Can Galactic Outflows Explain The Properties Of Lyα Emitters?

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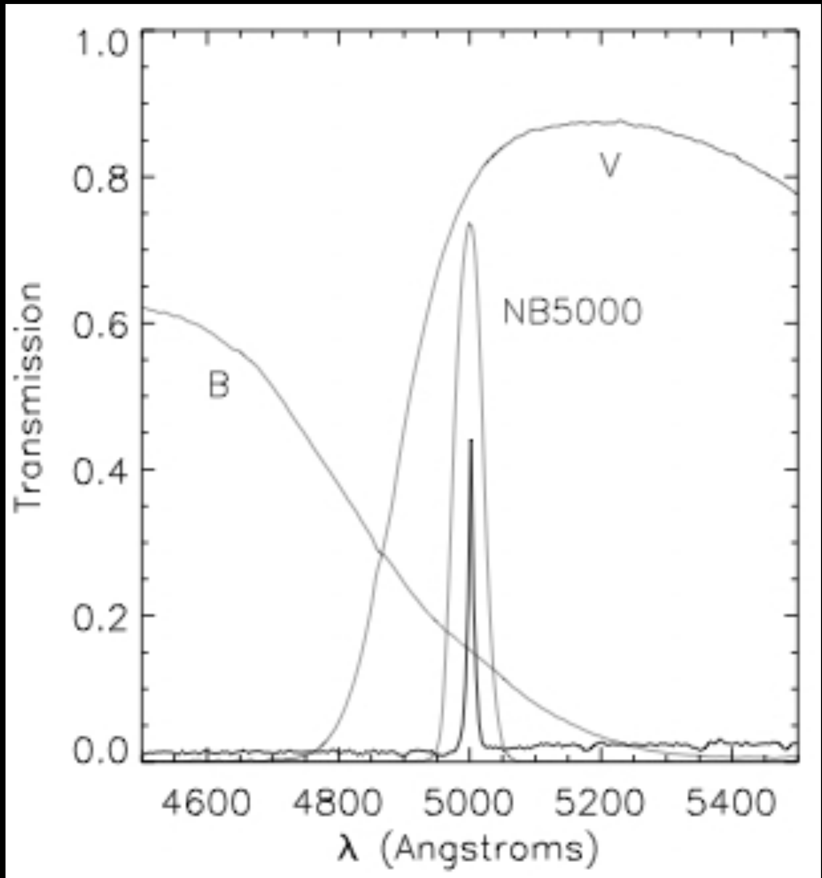
Multiwavelength views of the ISM
In high redshift galaxies
ESO-Chile June 27-30

Overview of Lyα emitters



Gronwall et al (2007)

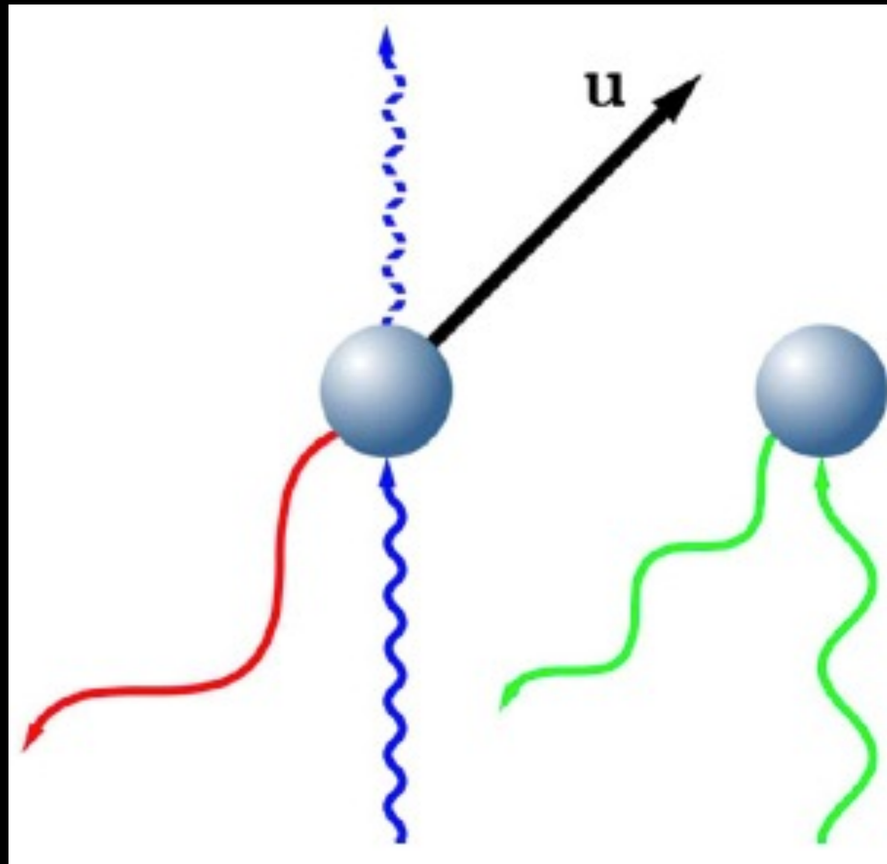
Lyα emitters

- Patridge & Peebles (1967): Tracers of high-z galaxies
- Nowadays LAEs are studied in the range $0<z<7$
  - Spectral & photometric properties
  - Large scale structure at high-z
  - Galaxy formation models
  - Constraints on reionization epoch

Overview of Lyα emitters

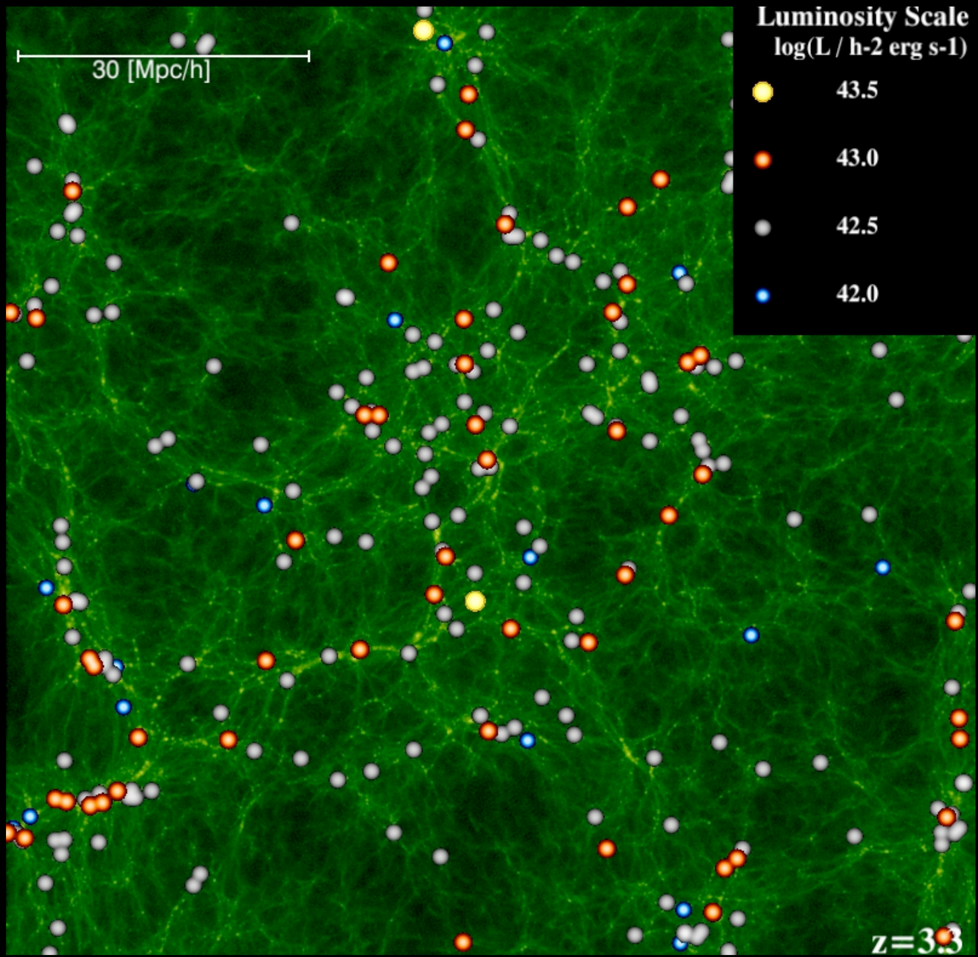
Lyα photons

- 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)

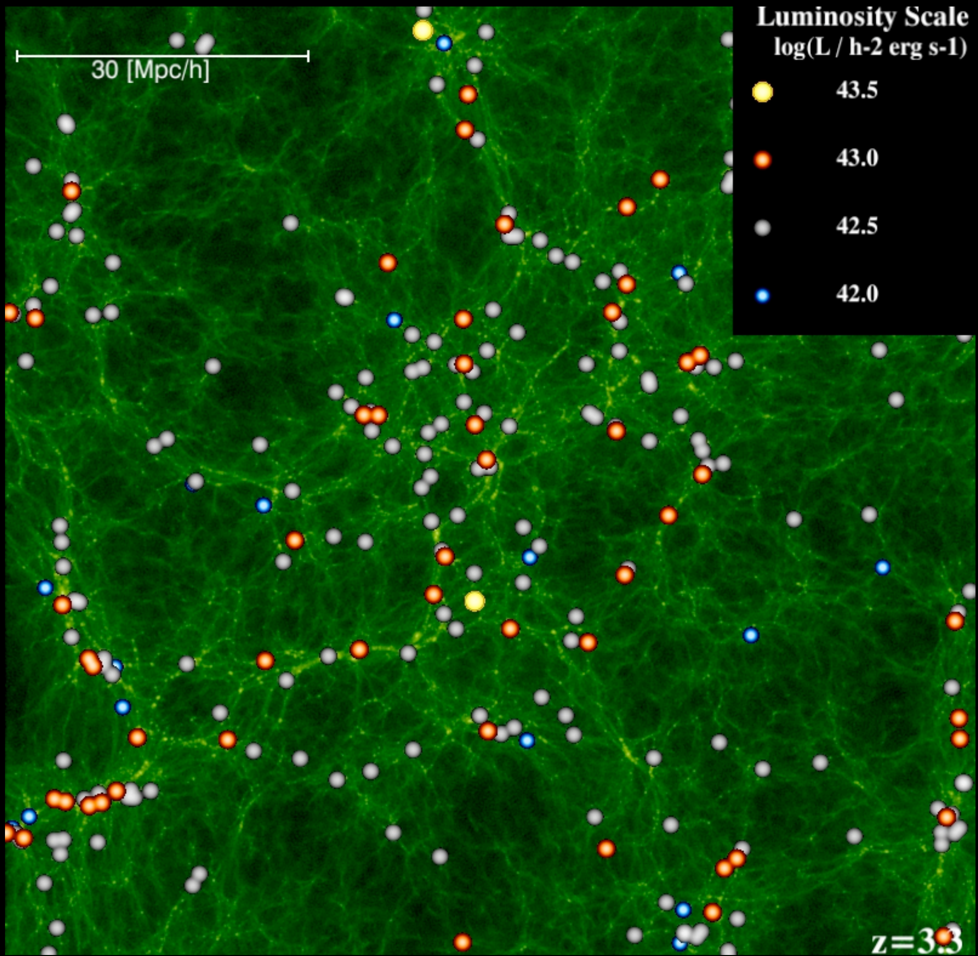
Modelling Lyα emitters



Orsi et al. (2008)

