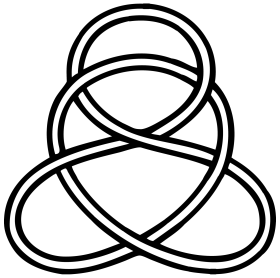
Star-formation and Feedback in "high" redshift dwarf galaxies



Ryan Trainor (Berkeley/Miller Institute)

with Charles Steidel, Eliot Quataert, Mariska Kriek, Gwen Rudie, Allison Strom, Shanon Oden, Anna de Graaff

Erb 2015 (Nature)

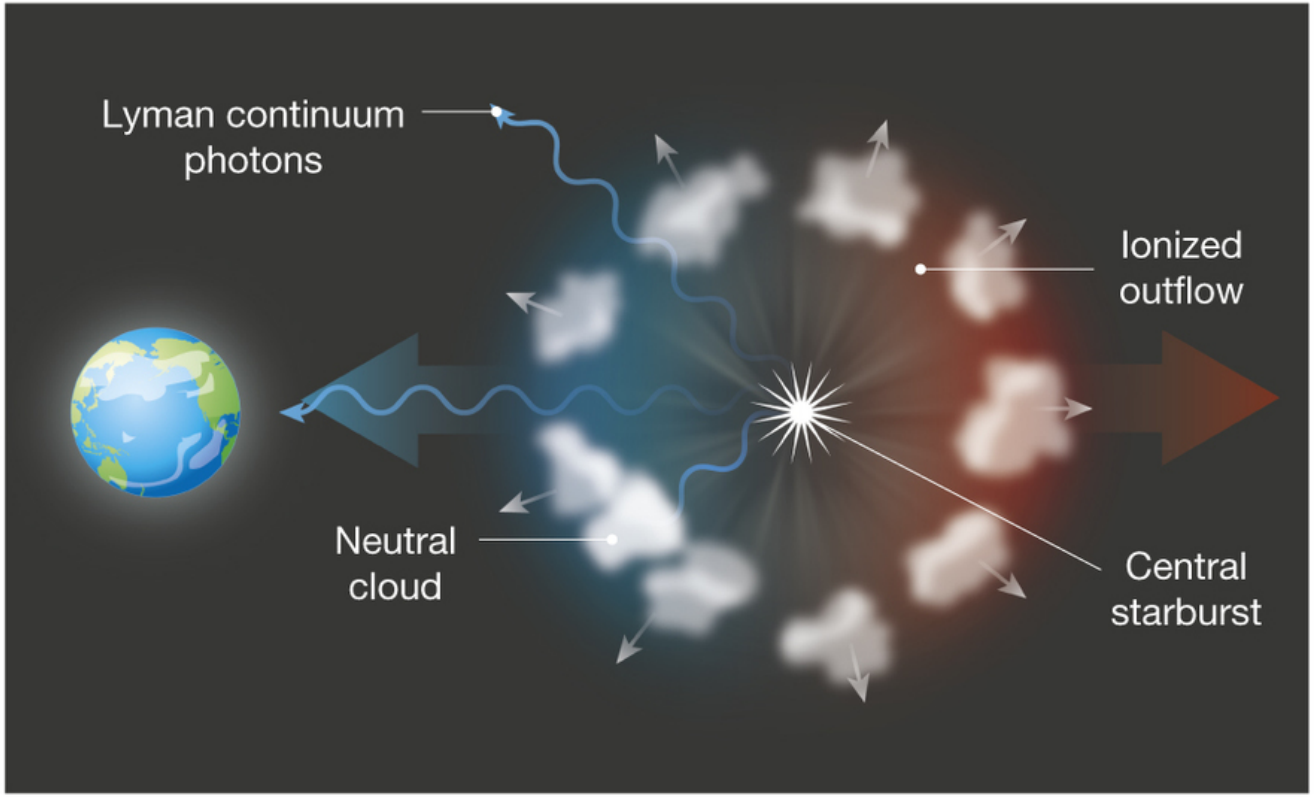
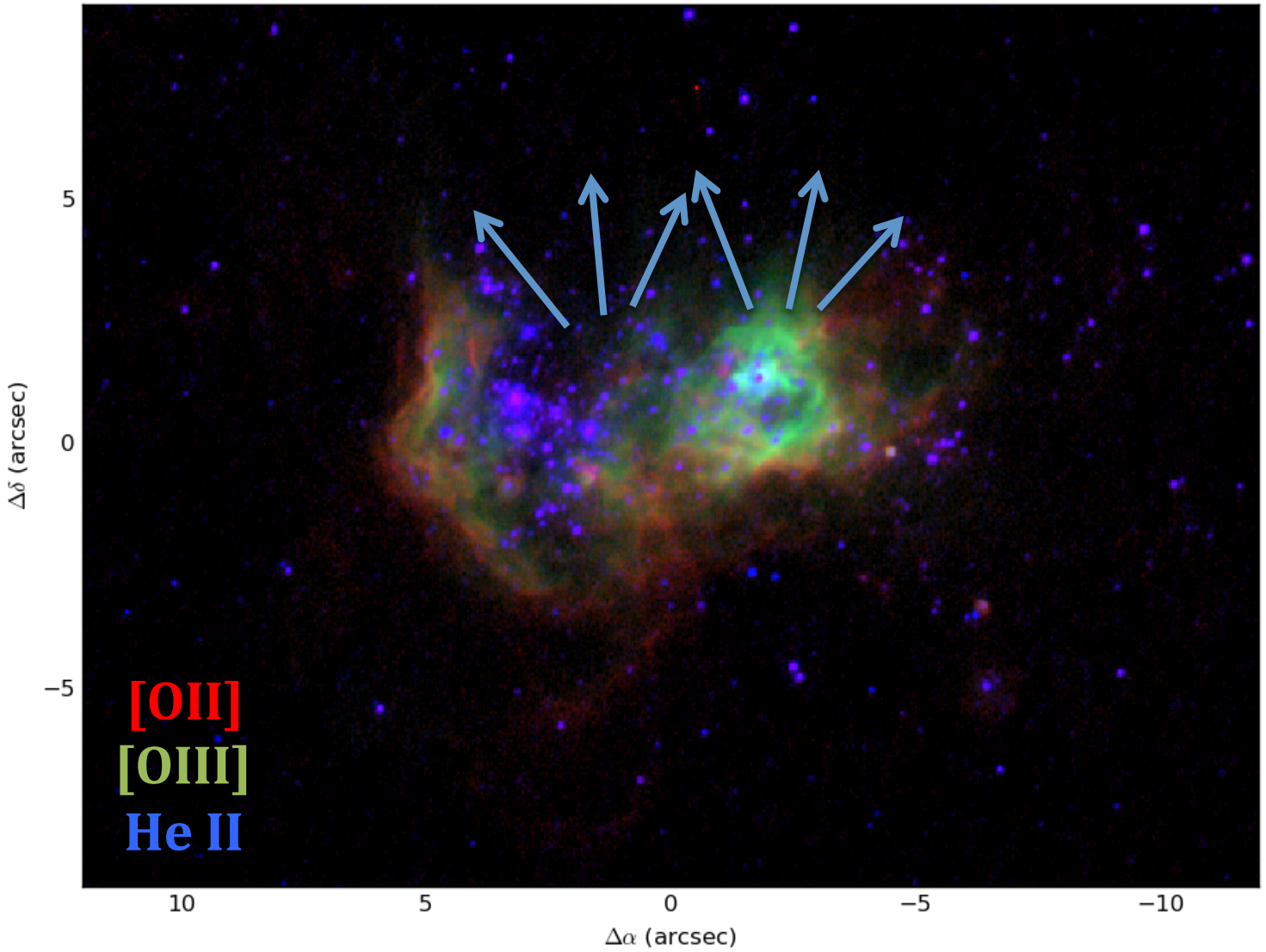
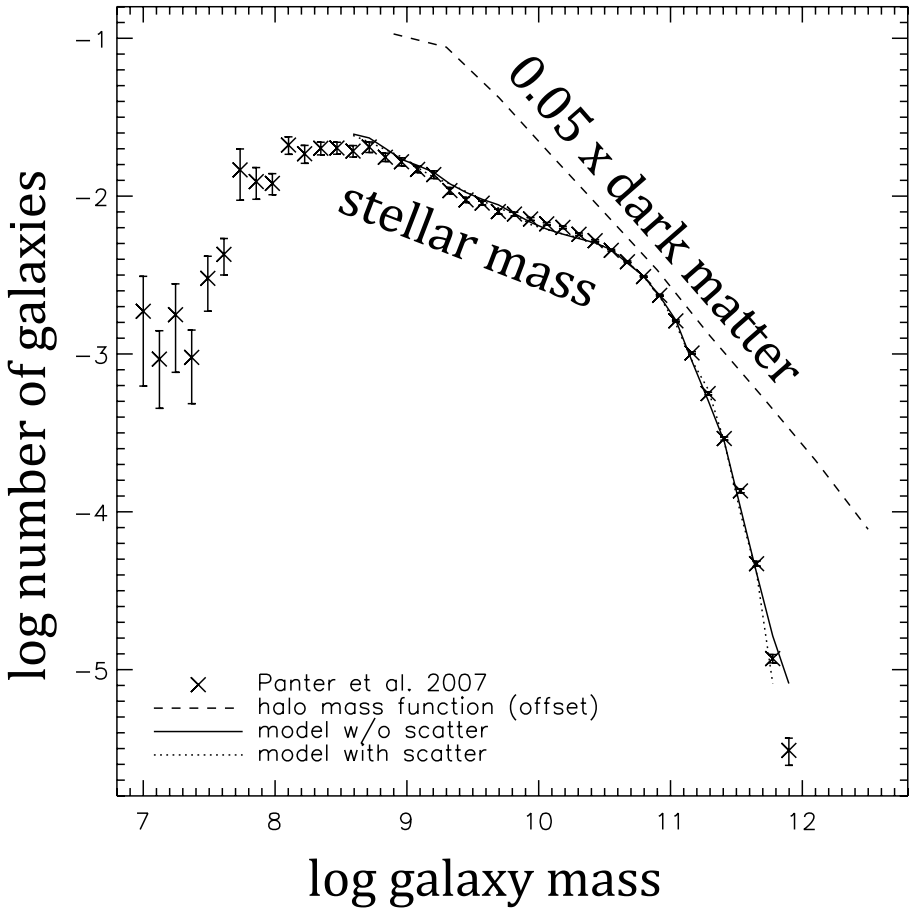


