

# The Mean Absorption Line Spectra of a Selection of Luminous $z \sim 6$ LBGs

(Harikane+20b, arXiv: 2005.11078)

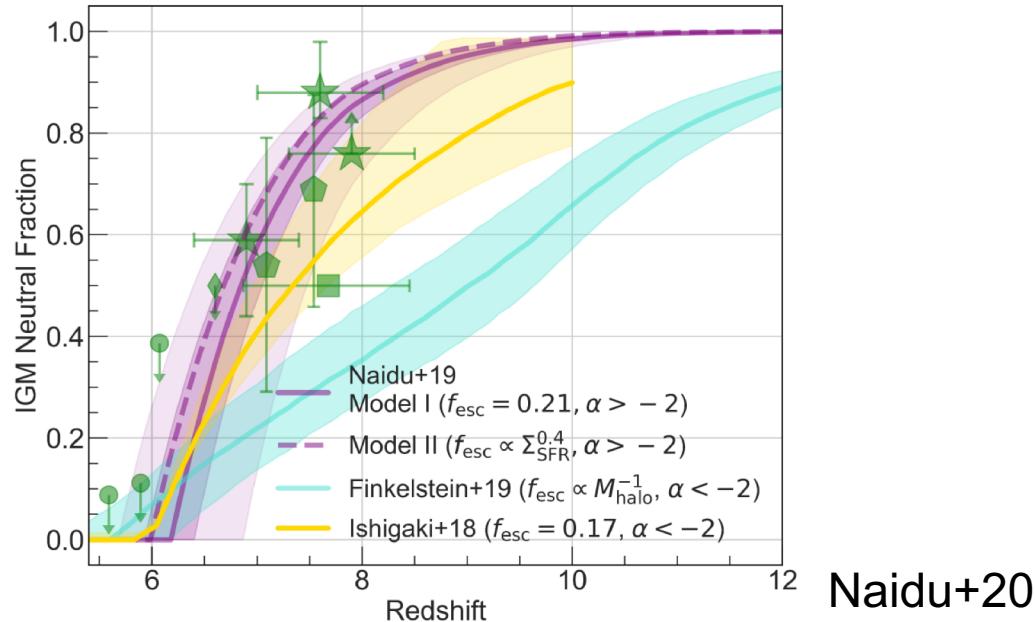
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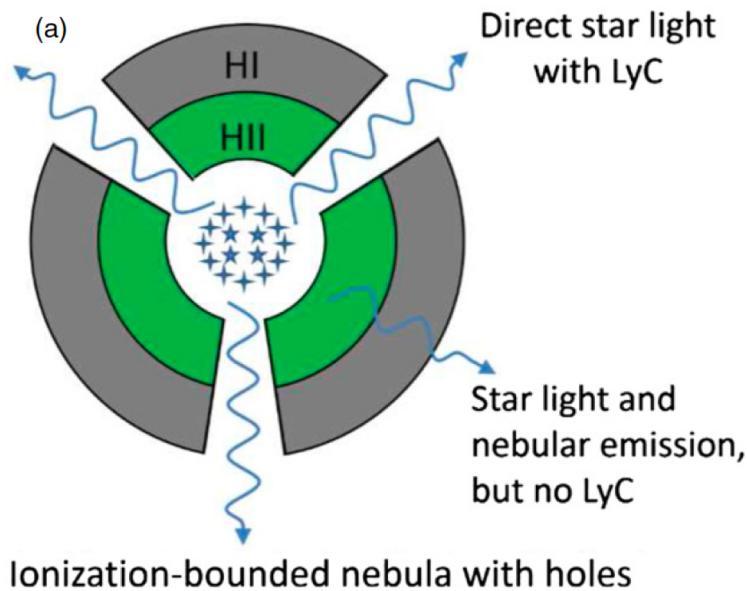
# Cosmic Reionization History