- Semianalytical model GALFORM (Baugh et al. 2005)
- Hierarchical CDM scenario
- Star formation histories modelling all the relevant physics of galaxy formation
- Model reproduces
  - Galaxy properties in the local Universe
  - Evolution of the LF in the IR (Spitzer)
  - Abundances of LBGs and SMGs at high-z
  - Abundance and clustering of Lyα emitters

Modelling Lyα emitters



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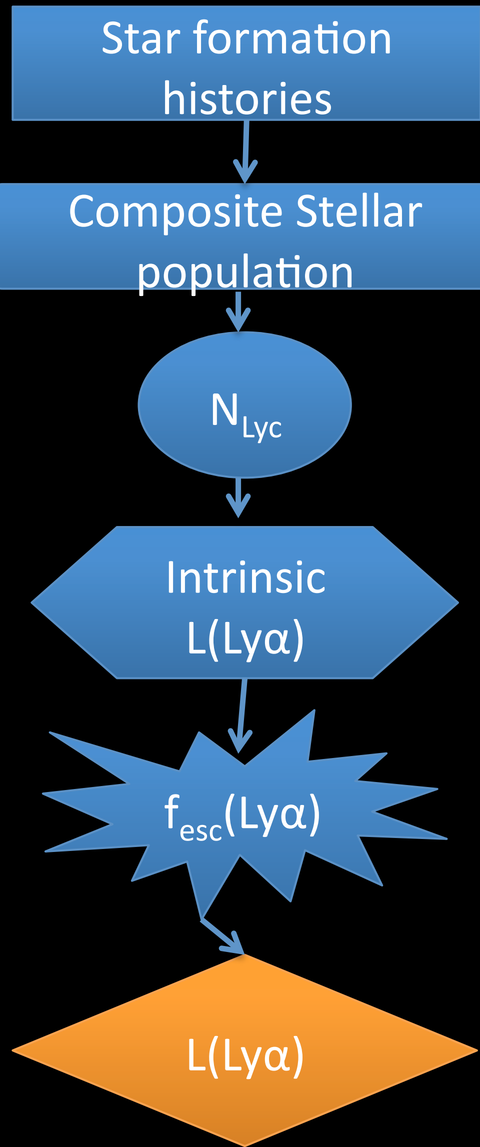

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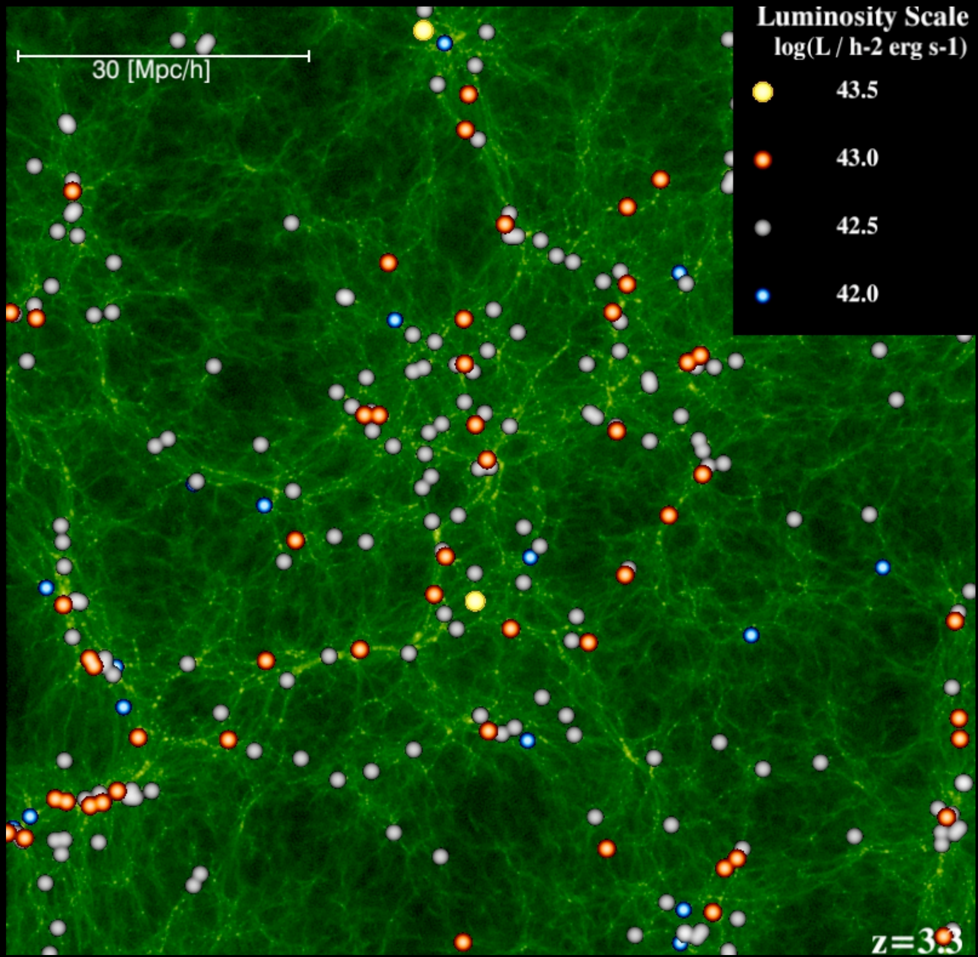

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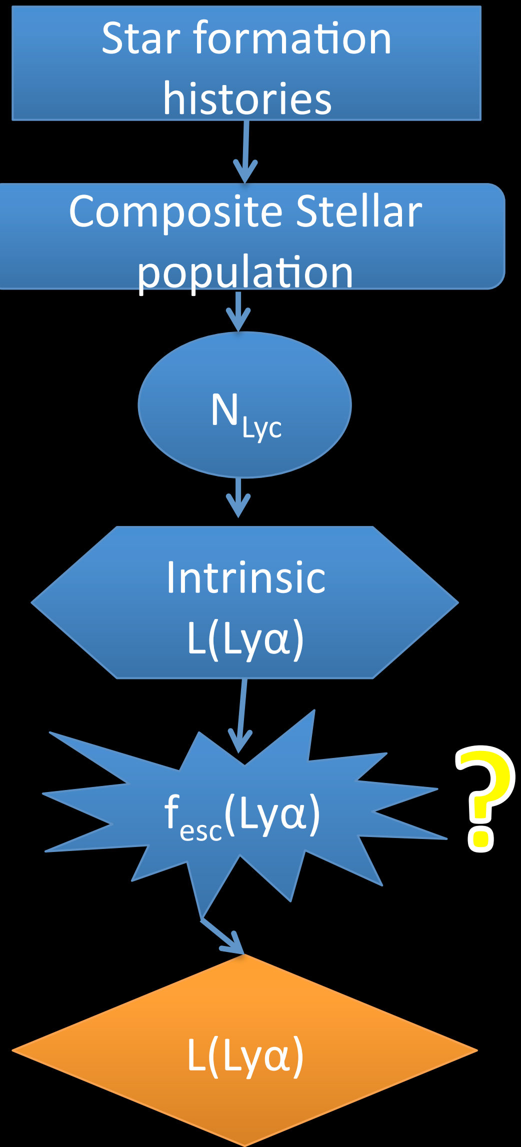
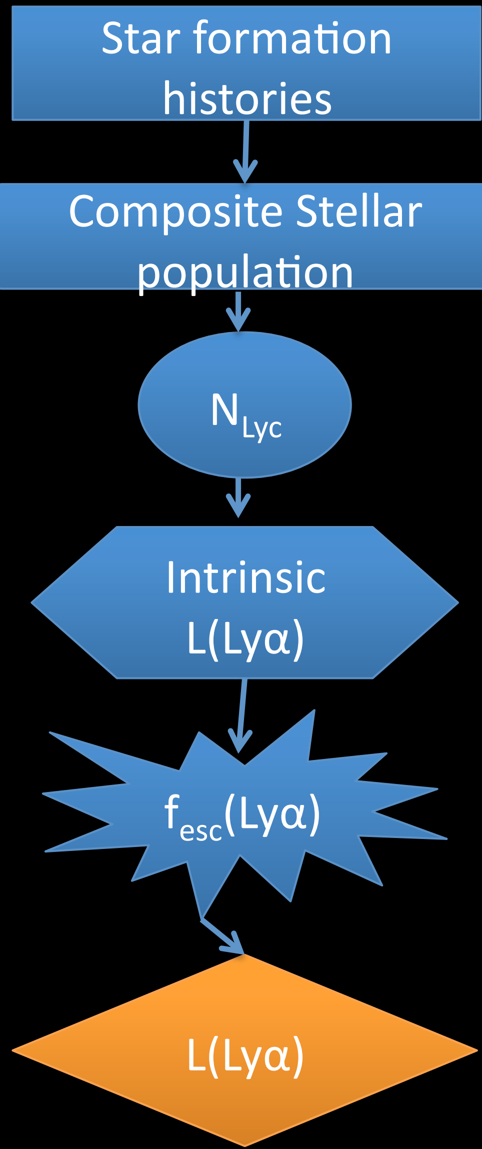