image by Matt Auger from Micheva, Oey, Jaskot & James (in prep.)

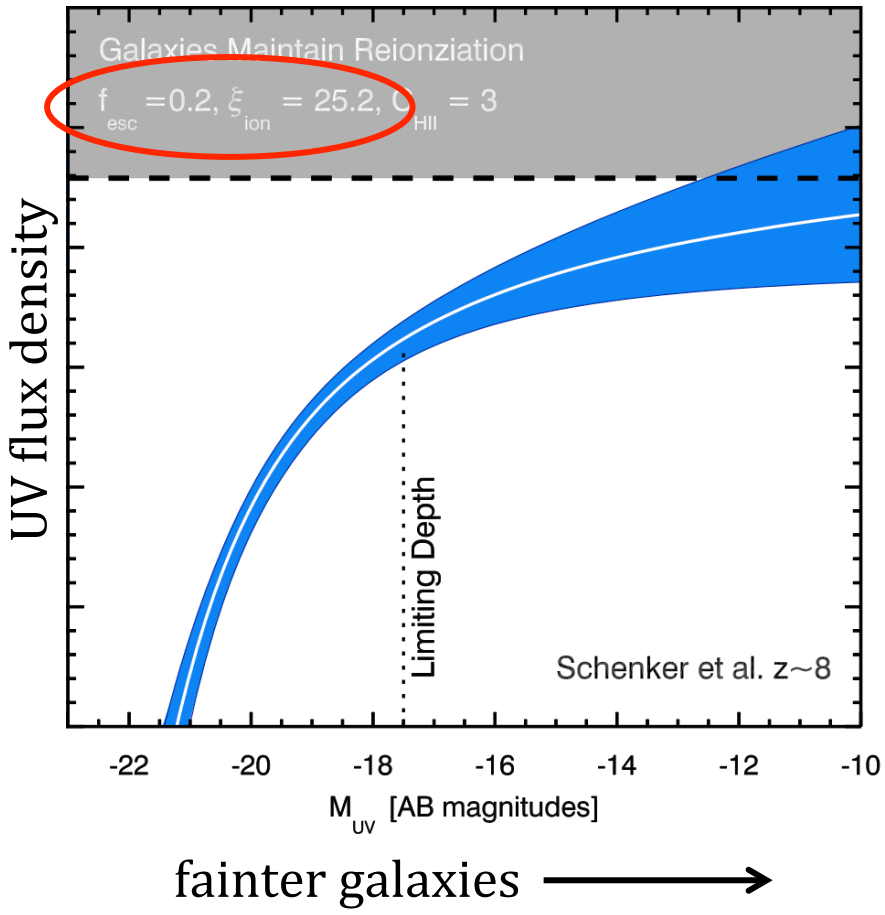


faint galaxies are the key?

Moster+2010



Robertson+2013



How does…

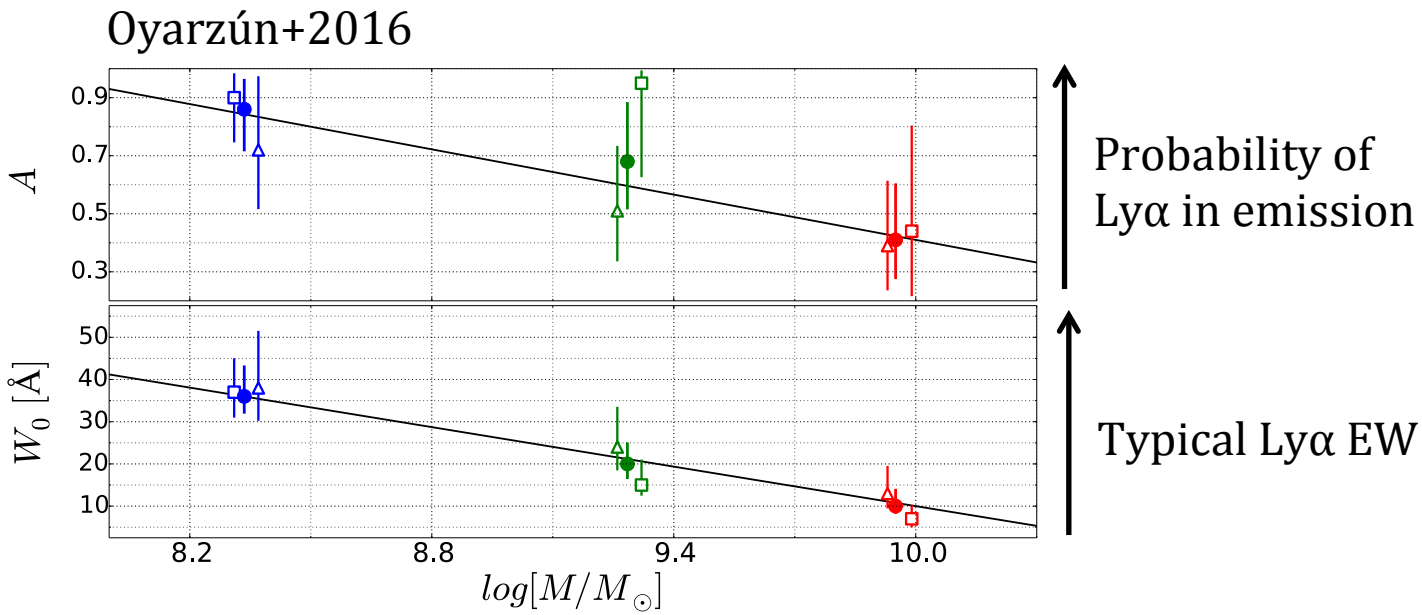
stellar feedback

star formation

photon escape

…vary across the GLF?