- Ionizing photon:  $\dot{n}_{\text{ion}} = f_{\text{esc}} \xi_{\text{ion}} \rho_{\text{UV}}$
- Escape fraction  $f_{\text{esc}}$  models
  - Constant  $f_{\text{esc}}=0.2$  (Robertson+13, Ishigaki+18)
  - Smaller in more luminous galaxies (Finkelstein+19)
  - Larger in more luminous galaxies (Naidu+20)

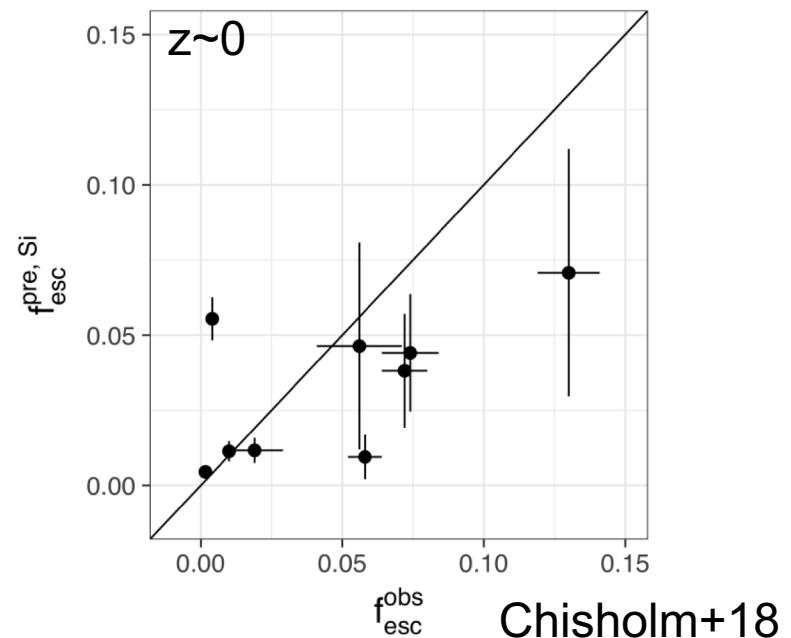


# Estimating $f_{\text{esc}}$ at High- $z$

- Direct measurement: difficult due to higher  $x_{\text{HI}}$
- Depth of abs line (e.g., SiII) -> covering fraction  $f_c$ 
  - $f_{\text{esc}} \sim 1 - f_c$
- This study: bright LBGs at  $z \sim 6$  from Subaru/HSC



