Testing feedback models with high-redshift metals

arXiv:1603.03332

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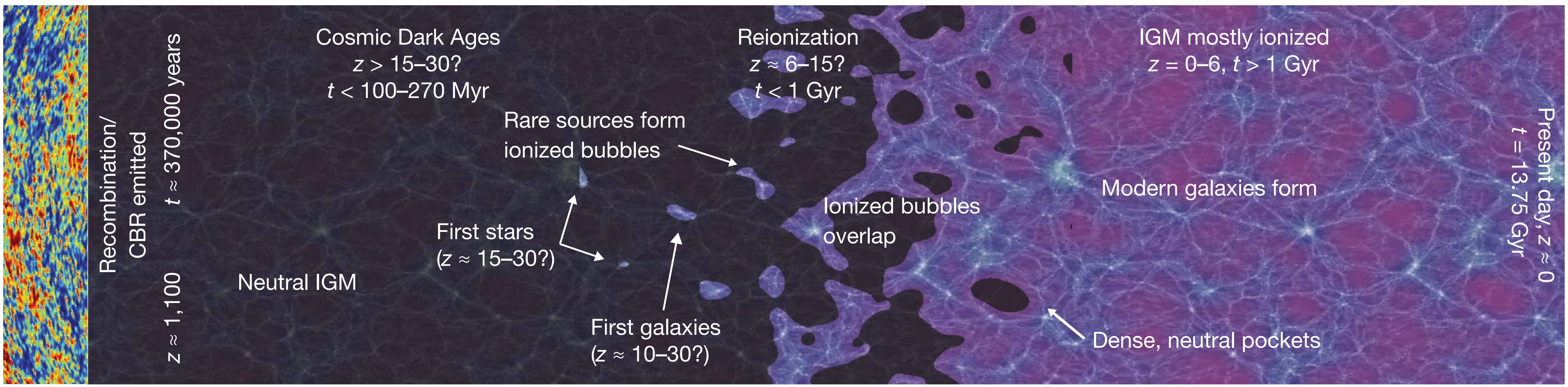
with Ewald Puchwein, Martin Haehnelt, Simeon Bird and James Bolton

As well as regulating star formation, feedback is important for metal enrichment

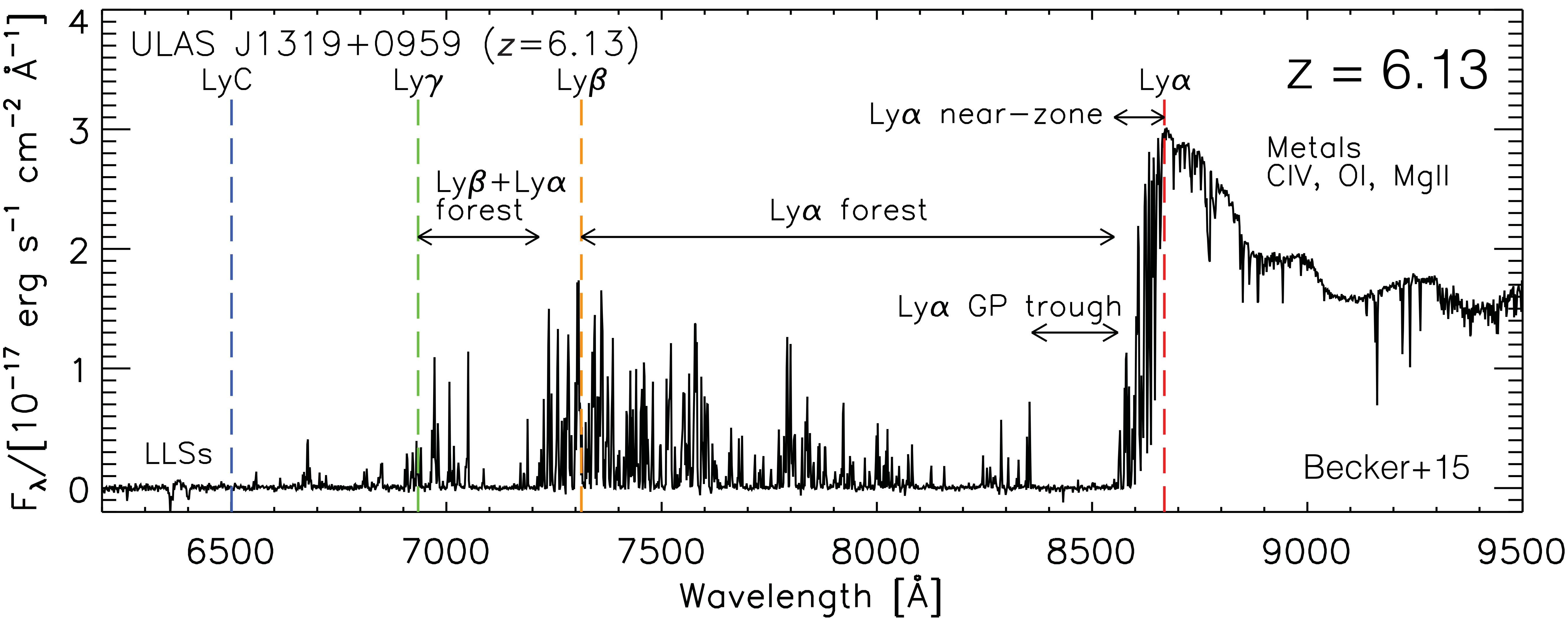
Open questions:

- How was the IGM enriched?
- When was it enriched?
- What is the metallicity of the IGM?

Important to test feedback schemes against different observations



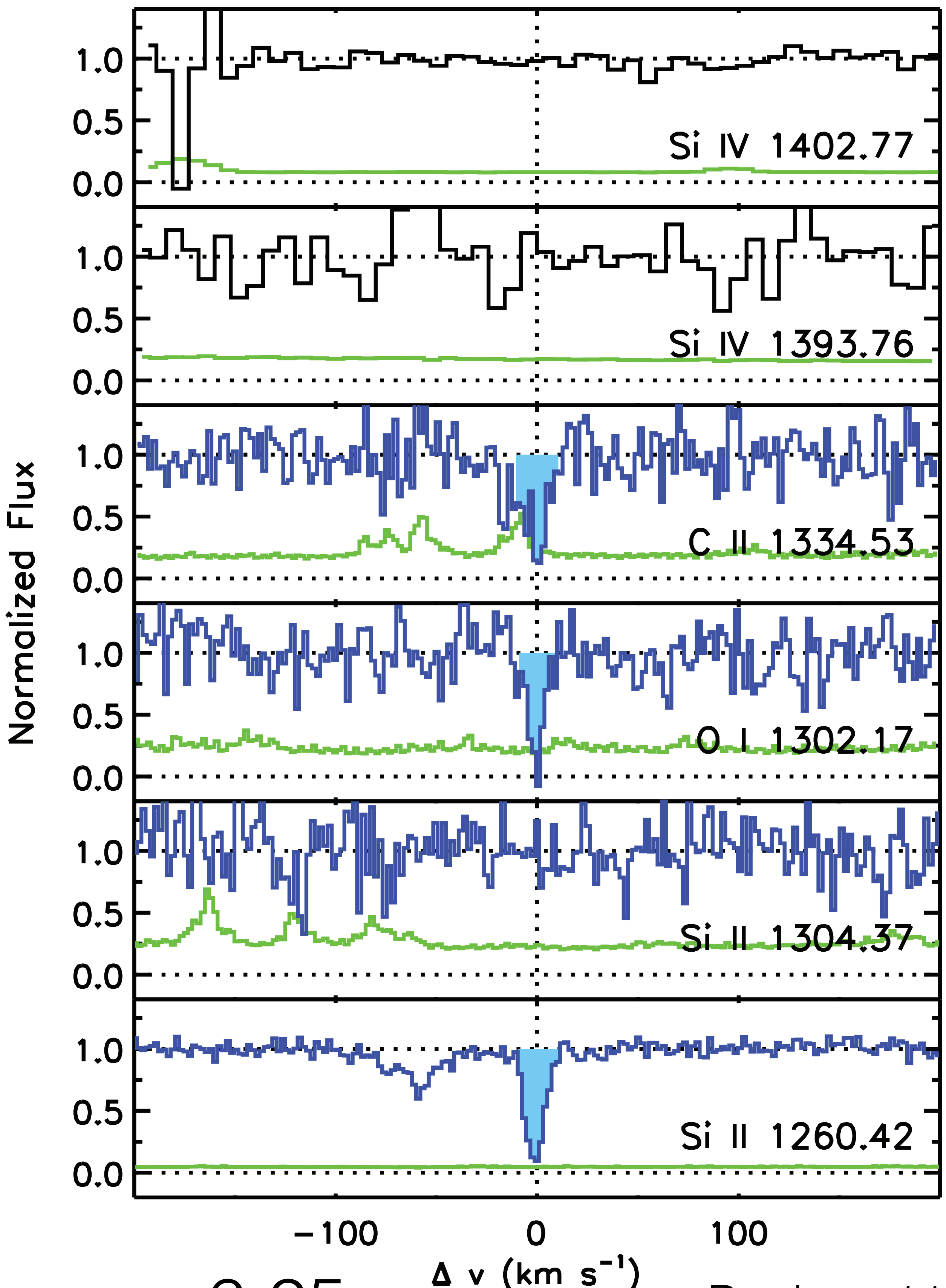
(ideally at high-redshift)