z=2-6 dwarfs are (mostly) LAEs

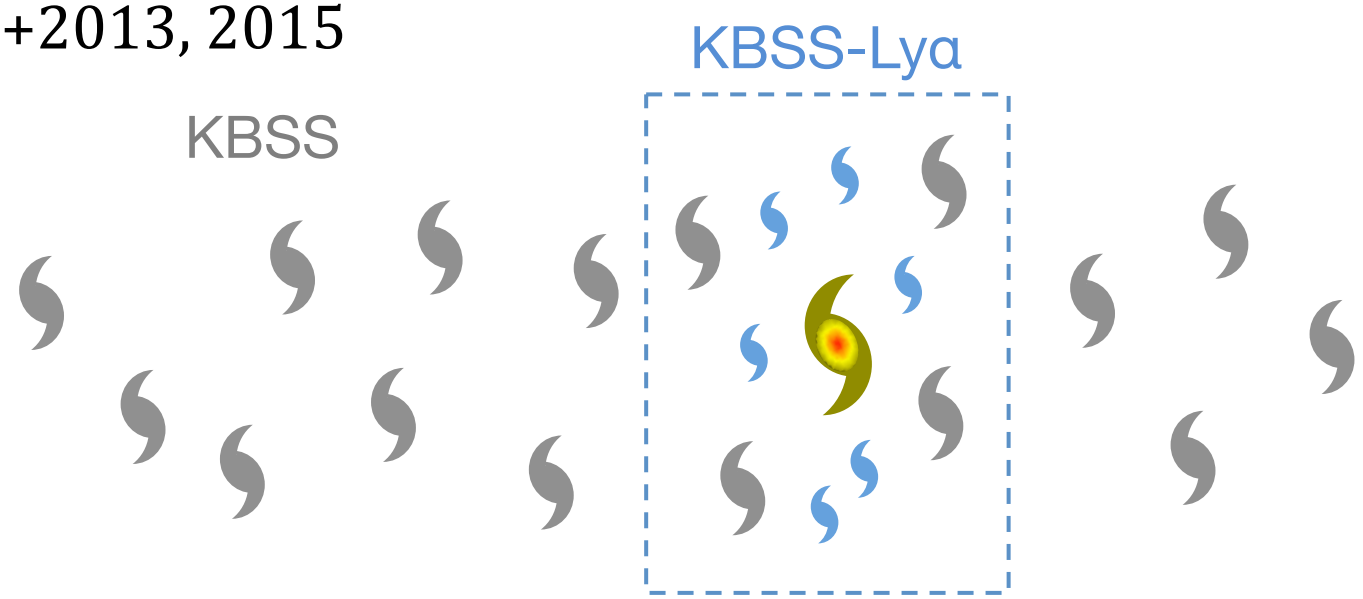


~80% of SF galaxies with $M_* \sim 10^8$ - $10^9\ M_\odot$ show strong Lyα emission (vs. 50% at $M_* \sim 10^{10}\ M_\odot$)

See also Shapley+03, Stark+14…

Keck Baryonic Structure Survey

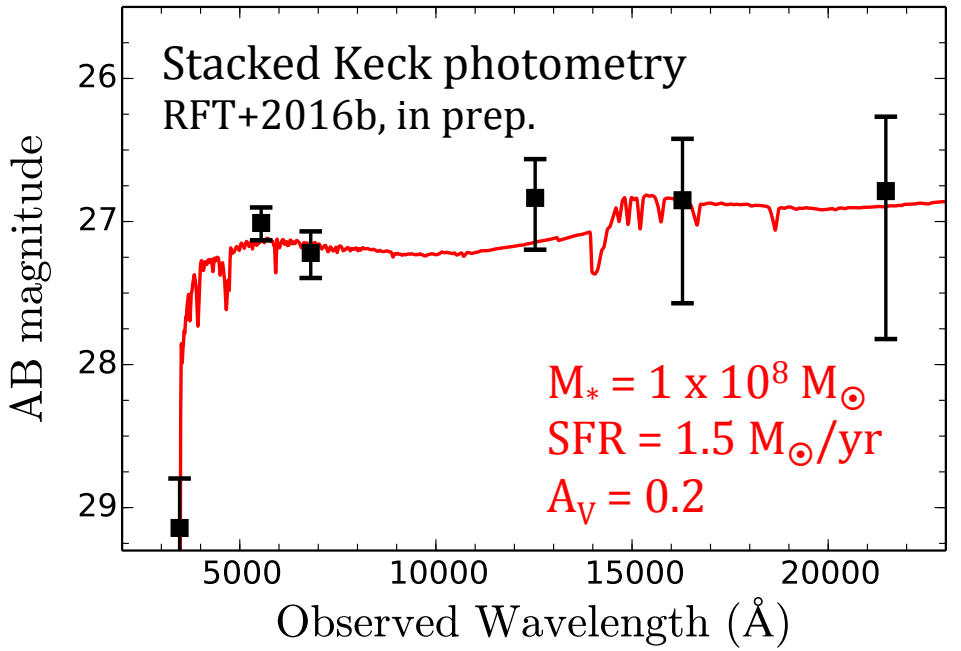
- **KBSS** includes 1000+ LBGs in QSO fields at z ≈ 2-3
  - $L \approx L_*$ galaxies, log $M_* \approx 9.5$–11.5, $M_{UV} \approx 20.5$
  - e.g., talks by Steidel, Strom
- **KBSS-Lyα** includes ~1000 LAEs, 318 with spectra
  - $L \approx 0.1\ L_*$ galaxies, log $M_* \approx 8$–9, $M_{UV} \approx 18$
  - Trainor+2013, 2015



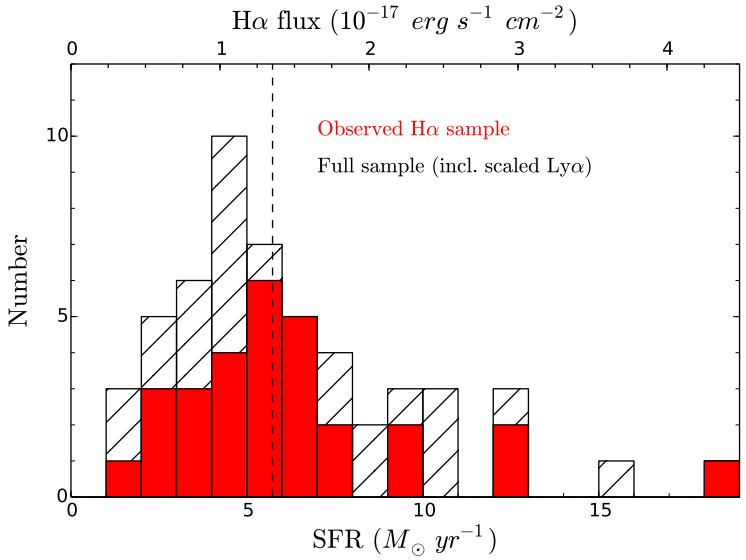
KBSS-Lyα LAE sample (z ~ 2 – 3)

- 1000 photometric LAEs
- 318 rest-UV spectra
- 55 rest-optical spectra (and counting…)