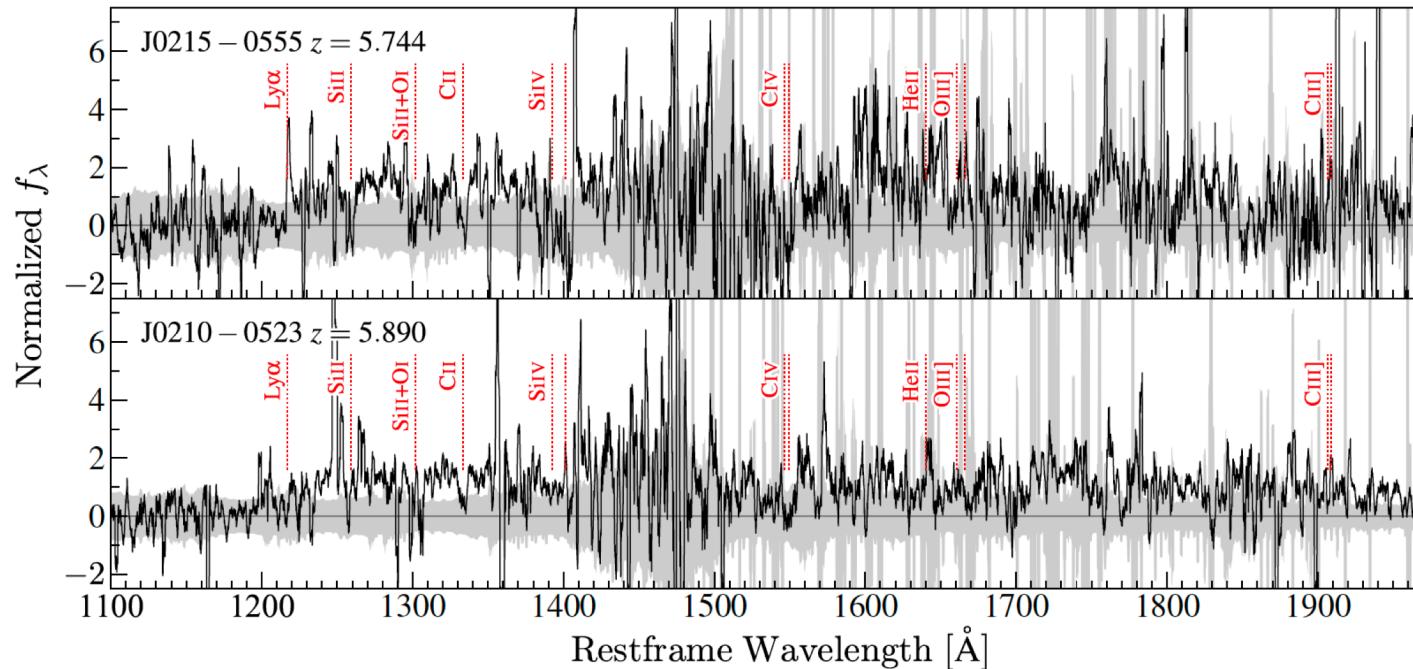
Zackrisson+13



Chisholm+18

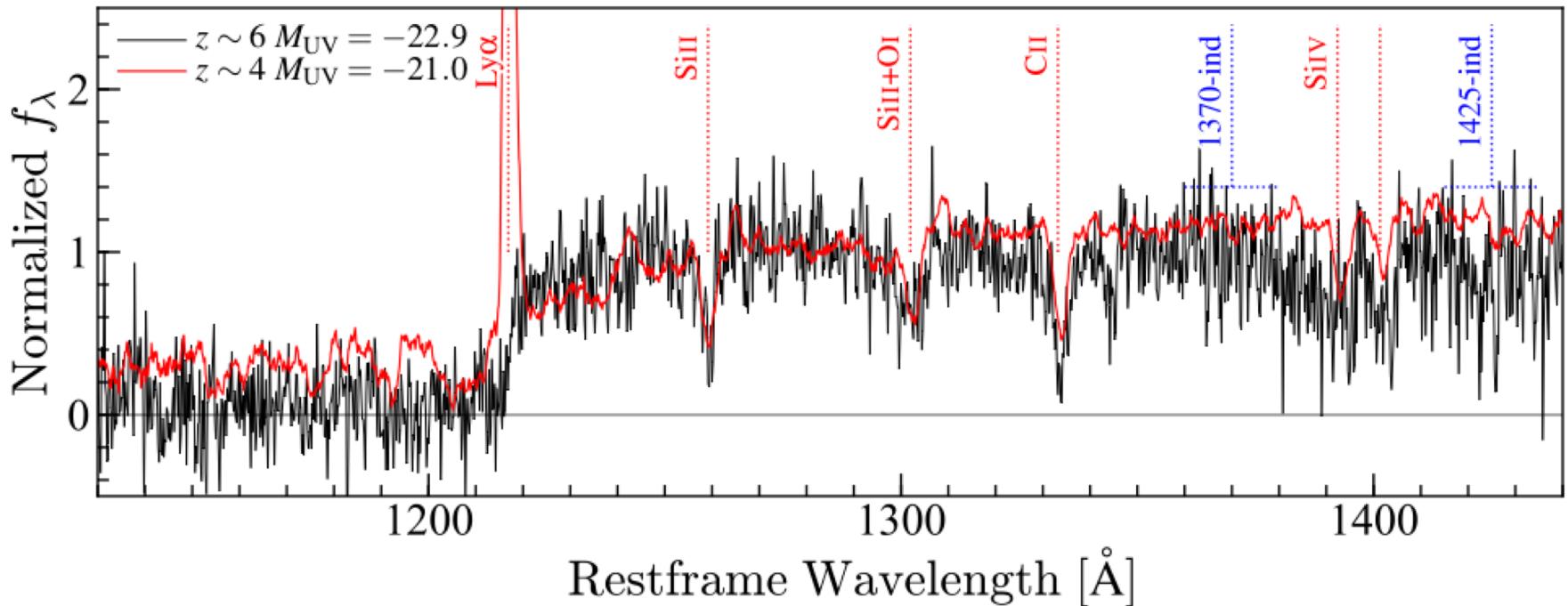
# Galaxy Sample

- 31 spec-z LBGs at  $z \sim 6$  ( $M_{\text{UV}} \sim -23$  mag)
  - Confirmed w/ Ly $\alpha$ , Lyman break, abs lines  
