The evolution of Lyα emitters in a hierarchical Universe

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Friday Lunch talk
Durham
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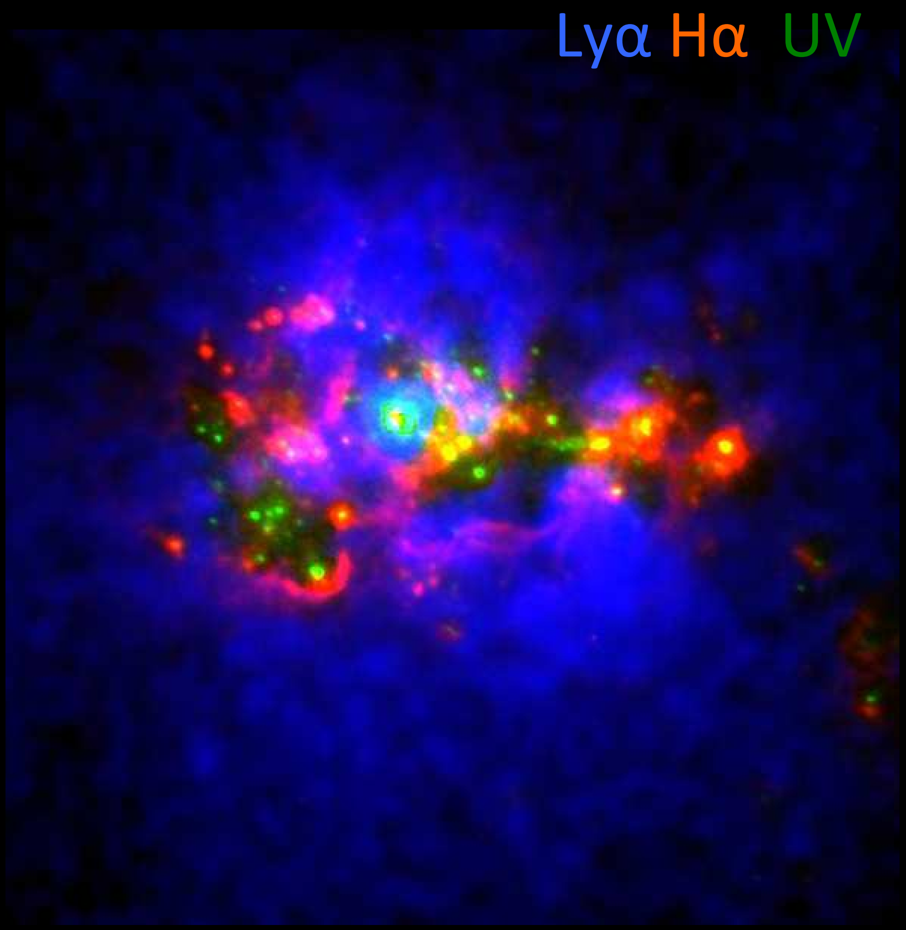
CENTRO DE ASTRO-INGENIERIA UC

Where does the Lyα emission comes from?



Local starburst ESO 338-IG04

Lyα is only weakly correlated with the Hα and UV continuum.

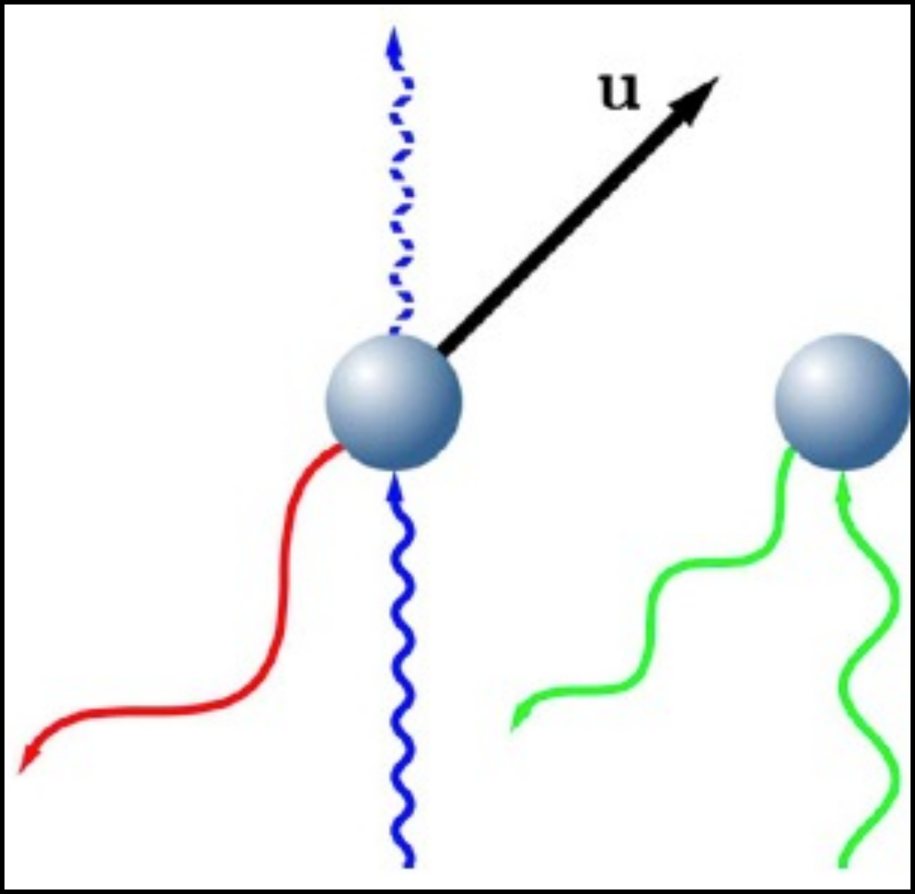
Most of the escaping Lyα emission comes from a diffuse extended component, where Lyα/Hα >> 10

Lyα transport and escape is primarily governed by resonant scattering

Östlin et al. (2009)

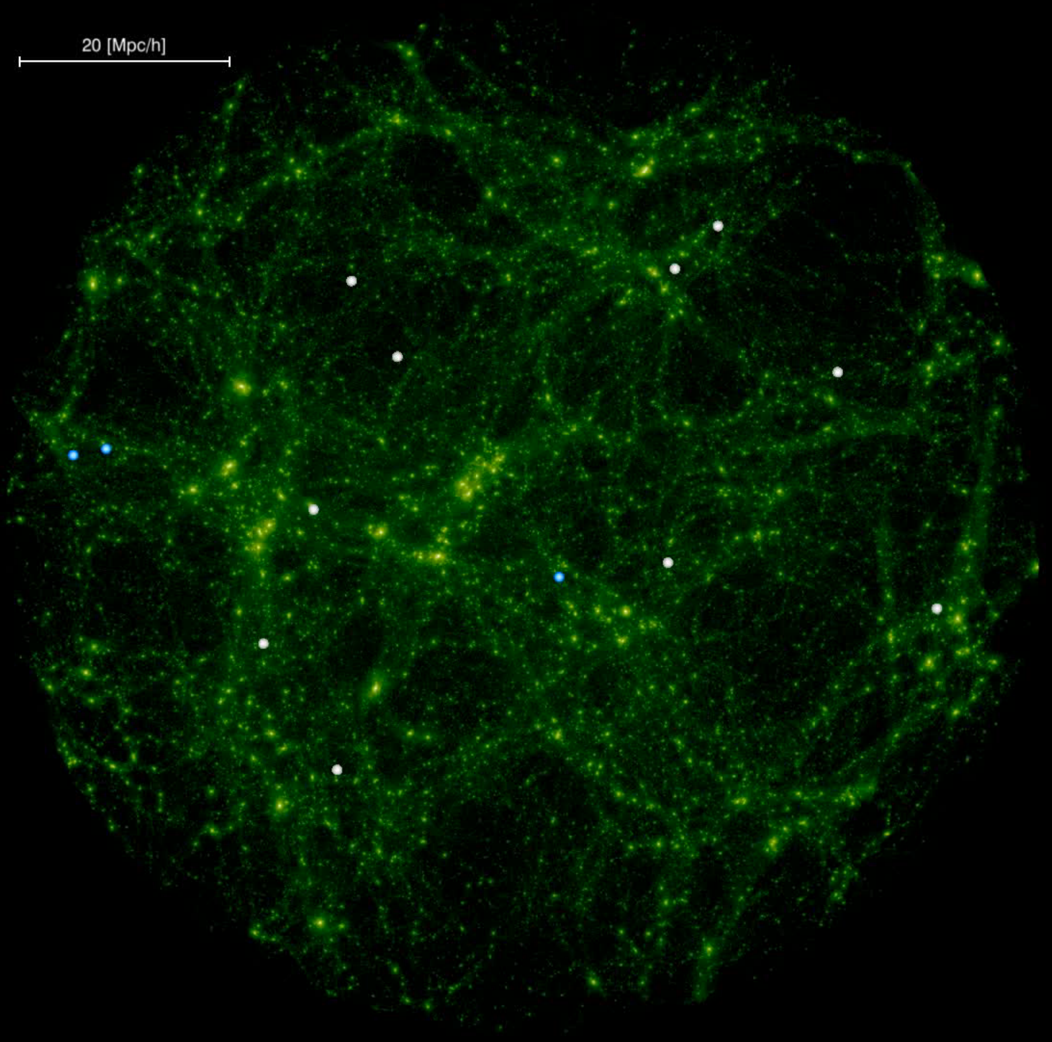
Lyα photons

- Strongest HI recombination line, at λ=1216Å
- Large scattering cross-section
  - Diffusion in frequency and space
  - Large path length
  - Interaction with dust
- Difficult radiative transfer problem

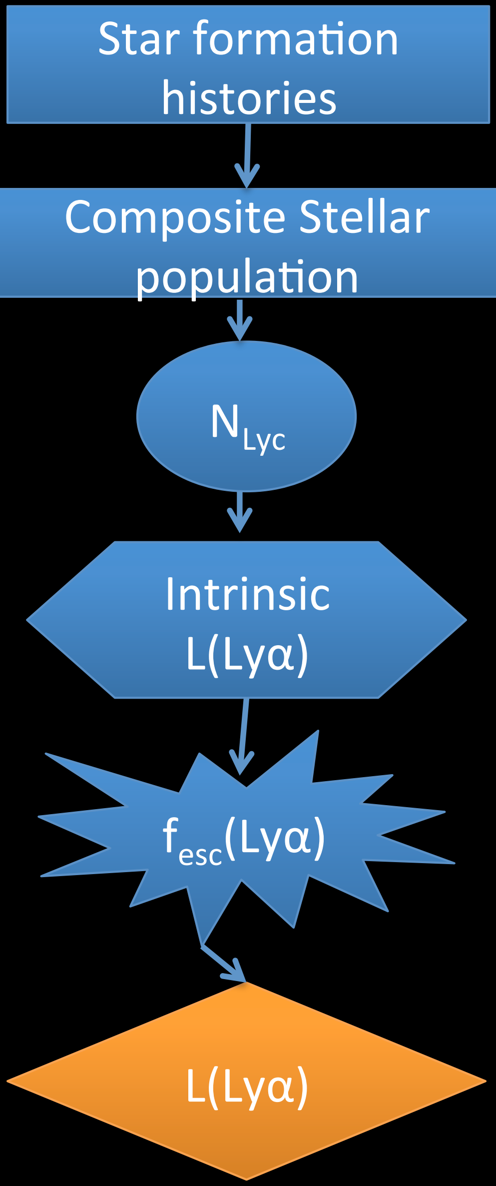


Laursen et al. (2009)

