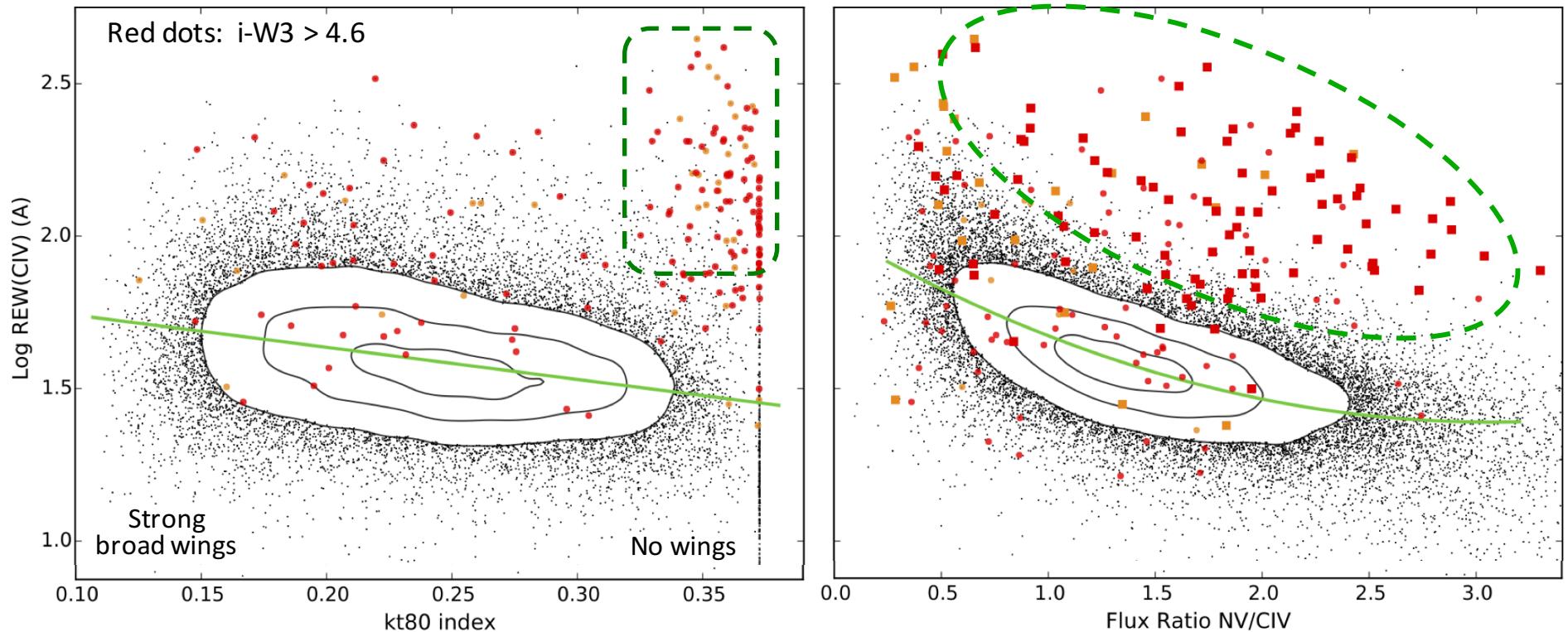


REW(CIV) depends
strongly on $i - W3$ color



Normal blue quasars:
 $<<1\%$ have $\text{REW}(\text{CIV}) > 150\text{\AA}$

Extremely red quasars:
 $\sim 50\%$ have $\text{REW}(\text{CIV}) > 150\text{\AA}$



ERQs are unique with:

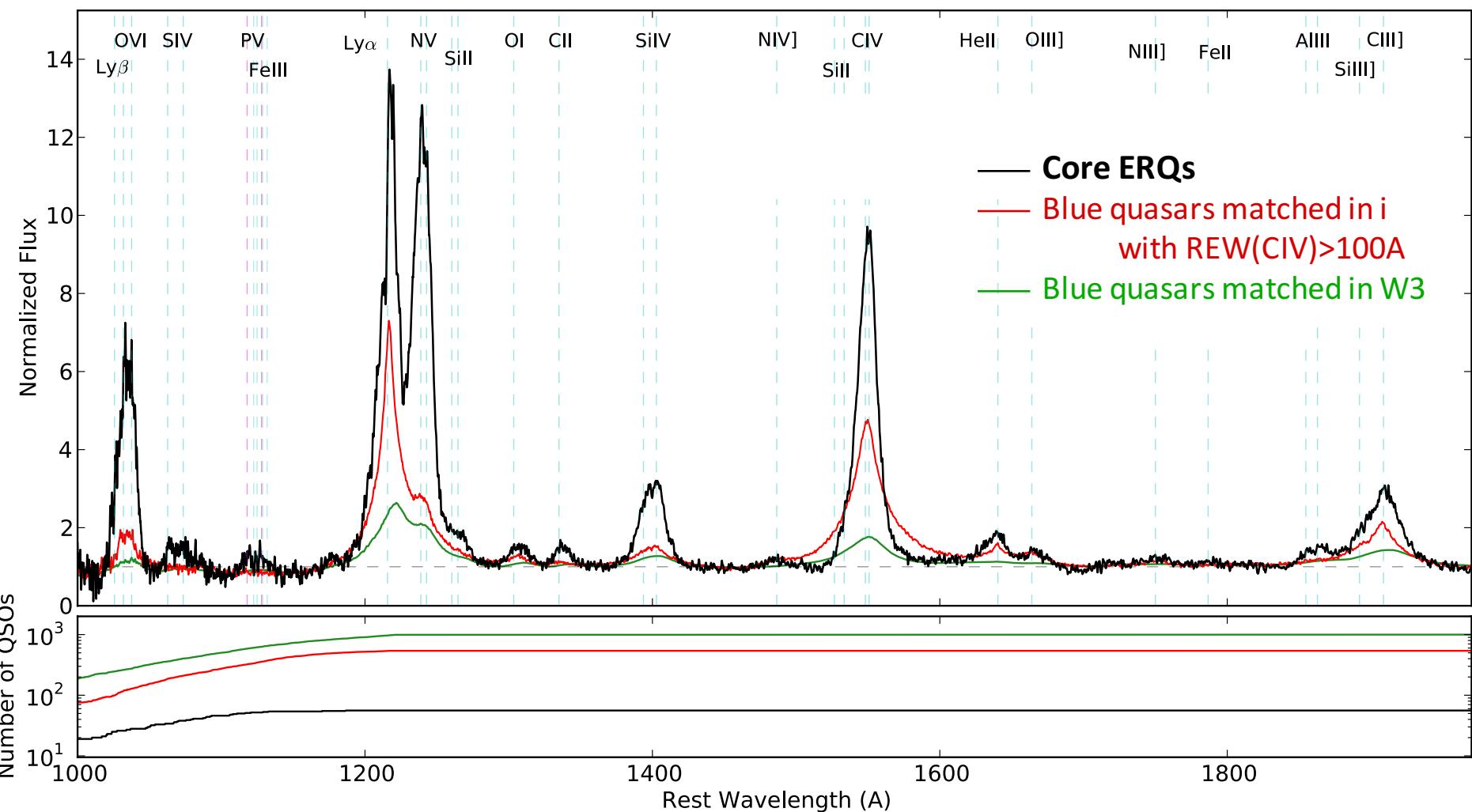
- Large REWs
- Wingless profiles
- Exotic line ratios
- (Outflow signatures)