(Subaru/FOCAS, GTC/OSIRIS, Matsuoka+16,18ab,19)
  - 2 LBGs observed with VLT/X-Shooter (7 hours)



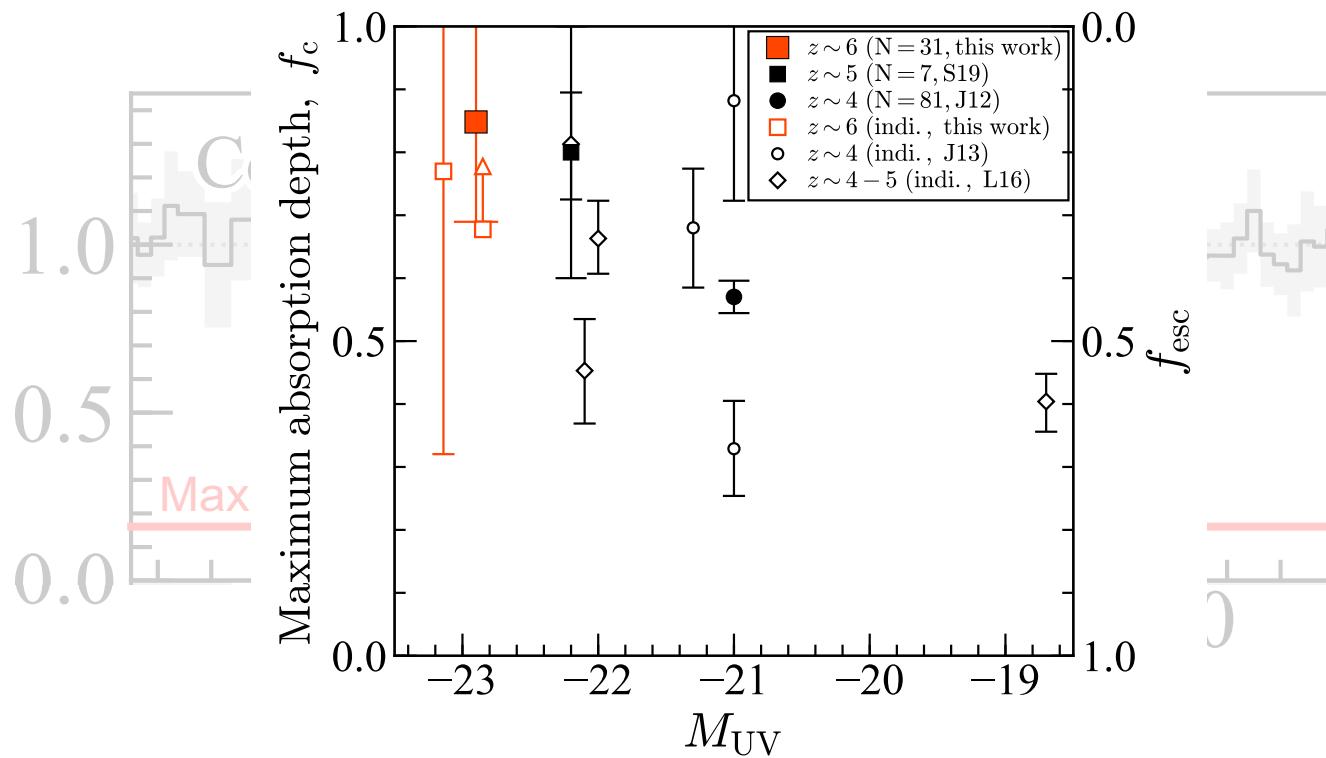
# Composite Spectrum

- Detect several absorption lines
- Deeper absorption than less luminous galaxies