Modelling Lyα emitters



Orsi et al. (2008)


Star formation histories

Composite Stellar population

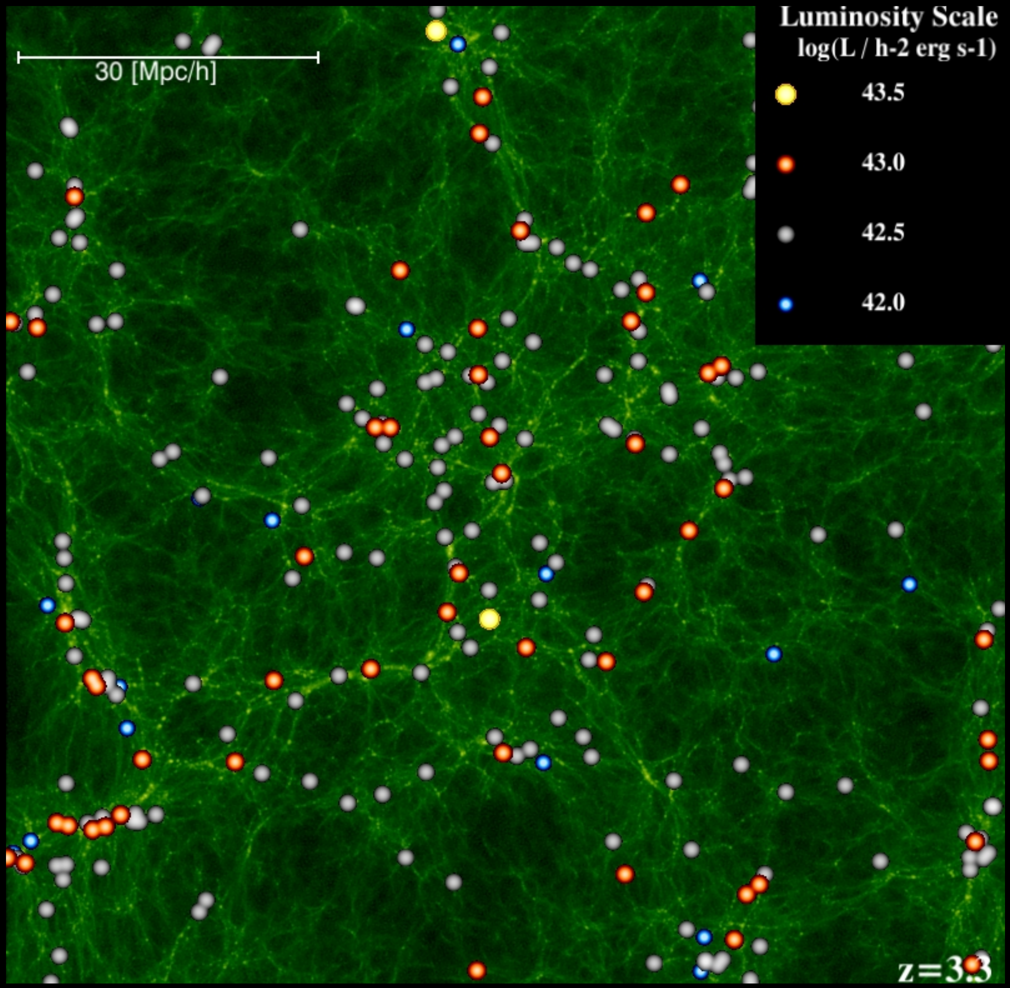
N_{Lyc}

Intrinsic L(Lyα)

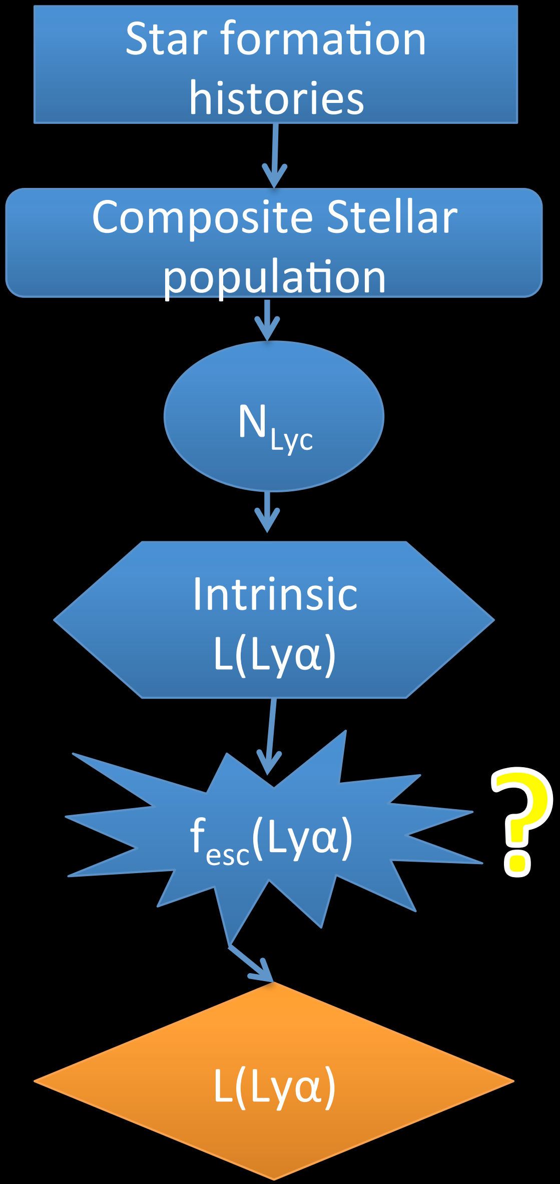
f_{esc}(Lyα)

L(Lyα)

Modelling Lyα emitters



Orsi et al. (2008)



Star formation histories

Composite Stellar population

N_{Lyc}

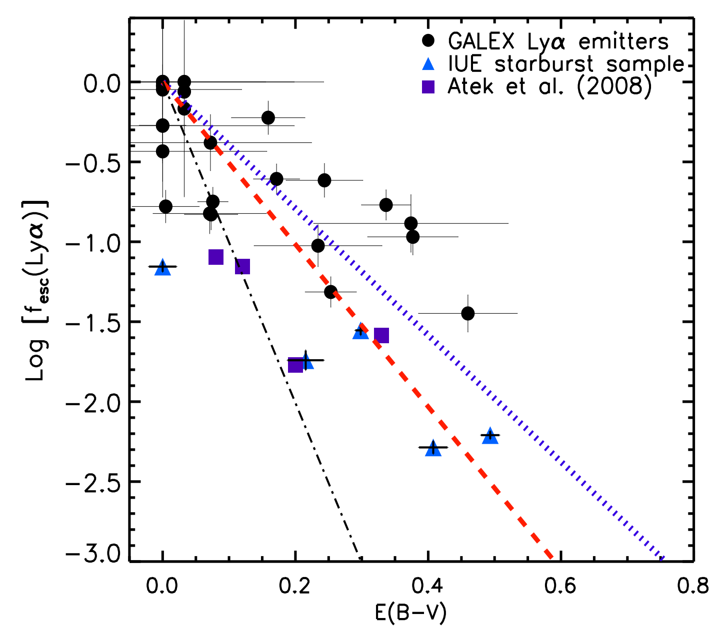
Intrinsic L(Lyα)

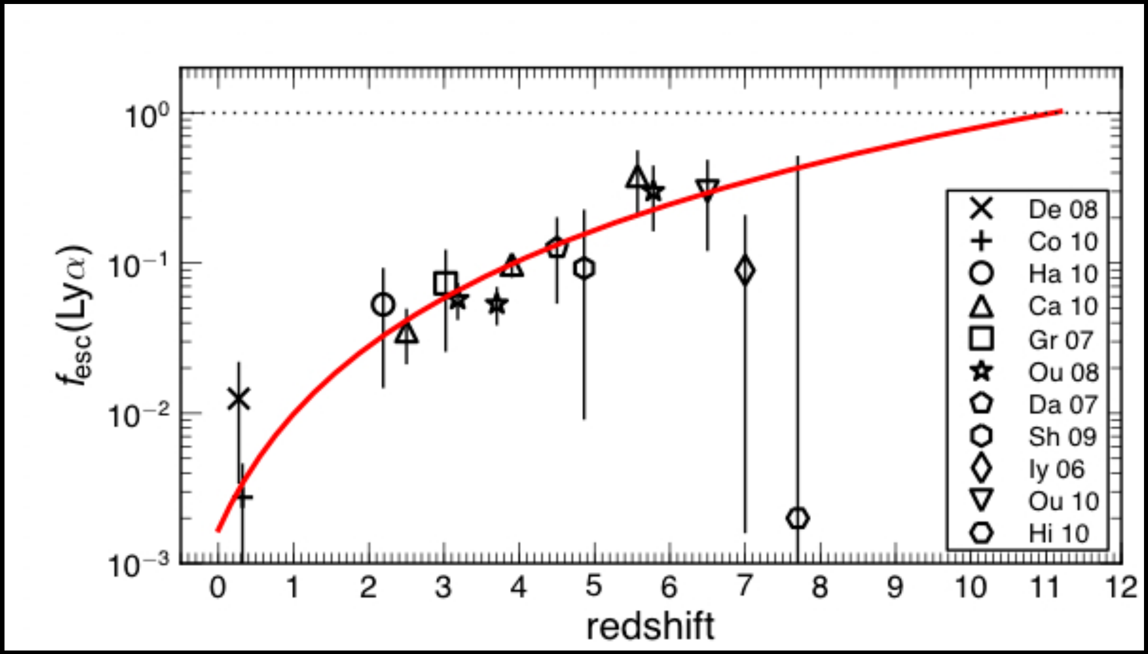
f_{esc}(Lyα)

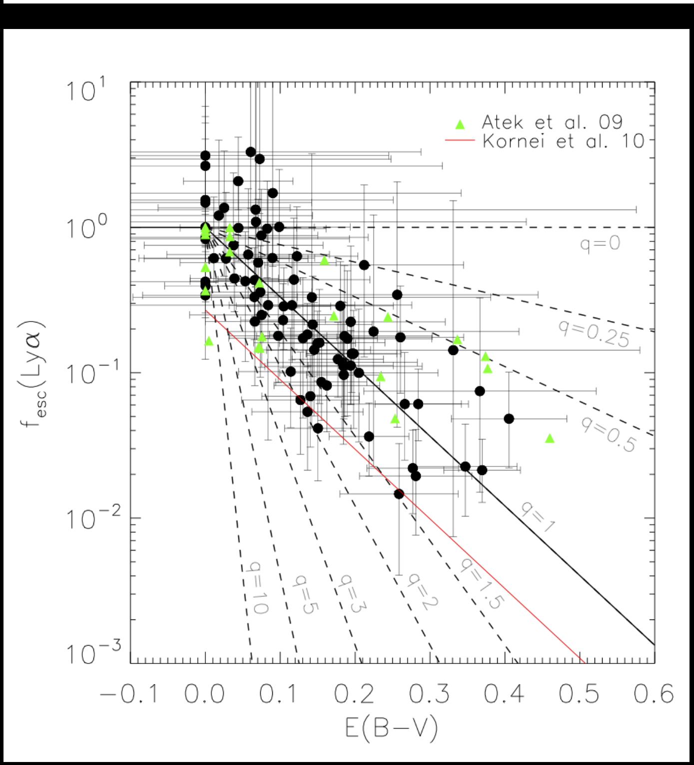
?