Stellar Masses ≈ 10^8 – 10^9 $M_\odot$



SFR ≈ 1 – 10 $M_\odot$ /yr



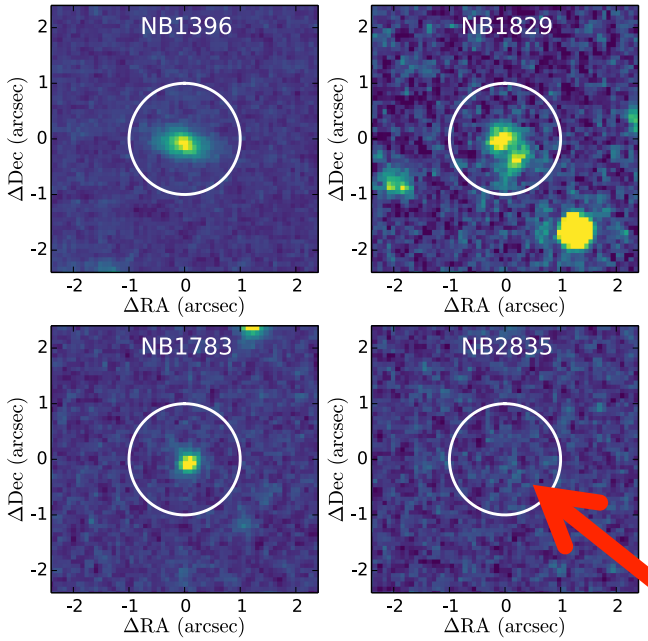
sSFR ≈ 3 – 10 Gyr^{-1}

[OIII]+HB EW ≈ 1200Å

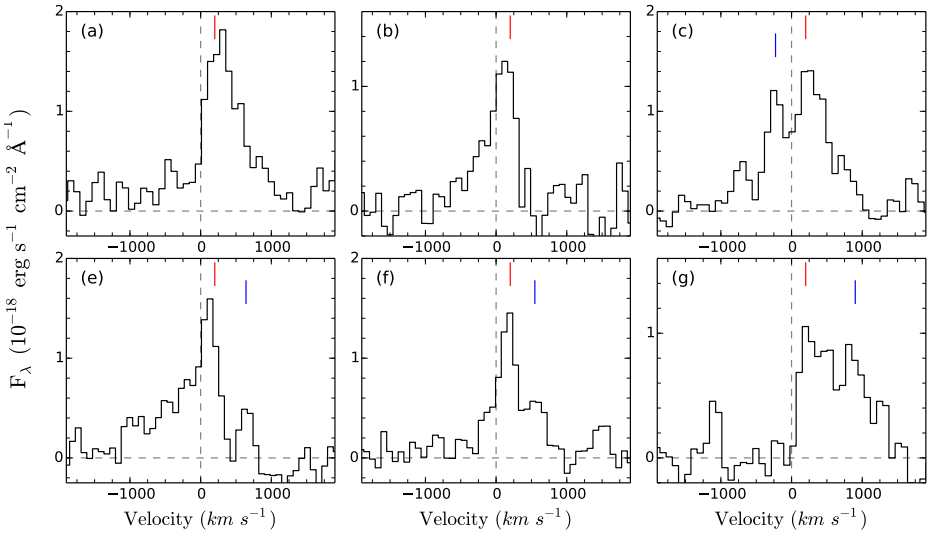
KBSS-Lyα LAE sample (z ~ 2 – 3)

Physical Morphologies

HST F160W images



Lyα Spectral Morphologies



Keck/LRIS Lyα spectra
RFT+2015

$m_{AB} > 28.3$

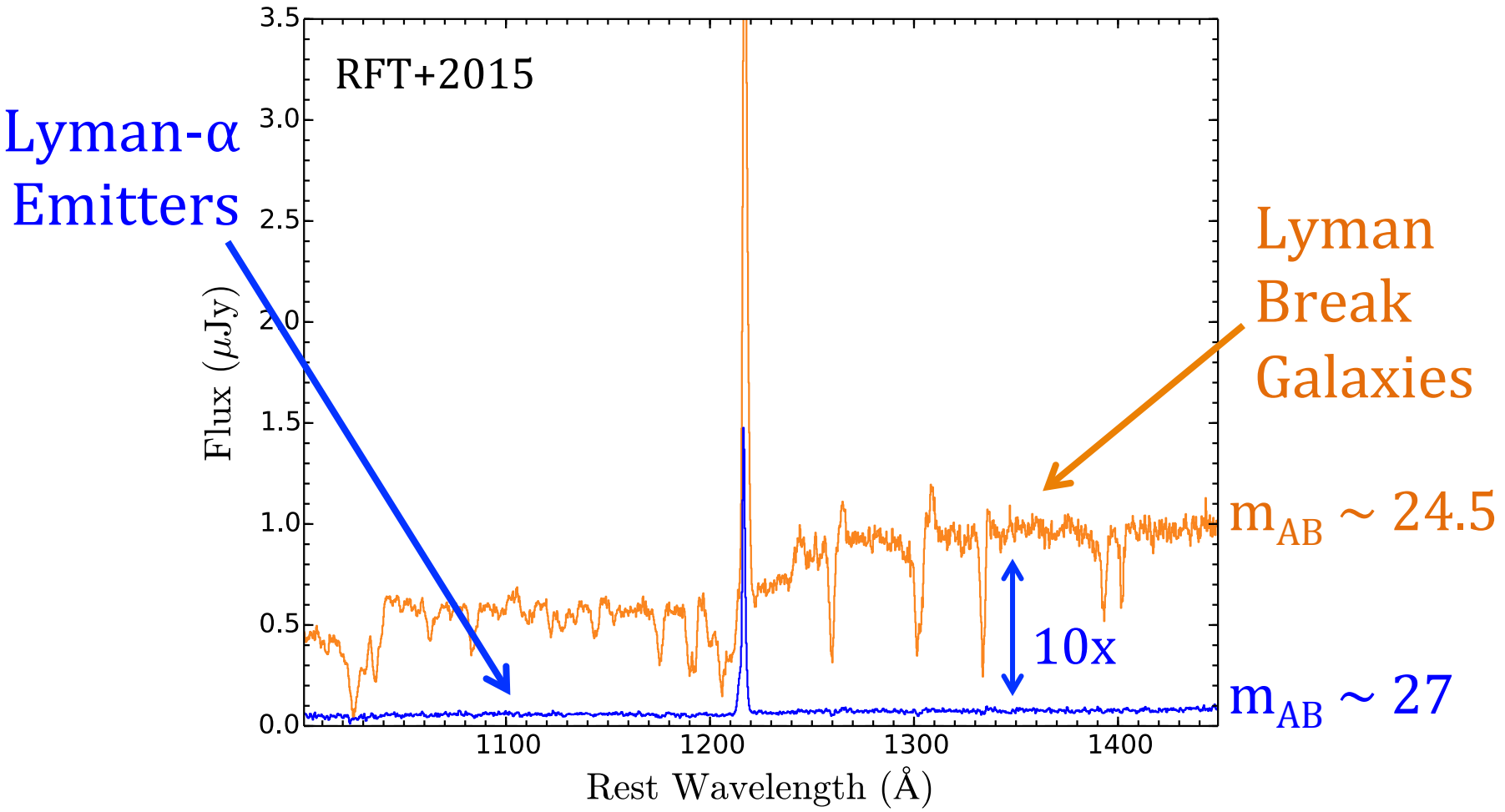
Anna de Graaff
(Edinburgh/
Berkeley/
Leiden)

Shanon Oden
(Berkeley > UCSB)