Modelling Lyα emitters

- The simplest approach:
  - $f_{esc}(Ly\alpha) = 0.02$
- Reproduces the LFs and clustering of Lyα emitters in the range $3<z<6$
  - See Le Delliou et al. (2005,2006), Orsi et al. (2008)



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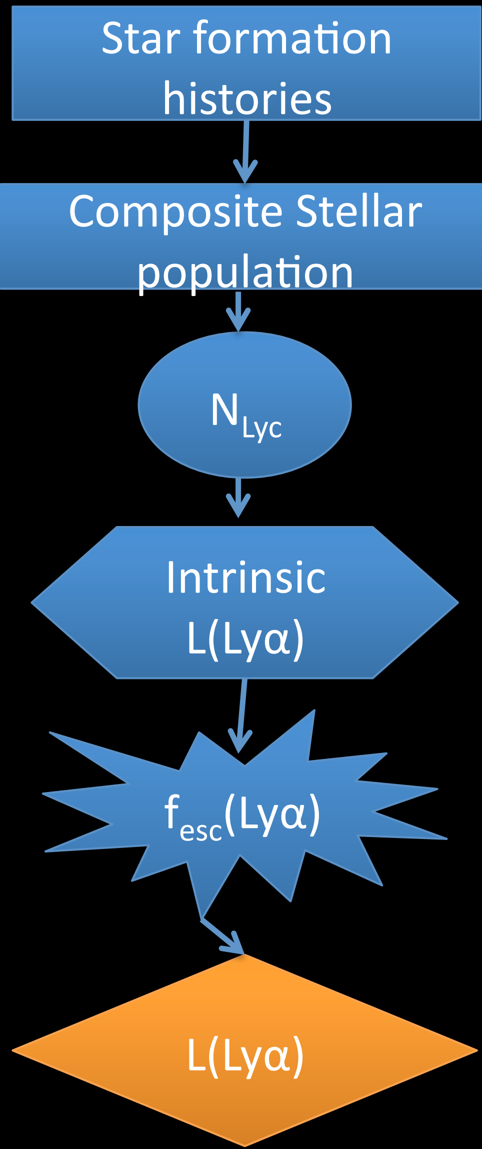
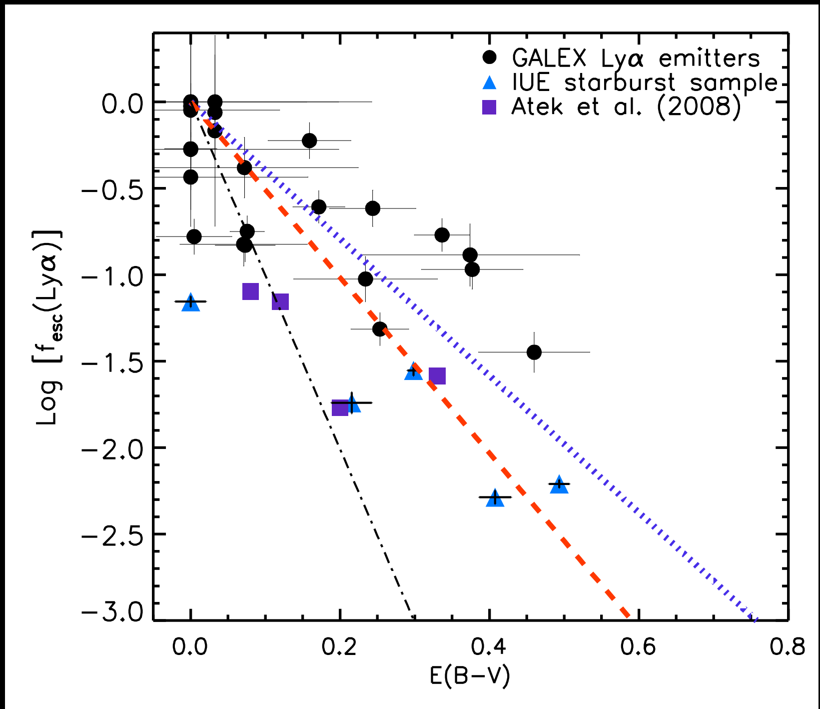
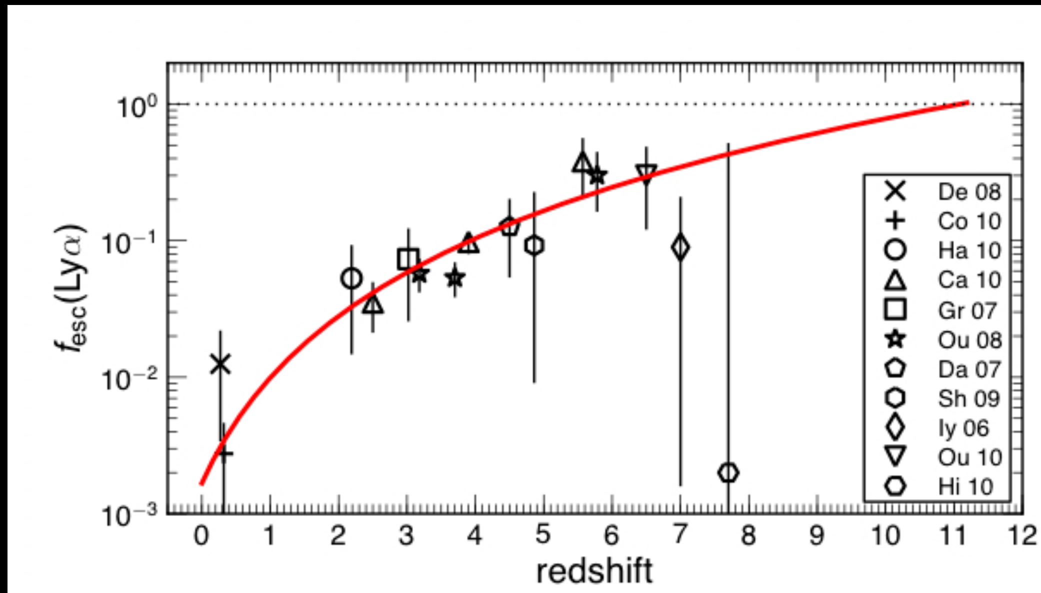
- However, f_{esc}(Lyα) is anything but constant!



Observational estimates of f_{esc}



Atek et al. (2009)



Hayes et al. (2011)

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

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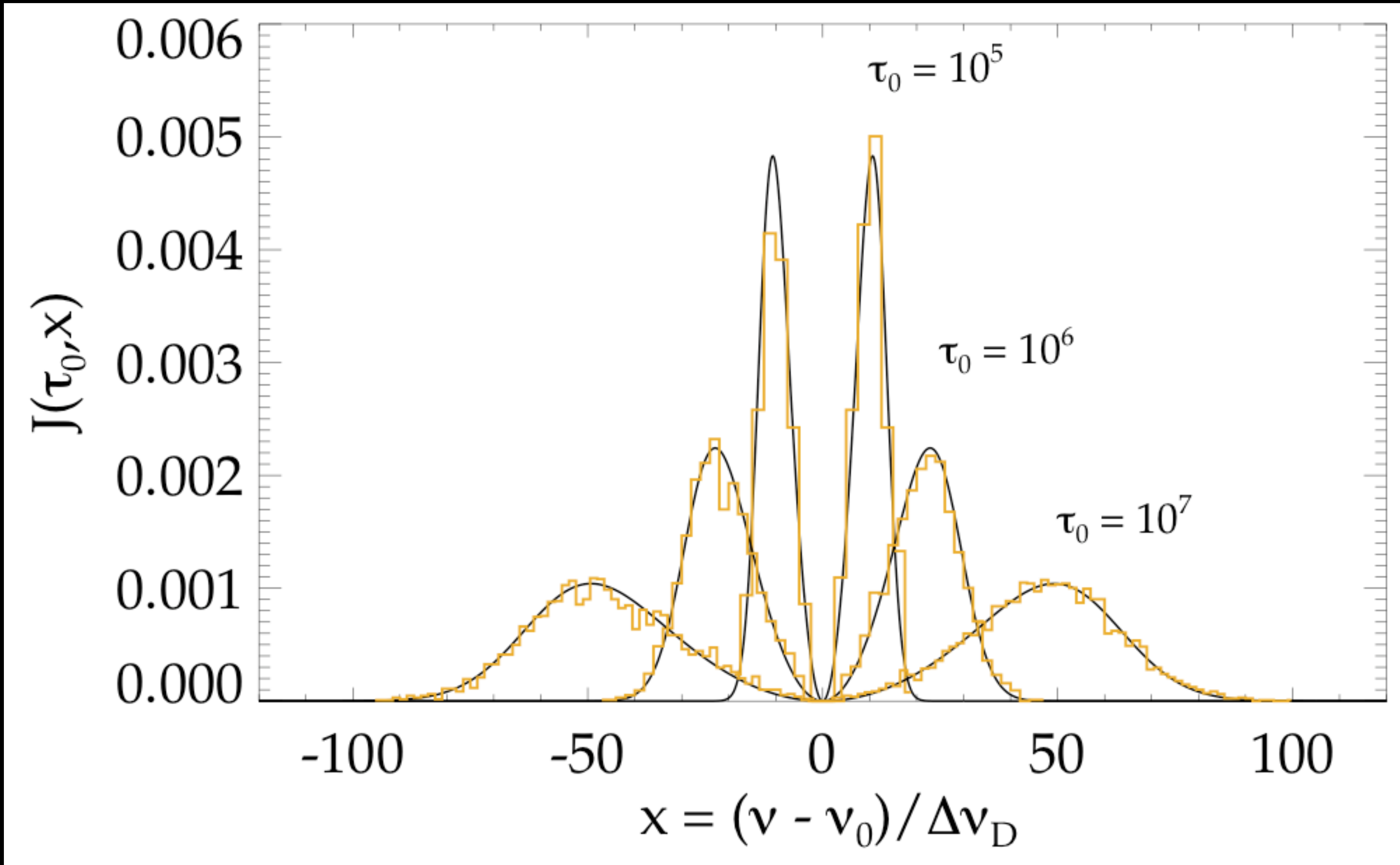
Semianalytical model + Lyα RT