Redefine “ERQs” using $i - W3 > 4.6$
 $(0.2 - 3.5 \mu\text{m rest})$

Also “core” ERQs: $\text{REW}(\text{CIV}) > 100\text{\AA}$

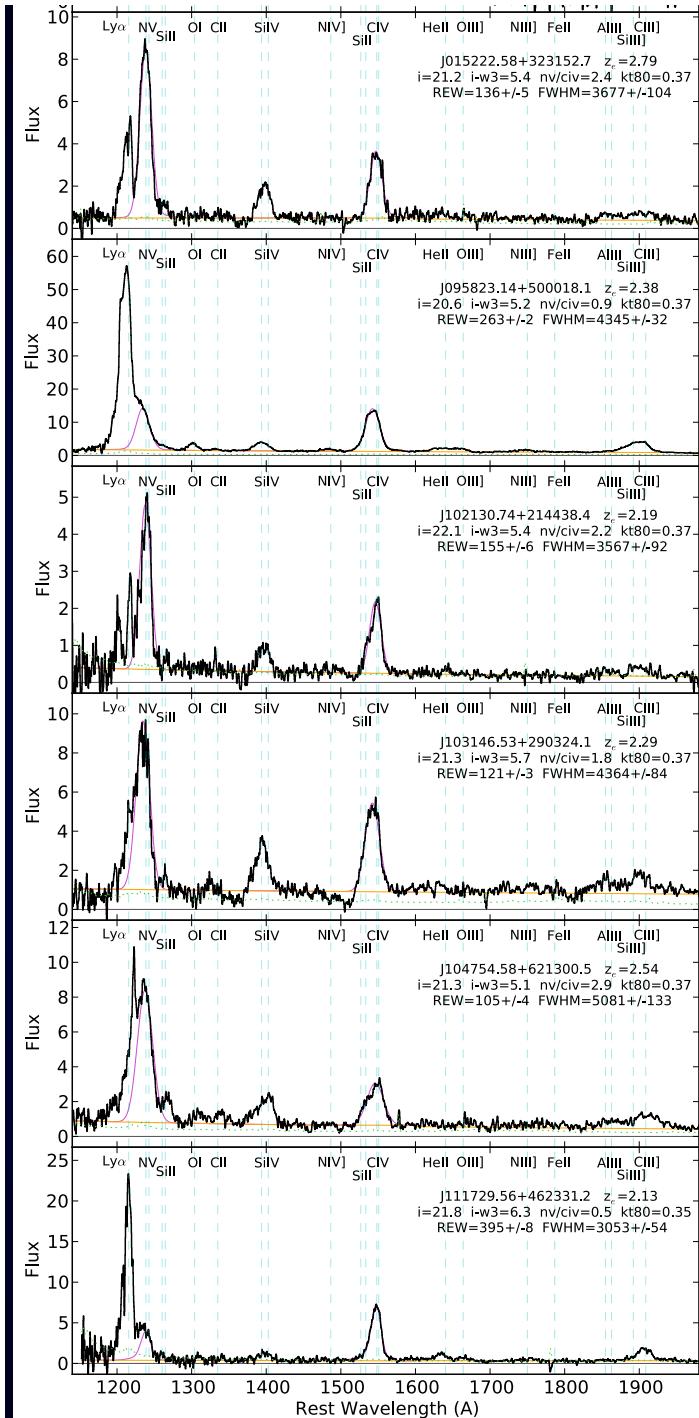
→ A distinct population
 with unique exotic physical conditions