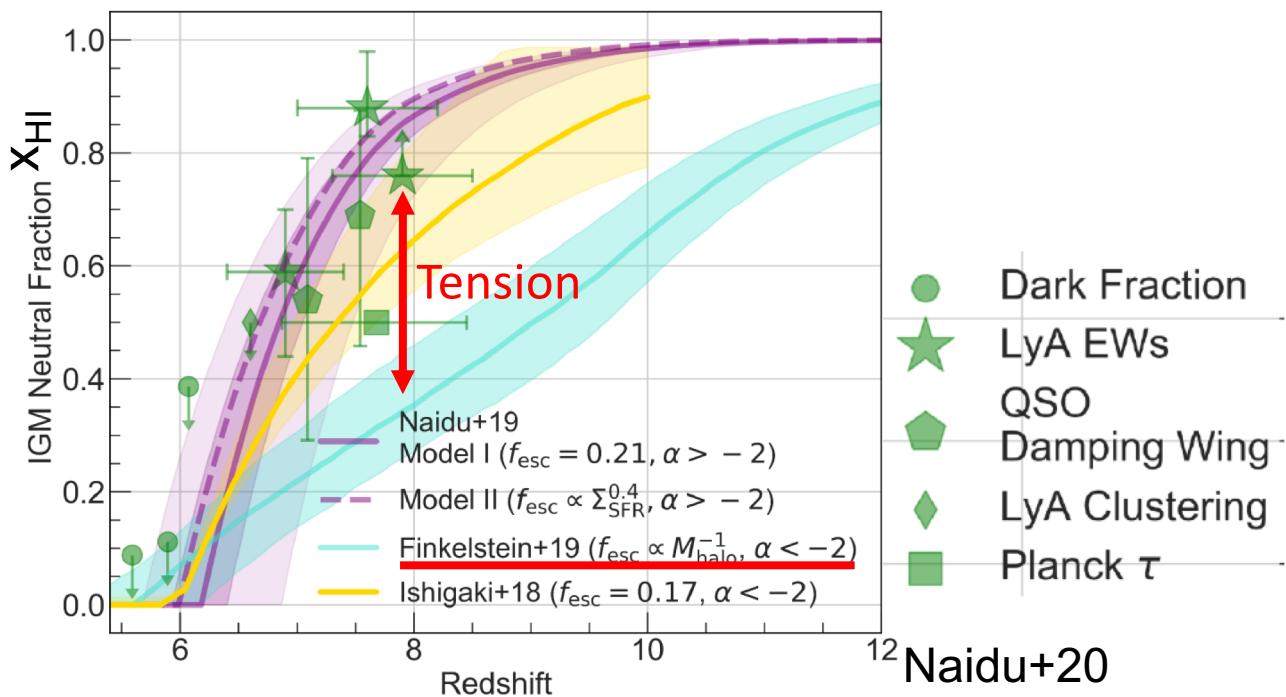
# Maximum Absorption Depth

- Mean absorption spectrum from Sill and CII
- Deeper absorption in more luminous galaxies
  - > Higher  $f_c$  (lower  $f_{\text{esc}}$ ) in luminous galaxies