L(Lyα)

Observational estimates of f_{esc}







Atek et al. (2009)
Blanc et al. (2011)
Hayes et al. (2011)

f_{esc}(Lyα) decreases with higher dust content?
f_{esc}(Lyα) increases with redshift?
The Lyα escape fraction can vary significantly!

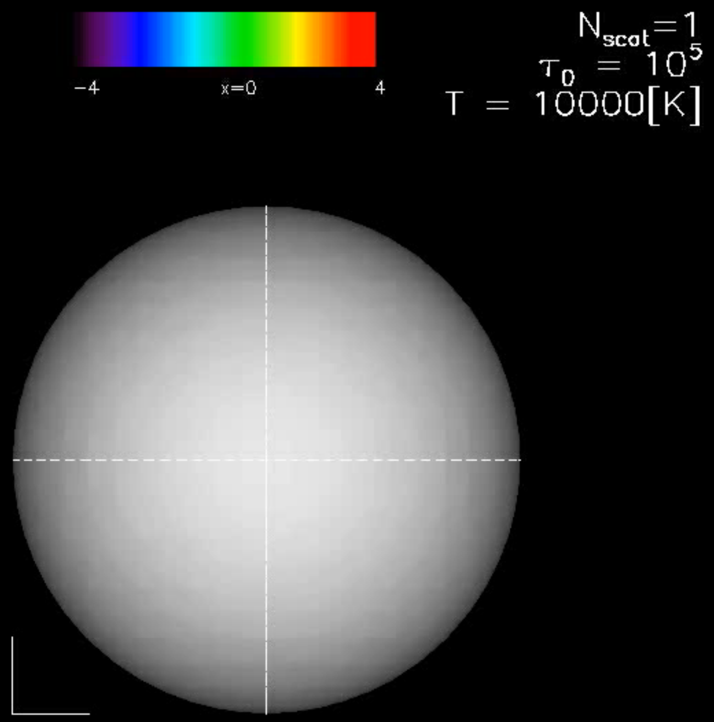
Monte Carlo Lyα radiative transfer

Motivation

- Reproduce the scattering and absorption of Lyα photons in the ISM
- Study Lyα emitters in a cosmological volume
- Obtain f_{esc} and line profiles

MC Lyα RT

- Follows the path of single photons as they scatter through an HI cloud
  - Count how many photons escape
  - Obtain frequency distribution



Semianalytical model + Lyα RT

➔ $f_{esc}(SFR, M_{gas}, R_{disk}, V_{circ}, Z_{cold}, \text{etc...})$

Simple outflow geometries

Galaxy properties control outflow properties:

$$
\begin{aligned}
M_{\rm shell} &= f_M \langle M_{\rm gas} \rangle, \\
R_{\rm out} &= f_R \langle R_{1/2} \rangle, \\
V_{\rm exp} &= f_V \langle V_{\rm circ} \rangle
\end{aligned}
$$

$$\tau_d = \frac{E_\odot}{Z_\odot} N_H Z_{\rm out}$$

Thin Shell

$$N_H(r) = \frac{X_H M_{\rm shell}}{4\pi m_H R_{\rm out}^2}$$

Galactic Wind

$$N_H = \frac{X_H \dot{M}_{\rm ej}}{4\pi m_H R_{\rm wind} V_{\rm exp}}$$

Lyα Line profiles comparison

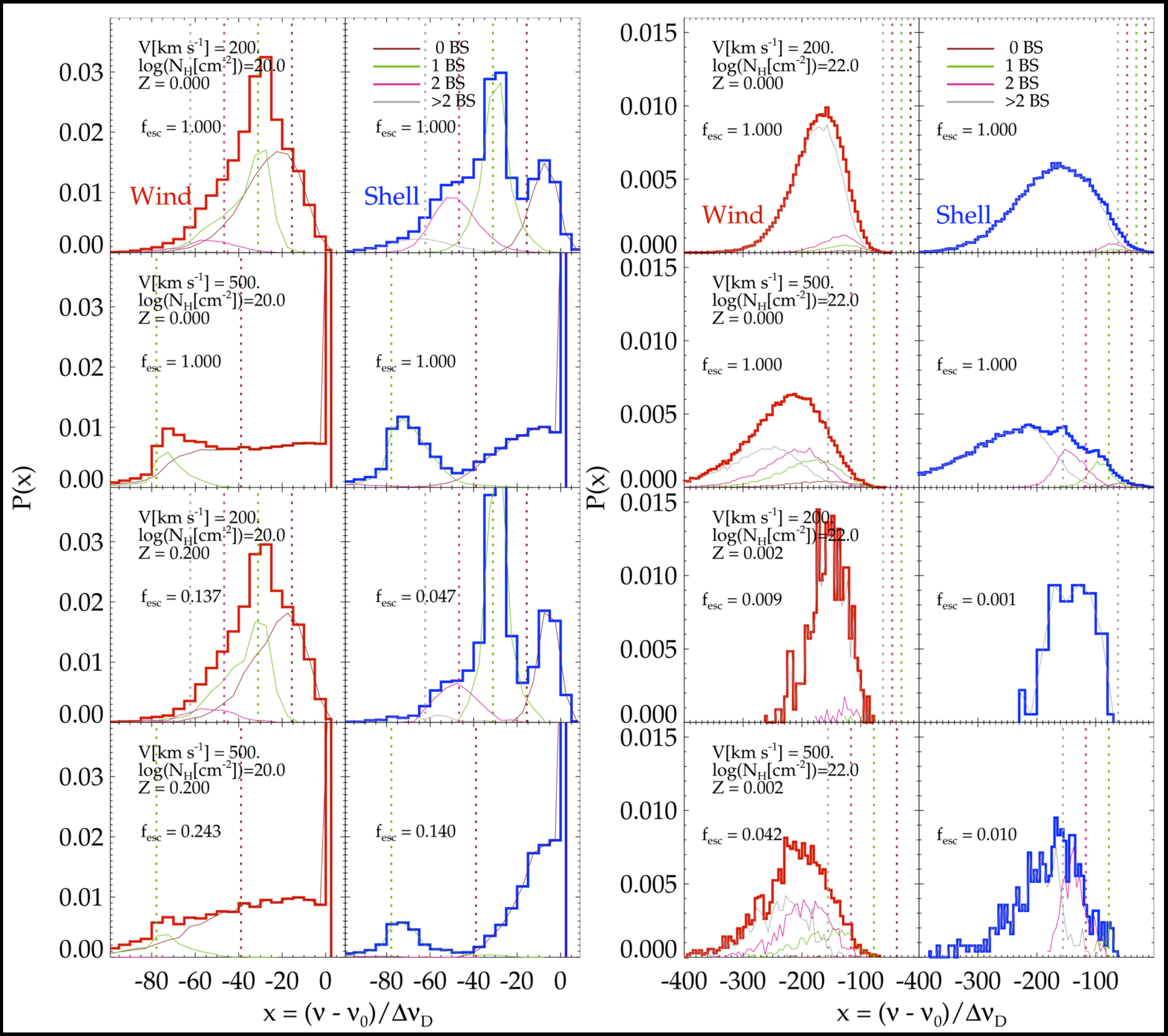
$N_H = 10^{20}$ [cm^{-2}]

$N_H = 10^{22}$ [cm^{-2}]

Z=0

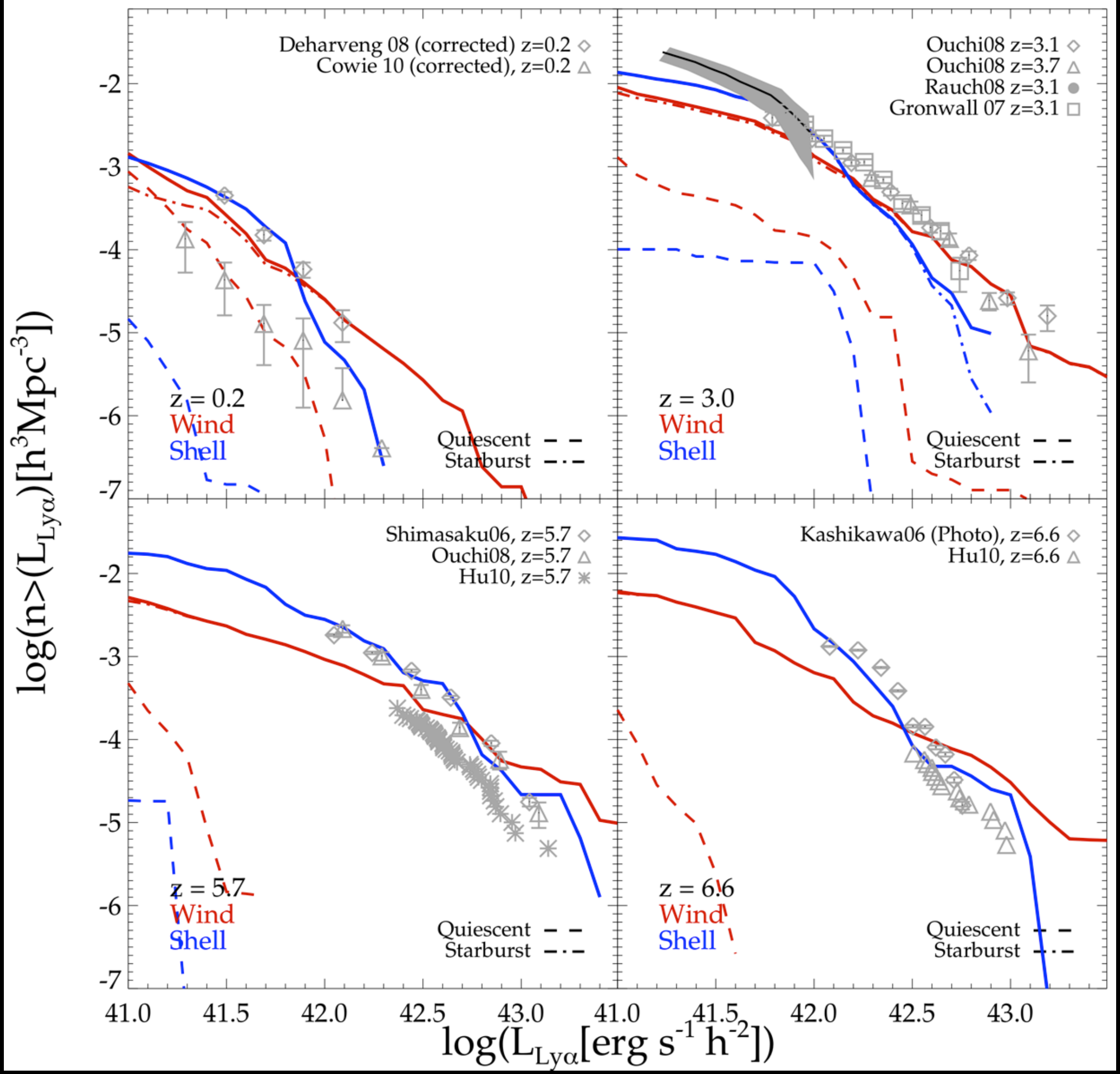
Z=0.2

Z=0..002



Orsi et al (2011)