Metal lines contain information about the enrichment/ionization state of the IGM

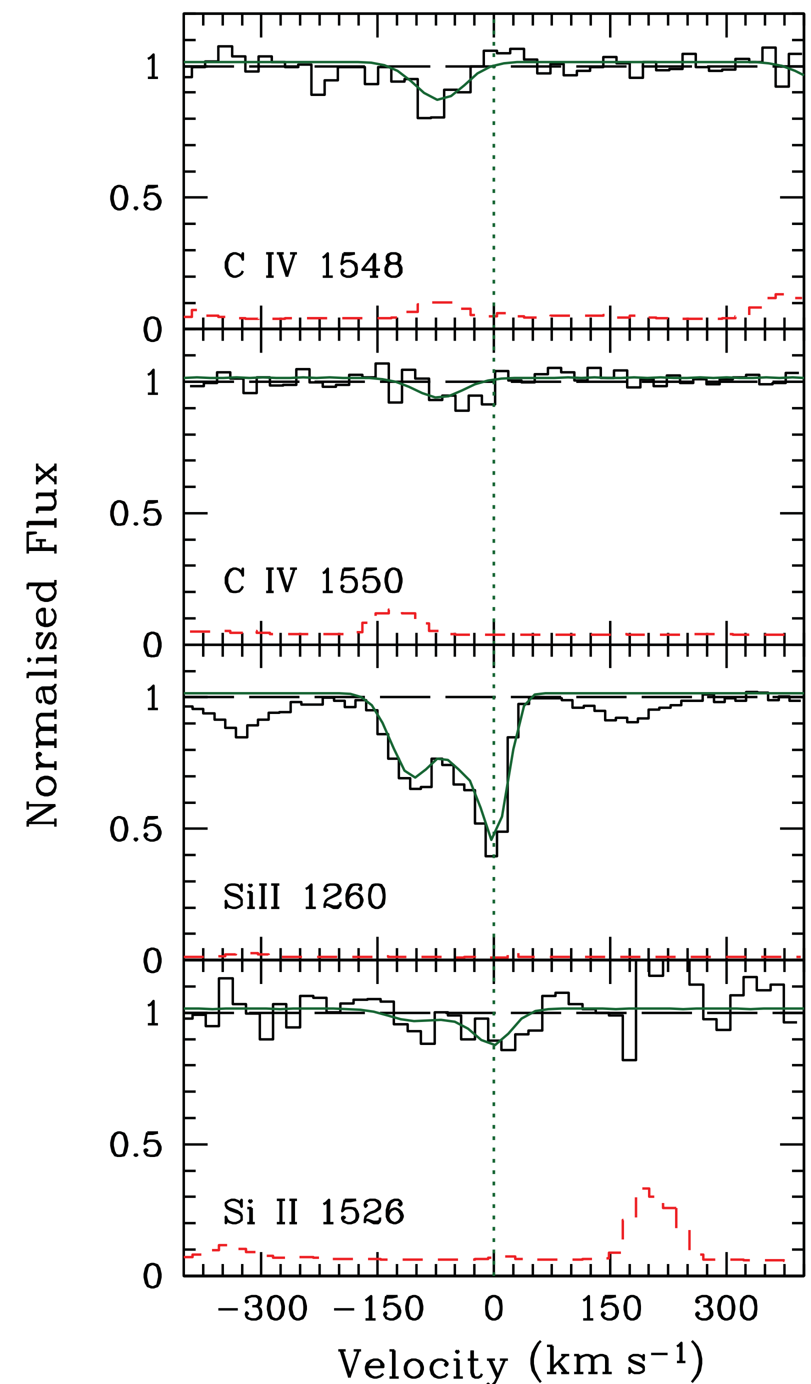
Great way to test feedback models

Nice sample of low- and high-ionization metal lines out past z = 6



z = 6.25

Becker+11



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D'Odorico+13

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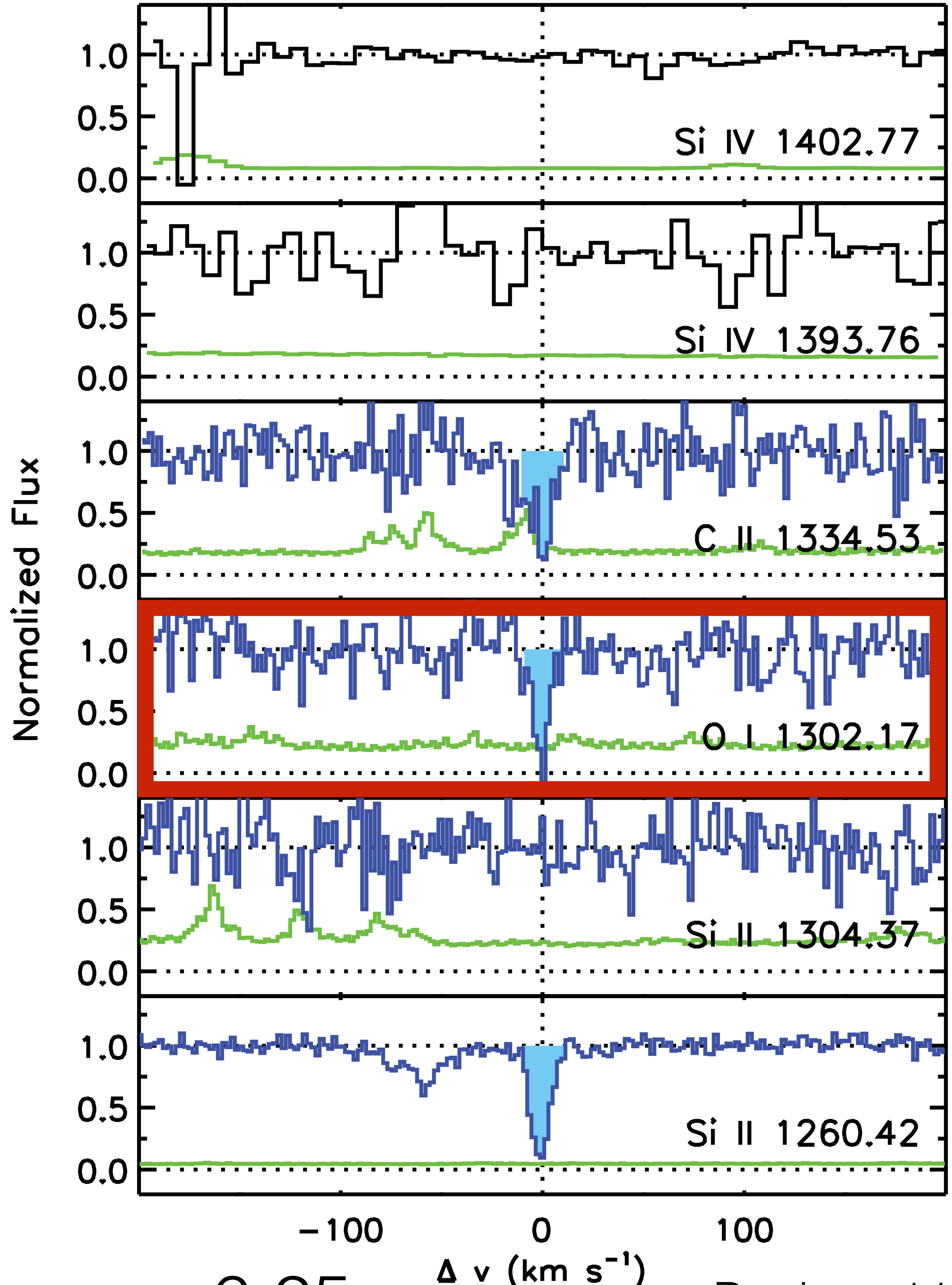

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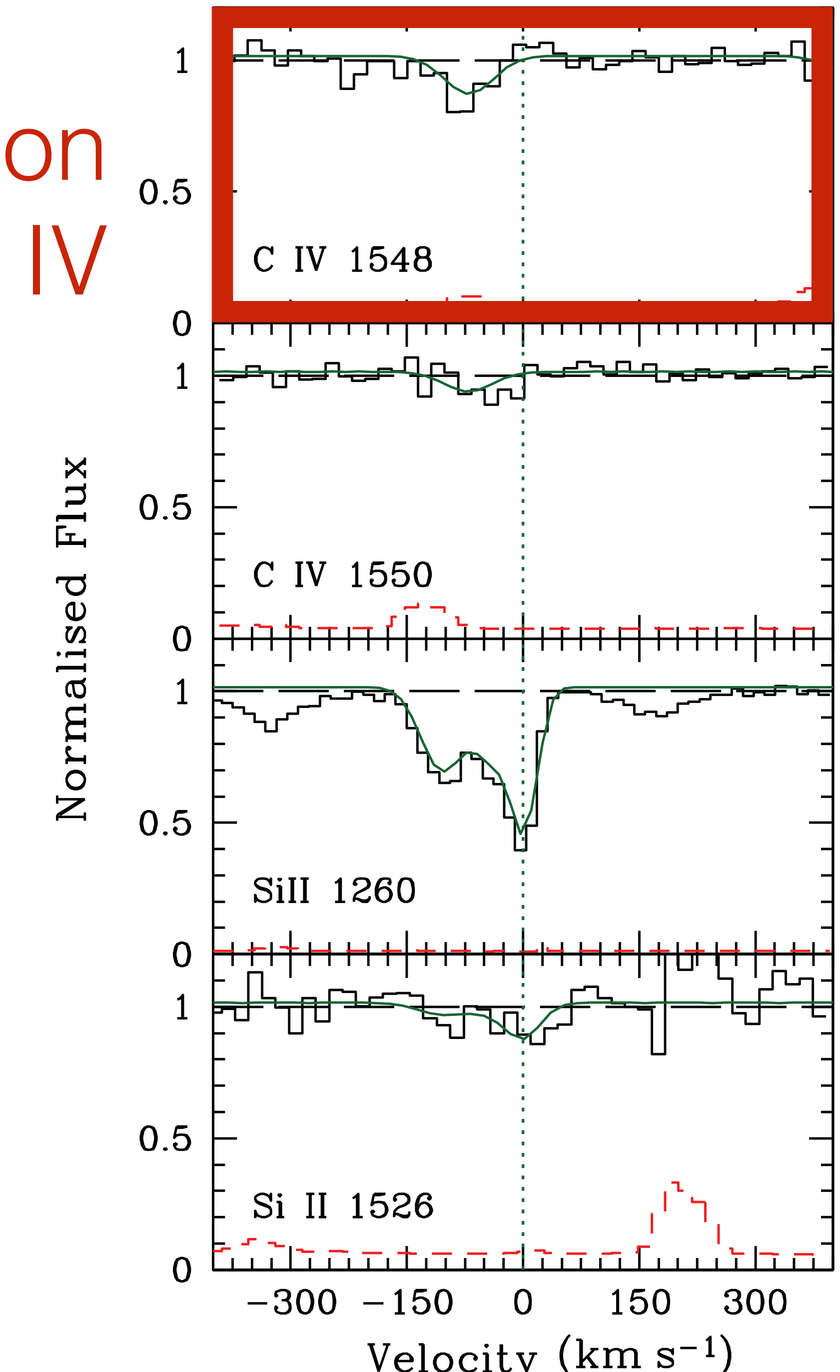
will focus on O I and C IV here