Ryan Trainor – IAP Galaxy Formation

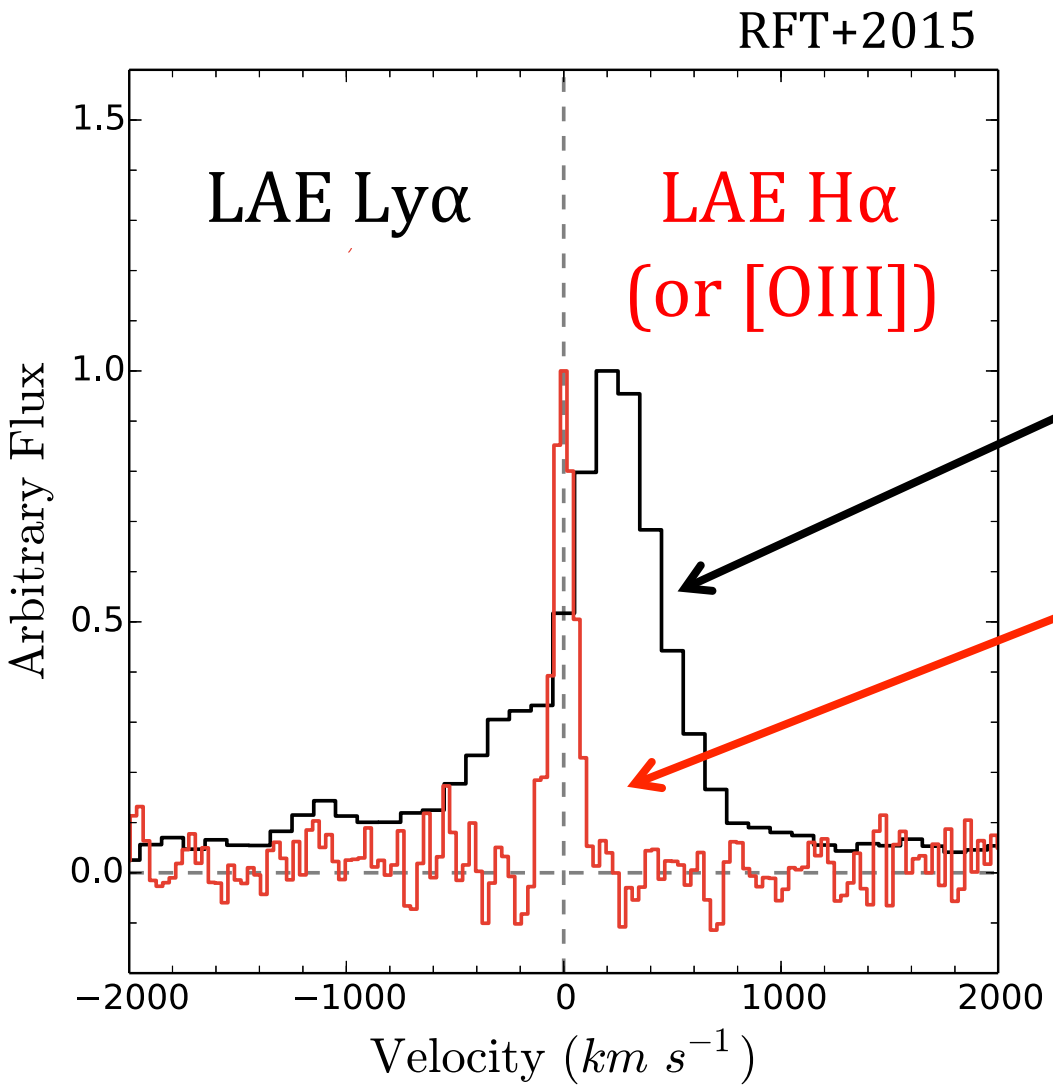
feedback in dwarfs

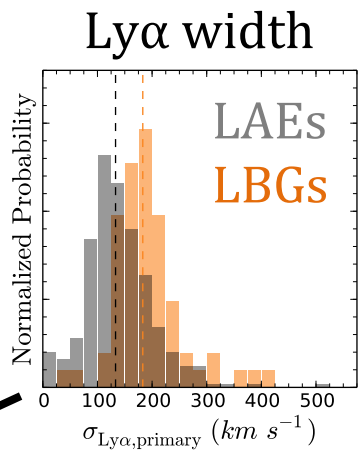
feedback physics in the UV spectrum

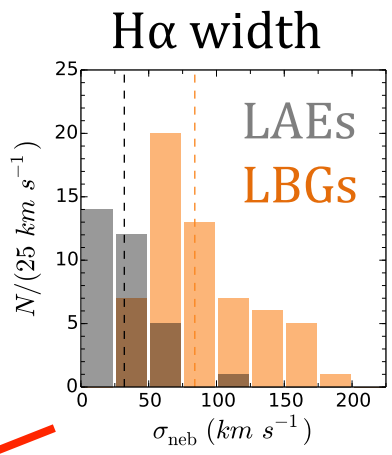


*675 object-hour Keck/*LRIS *composite spectrum*

gas kinematics in line emission







gas velocity & optical depth grow with galaxy mass/luminosity, drops with $W_{\mathrm{Ly\alpha}}$

see Erb+2014, RFT+2015

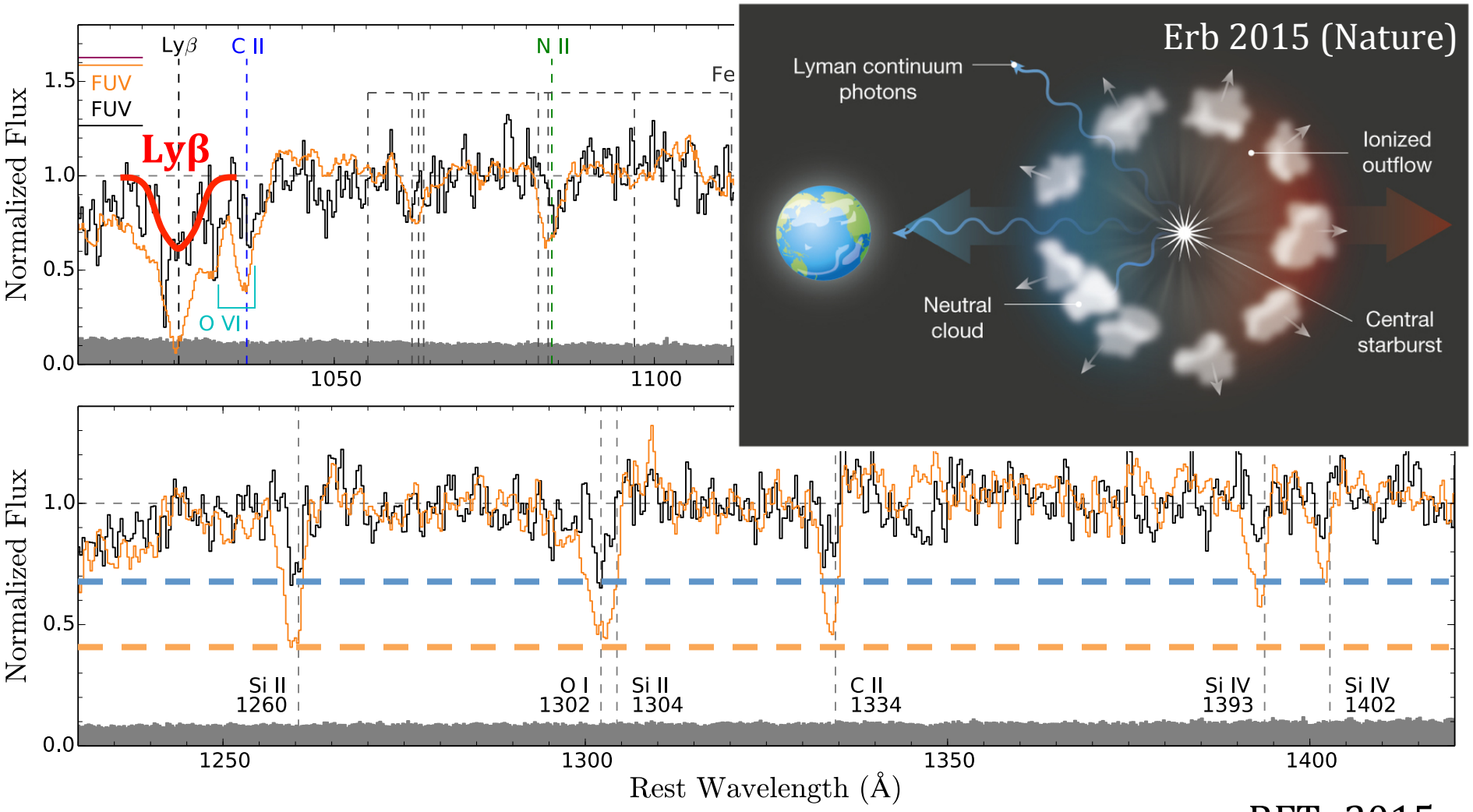
$f_{esc}(\mathrm{Ly\alpha}) \approx (\mathrm{Ly\alpha}/\mathrm{H\alpha})/8.3$