Matching the Lyα CLF

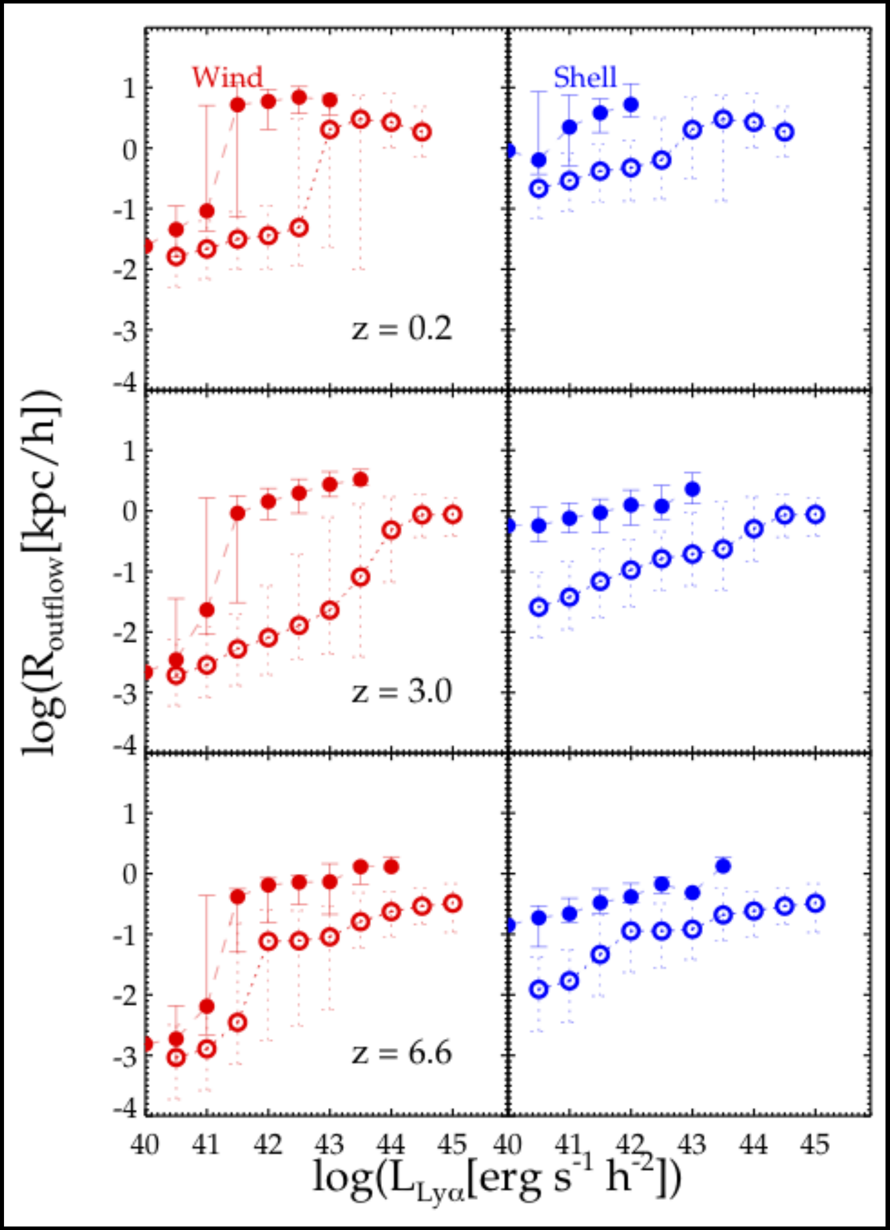


In order to find the value of the free parameters, we match the Lyα CLF over the redshift interval 0.2<z<6.6

As a consequence, starbursts dominate the abundance of Lyα emitters at high redshifts

Orsi et al (2011)

Outflow sizes

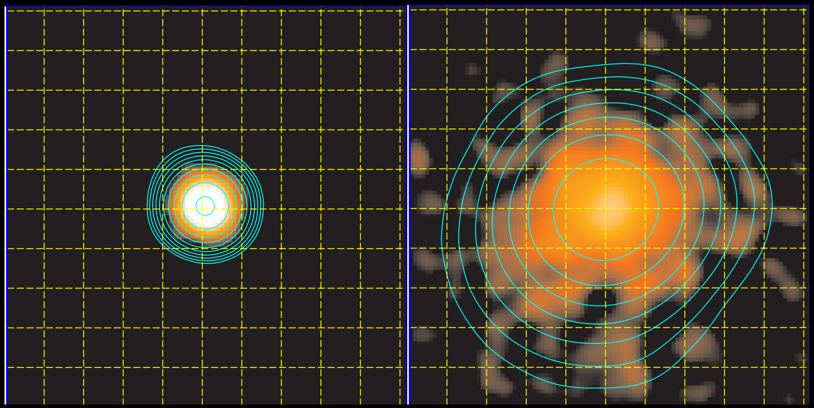


Both outflow geometries predict a large range of outflow radii

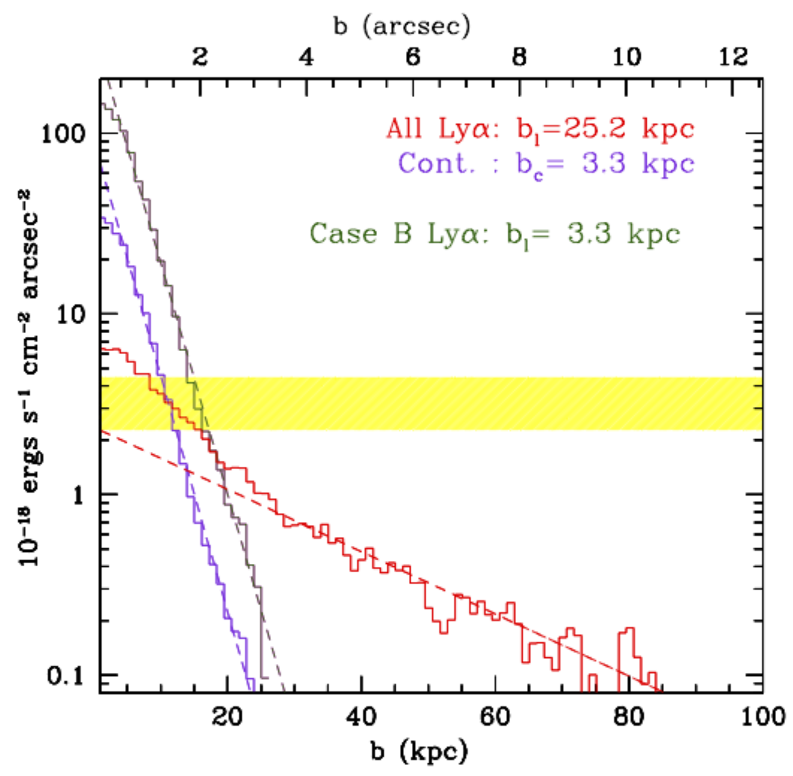
Larger outflows in galaxies with higher Lyα luminosities

Typical Lyα emitters have outflow radii of a few kpc/h.

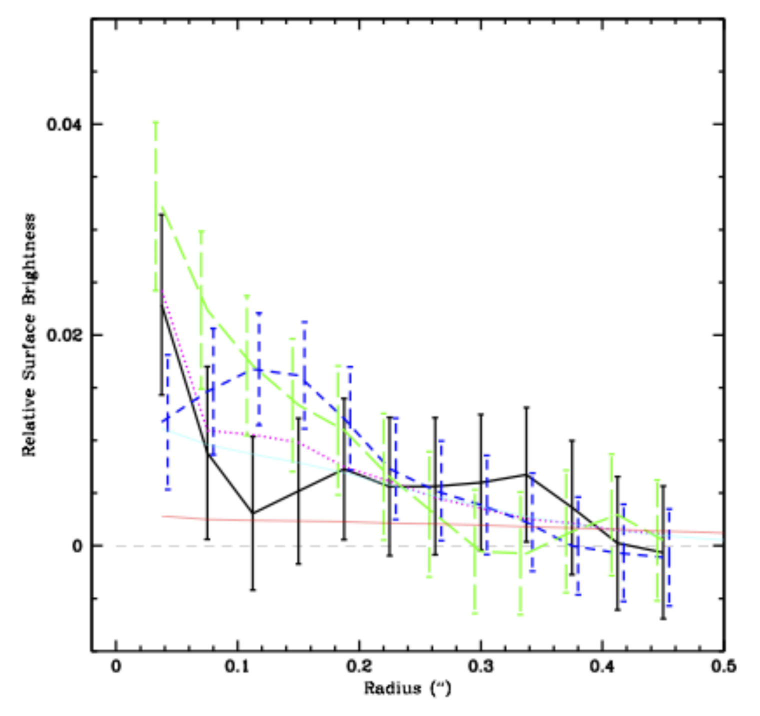
Are all Lyα emitters spatially extended?