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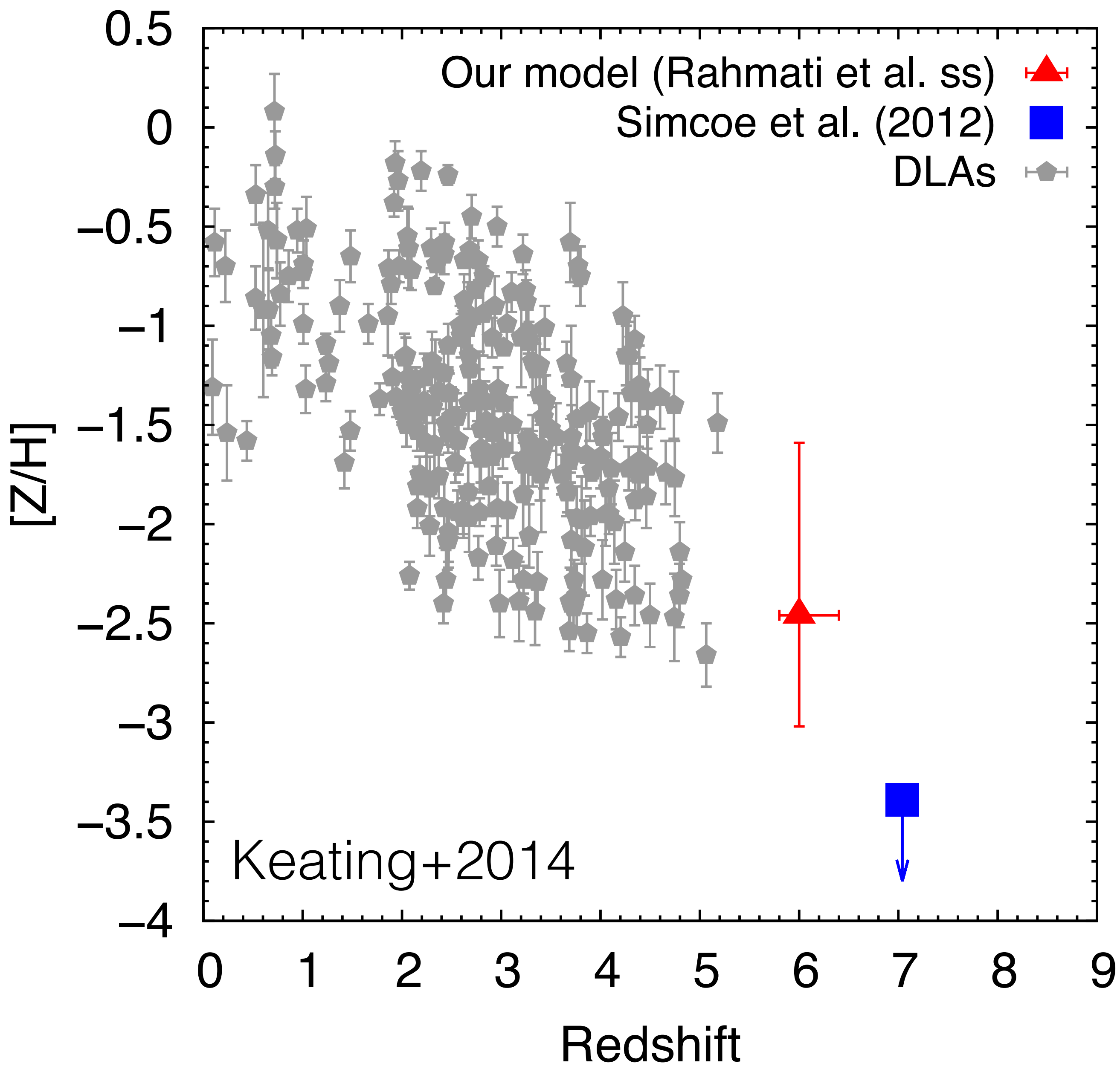
Previously: Used O I absorption to measure the IGM metallicity at z ~ 6



Simple model:

$$Z = 10^{-2.65}\, Z_{\odot} \left(\frac{\Delta}{80} \right)^{1.3}$$

(but degeneracy between metallicity and UV background)

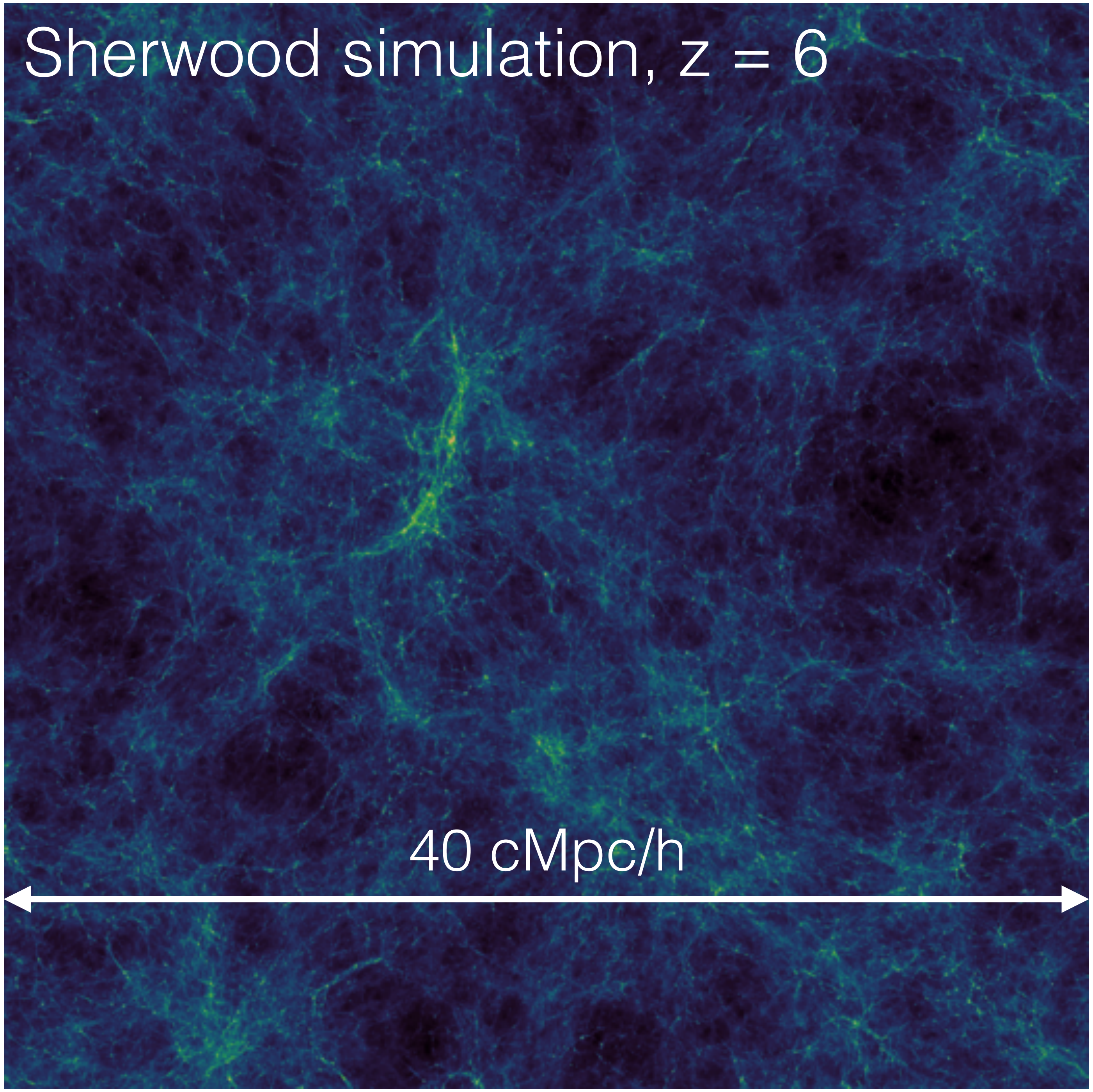
Four feedback models, two different codes

AREPO:

- Illustris
  (Vogelsberger+14)
- + 2 feedback variations
  (Bird+14,15)