≈ 5-10% for LBGs

≈ 30% for LAEs

metal-enriched outflows

LAE composite
LBG composite

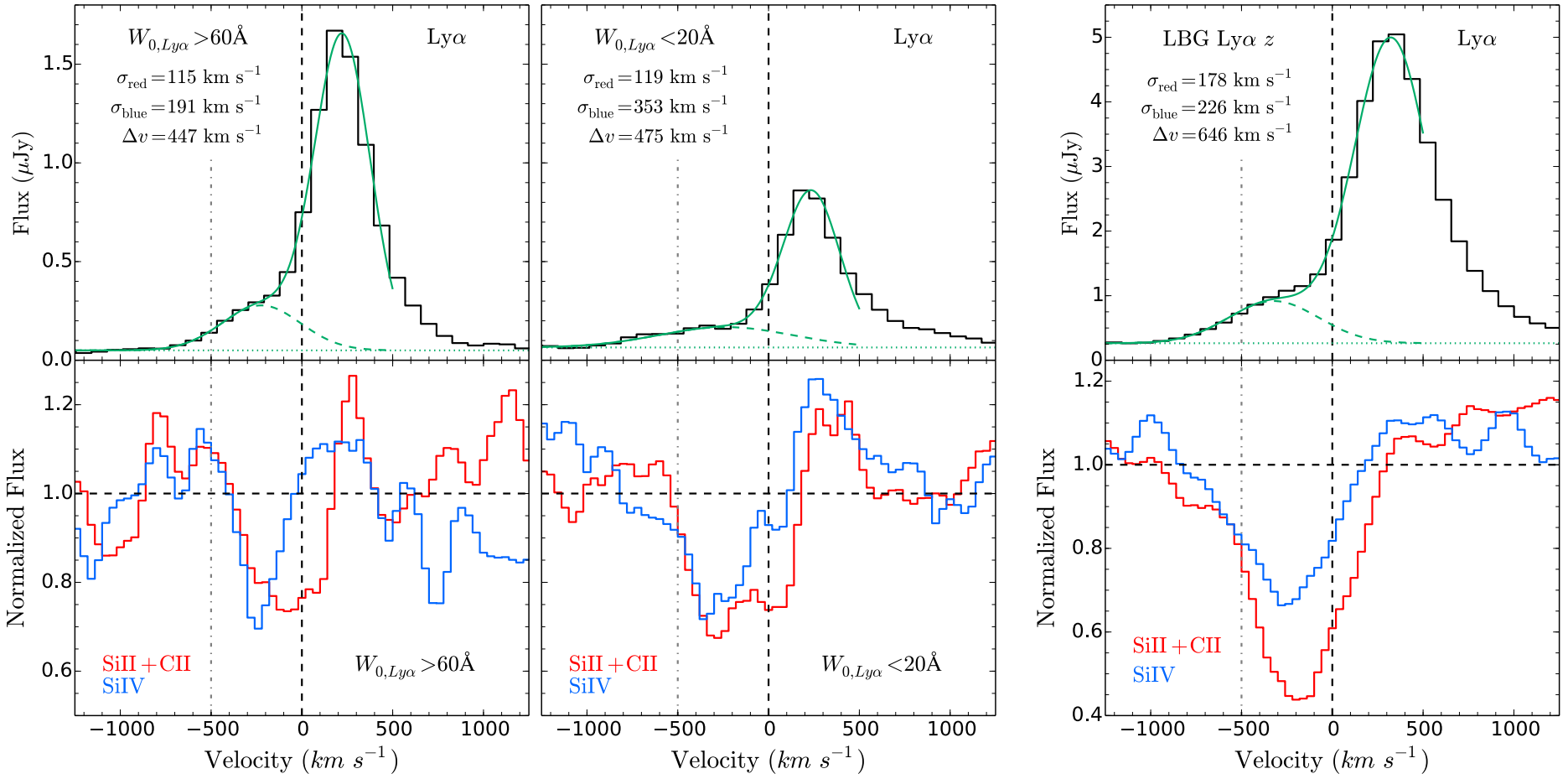


RFT+2015

see also Henry+2015, Rivera-Thorsen+2015 for local analogs

correlated absorption and emission

As Lyα EW increases (or luminosity decreases), outflow velocity decreases

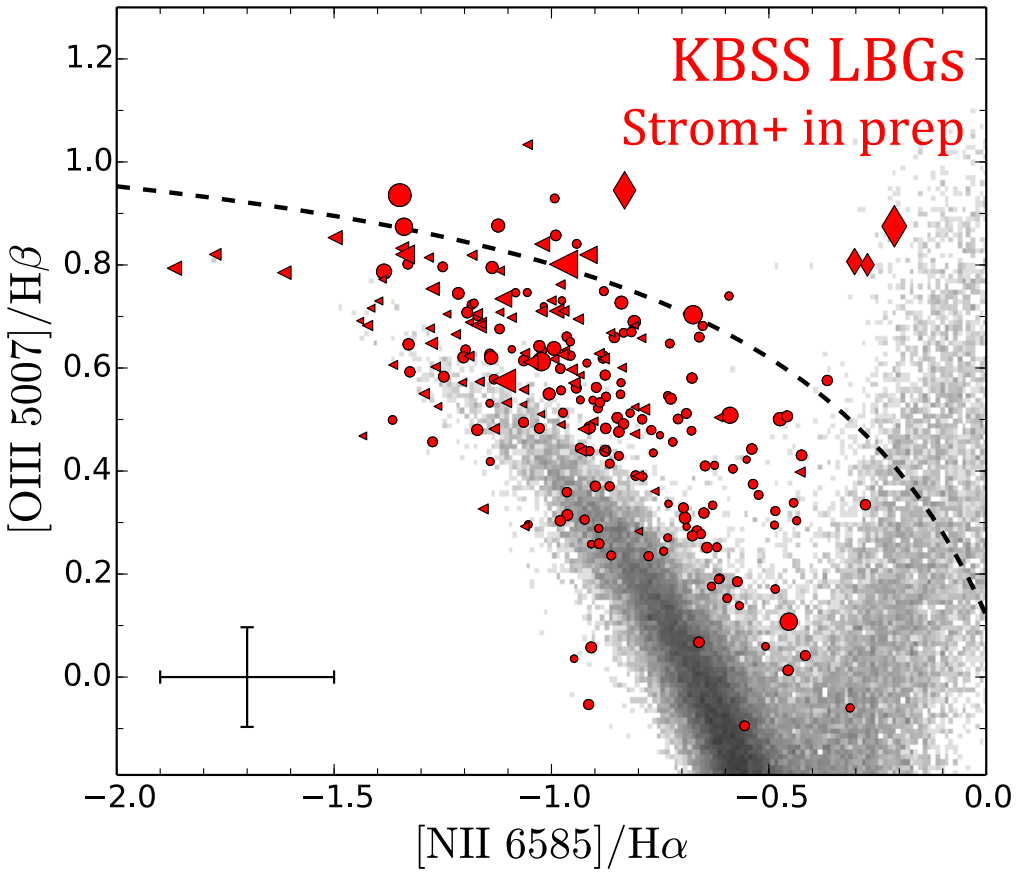


$$v_{out} \propto \sigma_{neb}$$

RFT+2015

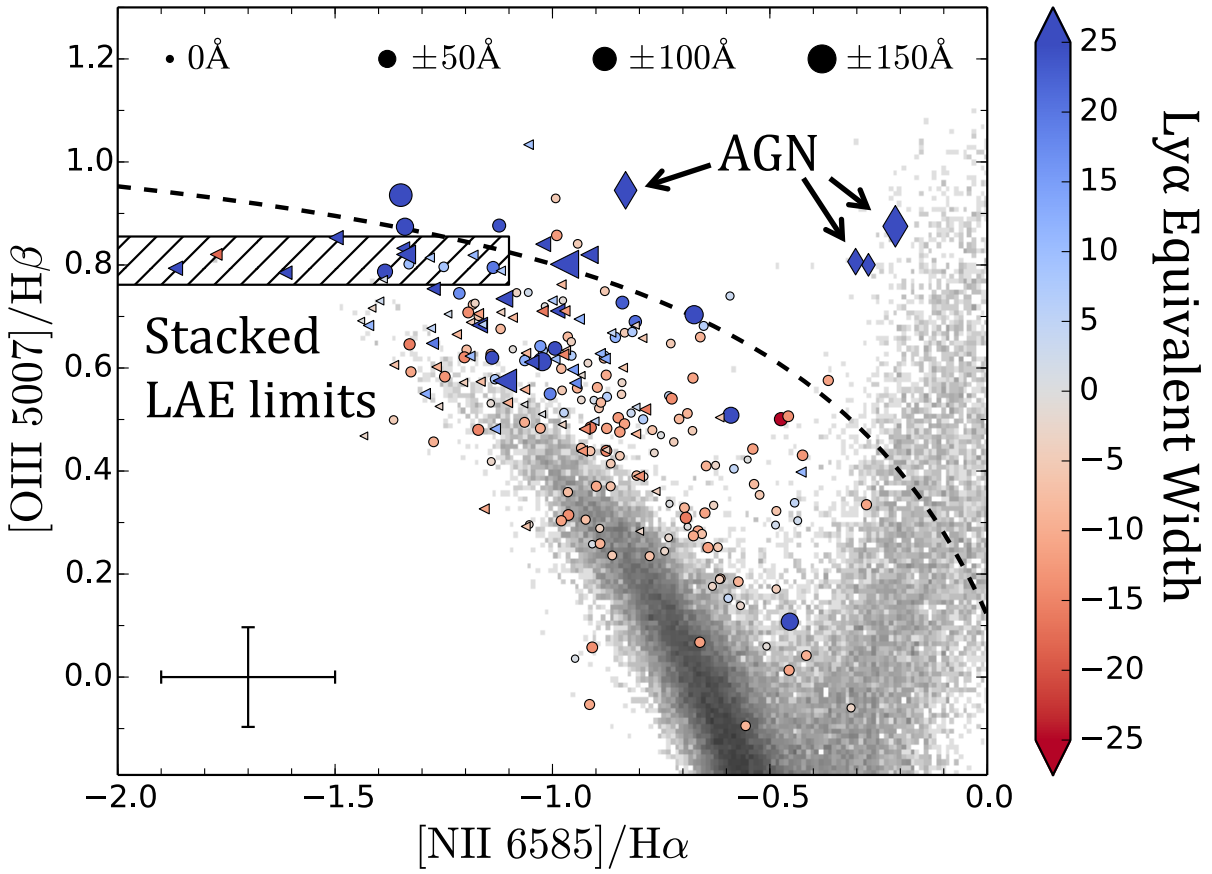