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

Lyα spectra from a homogeneous, static sphere



Galactic Outflows

Thin Shell

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

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

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

Galactic Wind

$$\dot{M}_{ej} = [\beta_{\rm reh}(V_{\rm circ}) + \beta_{\rm sw}(V_{\rm circ})]\,\psi$$

$$\dot{M}_{\rm ej} = 4\pi r^2 V_{\rm exp} \rho(r)$$

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

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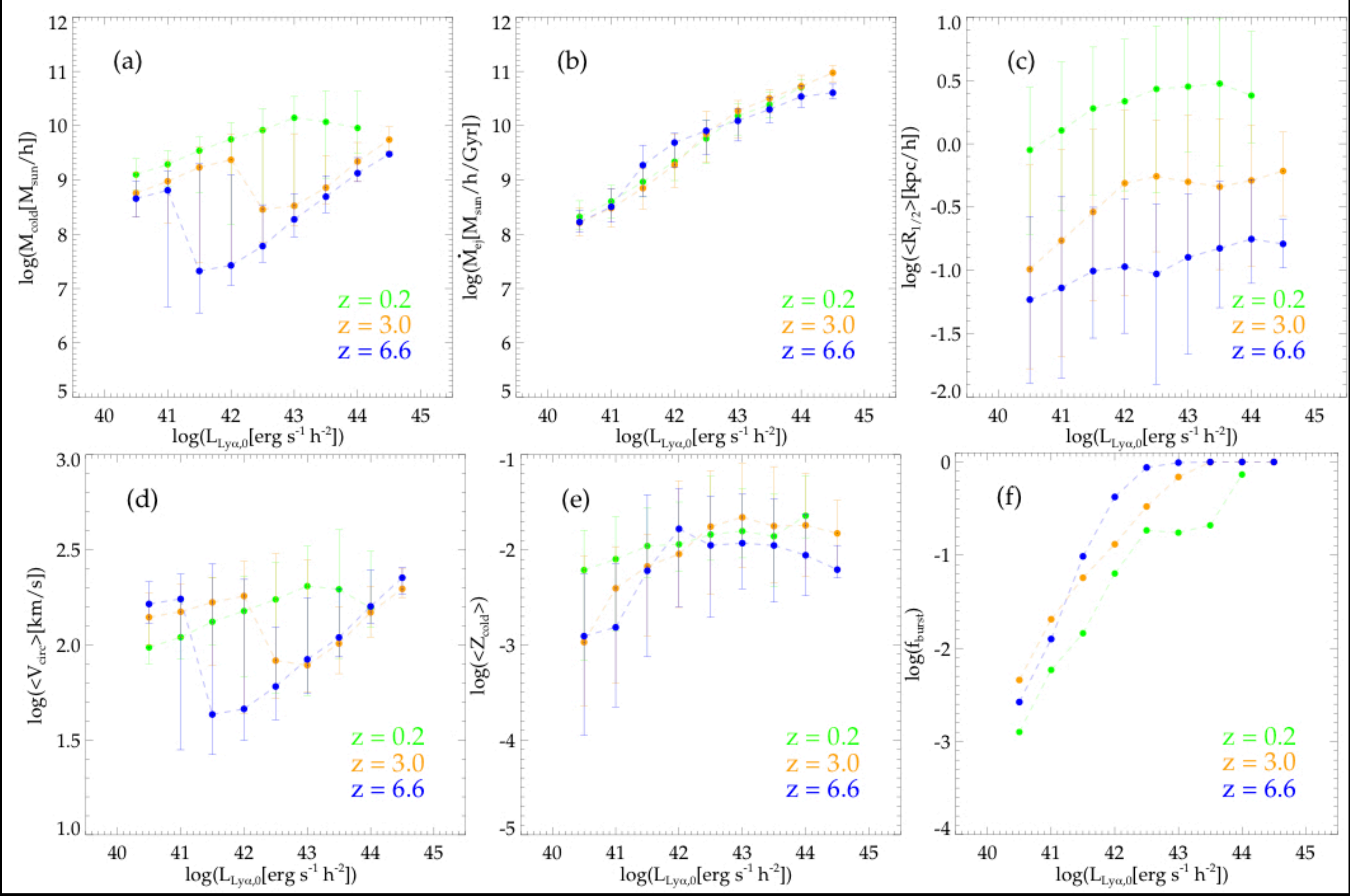
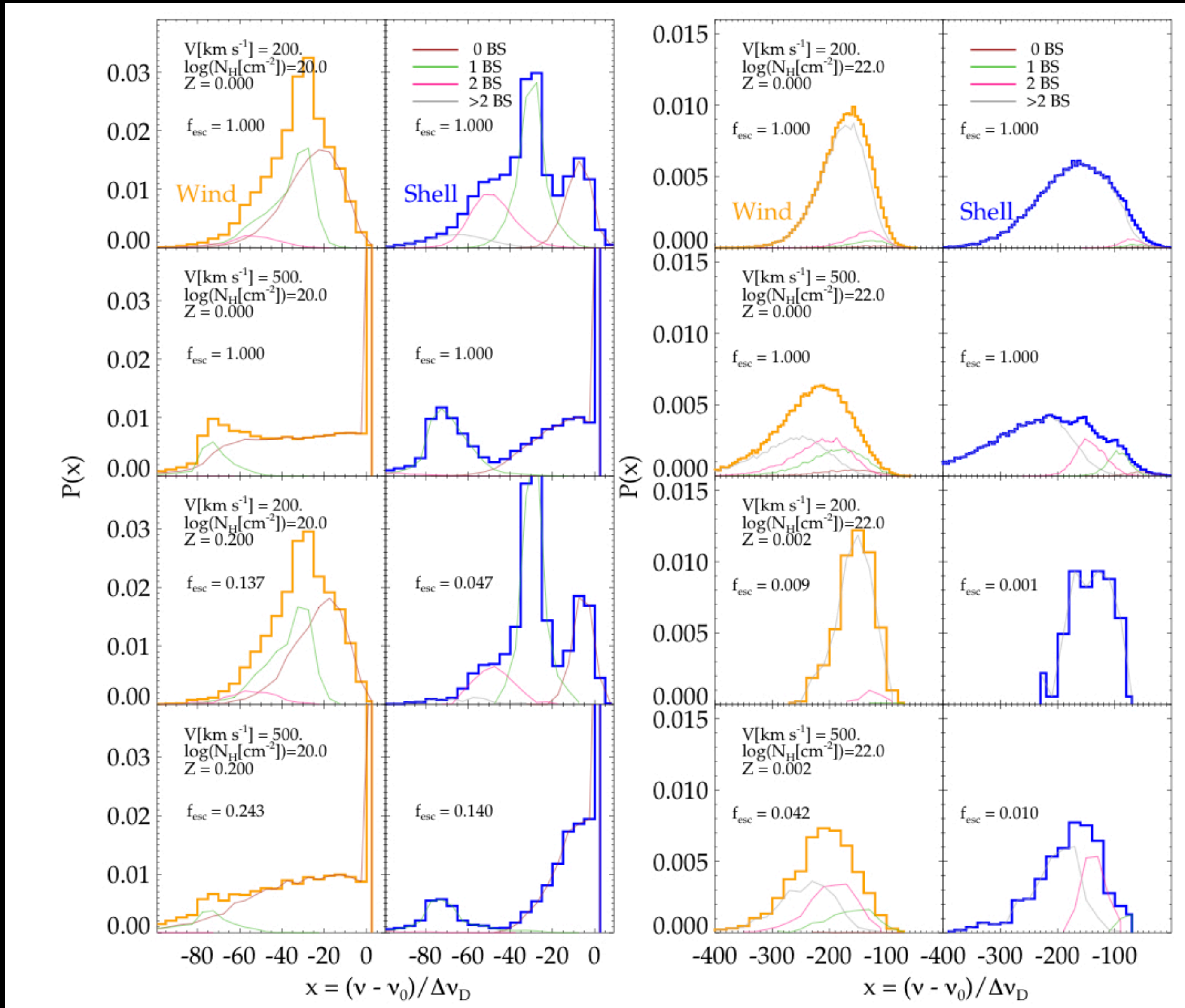
3 free parameters: f_M, f_R, f_V