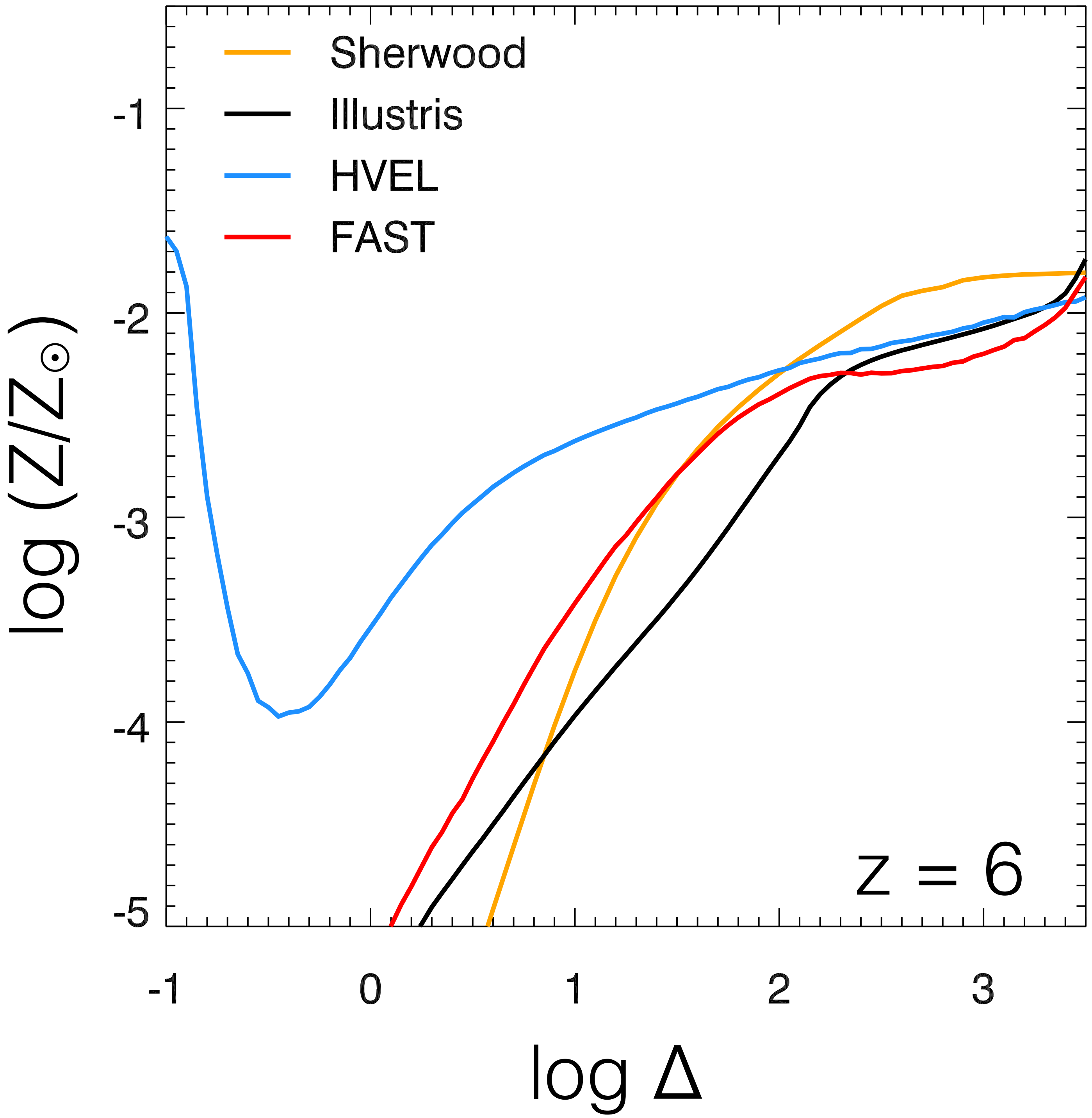
GADGET-3:

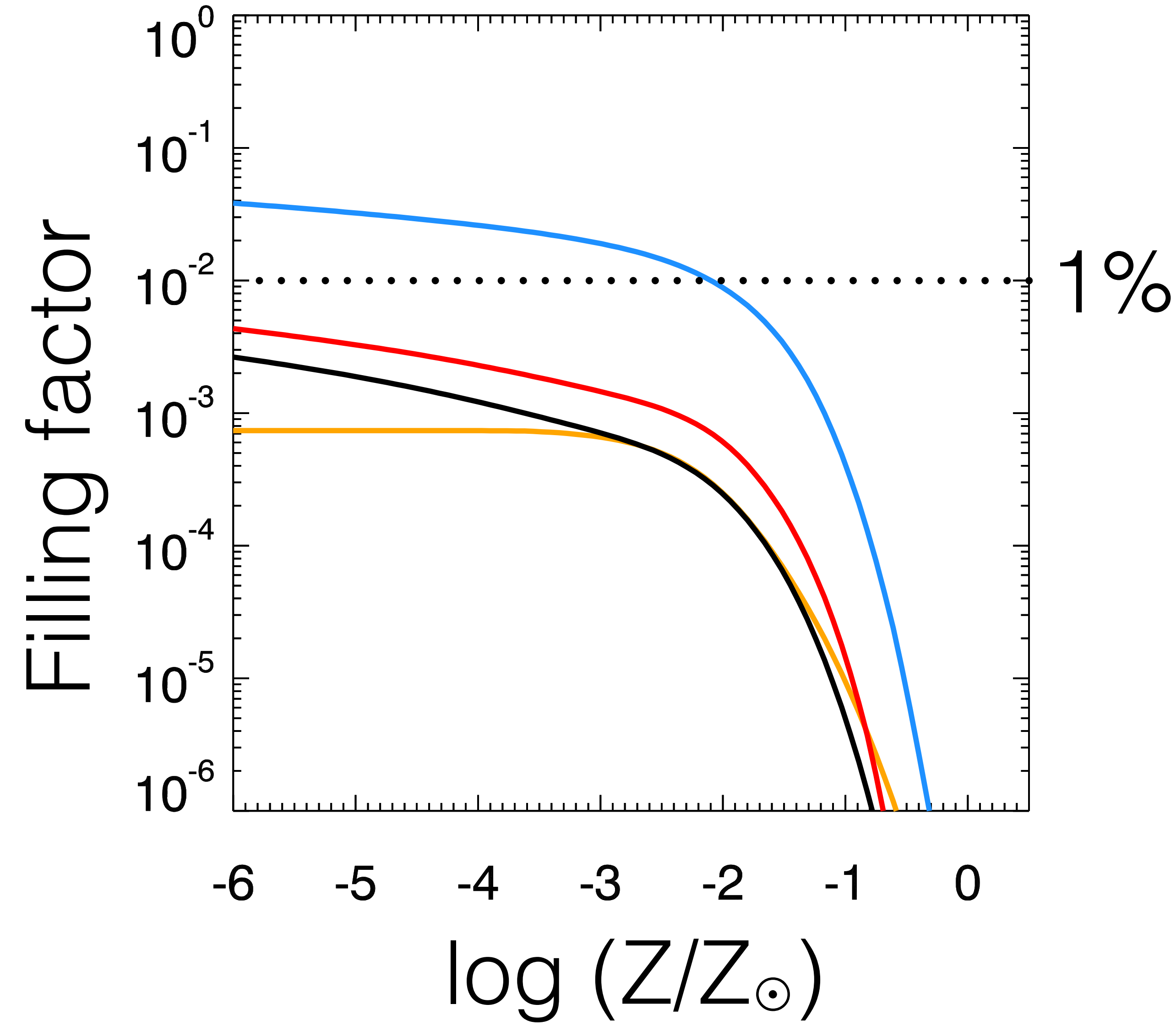
- Sherwood
  (Bolton+16)

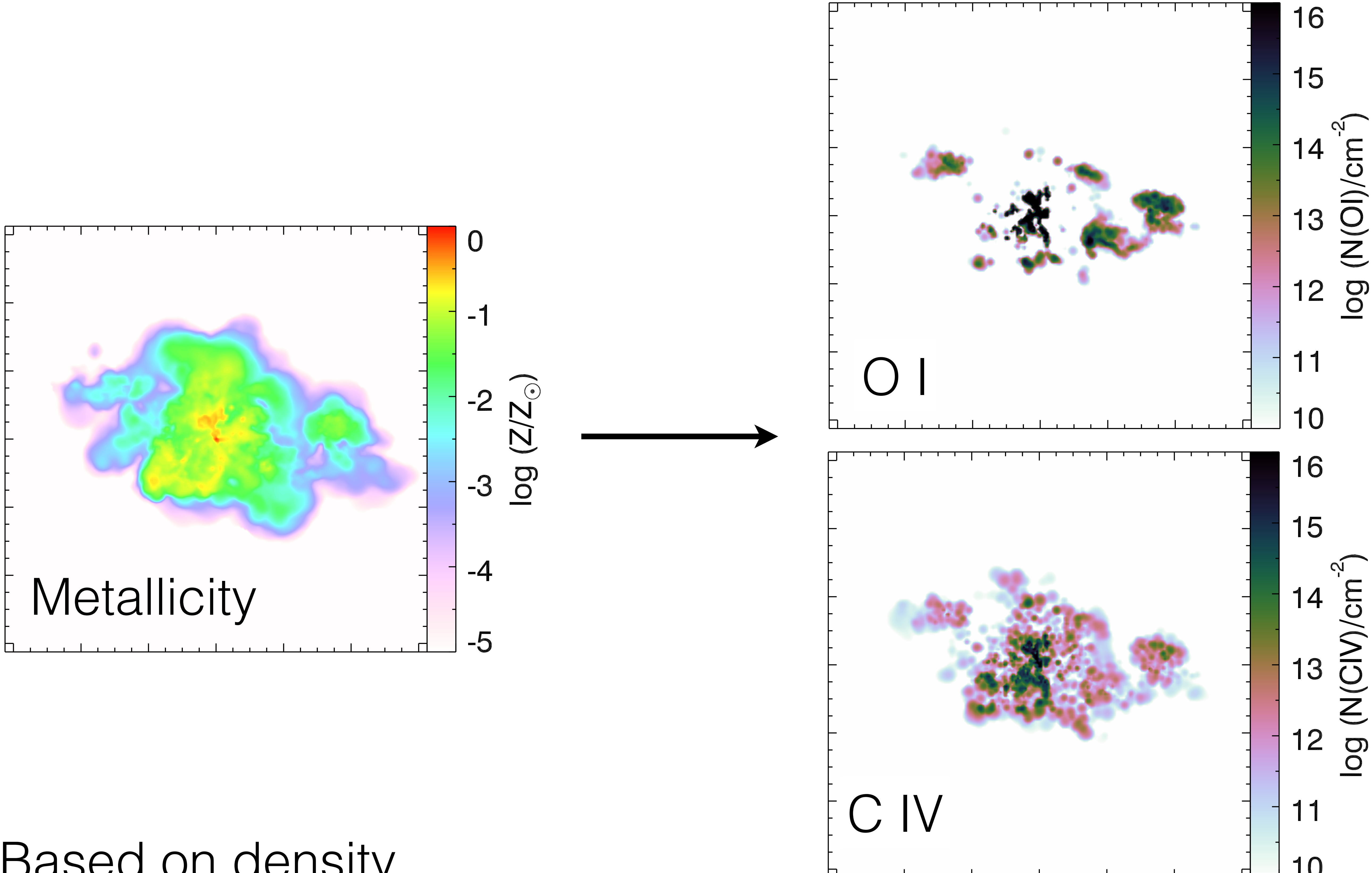


Three "reasonable" models, one "extreme"