star formation in dwarfs

LBG BPT diagram



RFT+2016a, in prep.

BPT-Lyα relation (LBGs)



RFT+2016a, in prep.

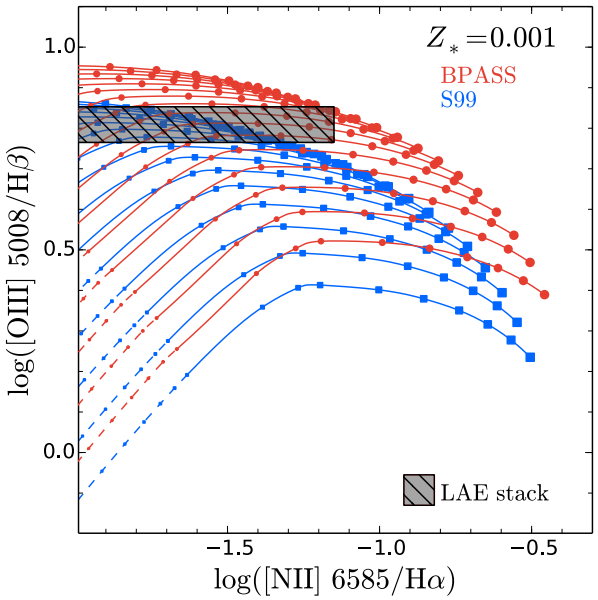
See also: Hagen+2016, Nakajima+2013

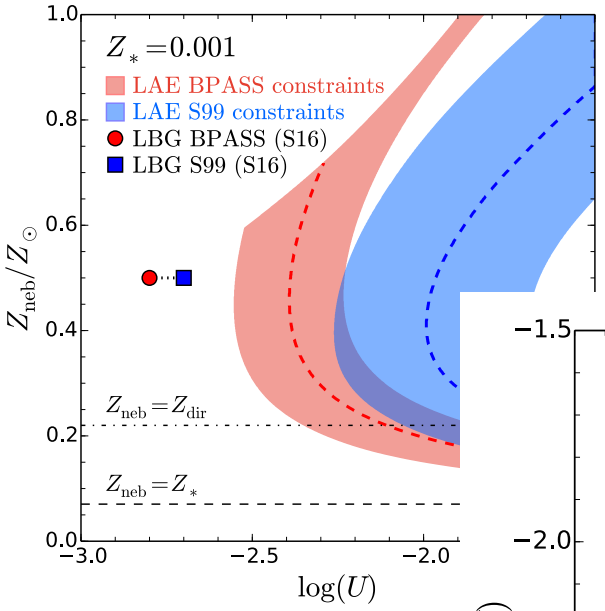
KBSS LBGs show a gradient in $W_{\mathrm{Ly}\alpha}$

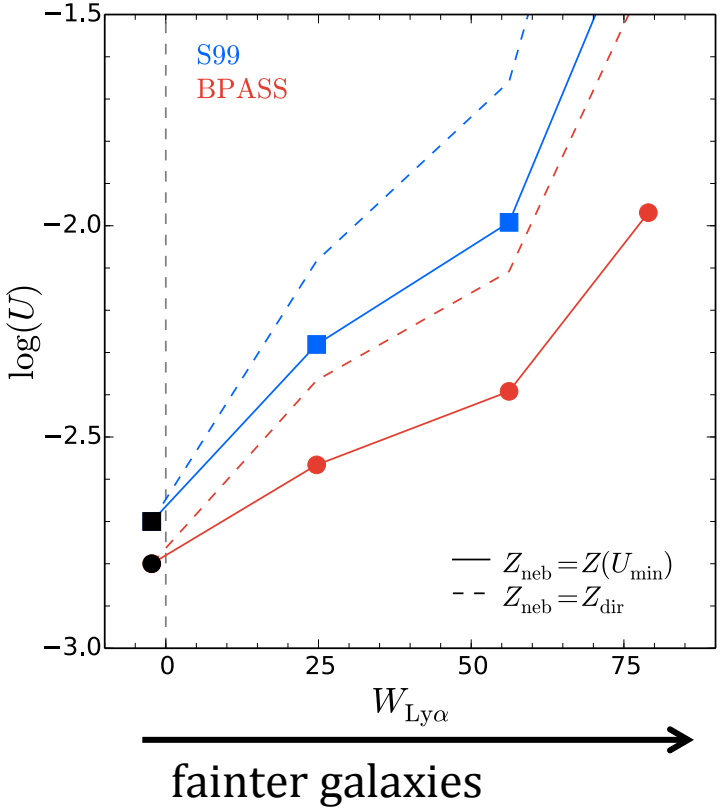
- Emitters have high ionization, low metallicity
- Absorbers have low ionization, high metallicity