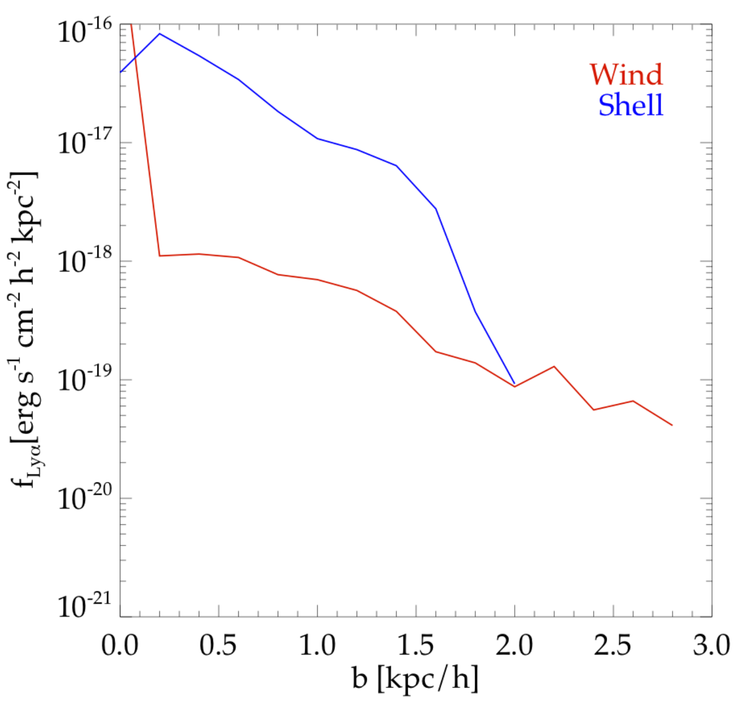


Steidel et al. (2011)
Lyα stacking of UV-selected sample
Extended emission out to ~ 80kpc



Note, however, Bond et al. (2009,2010) evidence of compact Lyα emission, less than ~ 2kpc

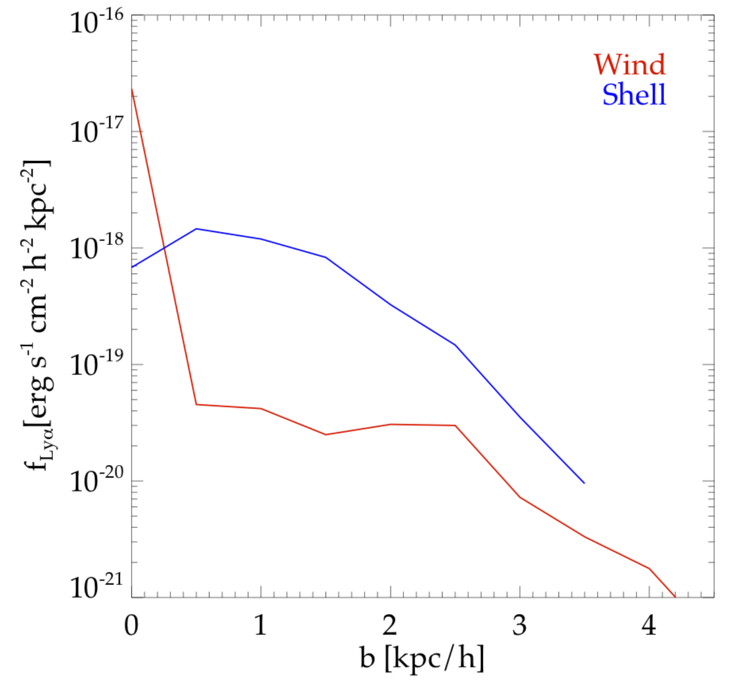




In our models, typical Lyα emitters $\log(L_{Ly\alpha}\ [\mathrm{erg\ s^{-1} h^{-2}}]) > 41.5$

extend to 2-3 kpc/h

The Shell geometry predicts a more compact SB profile than the Wind geometry

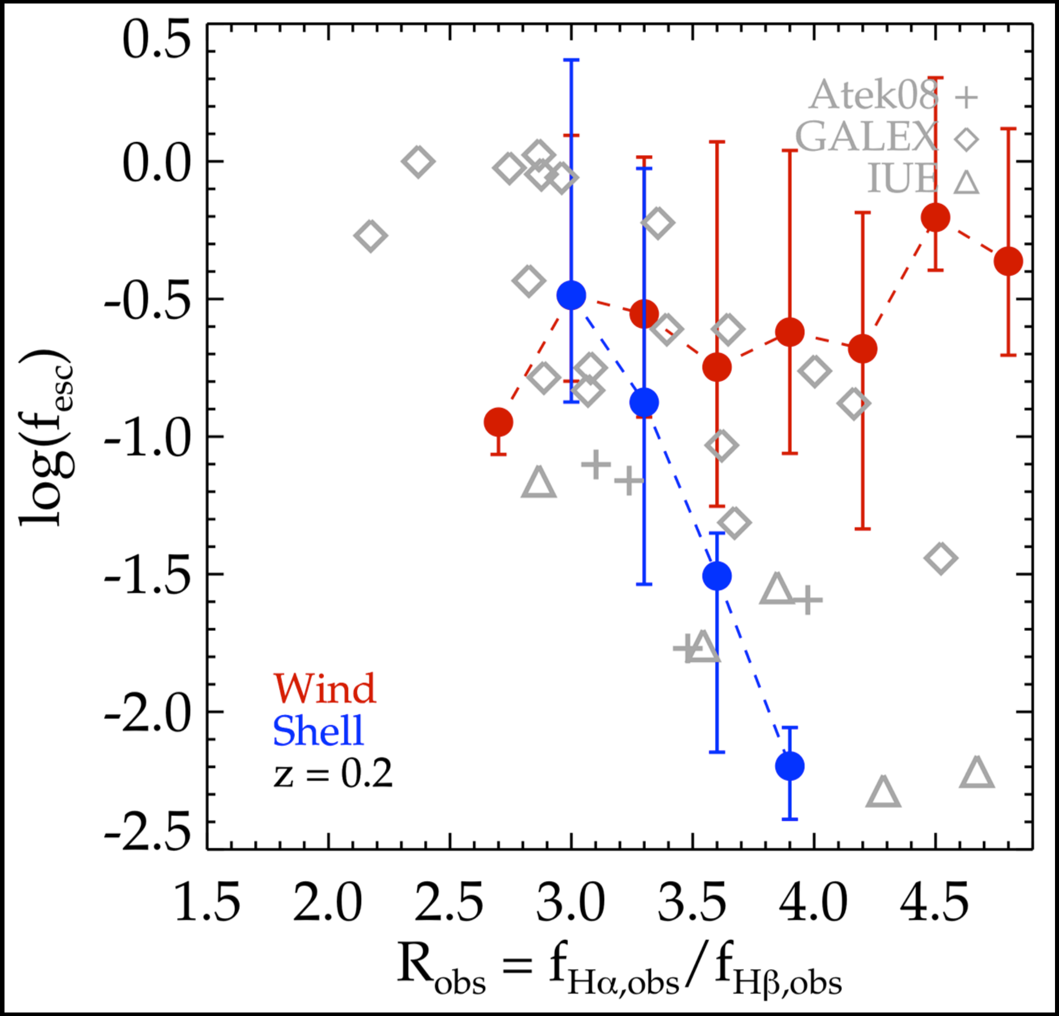


When applying a UV selection like in Steidel et al. (2011)

$23.4 < m_{UV} < 25.5$

SB profiles of both geometries extend to ~3.5-4 kpc/h

Lya escape fractions

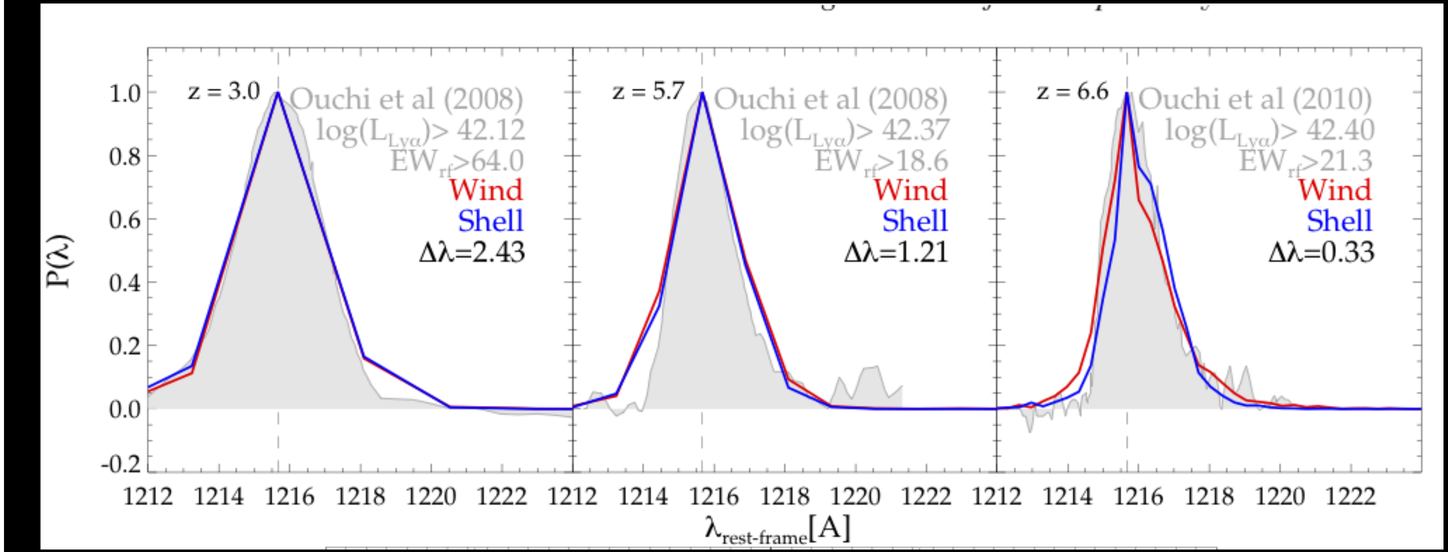


Outflow geometries are consistent with observed f_{esc}

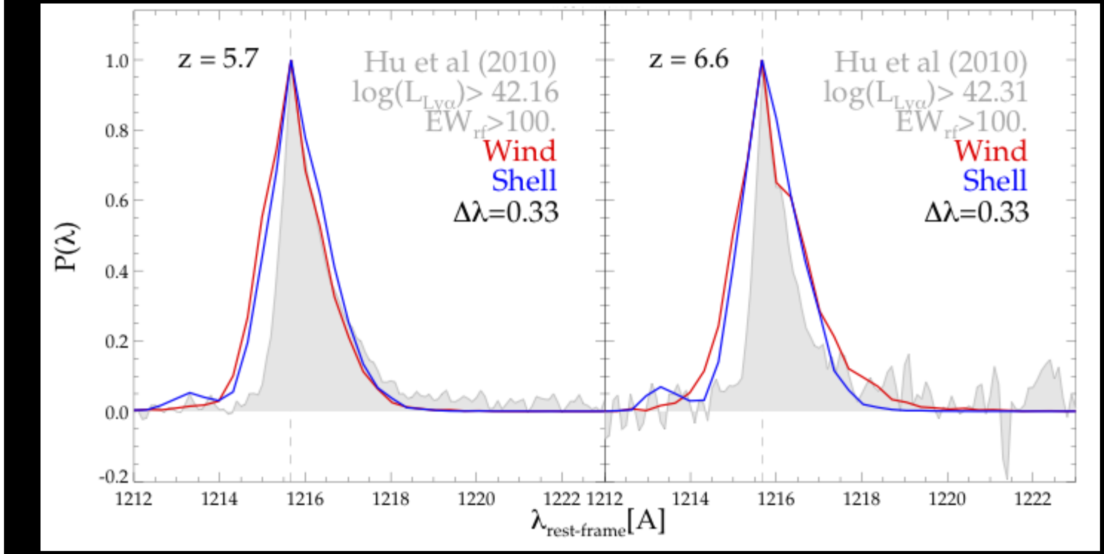
Shell geometry reproduces the observed steep decline of f_{esc}

Orsi et al (2011)