Faster winds more efficiently enrich the low-density IGM

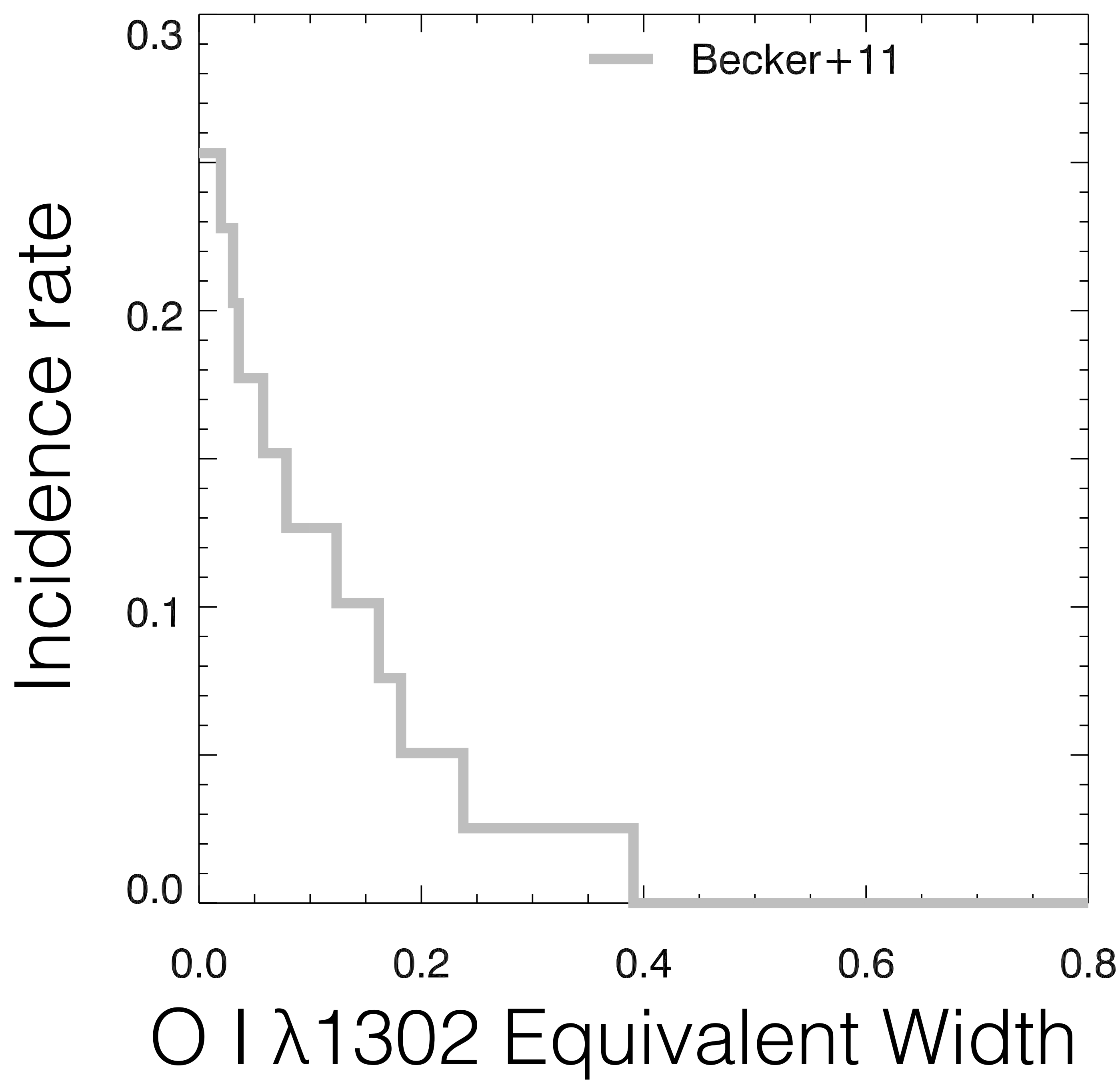


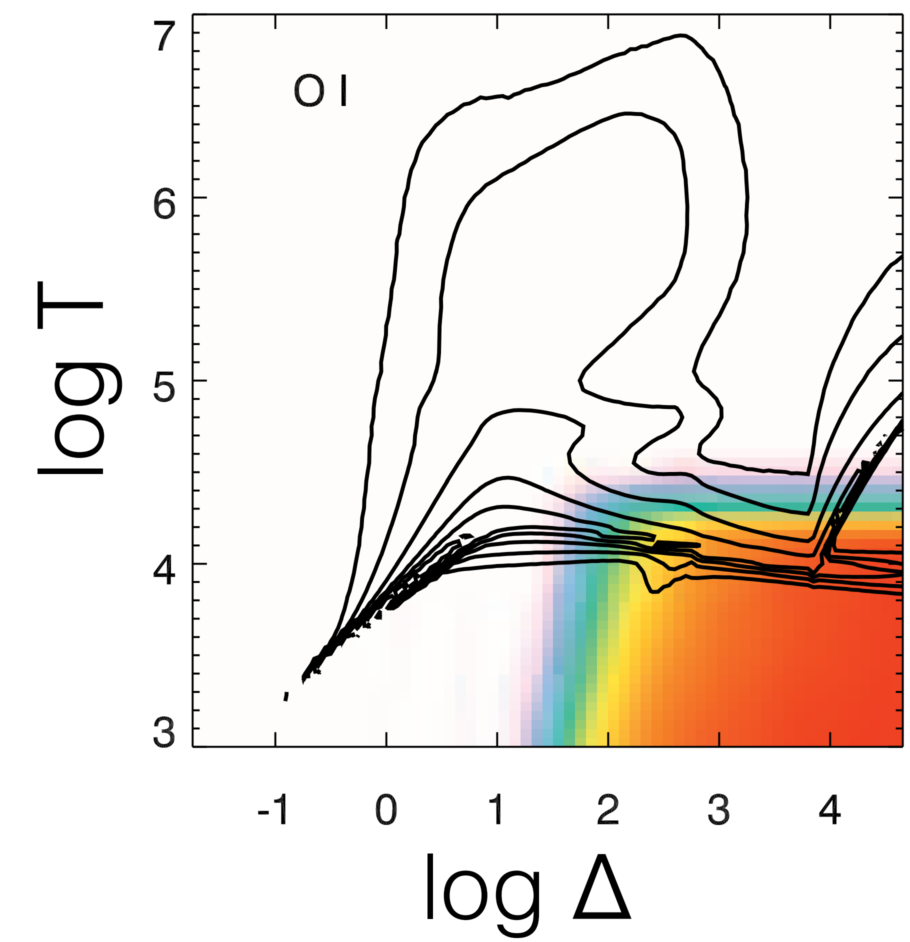




Based on density,
temperature, UV background

Cumulative distribution of equivalent widths: O I





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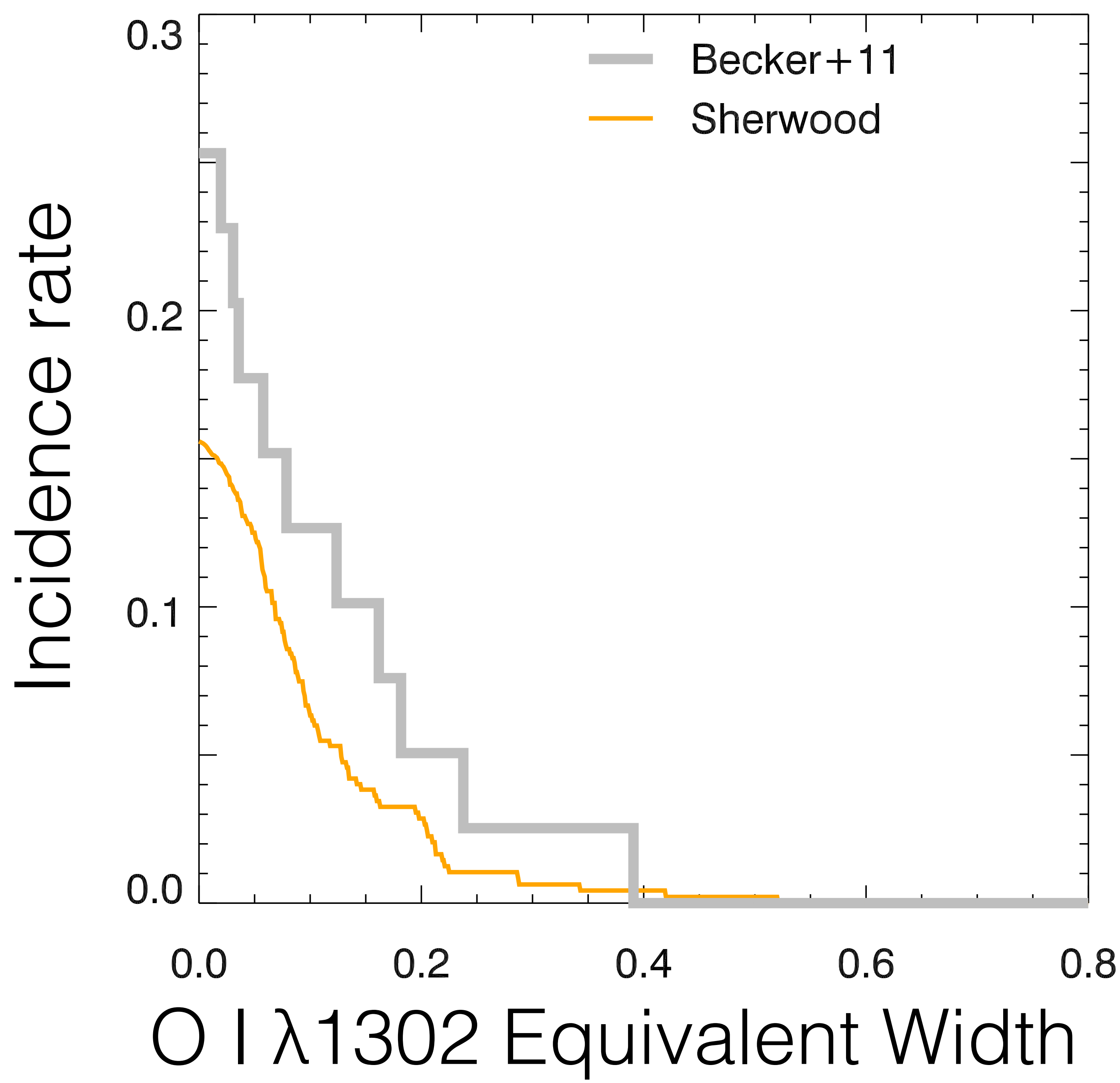