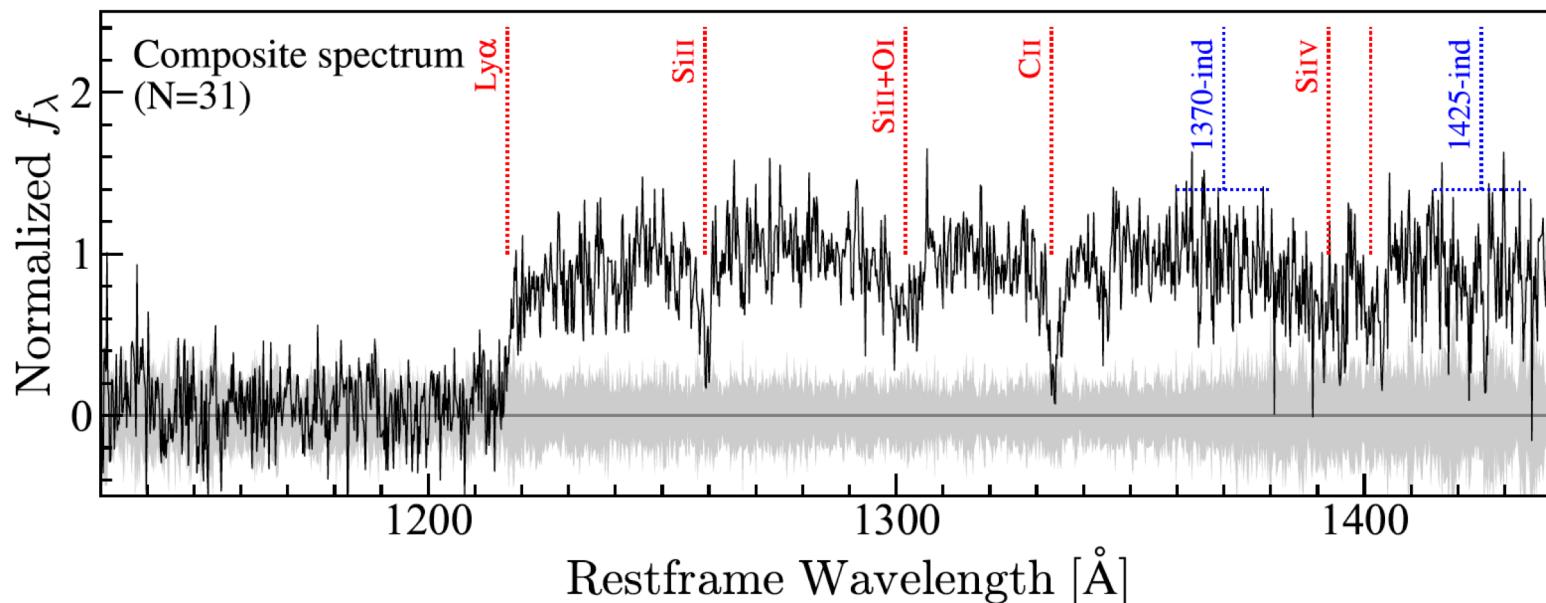
# Reionization History

- Lower  $f_{\text{esc}}$  in more luminous galaxies
  - Supporting Finkelstein's model
- Tension with some model-dependent  $x_{\text{HI}}$  results (e.g., LAE fraction, damping wing)