Median Spectra



ERQs strongly favor large REWs,
wingless profiles, odd flux ratios

Strong relationship to $i - \text{W3}$ color

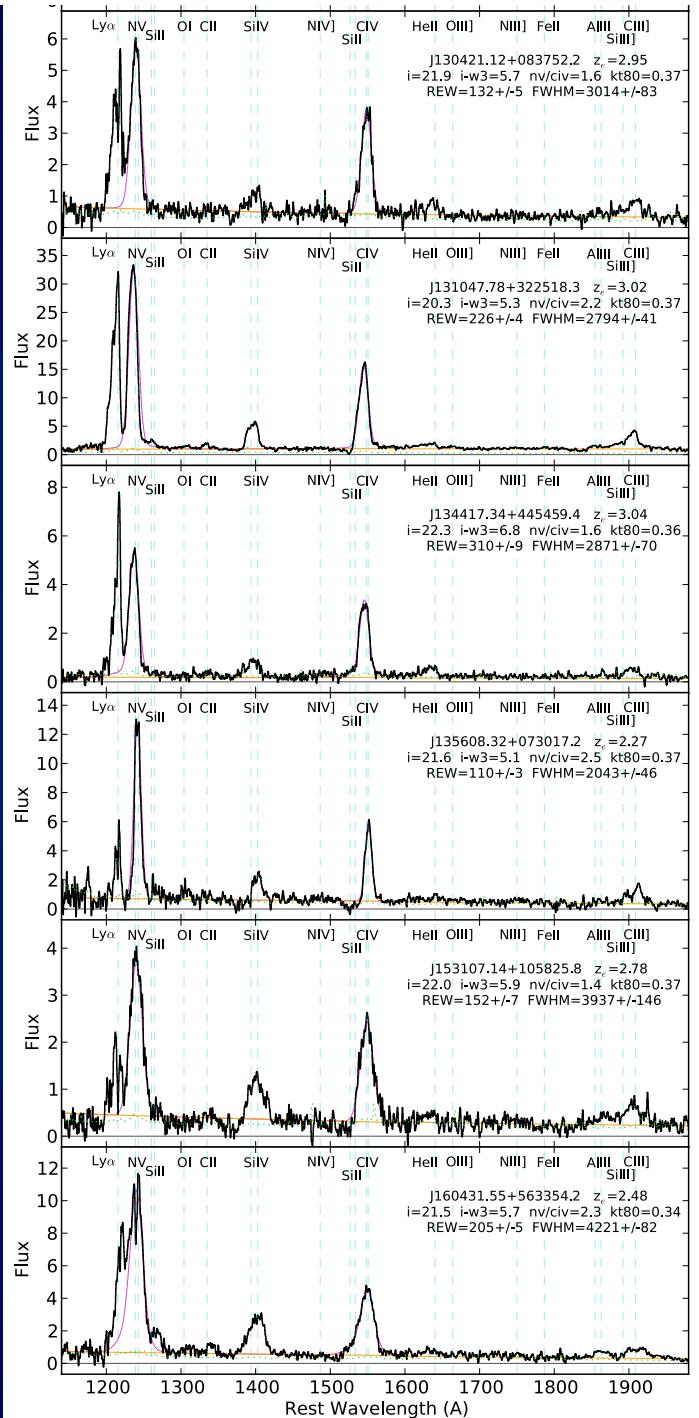


Several hundred ERQs

$i-W3 > 4.6$

Peculiar Properties:
Large REWs
Wingless line profiles
Large NV/CIV, NV/Ly α

And:
Powerful Outflows

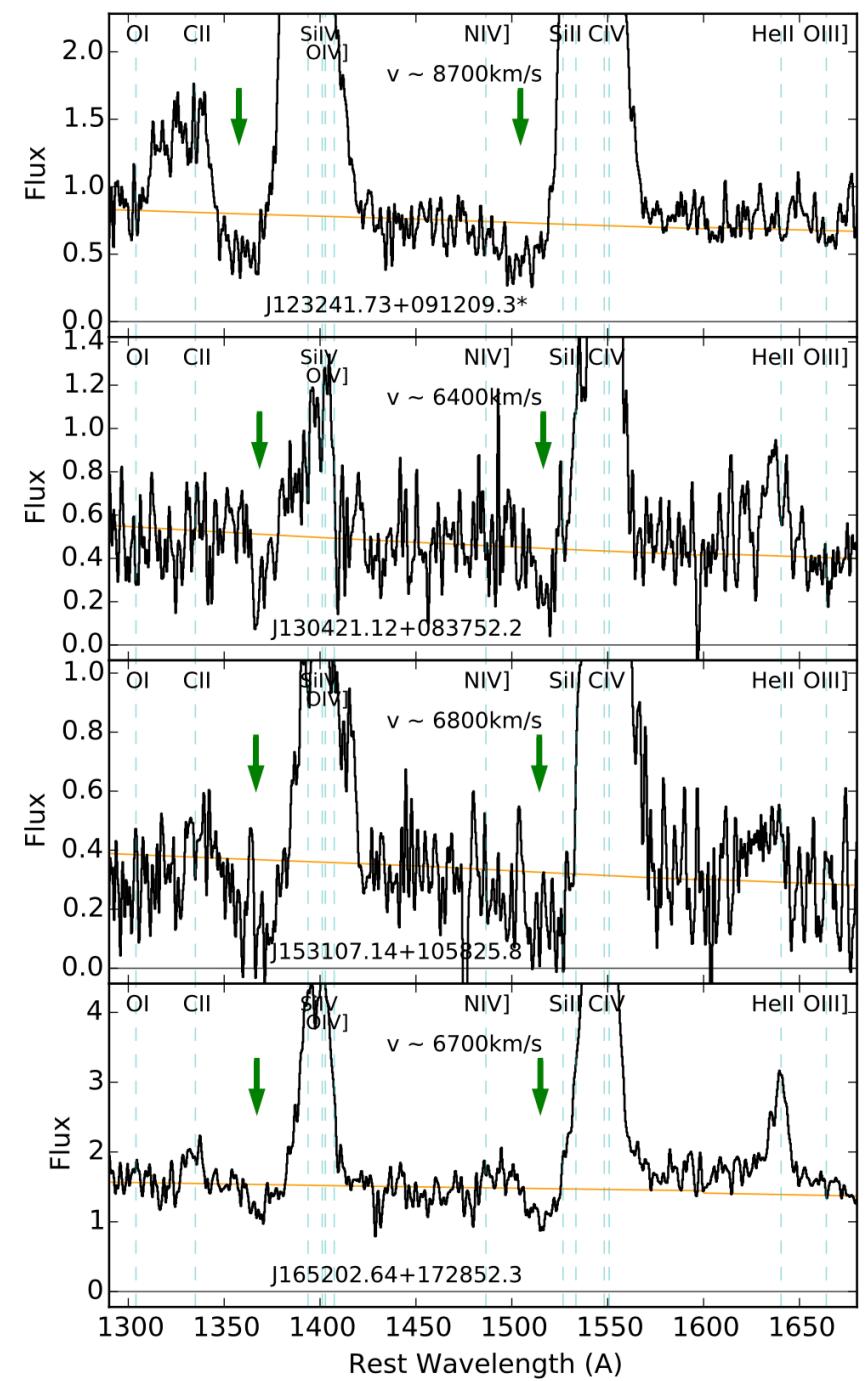


Outflow Evidence 1.:

30-65% have BAL outflow lines

2-5x greater than other BOSS quasars

Like other red quasar samples (Urrutia+09)



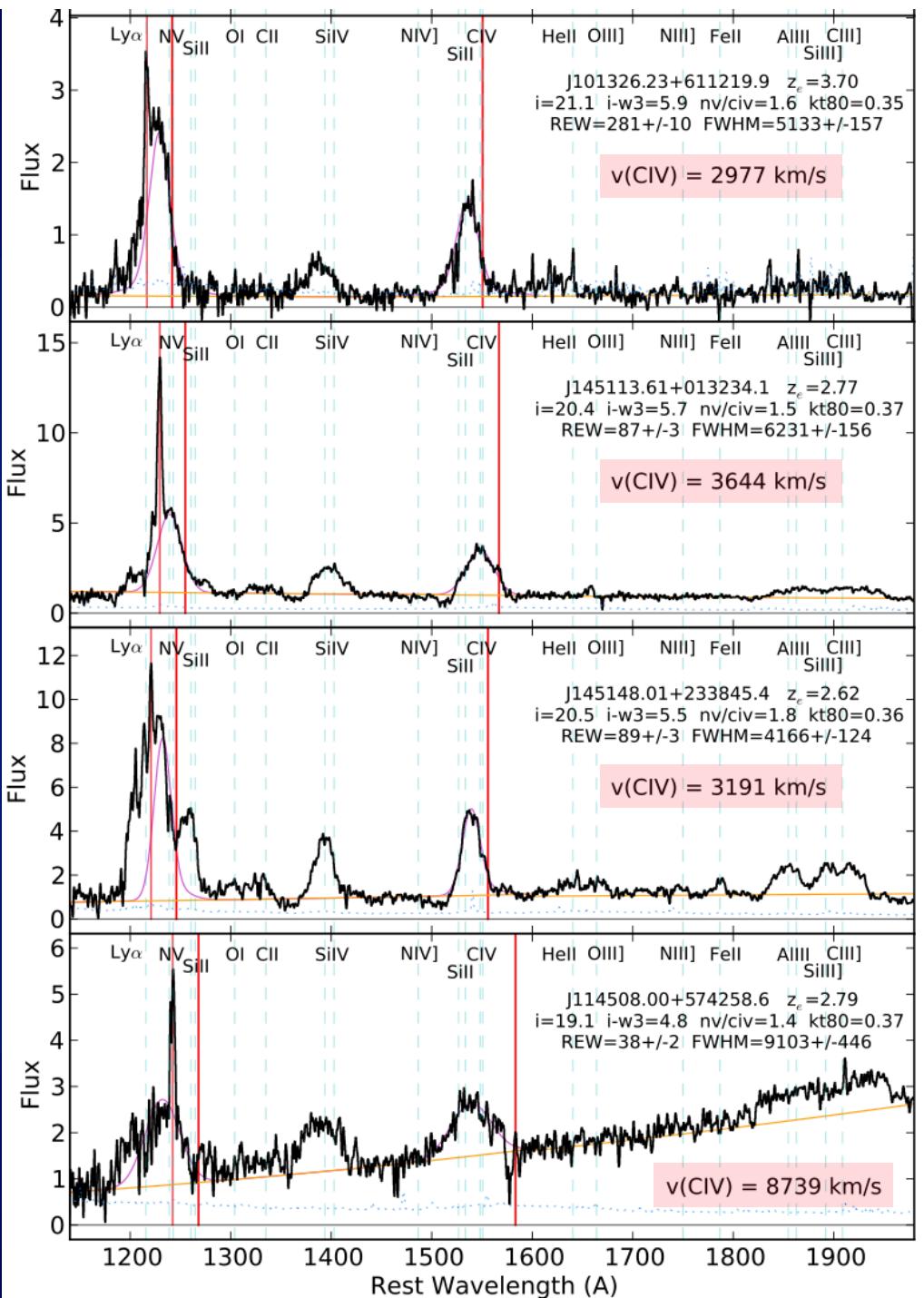
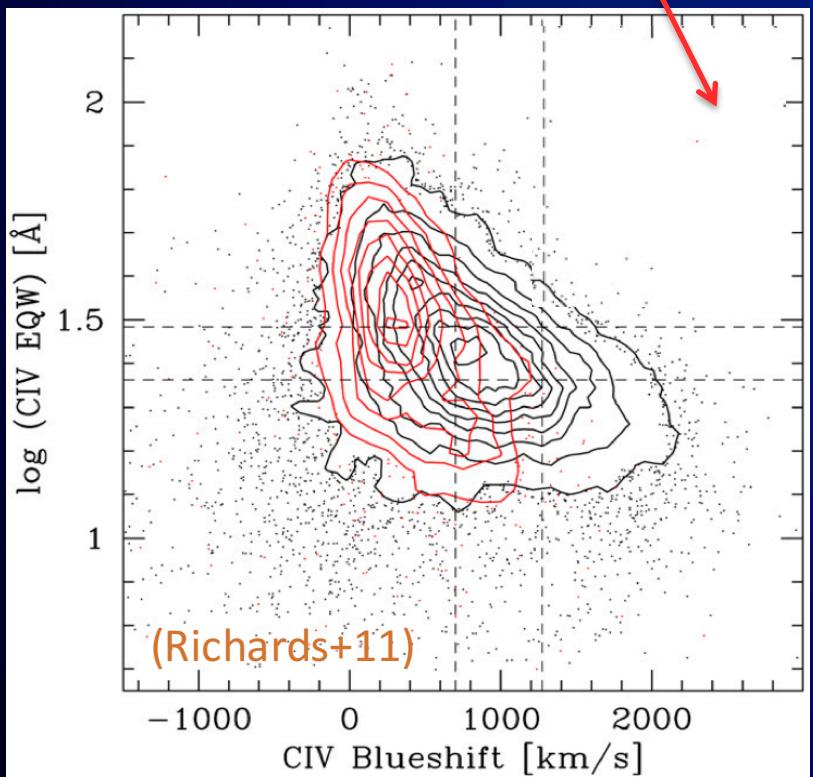
Outflow Evidence 2.:

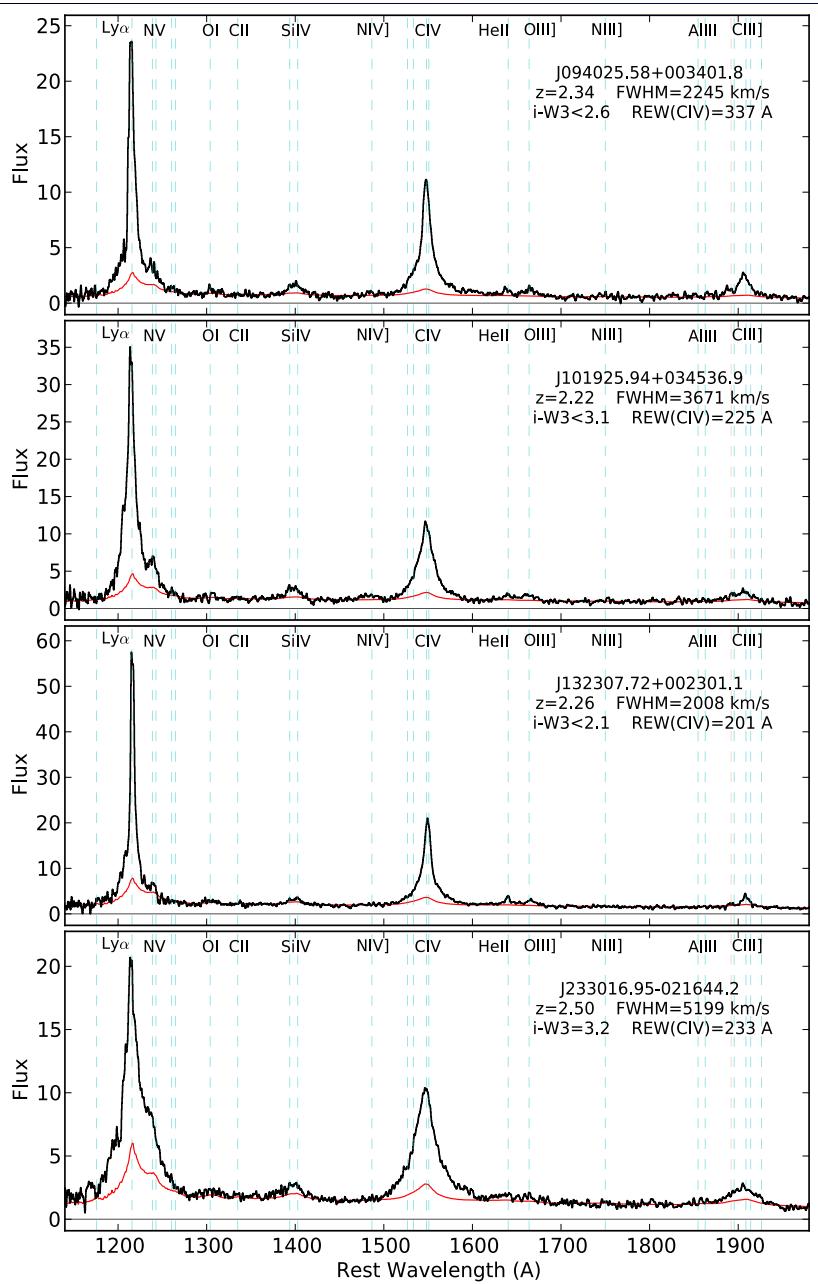
Common *large* CIV blueshifts

Spikes are Ly α at v=0 (also OI, SiII, FeII)

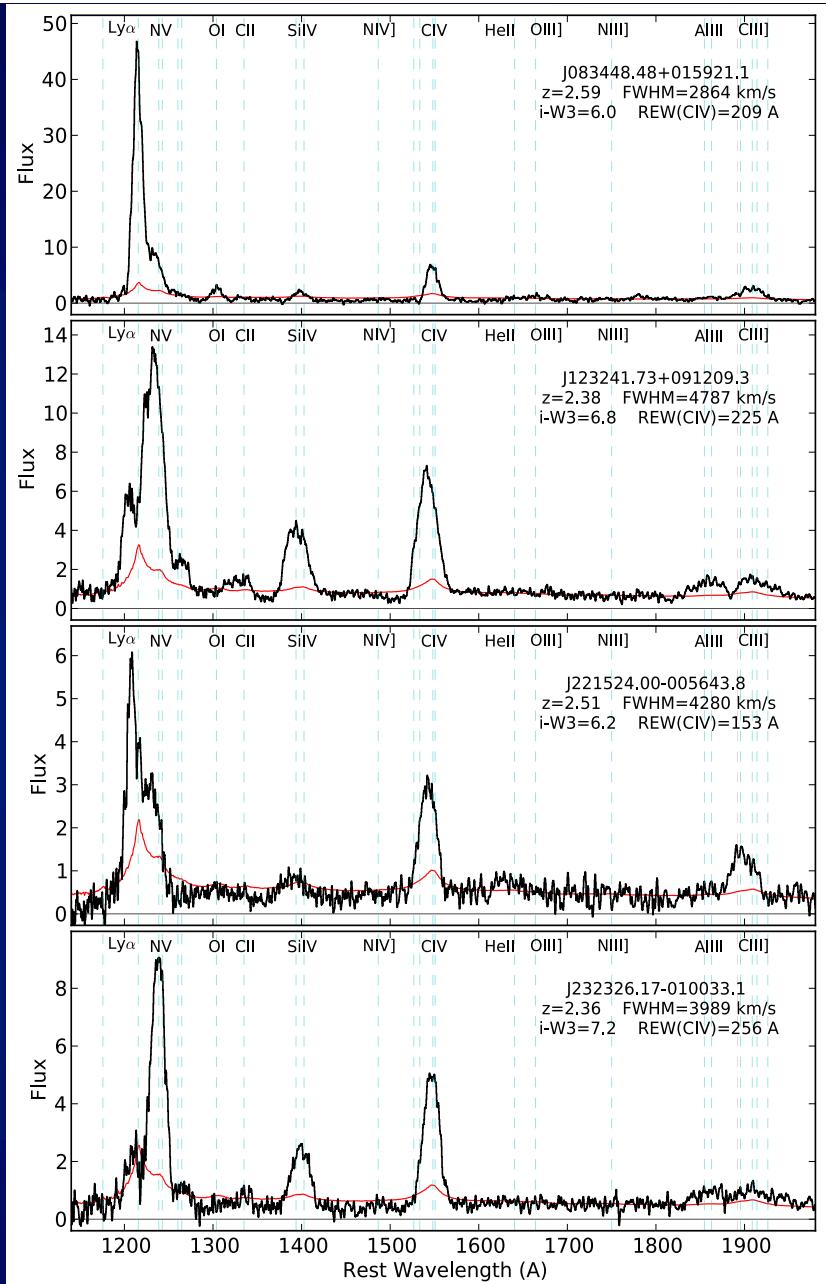
~7% of ERQs have blueshifts >2500 km/s
compared to <0.1% in SDSS overall