different for each outflow model

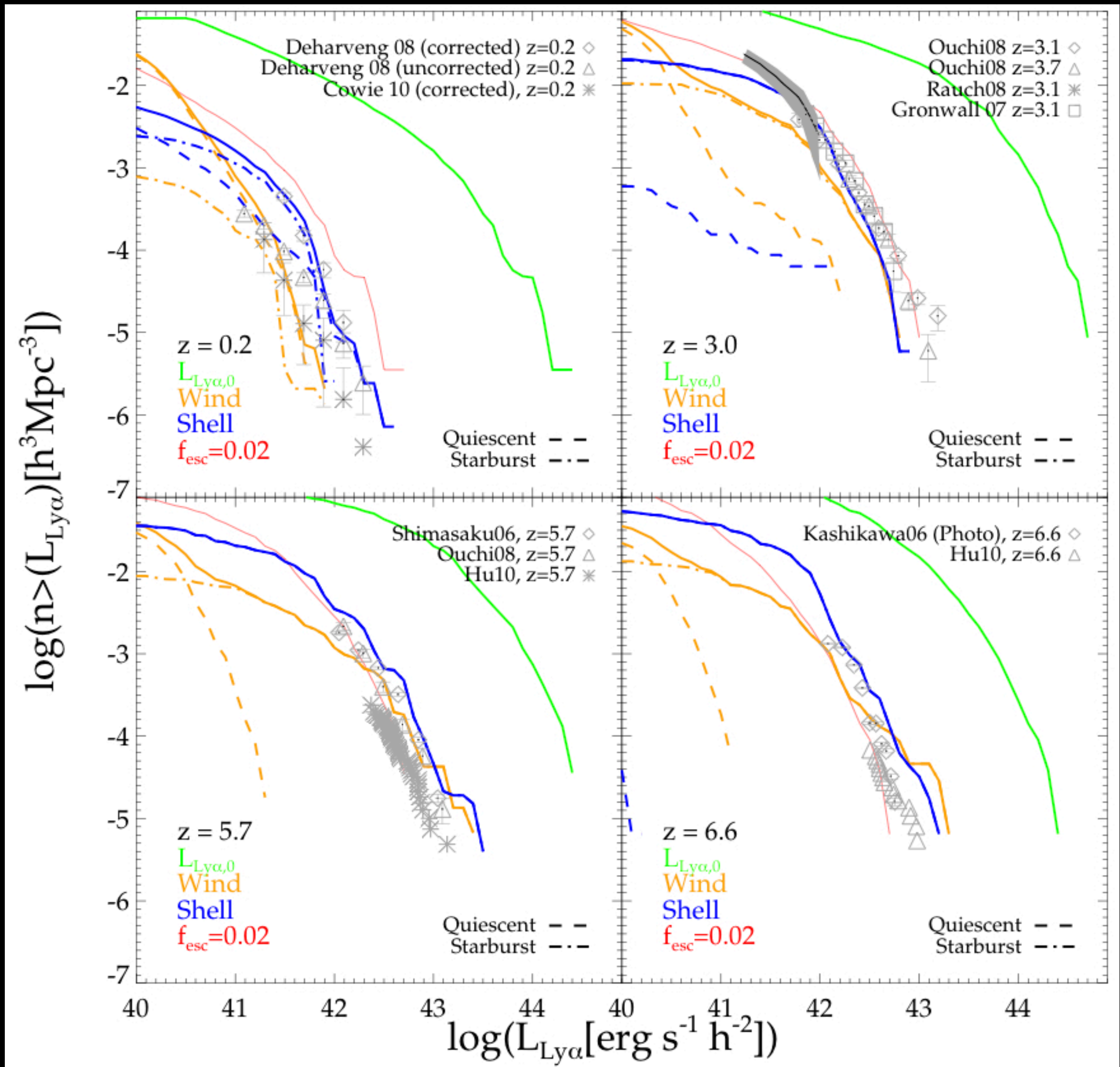
Relevant galaxy properties



Lyα line comparison



Matching the Lyα CLF

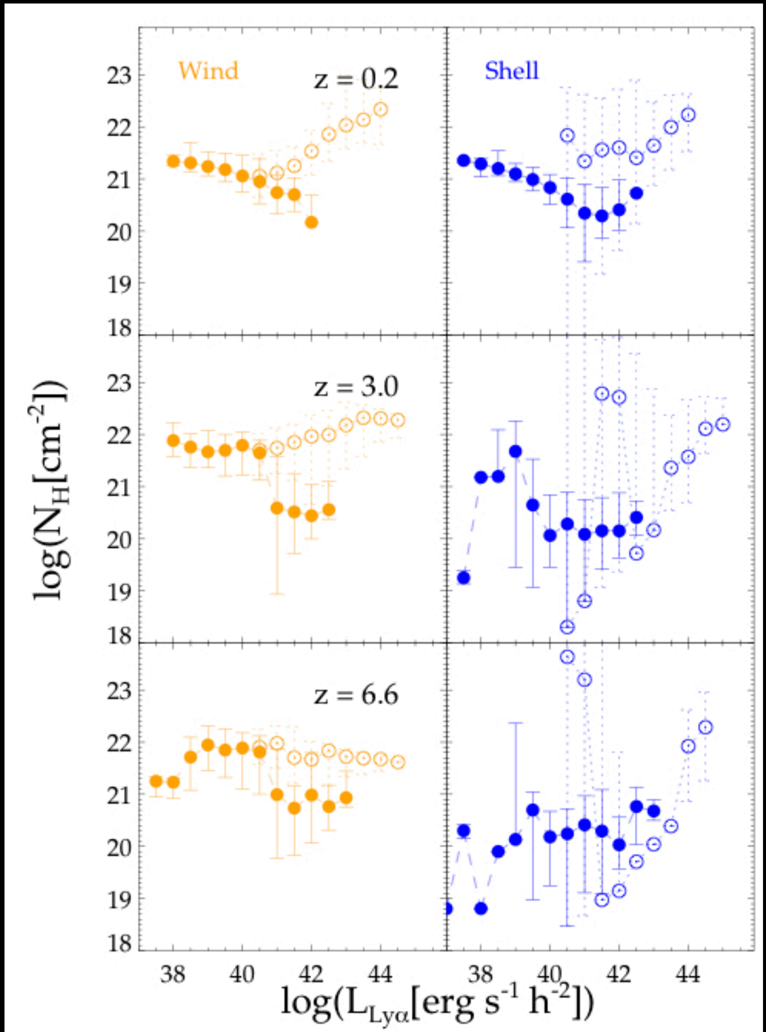


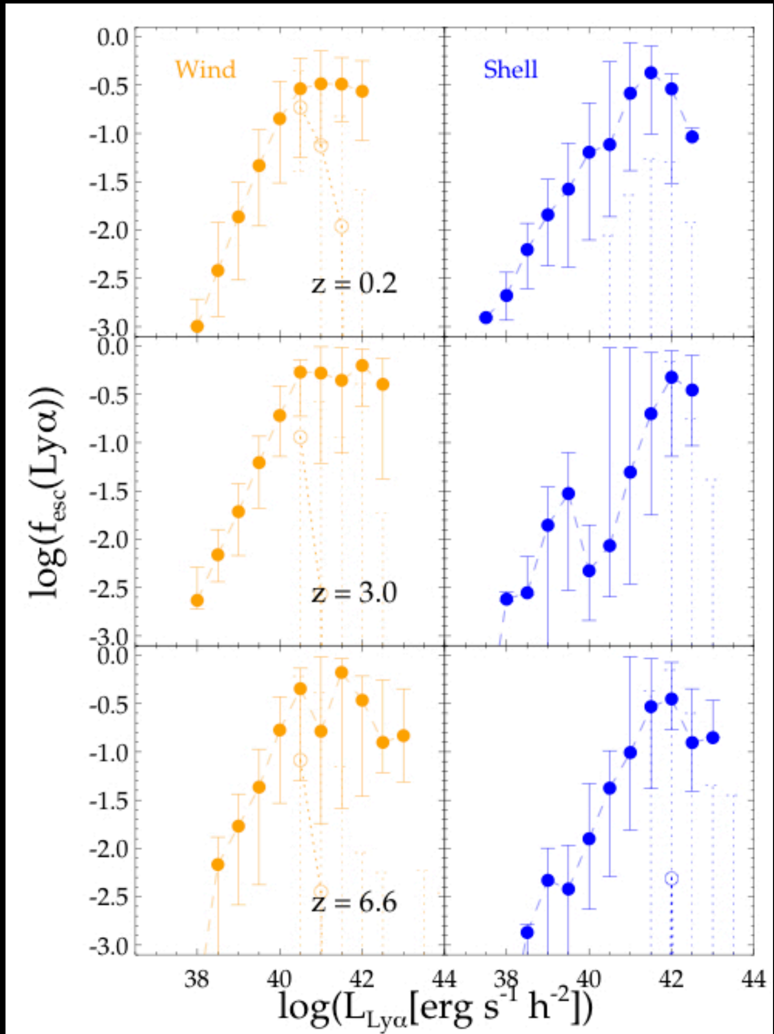
- Single set of parameters fails at reproducing the CLF over the whole redshift range
- Star forming regions in ULIRGs and SMGs grow with redshift
- Hence, we model a simple evolving outflow radius scaling:

$$f_R^b = a(1+z)^b,$$

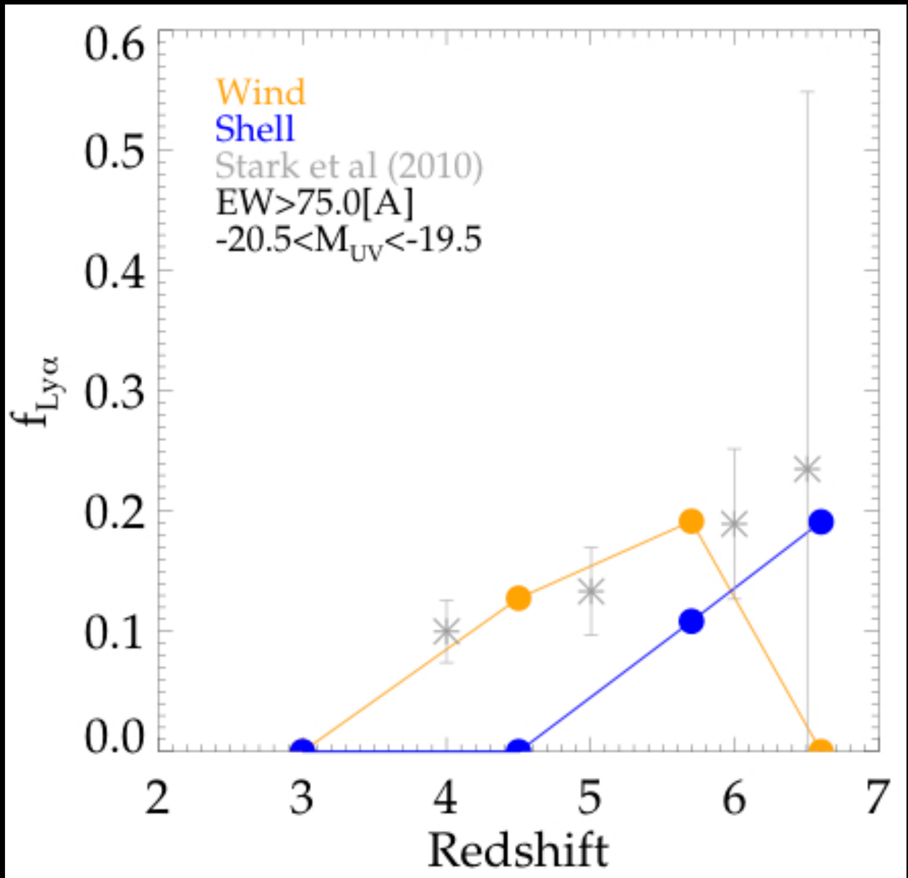
- As a consequence
  - Starbursts dominate the abundances at high-z
  - outflows at z>3 are galactic-scale sized