Composite Lyα line profiles



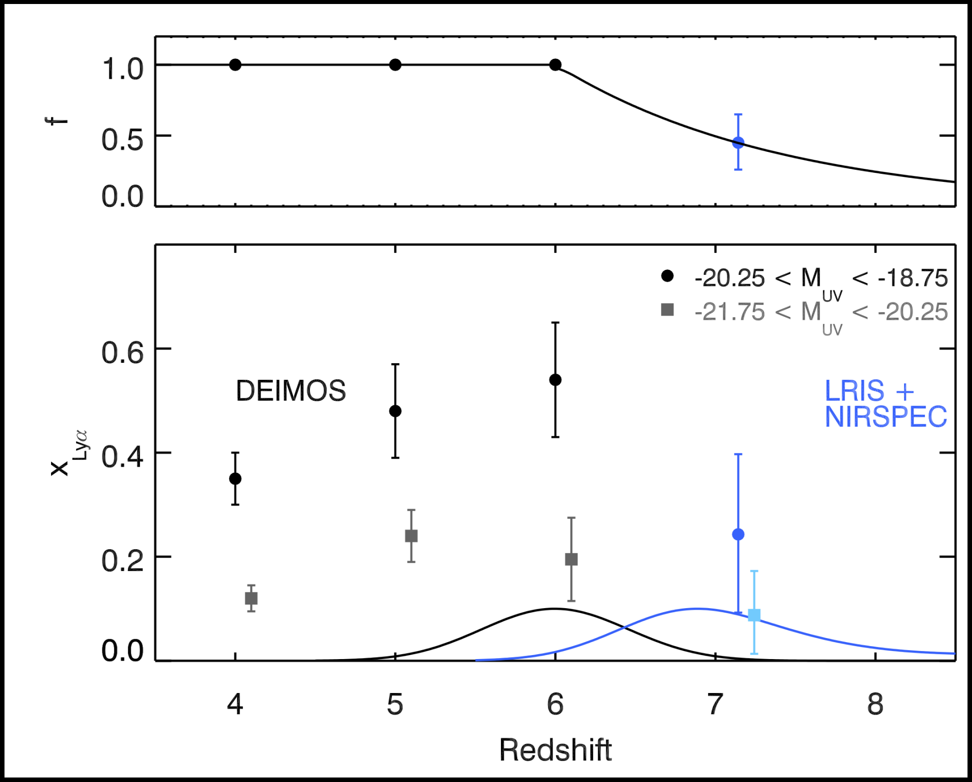
Our model can reproduce the observed composite spectra of Ouchi et al. (2008,2010)



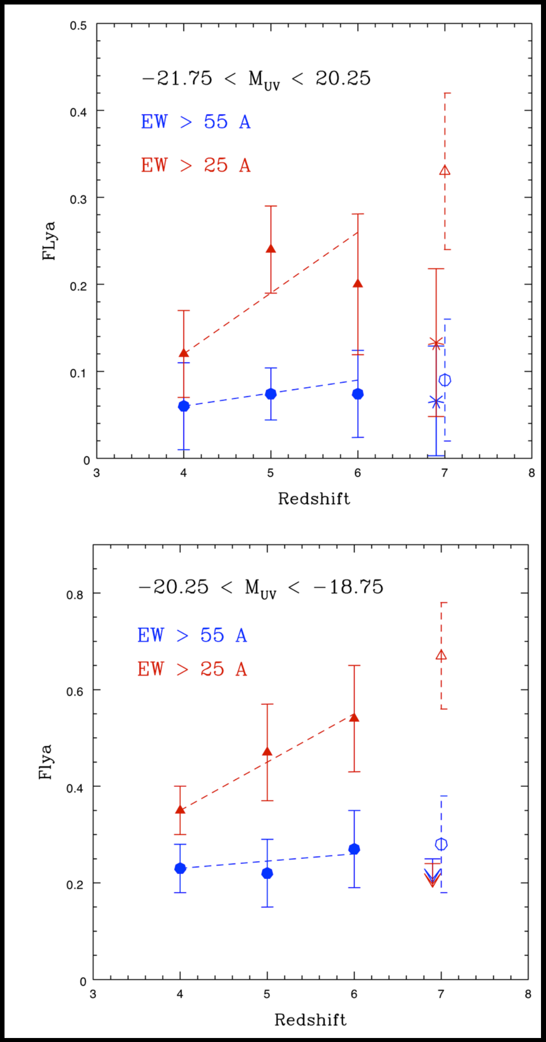
Excess of blue photons when reproducing Hu et al. (2010) composite spectra

Orsi et al (2011)

The fraction of Lyα emitters in LBG samples: tracing the evolution of neutral hydrogen in the IGM?



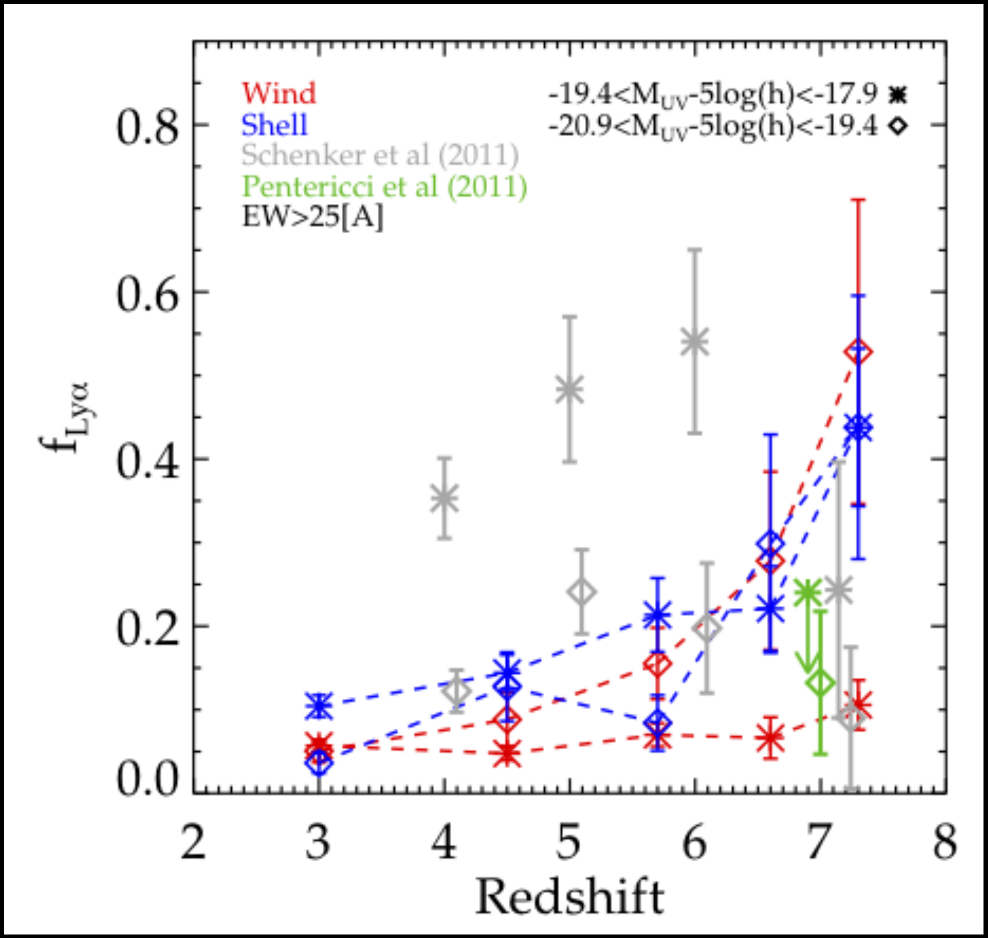
Schenker et al. (2011)



Pentericci et al. (2011)

Decline in the fraction of Lyα emitters at z>7
is possibly caused by attenuation due to the IGM

The fraction of Lyα emitters in LBG samples: tracing the evolution of neutral hydrogen in the IGM?



Orsi et al (2011)

- Our model does not include attenuation of Lyα due to the IGM

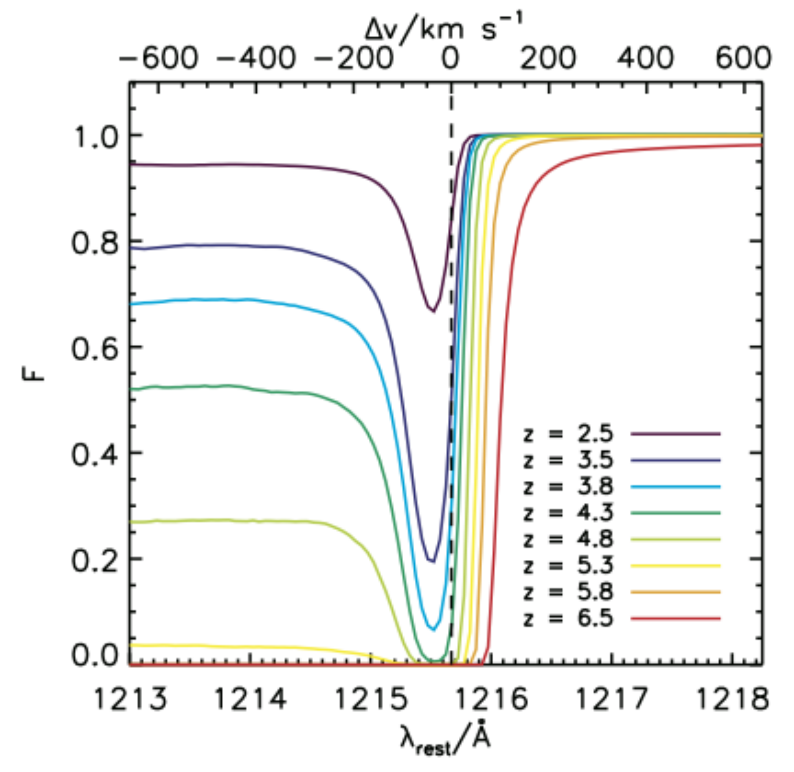
Partial agreement between model and observations

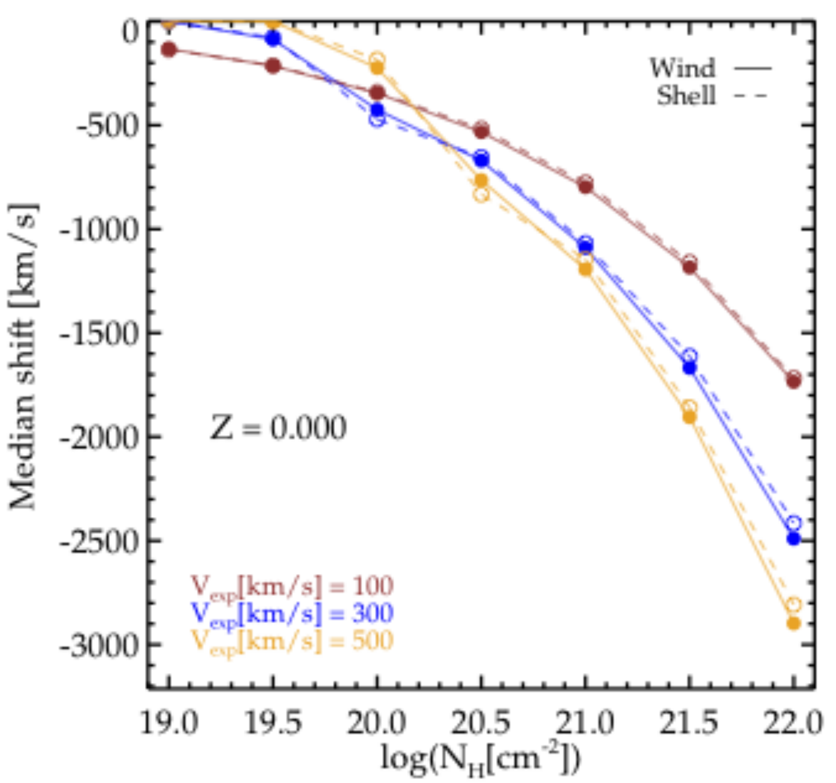
Observational decline at z~7 could evidence the presence of a higher neutral hydrogen fraction in the IGM

The fraction of Lyα emitters in LBG samples:
tracing the evolution of neutral hydrogen in the IGM?