Outflow-dominated BLRs





Outflow Evidence 3.: VLT – Xshooter spectra: [OIII] 5007

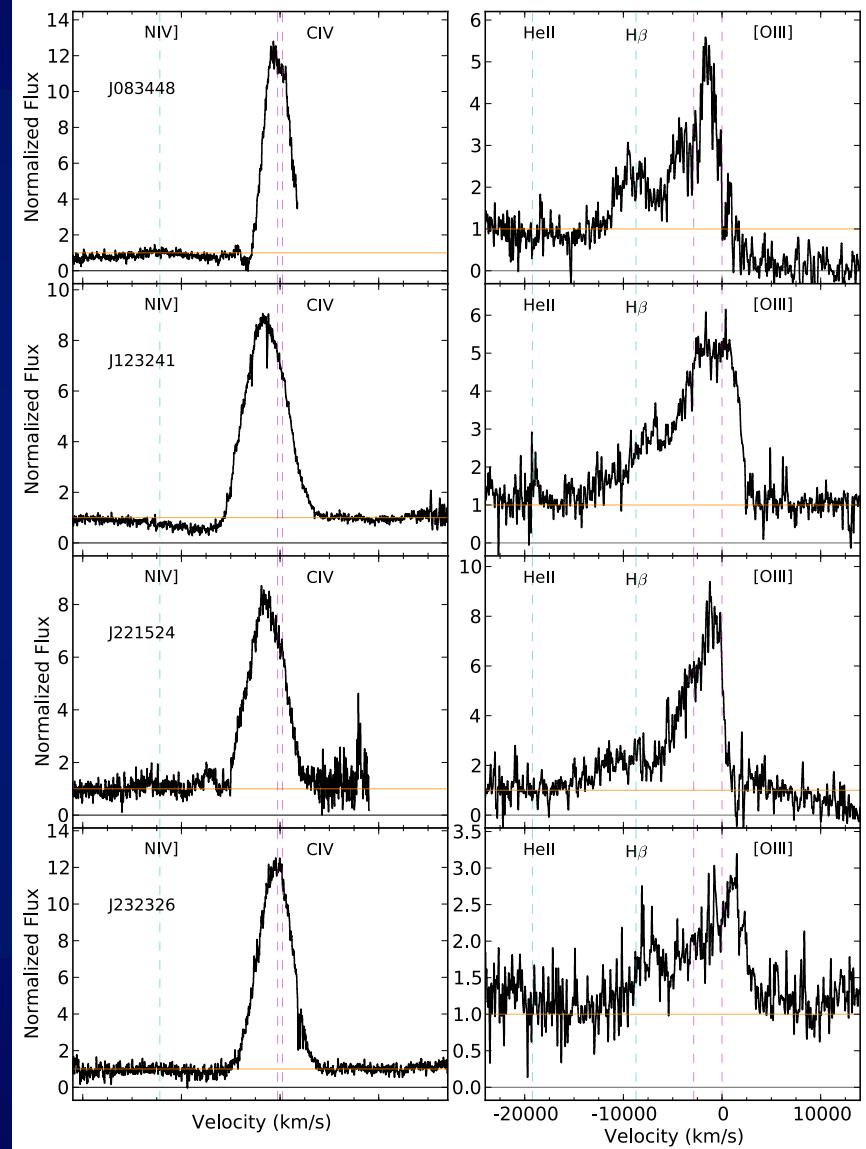
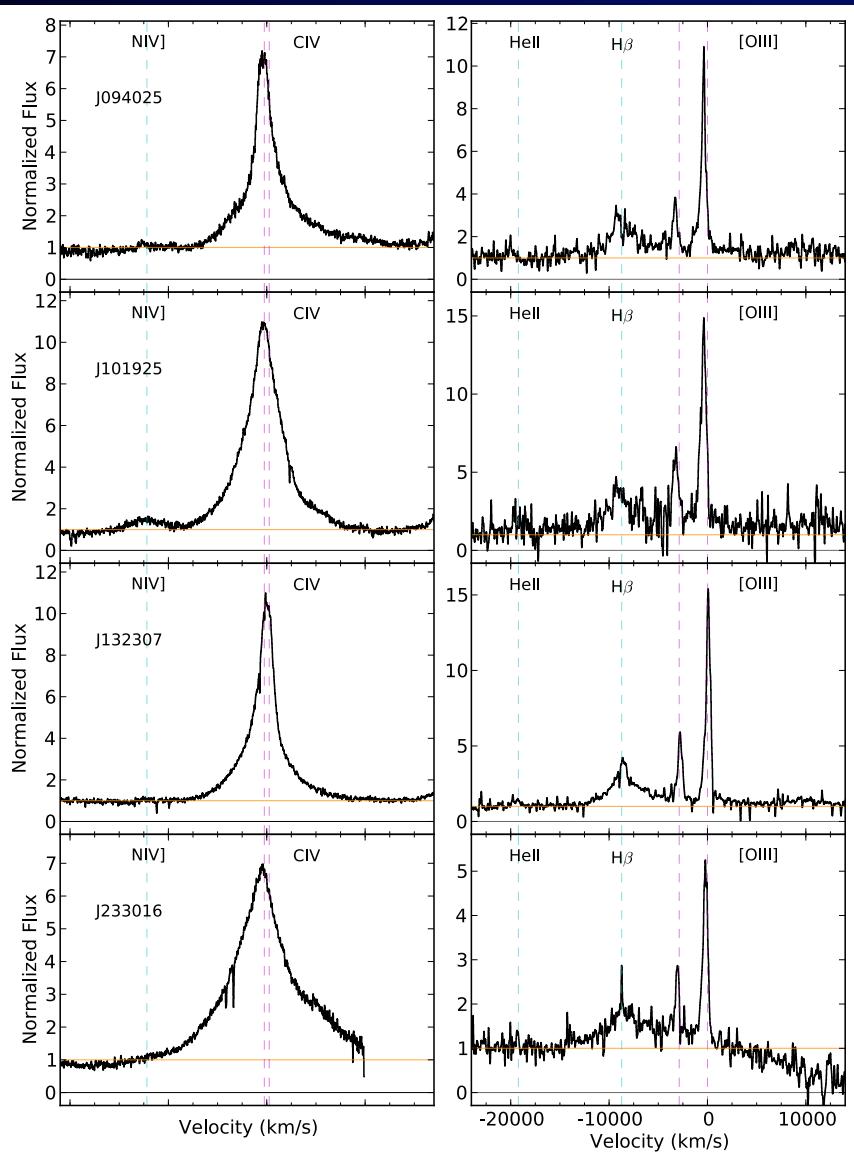


Blue quasars with REW > 150Å

ERQs with REW > 150Å

Normal [OIII], FWHM \sim 500-800 km/s

[OIII] FWHMs & wings up to 5000 km/s
Extended (>1 kpc) quasars-driven outflows
(Zakamska+16, Hamann+ in prep.)