Average faint LAEs consistent with highest-ionization LBGs (talk by Erb)

many (hard) ionizing photons



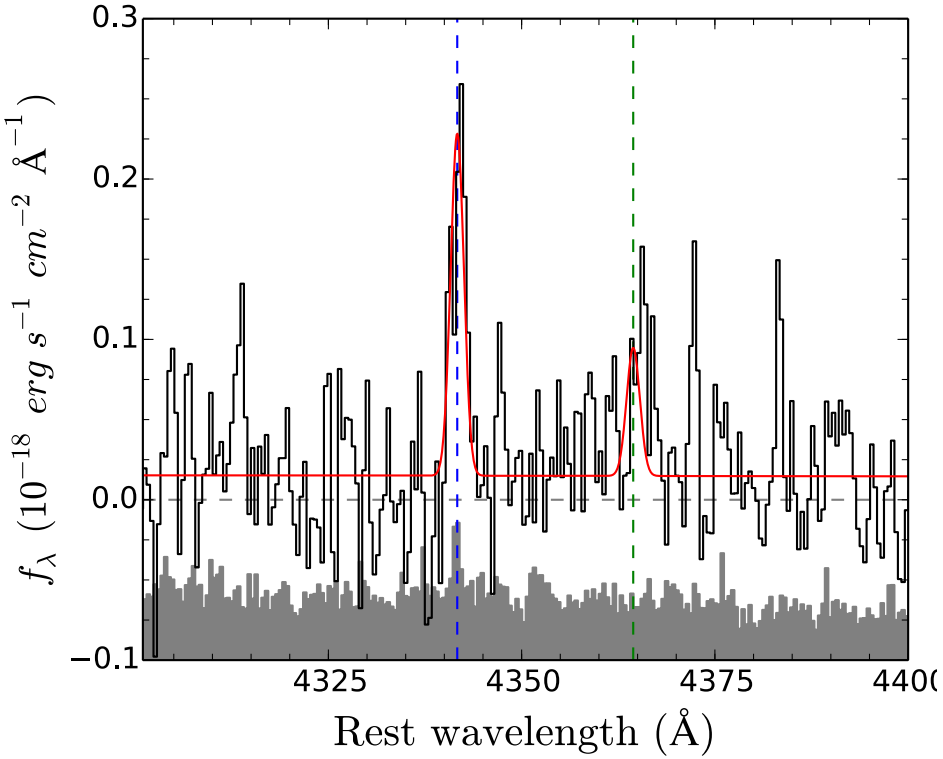




High [OIII]/Hβ ratios require high U, moderately low Z_{gas} (oxygen)

Harder stellar spectra (low Z_* or Fe, binaries) reduce requirement on U and provide more ionizing photons

faint LAEs are low-metallicity tail



[OIII] 4363

T_e = 18,000K

Z_{dir} = 0.13 $Z_\odot$

Z_{Cloudy} = 0.22 $Z_\odot$

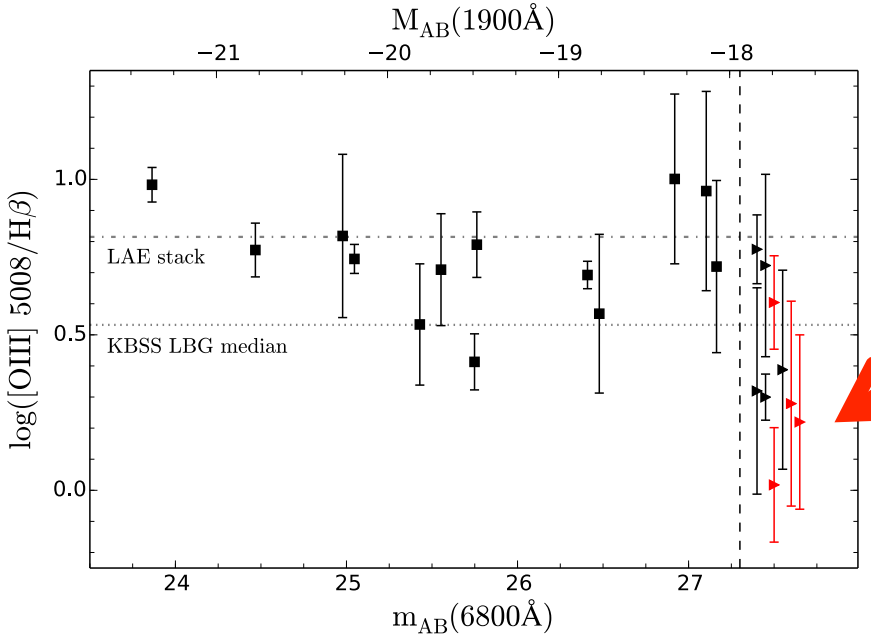
Strong lines

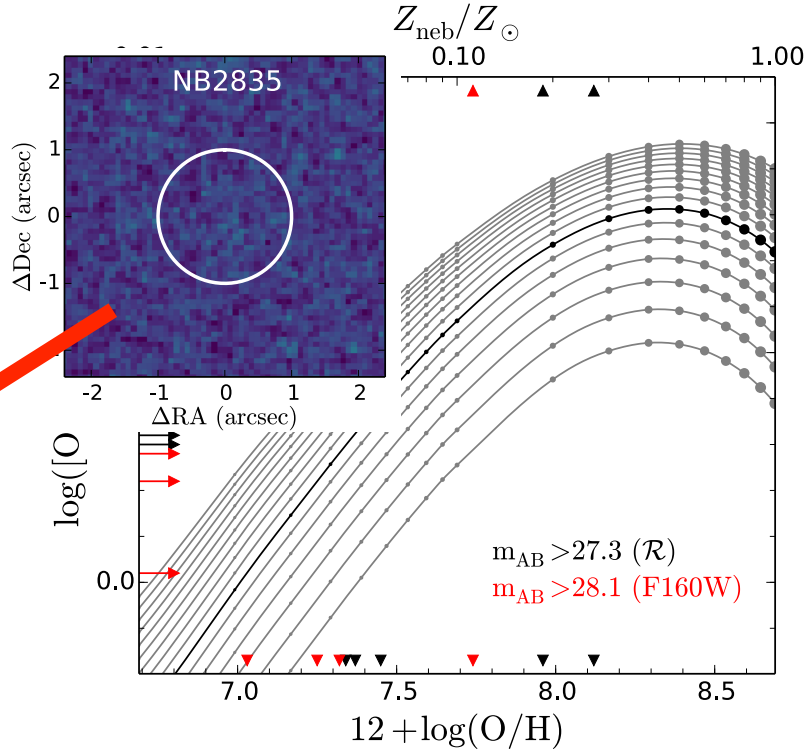
Z_{N2} < 0.30 $Z_\odot$

Z_{O3N2} < 0.30 $Z_\odot$

Also low dust: $E(B\text{-}V)_{neb} \approx 0.06$ (variation with lum.)

ultra faint, metal-poor galaxies





Downturn in [OIII]/Hβ for faintest LAEs (undetected in continuum)

F160W > 28.3 (3σ)

See also Henry+13, Masters+14

6 objects consistent with

$Z = 2\text{-}6\% \, Z_\odot$

summary

dwarf galaxies (faint LAEs) have…

- low-velocity outflows
- low gas covering fractions (including HI)
- blue Lyα components
- small sizes
- high Lyα escape fractions
- low metallicities
- low dust content
- high ionization parameters

…compared to more luminous LBGs

* likely LyC leaker properties

(talks by Heckman, Verhamme, etc.)