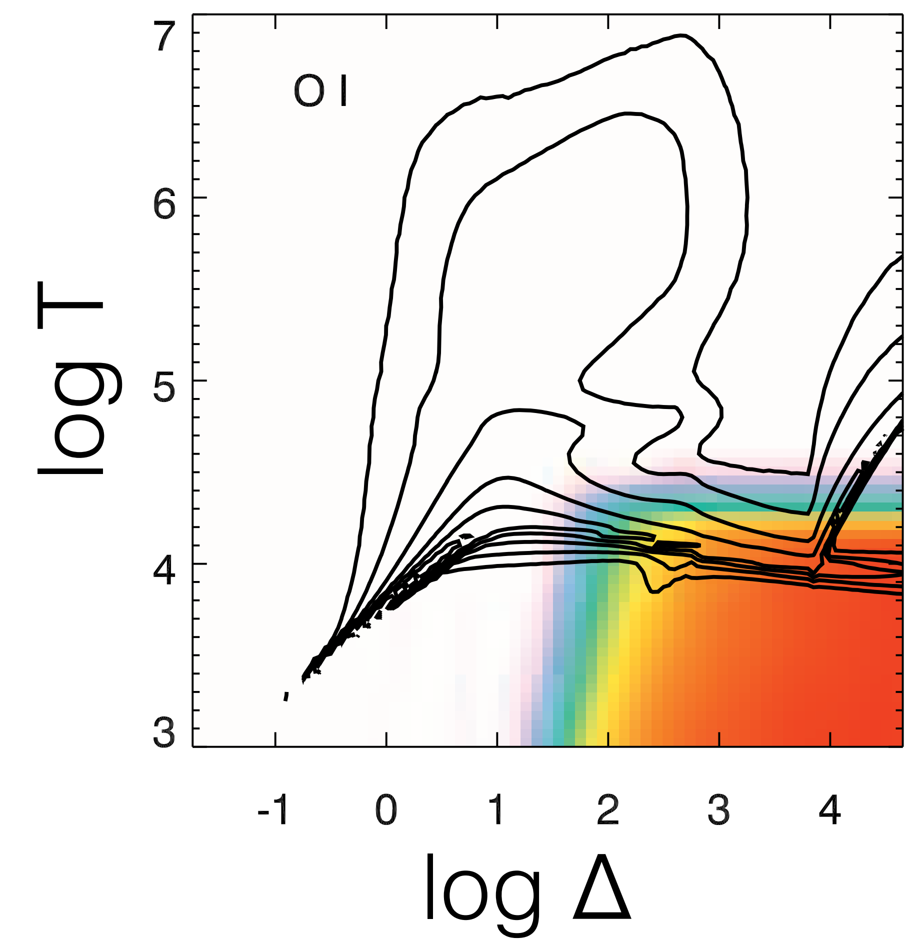

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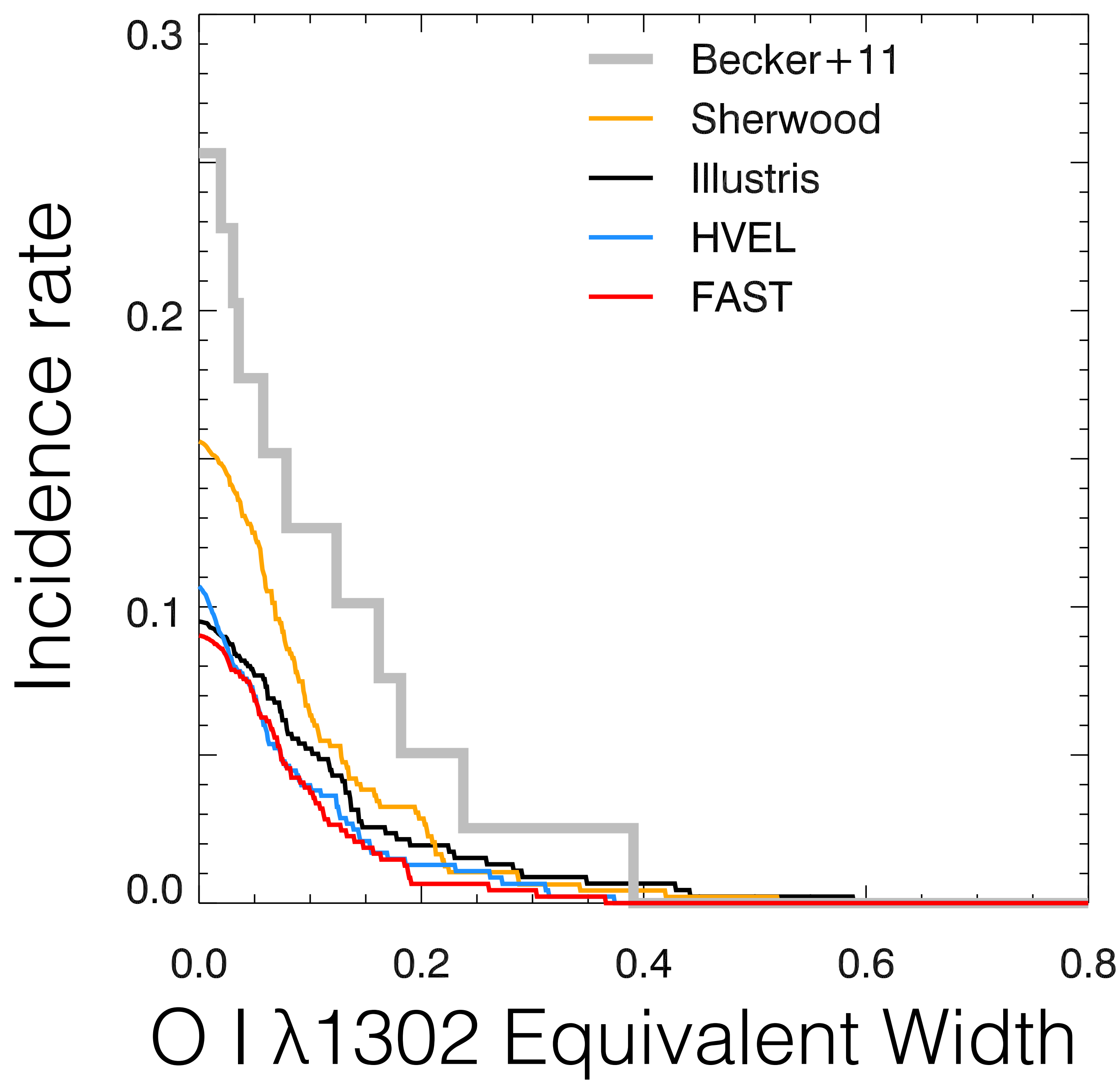