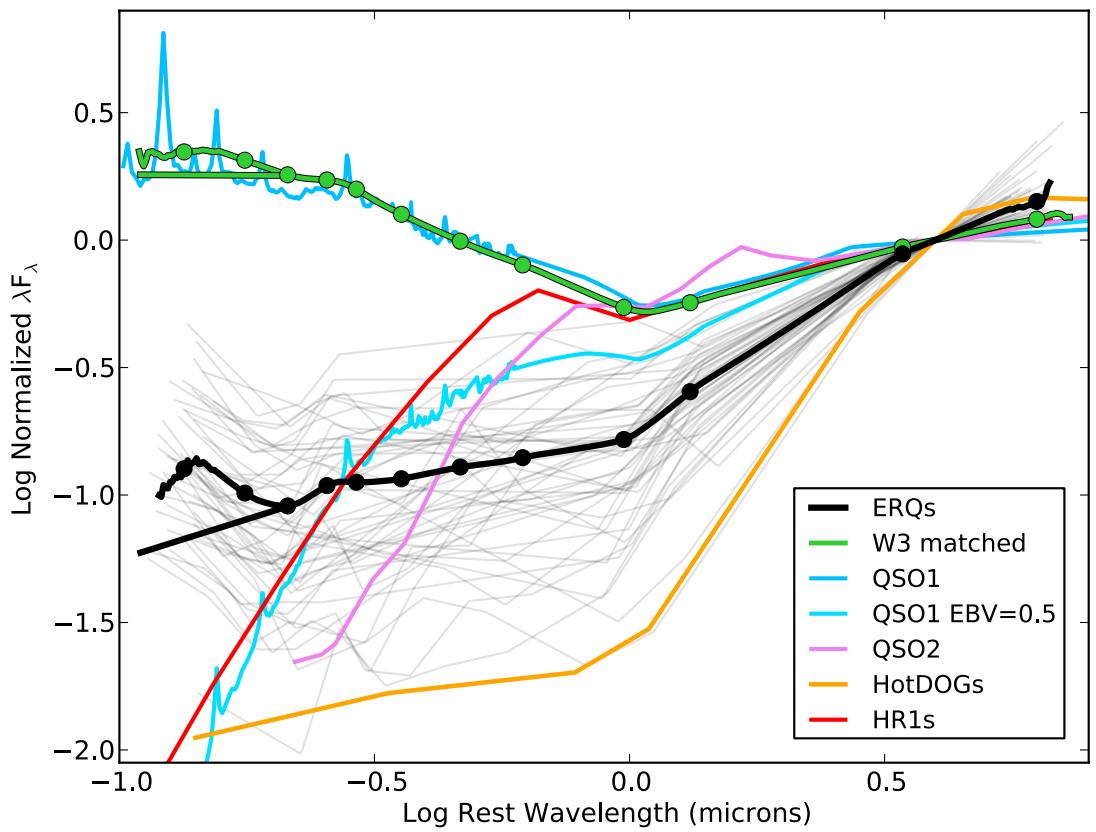
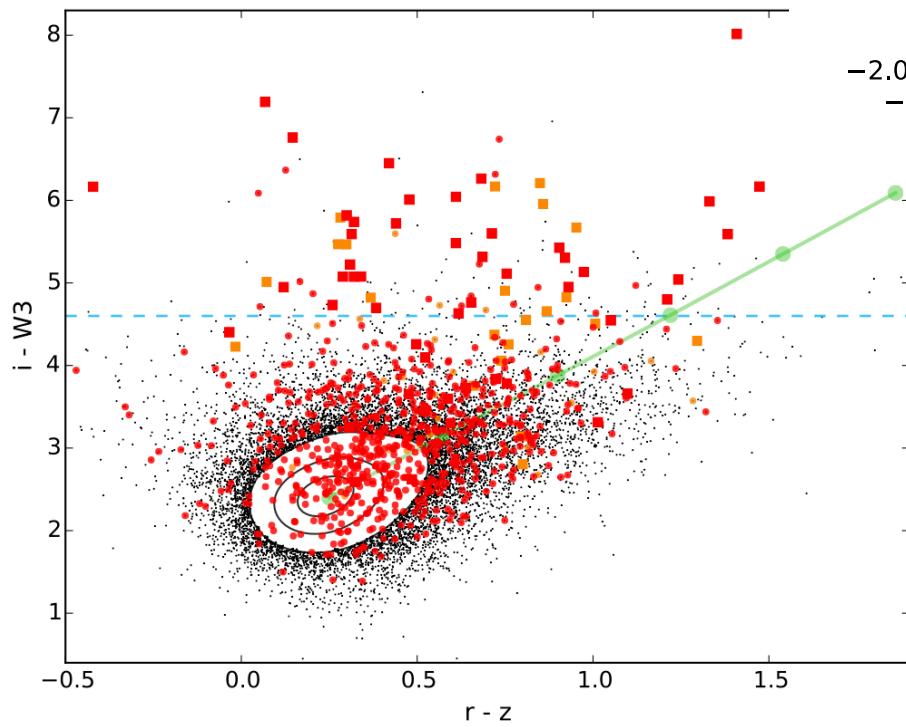
Blue quasars with REW $>$ 150Å

ERQs with REW $>$ 150Å

ERQ properties:

$L_{\text{bol}} \sim 10^{47}$ ergs/s
based on W3 mags ($\sim 3.5 \mu\text{m}$ rest)

SEDs and exotic emission lines are:
Not consistent with normal Type 1s
behind a simple dust screen



Patchy obscuration could suppress the UV without UV reddening

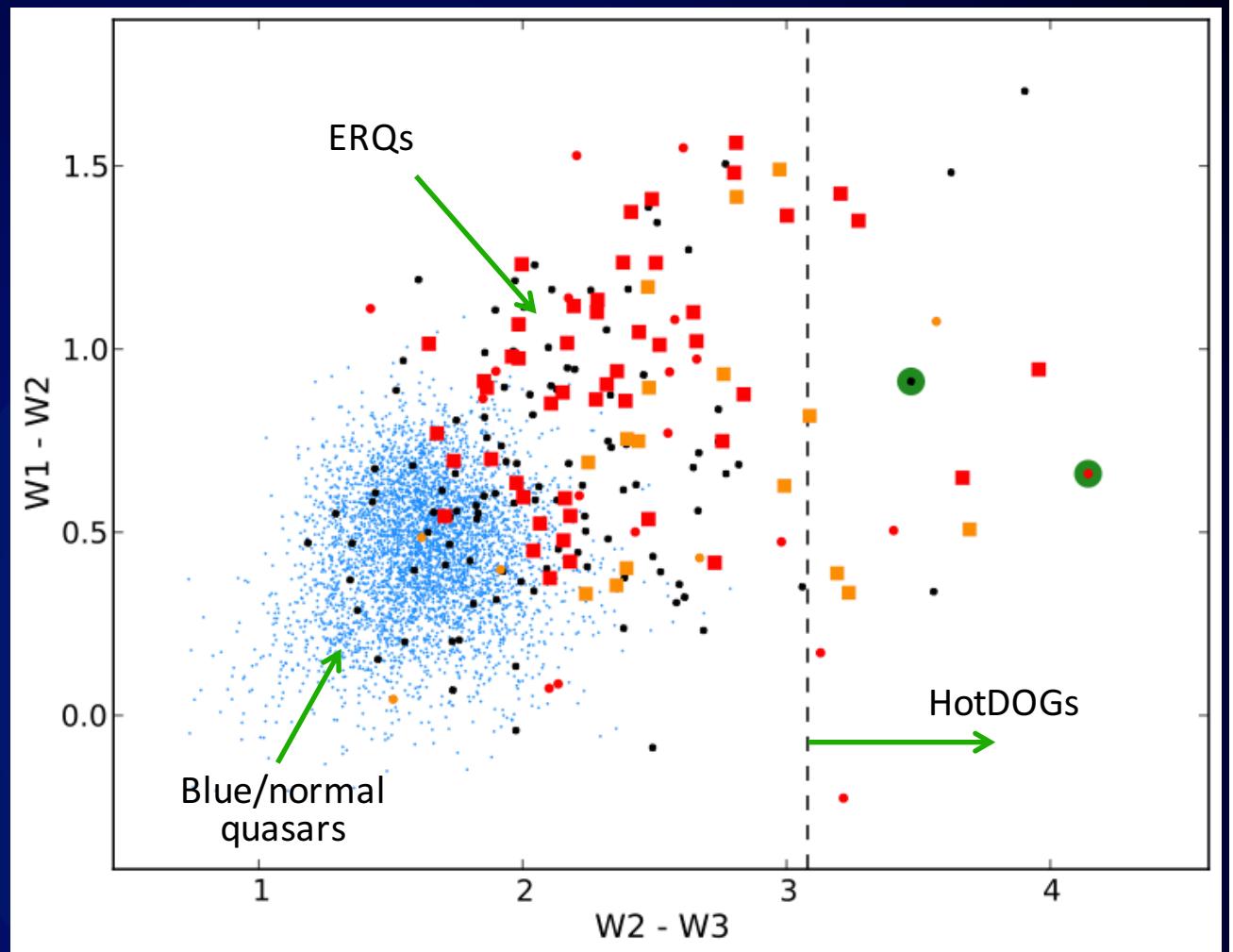
Overlap with “Hot” dust obscured galaxies (HotDOGs):