Laursen et al (2011)

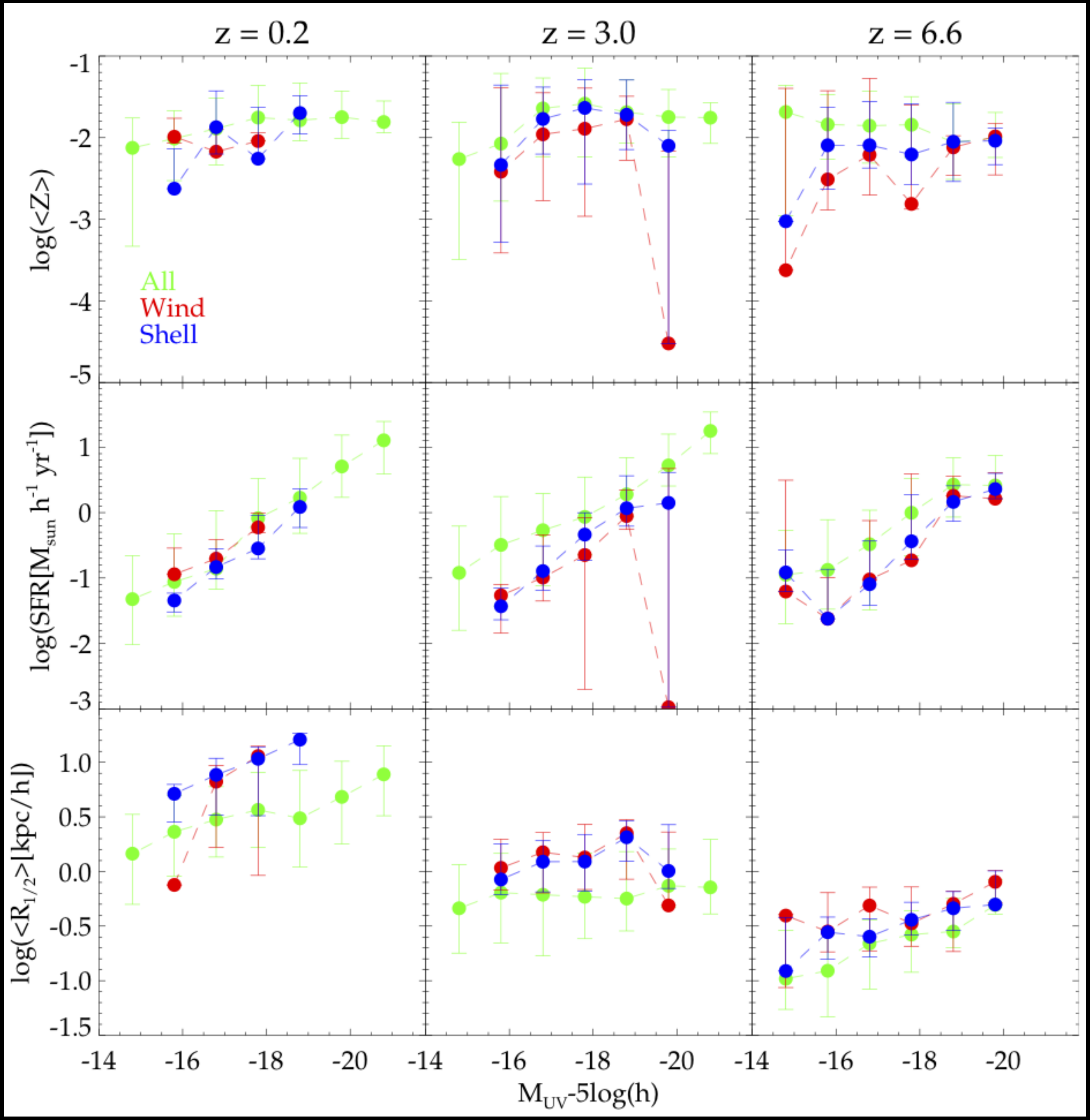
Orsi et al. (2011)





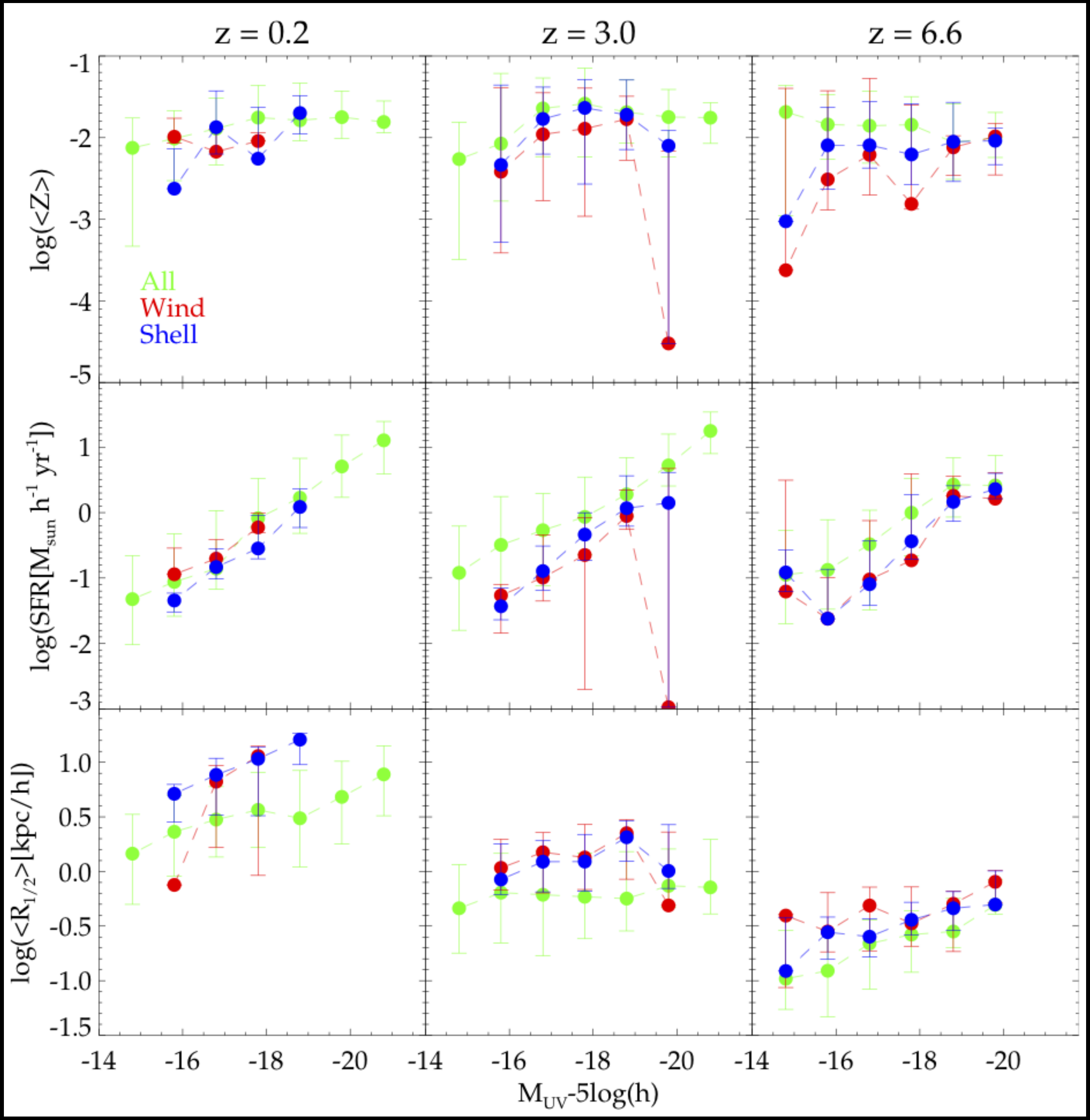
- IGM is nearly transparent for photons with λ > 1216 Å
- At z ~7, our outflow models predict velocity offsets > 500 km/s
- Therefore, in our model, the IGM would not be able to attenuate Lyα photons

The Nature of Lyα emitters



Orsi et al (2011)