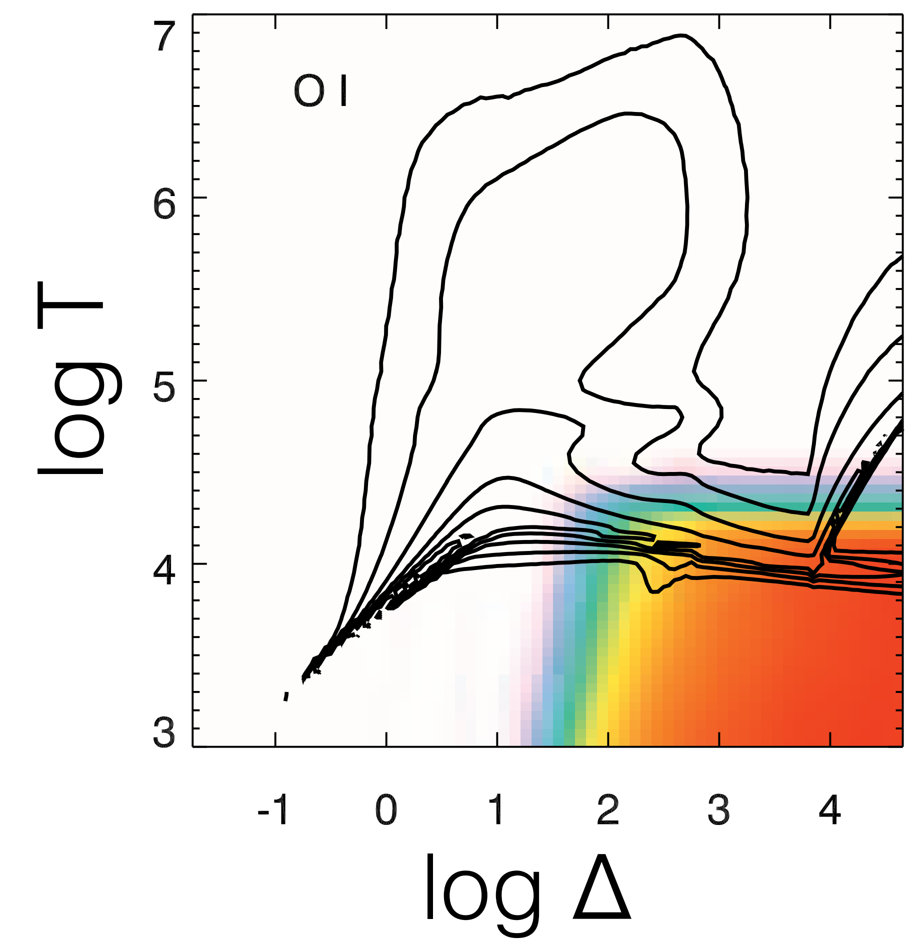

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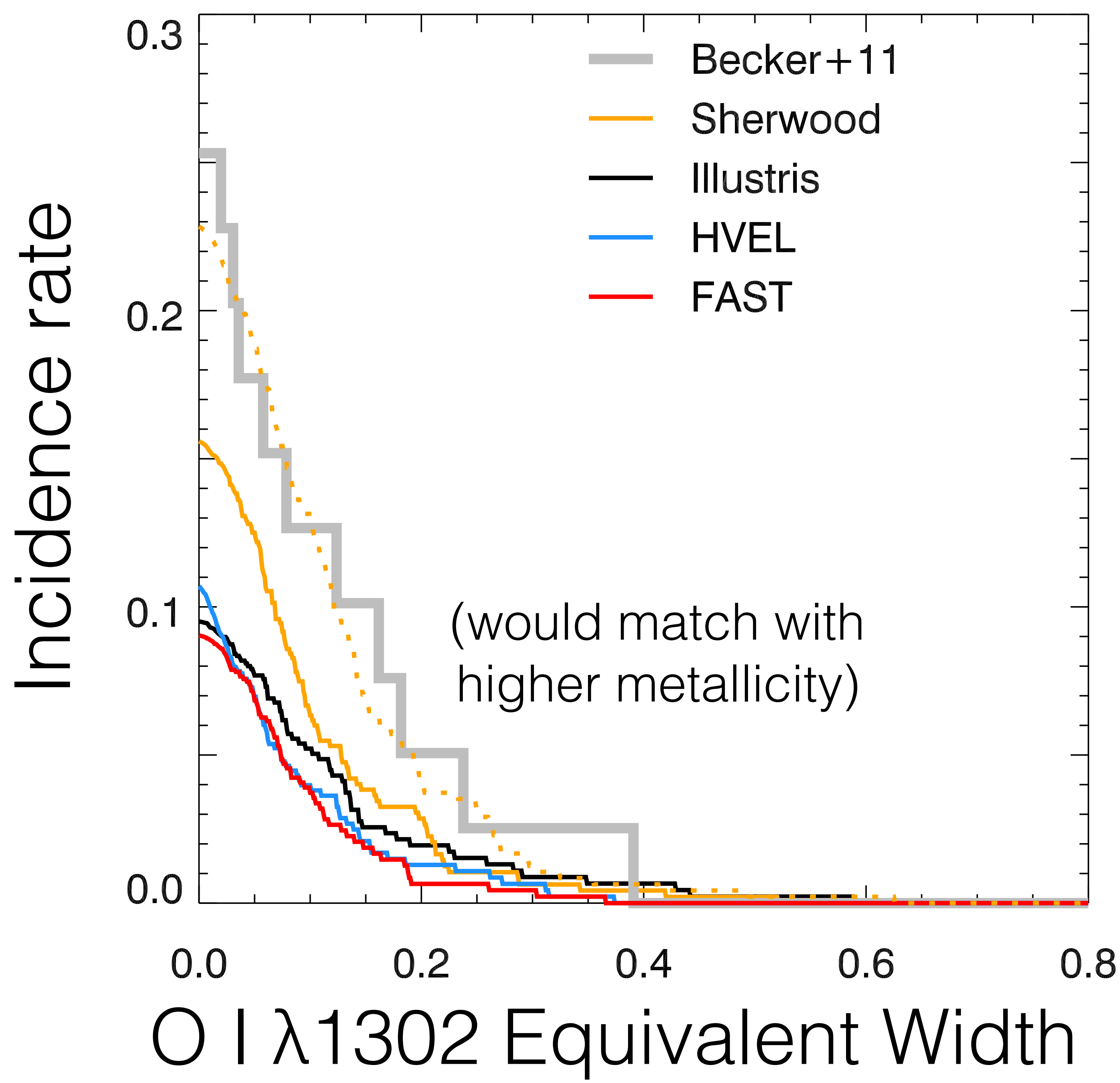
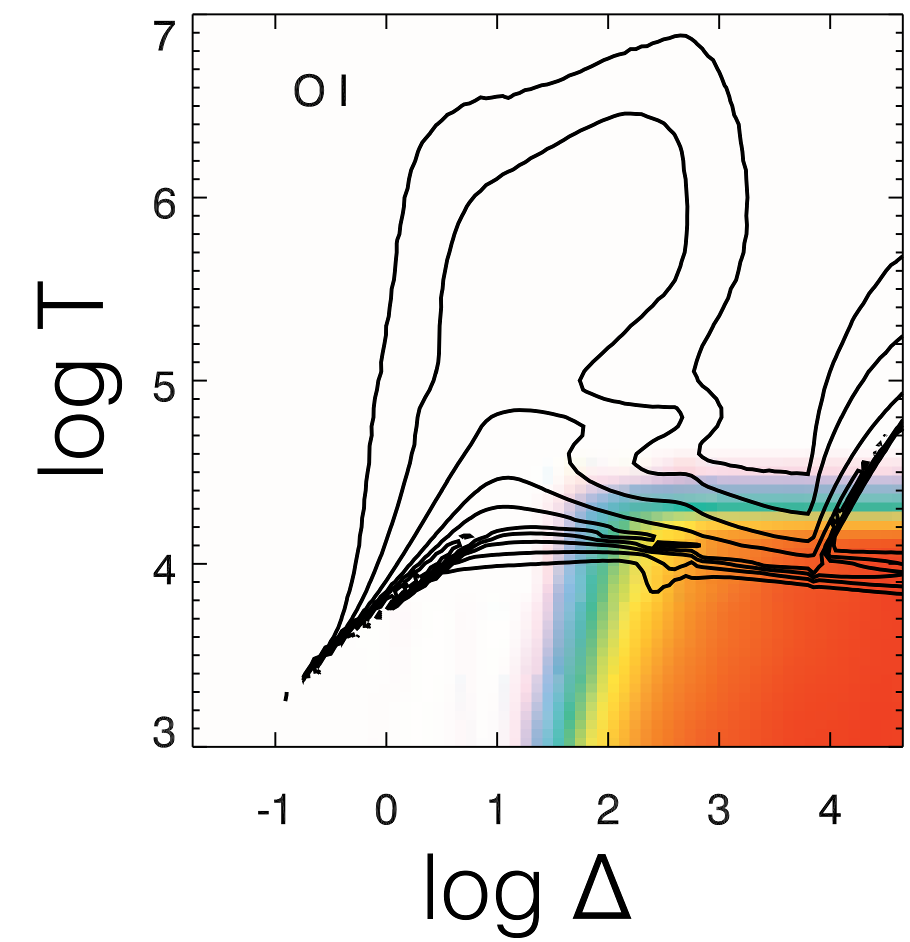
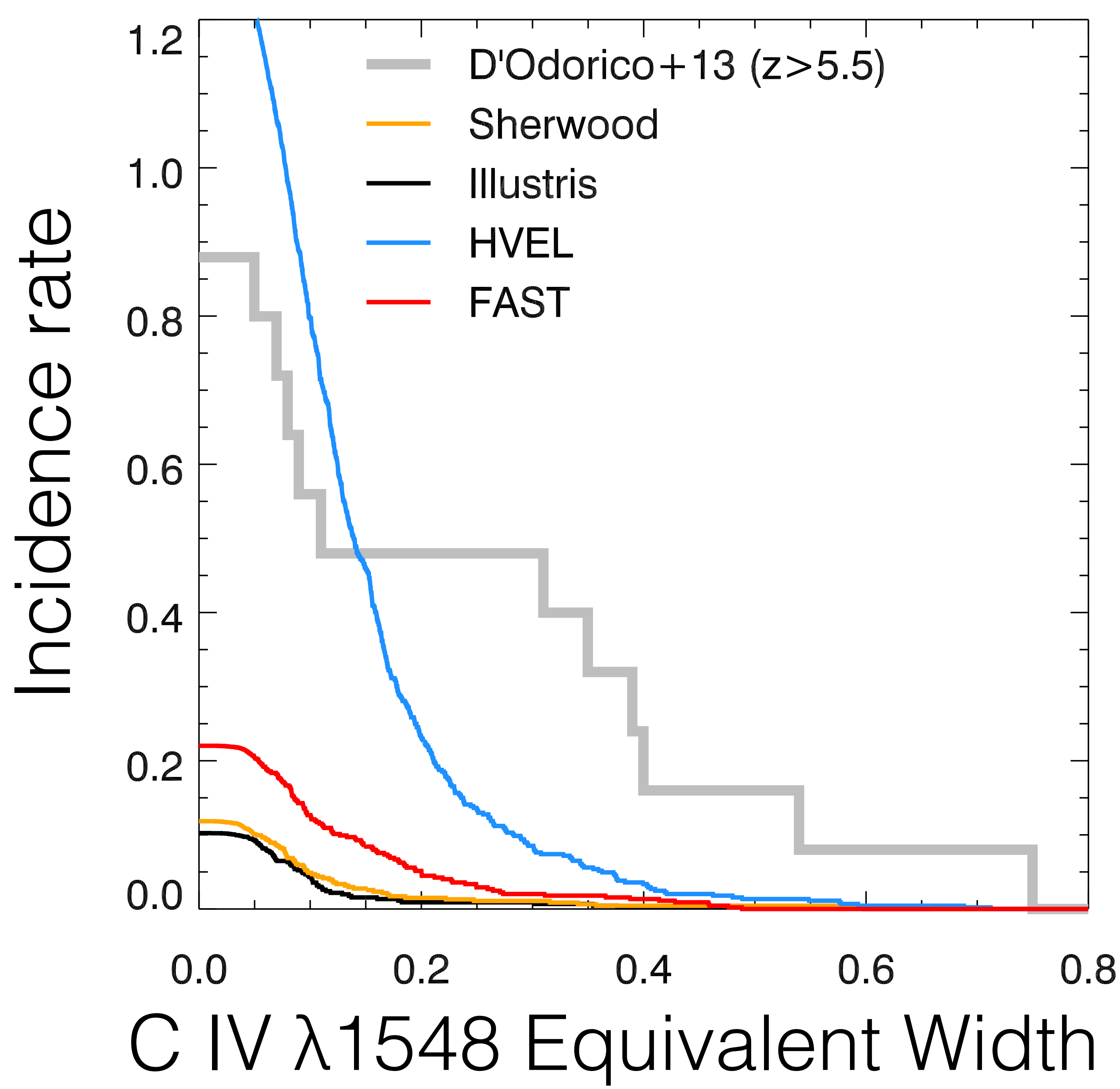
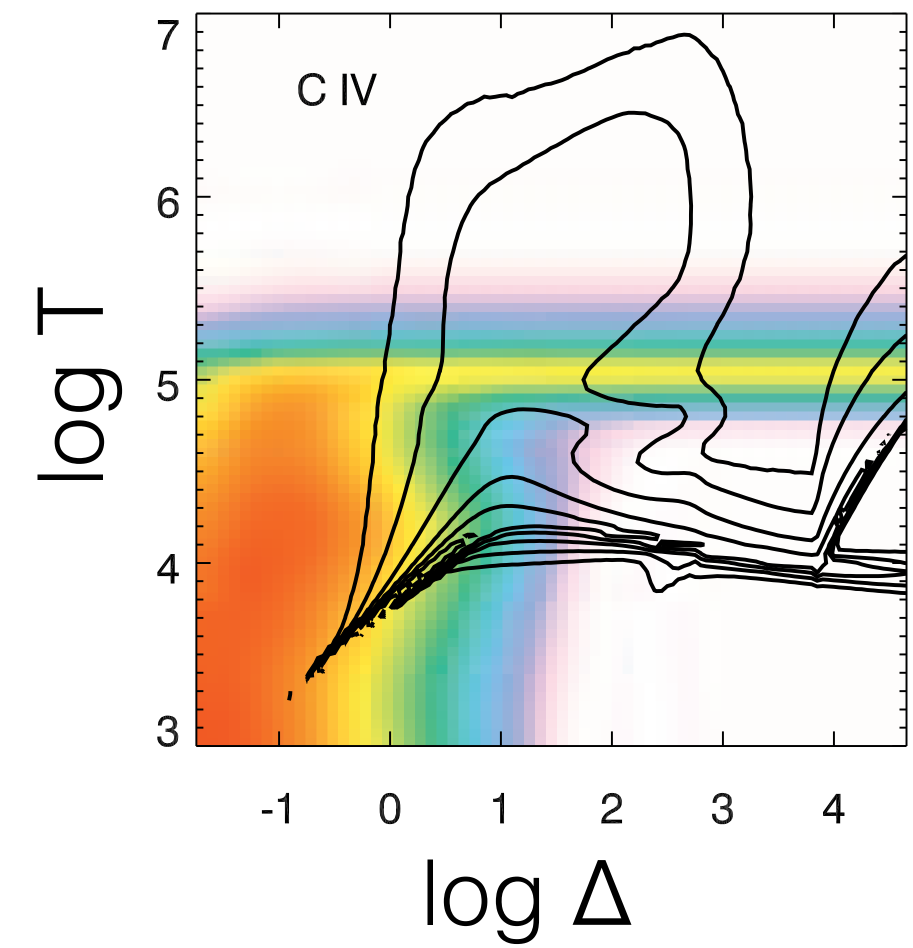