Column densities and escape fractions



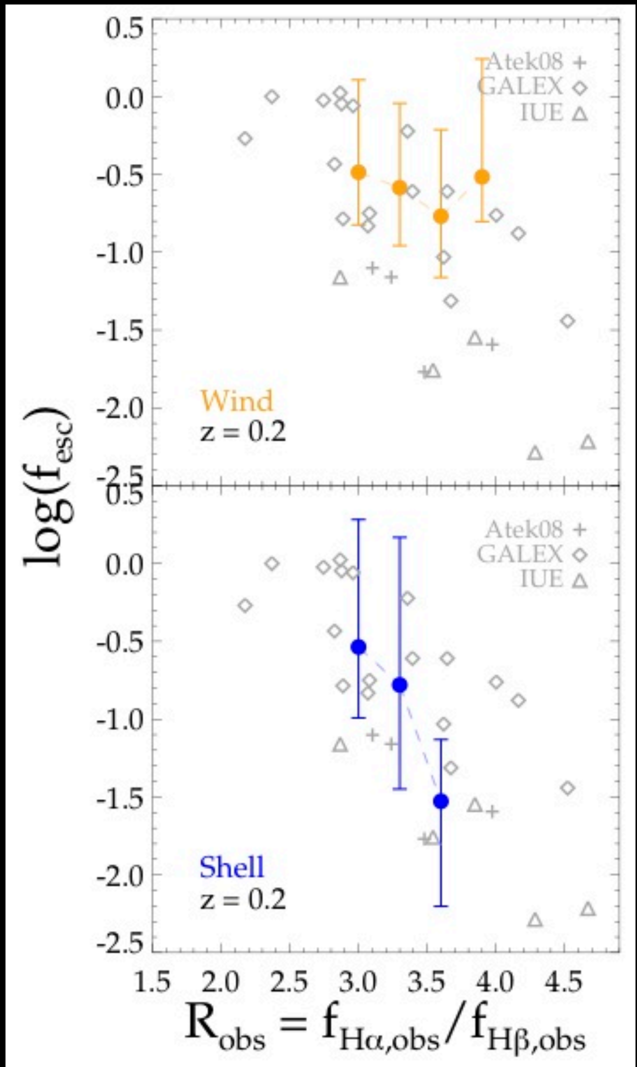


Fraction of Lyα emitters



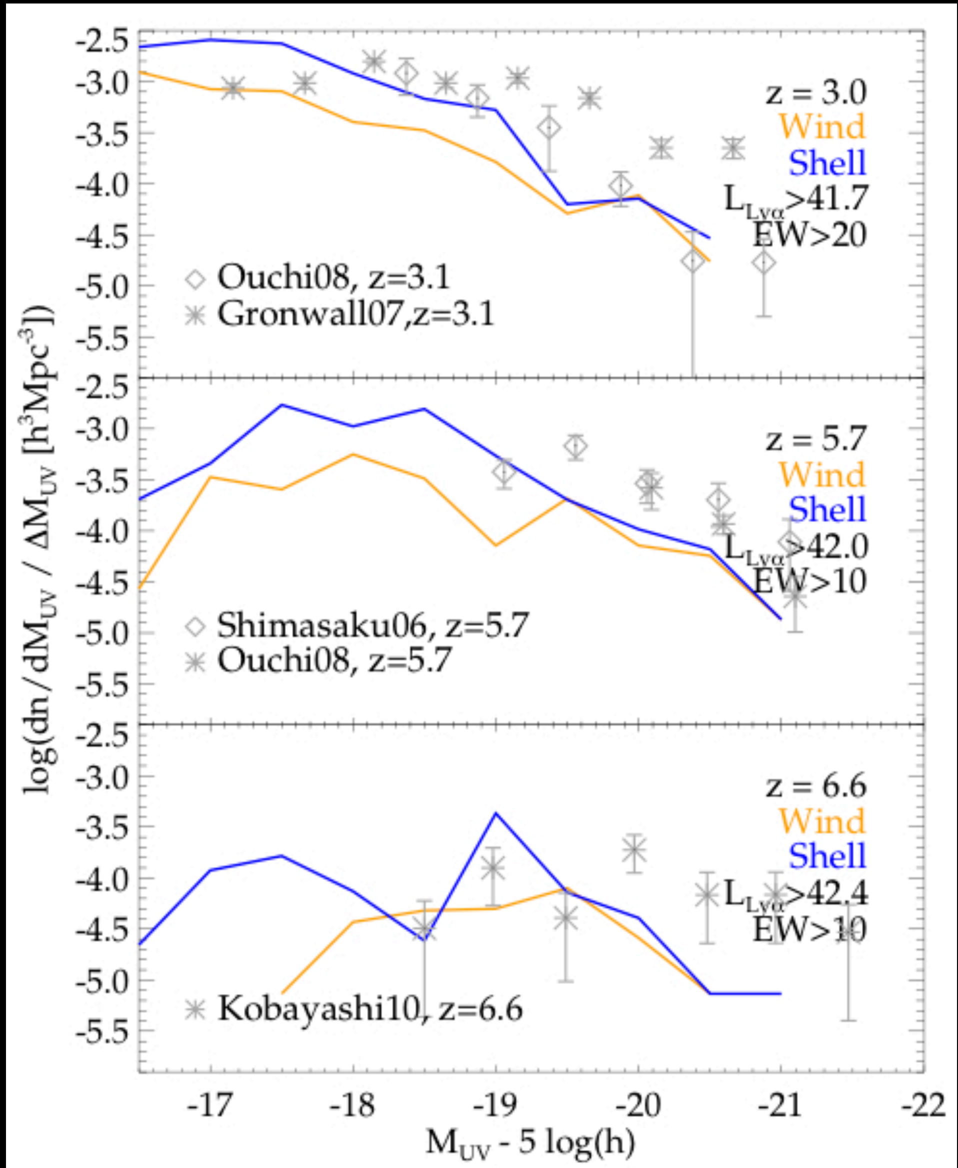
- Less than 30% of high-z LBGs have strong Lyα emission (Stark et al. 2010,2011)
- Given the observational constraints our models give a reasonable agreement
- Suggests that Lyα emitters have particular characteristics

Escape fractions again



Both models reproduce the f_{esc} inferred observationally remarkably well!