The Nature of Lyα emitters

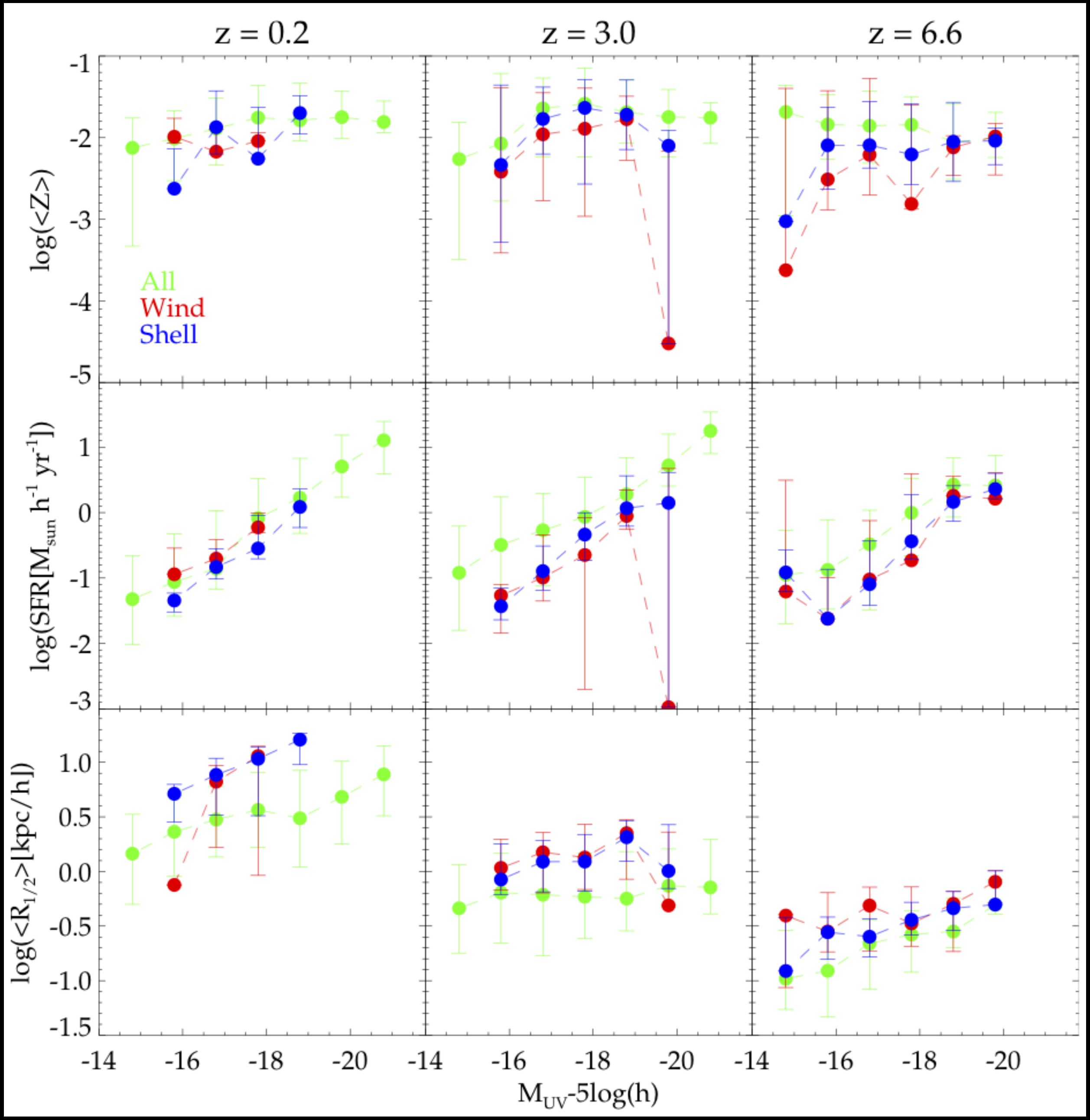


Orsi et al (2011)

Typical Lyα emitters have

… than the bulk of the galaxy population at the same UV magnitude

The Nature of Lyα emitters



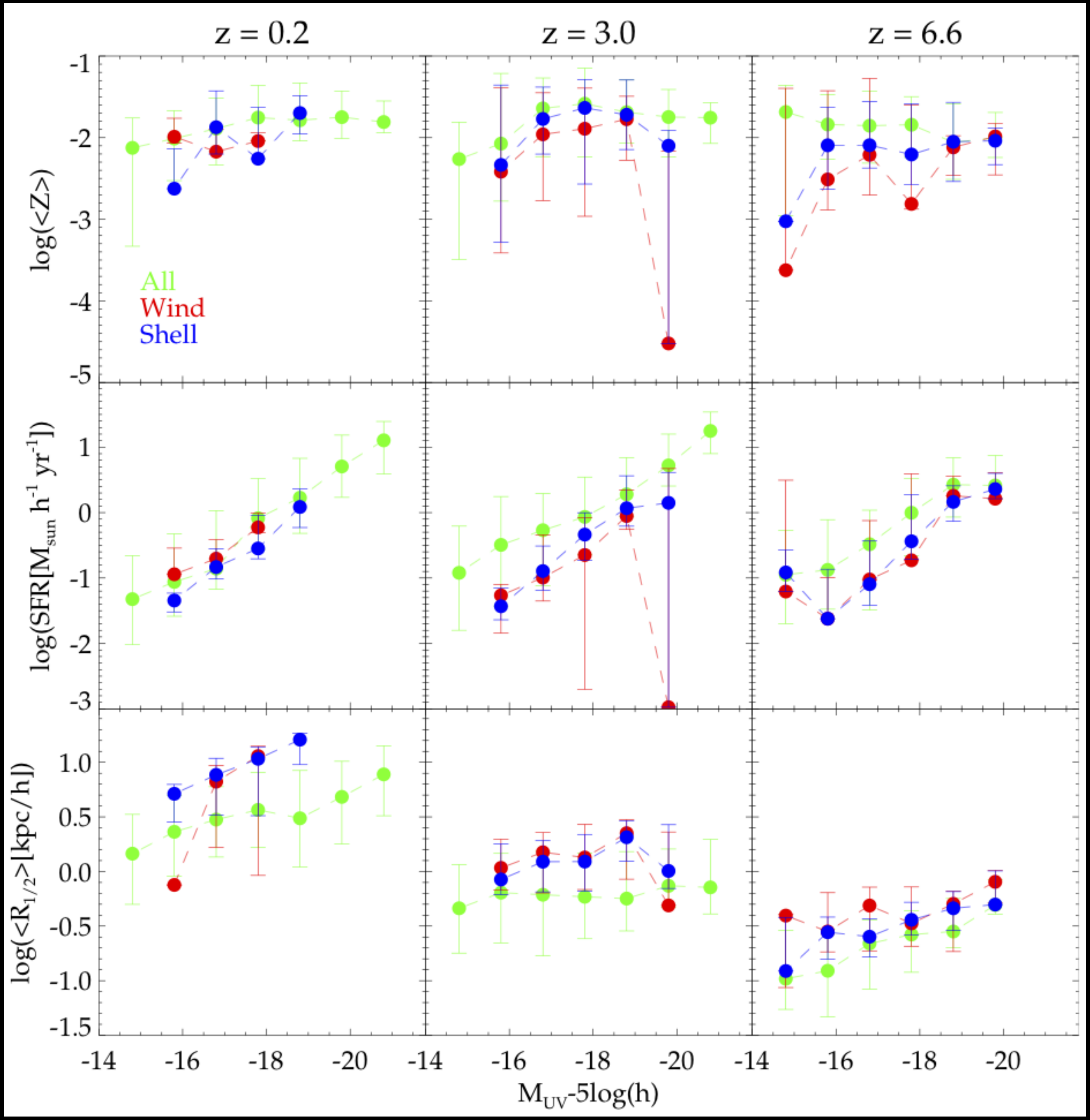
Orsi et al (2011)

Typical Lyα emitters have

- ➢ Lower Metallicities

… than the bulk of the galaxy population at the same UV magnitude

The Nature of Lyα emitters



Orsi et al (2011)

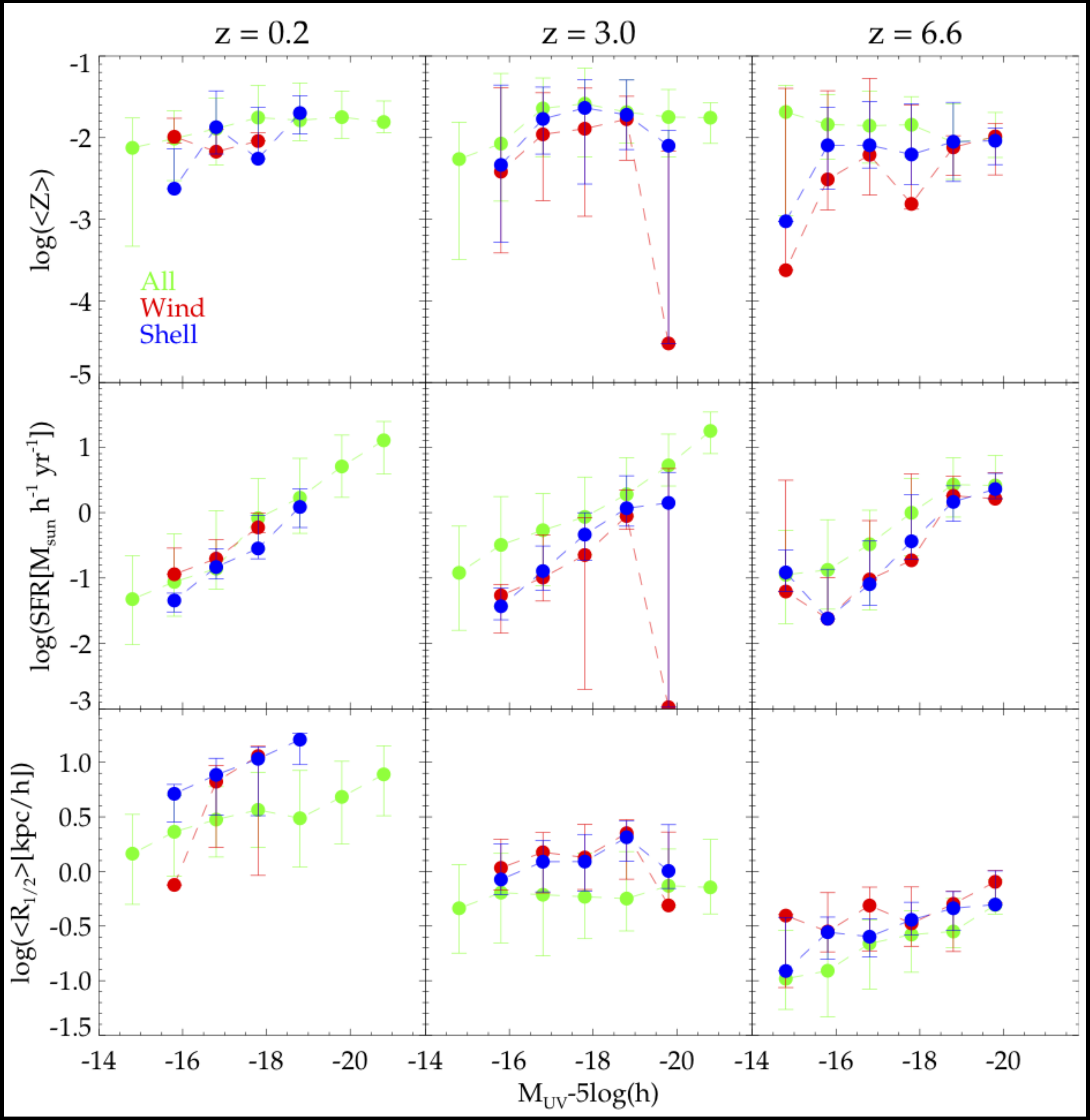
Typical Lyα emitters have

- ➢ Lower Metallicities

- ➢ Lower Star Formation Rates

… than the bulk of the galaxy population at the same UV magnitude

The Nature of Lyα emitters



Orsi et al (2011)

Typical Lyα emitters have

- ➢ Lower Metallicities
- ➢ Lower Star Formation Rates
- ➢ Larger sizes

… than the bulk of the galaxy population at the same UV magnitude

Conclusions

- Modelling in detail the escape of Lyα photons is necessary to understand the properties of this galaxy population
- The Lyα emission properties of our outflow models depend on the interplay of many physical parameters: Z, N_H, V_{exp} and the geometry
- Lyα emitters are predicted to have (in UV magnitude bins)
  - Lower metallicities
  - Lower Star formation rates
  - Larger sizes
- Outlook
  - Can we use the observed sizes of Lyα emitters to constrain the models furthermore?
    Bond et al. (2010), Steidel et al. (2011), Matsuda et al. (2012)
  - Study the impact of other outflow geometries: e.g. clumpy outflows (Dijkstra et al. 2012)
  - Combine with a different semi-analytical model (for example, production rate of Lyc photons is crucial to match model free parameters)
  - Incorporate attenuation due to neutral IGM