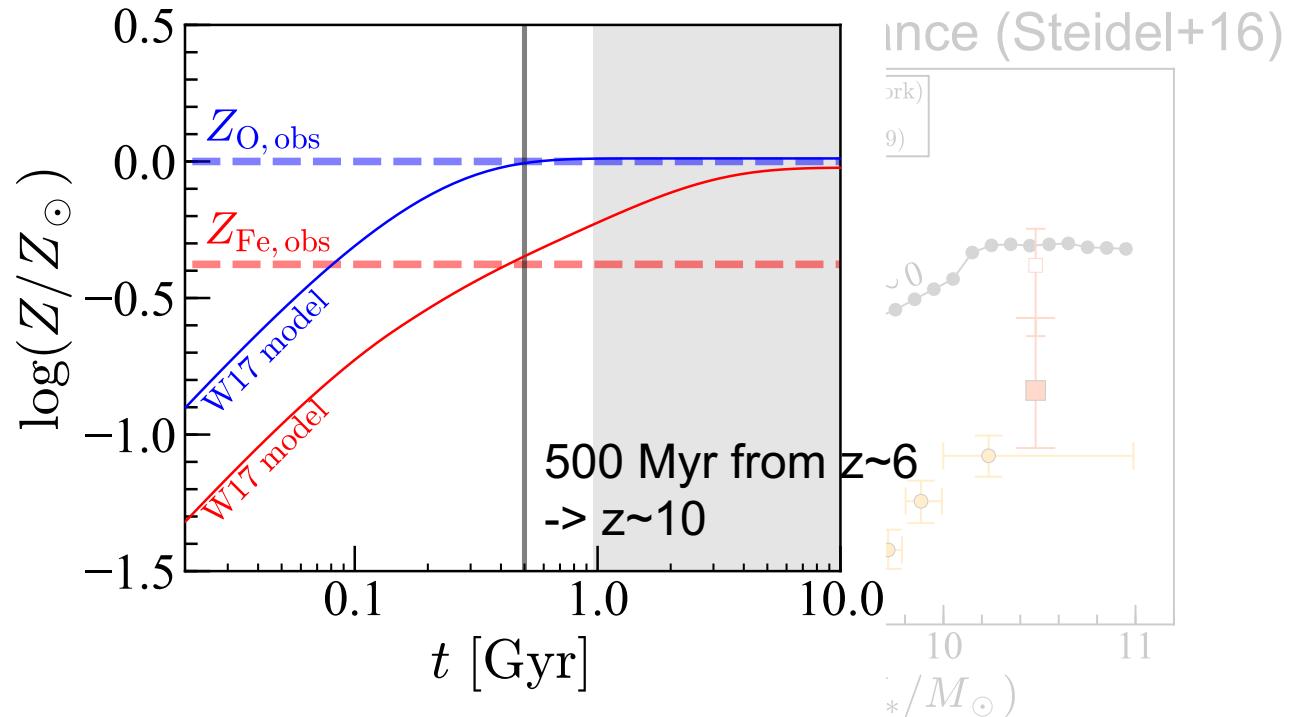
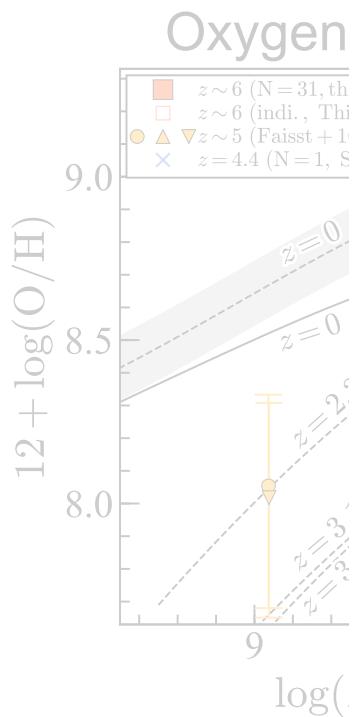
# Metal Absorption Lines

- Signature of metal enriched ISM and stars
  - Gas-phase metallicity ( $Z_{\text{gas}}$ -EW relation Faisst+16)
  - Stellar metallicity (fit w/ BPASS, Steidel+16)



# Gas-phase and Stellar Metallicities

- $Z_{\text{gas}} \sim 1 Z_{\text{sun}}$ ,  $Z_* \sim 0.4 Z_{\text{sun}}$   
-> O/Fe~2 (O/Fe)<sub>sun</sub>, enrichment by core-collapse SNe
- Comparison w/ chemical evolution model  
-> Chemical enrichment began at  $z \sim 10$



# Summary

## Absorption spectra of $z \sim 6$ luminous LBGs

- Higher covering fraction in more luminous LBGs
  - Supporting Finkelstein's model, tension with some  $x_{\text{HI}}$
- Already metal enriched ( $Z_{\text{gas}} \sim 1 Z_{\text{sun}}$ ,  $Z_* \sim 0.4 Z_{\text{sun}}$ )
  - Metal enrichment began at  $z \sim 10$