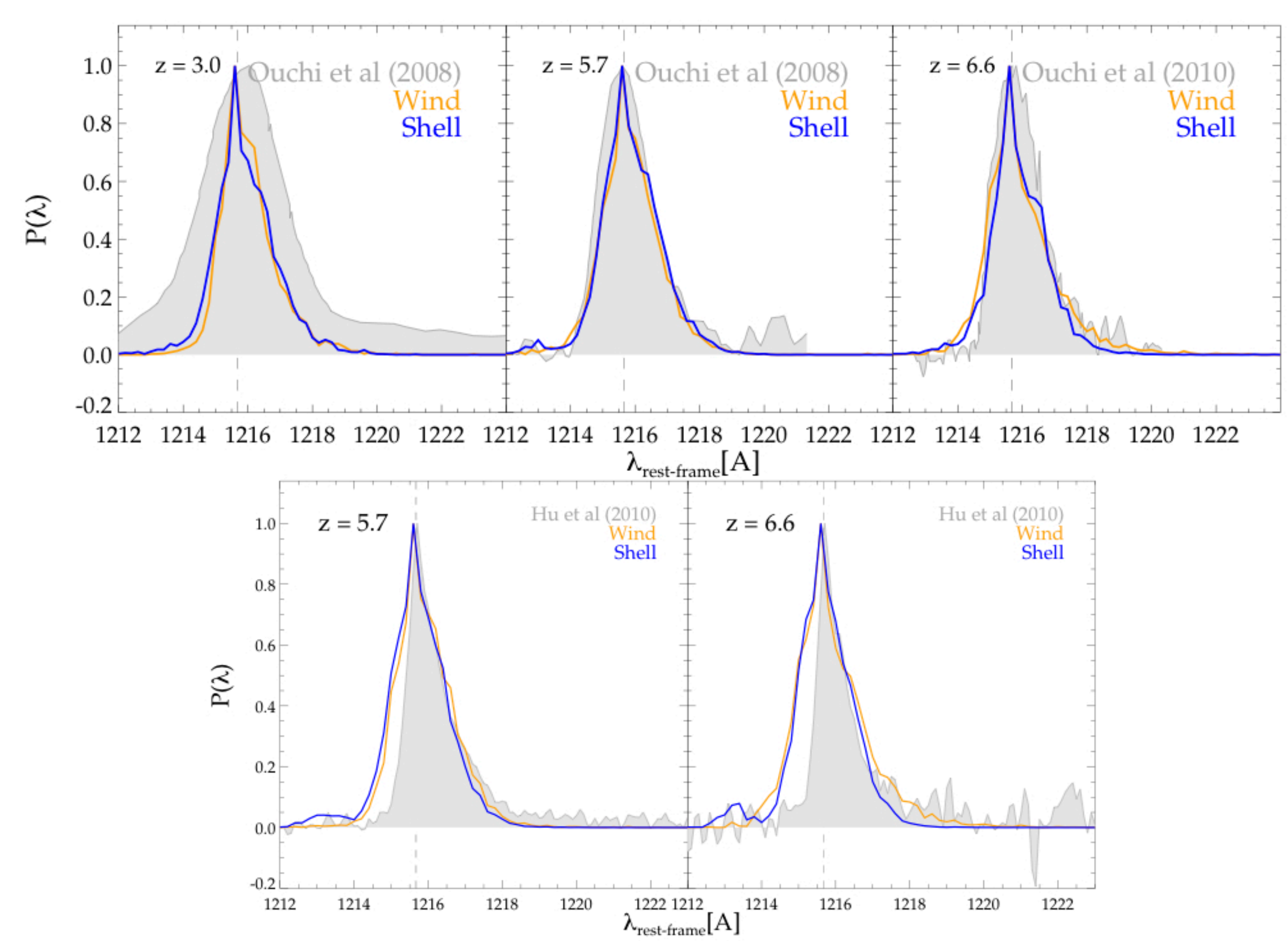
UV luminosity function of Lyα emitters



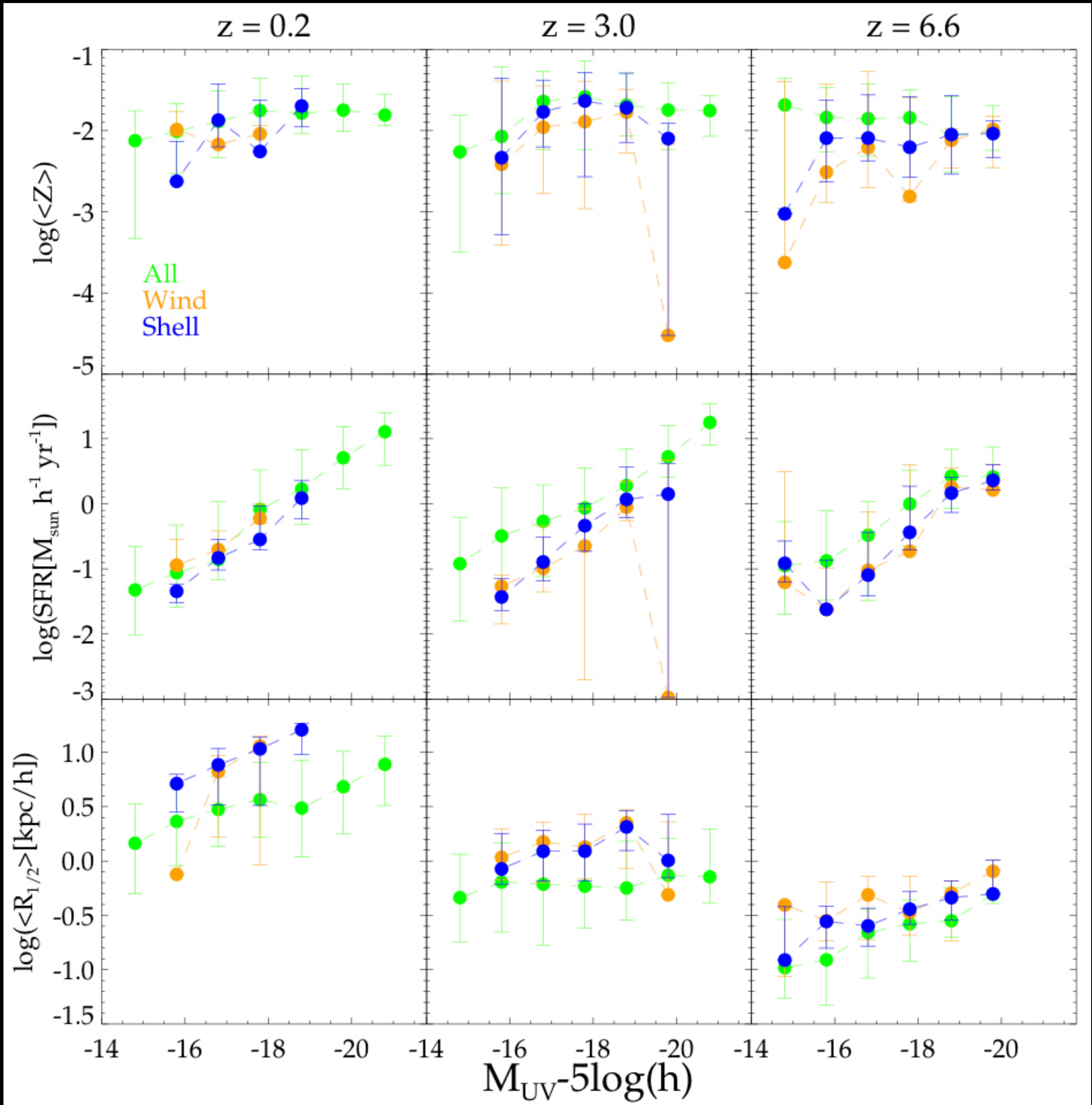
Models do not match the UV LF well

Attenuation of the Lyα line due to the IGM needed?
(most likely, yes)
-- Future work

Lyα line profiles



The Nature of Lyα emitters



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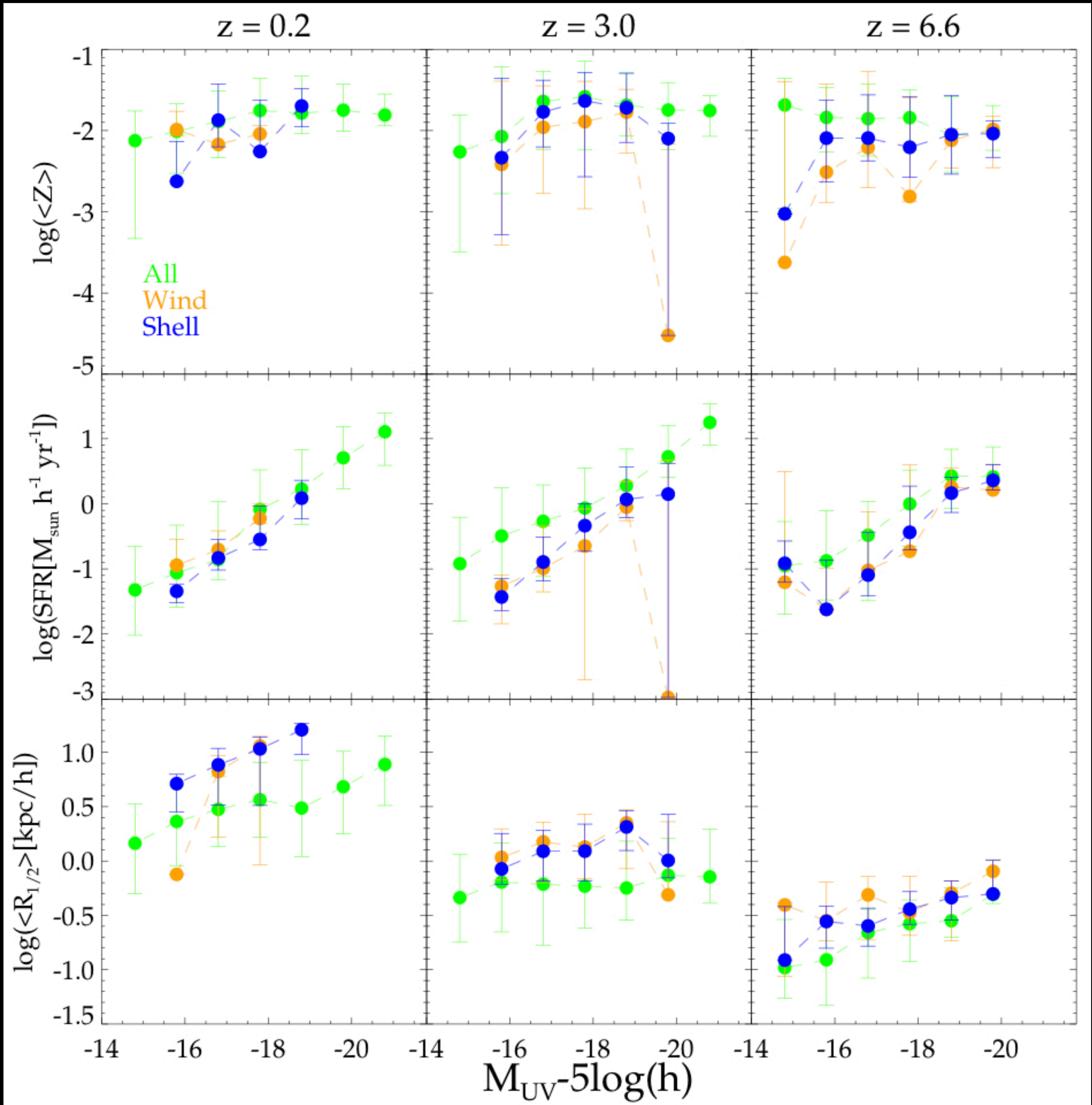

Typical Lyα emitters have

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

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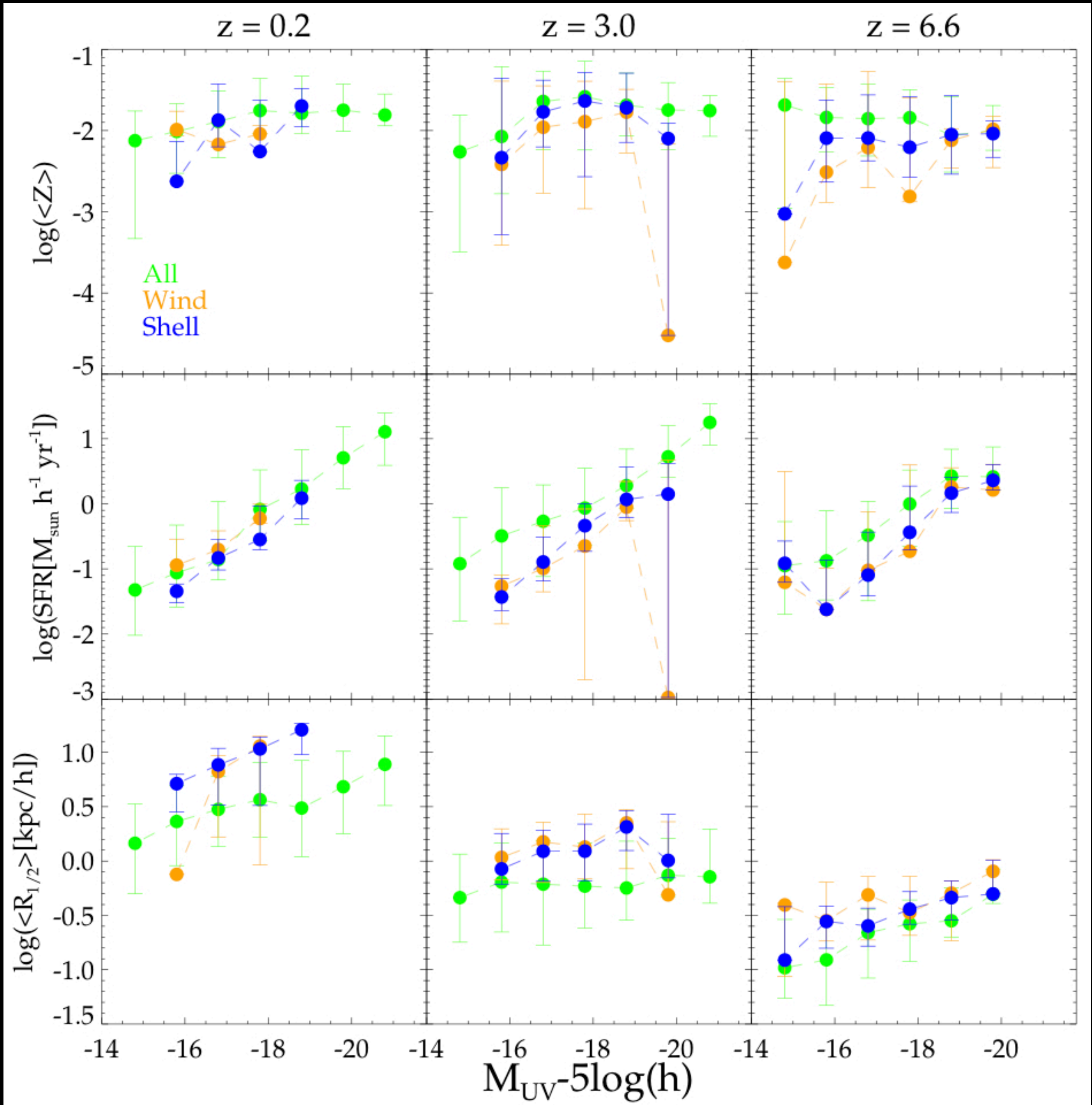