ERQs are generally less red, more uniform & extreme AGN, similar sky densities

Polletta+07, Mateos+12, Banerli+13, Tsai+15, Assef+15

Overlap with “Hot” dust
obscured galaxies
(HotDOGs):

ERQs are generally less red,
more uniform & extreme
AGN, similar sky densities



Powerful Outflows

across scales

<1 pc to >1 kpc

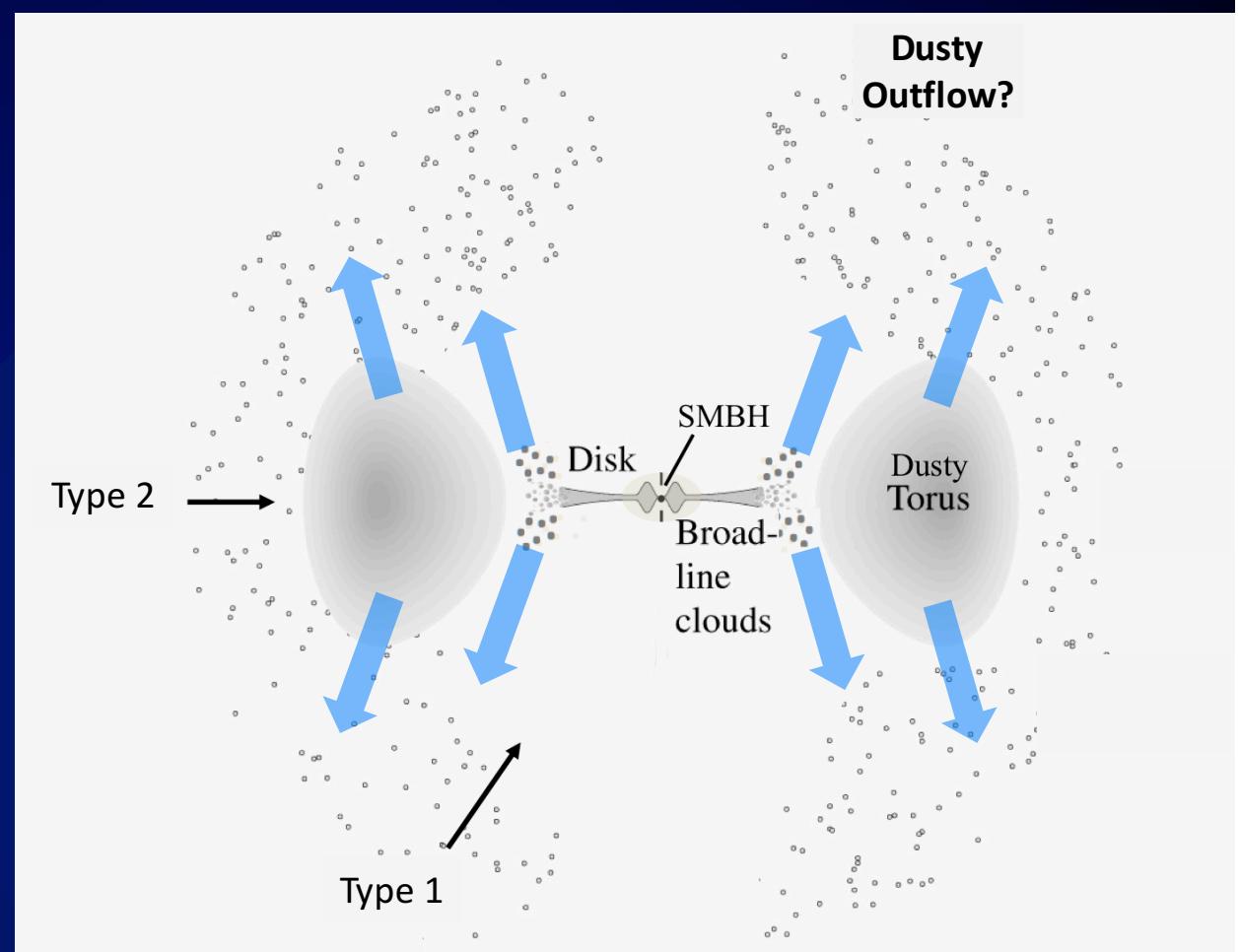
BAL-like winds

Large REWs

BLR outflows

Broad blueshifted
[OIII] 5007

Closely tied to i-W3 color

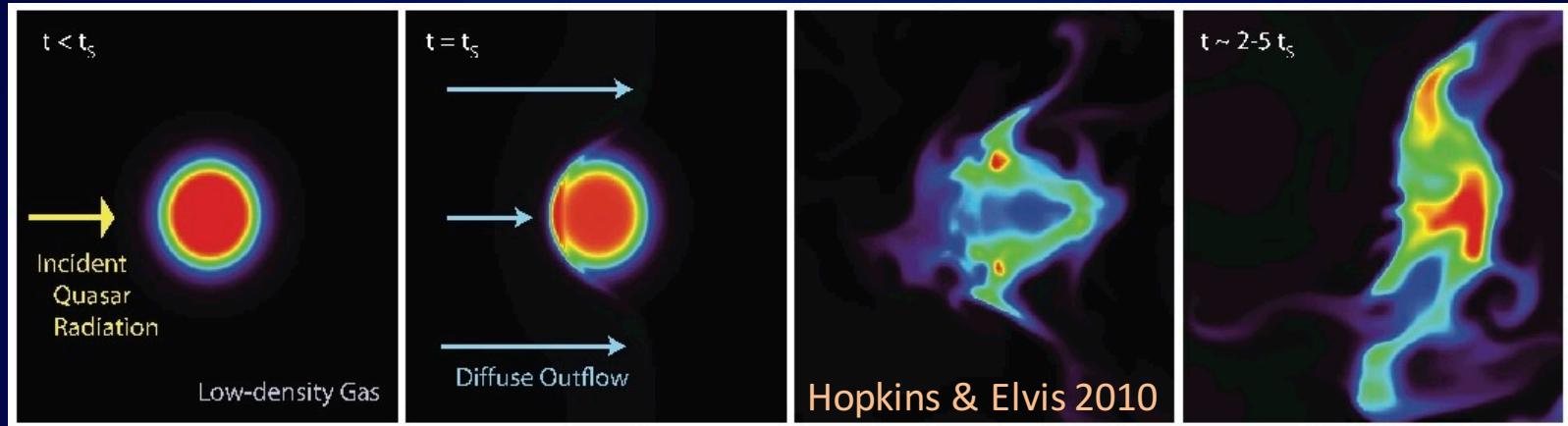


Outflows enhanced by high accretion rates?
high metallicities?