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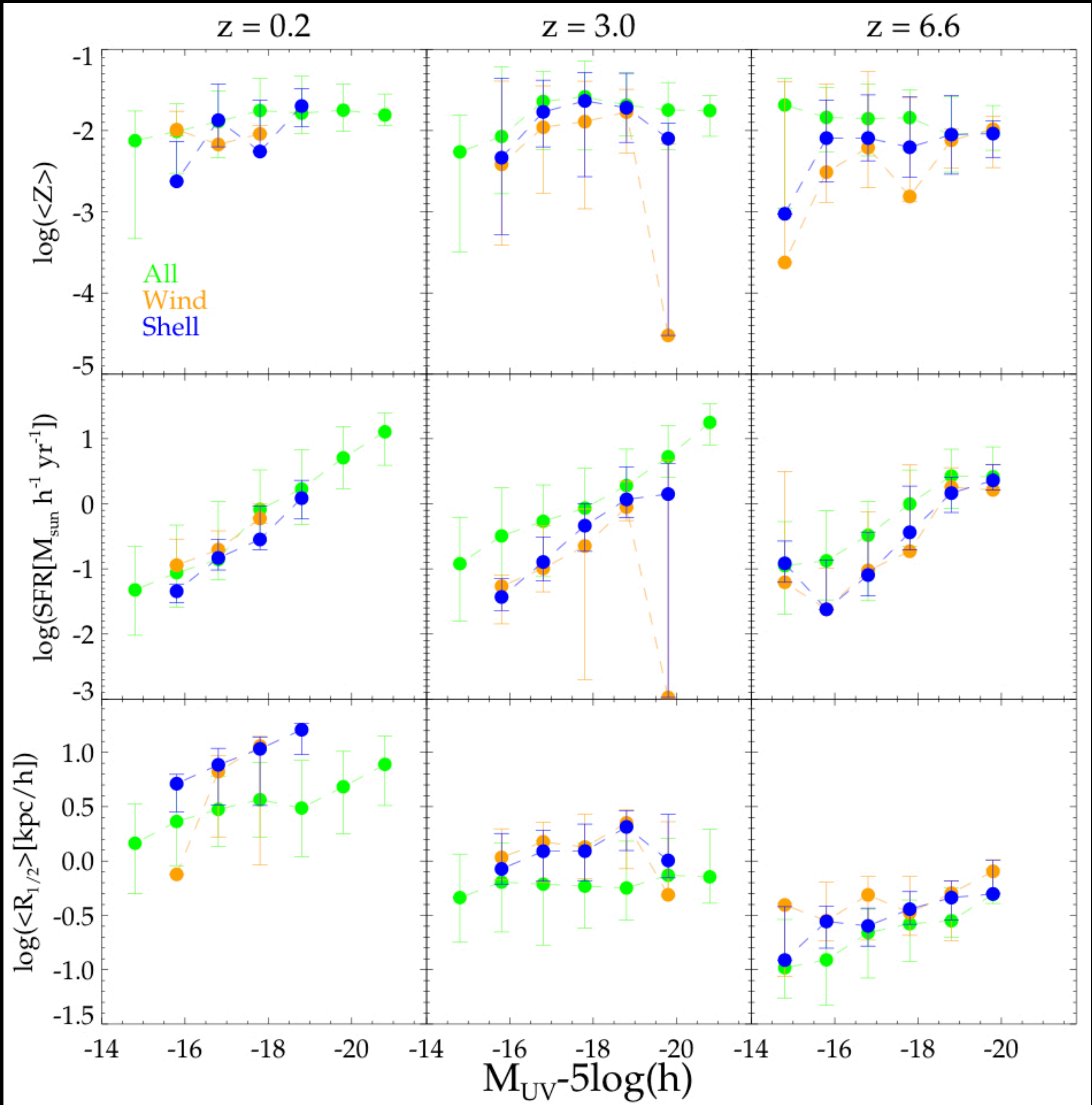

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➢ Lower Star Formation Rates

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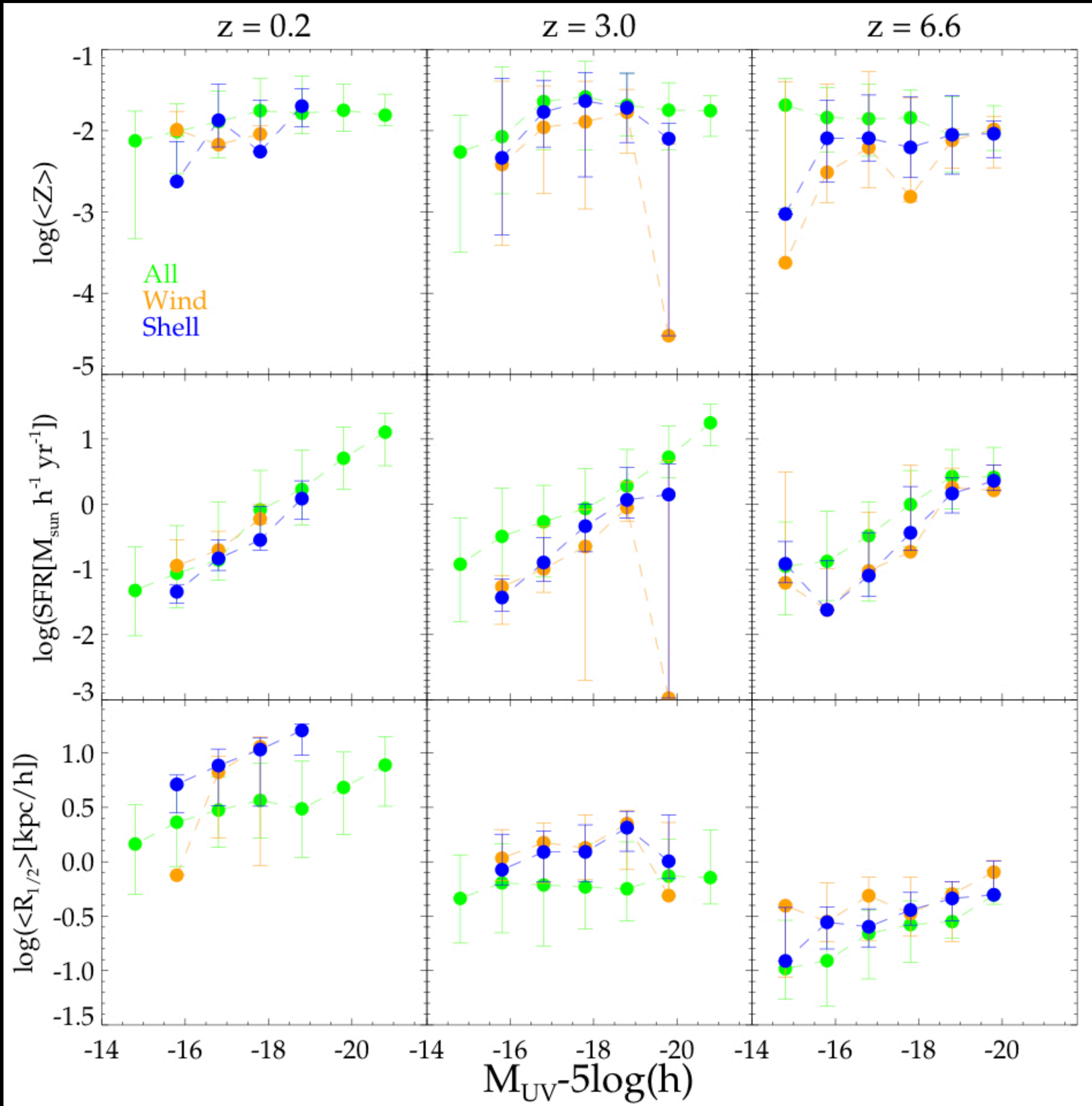

Typical Lyα emitters have

- Lower Metallicities
- Lower Star Formation Rates
- Larger sizes

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

Conclusions

- A physical model for the escape of Lyα photons is necessary to understand the properties of this galaxy population
- Our simple modelling of galactic outflows allow us to reproduce a variety of observational properties of Lyα emitters
- Lyα emitters are predicted to have
  - Low metallicities
  - Low Star formation rates
  - Larger sizes
- Further improvements are possible:
  - Evolving outflows (Tenorio-Tagle et al., 1999)
  - Multi-phase ISM (Neufeld, 1991; Hansen & Oh, 2006)
  - Effect of the IGM (Dijkstra et al. 2007, Kobayashi et al. 2007)