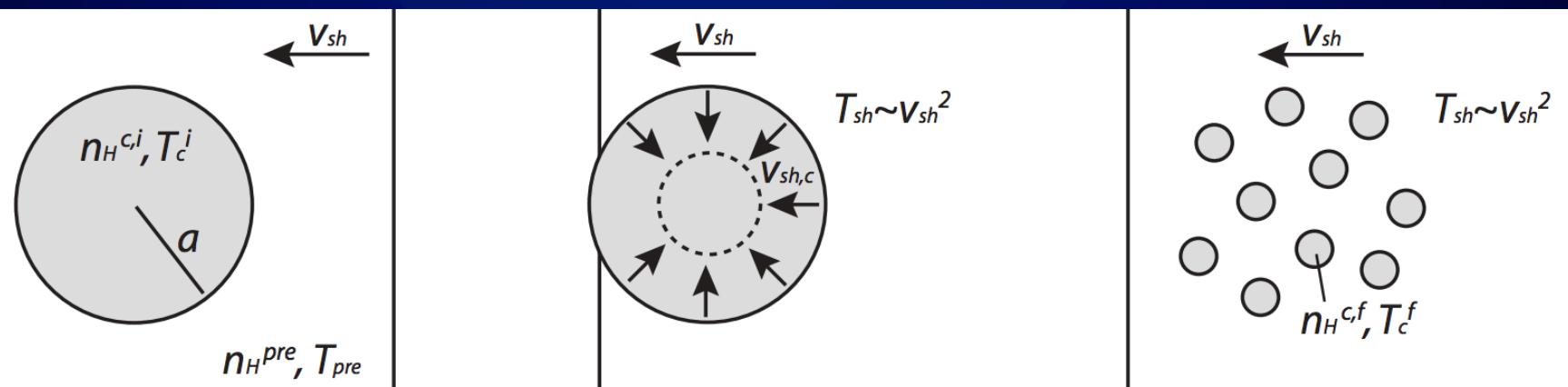
Obscuration by outflowing
dusty clumpy torus?

Obscuration on galactic scales?

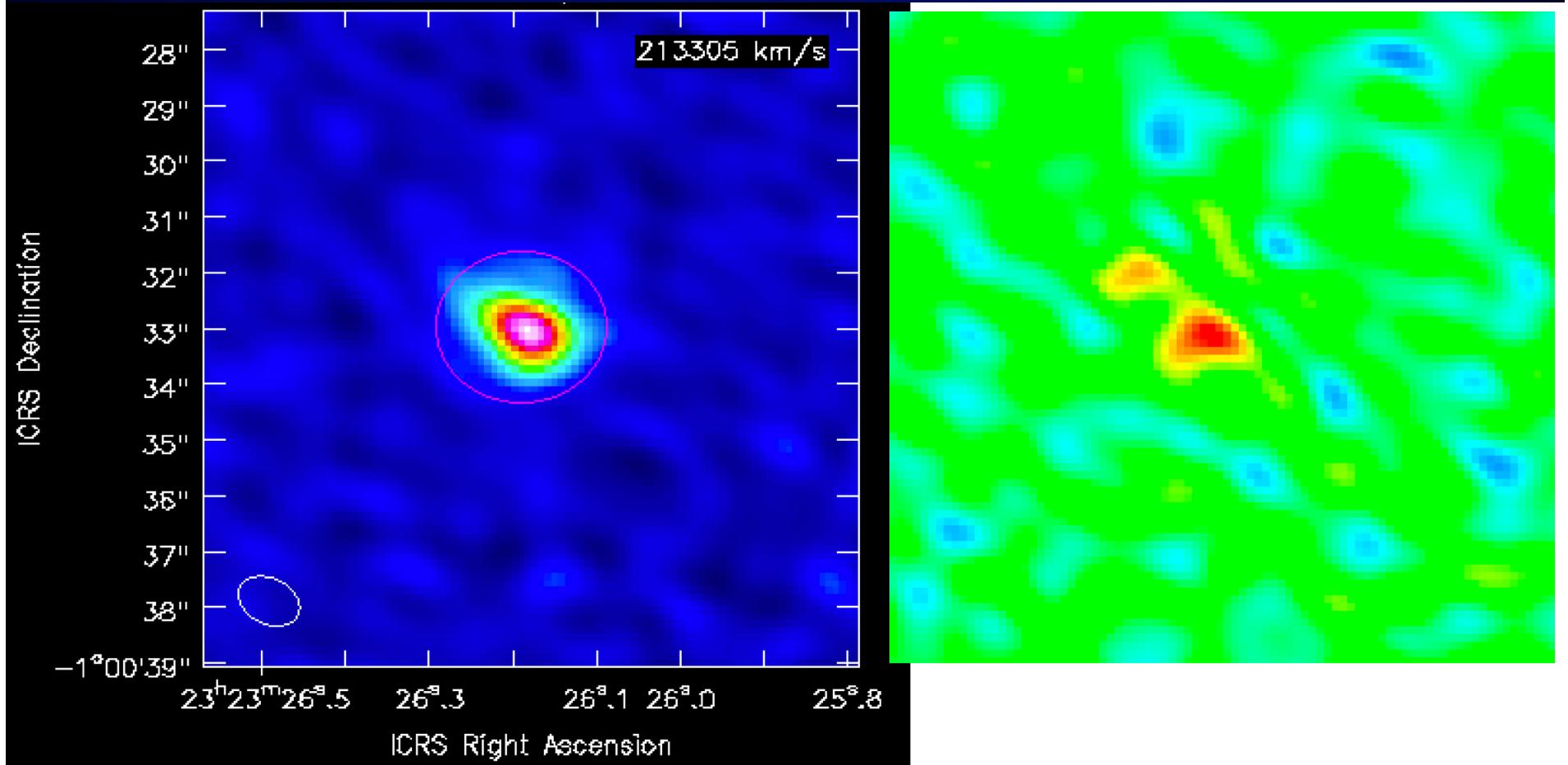
- Well-timed evolution between quasar properties and dusty host galaxies (seems unlikely)
- Direct interaction: Quasar outflows that shred & disperse dusty ISM clouds



Faucher-Giguere+12,13



2 ERQs with ALMA: band 6, ~385 μ m (rest)



Continuum: 1.57 ± 0.026 mJy
 $L_{\text{FIR}} \sim 3 \times 10^{12}$ ergs/s (for Arp 220 SED)
SFR ~ 300 Mo/yr

[CI](2-1):
Strong in one 100 km/s channel
Redshift problems

Summary:

- Several hundred ERQs via $i - W3$ at $2.0 < z < 3.4$:
- $L \sim 10^{47}$ ergs/s, very large REWs, odd line ratios, BAL-like outflows, BLR outflows
- Broad blueshifted [OIII] → unprecedented high-speed outflows at $>\sim 1$ kpc
- Exotic properties tied to extreme red UV- MIR color
- Not consistent with normal quasars behind a dust reddening screen
- Powerful outflows! High accretion rates? High metal abundances?
- A specific blowout phase of quasar/galaxy evolution?
- SMG-like star formation rates?
- Evolution tests: disturbed ISM/CO kinematics? higher star formation rates? (ALMA)
higher merger rates? (HST - Zakamska), ...