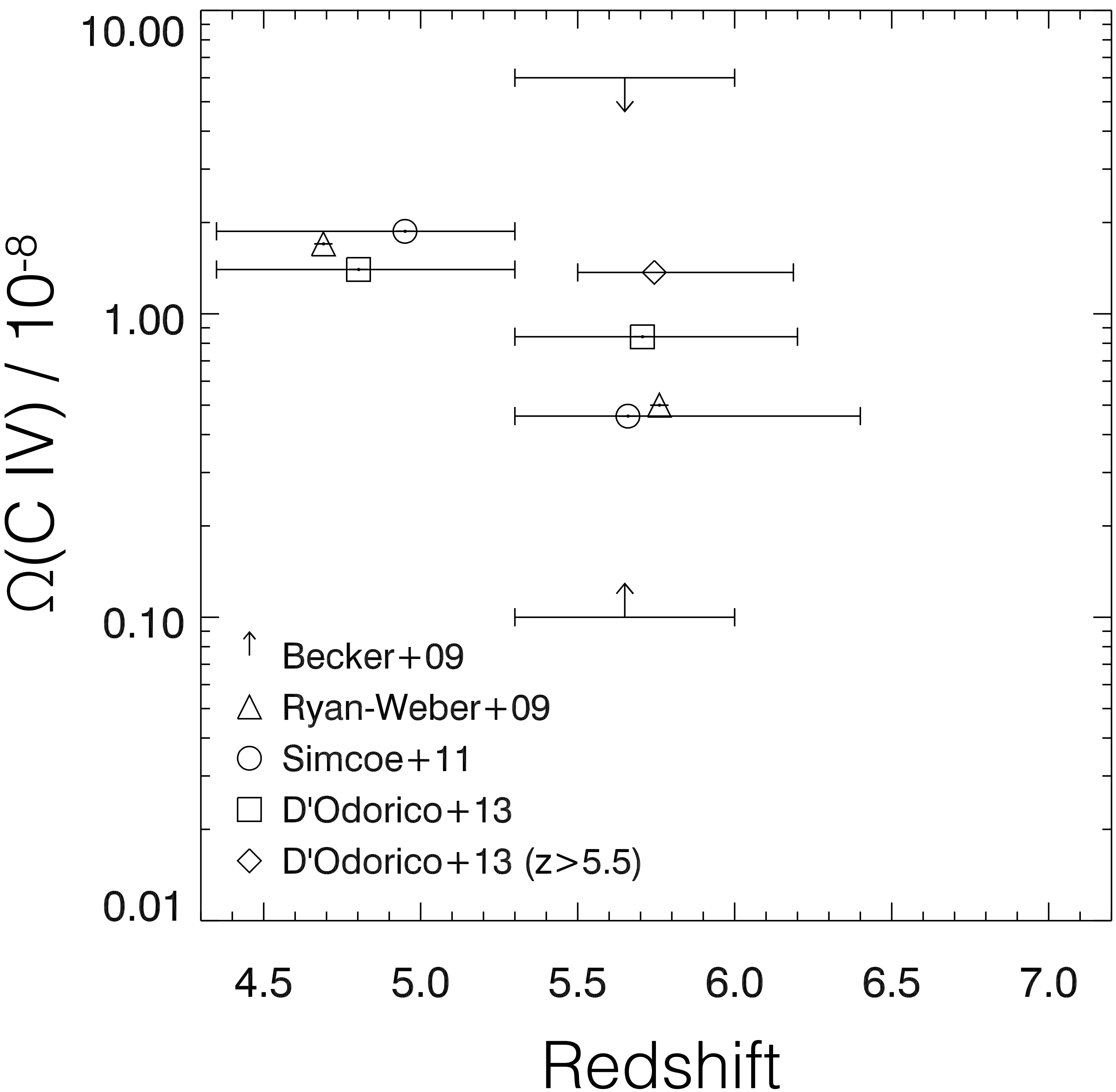


Cumulative distribution of equivalent widths: C IV





Evolution of C IV mass density with redshift



$$\Omega_{\mathrm{C\,IV}} = \frac{H_0\, m_{\mathrm{C\,IV}}}{c\, \rho_{\mathrm{crit}}} \int N f(N) \mathrm{d}N$$

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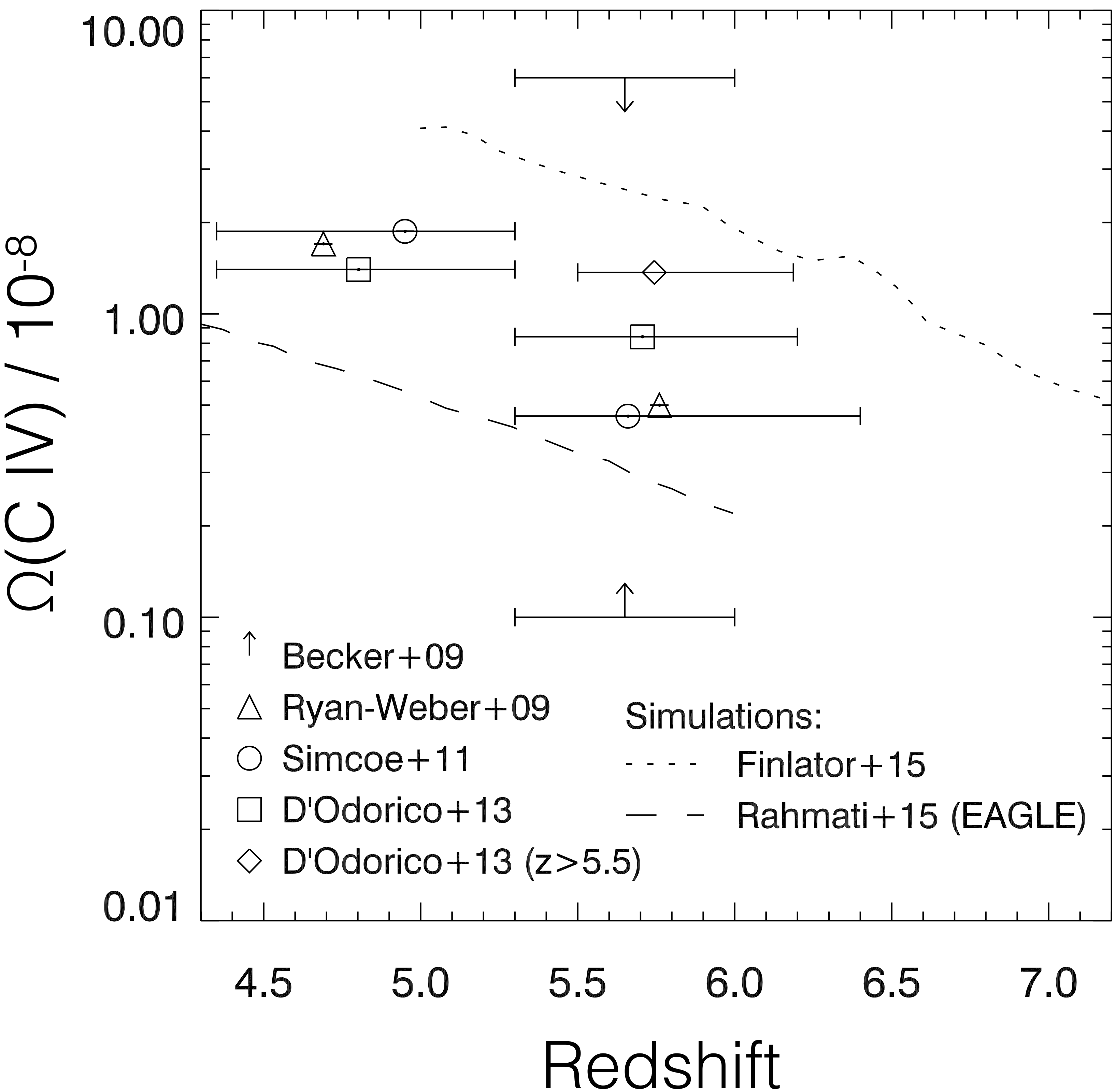

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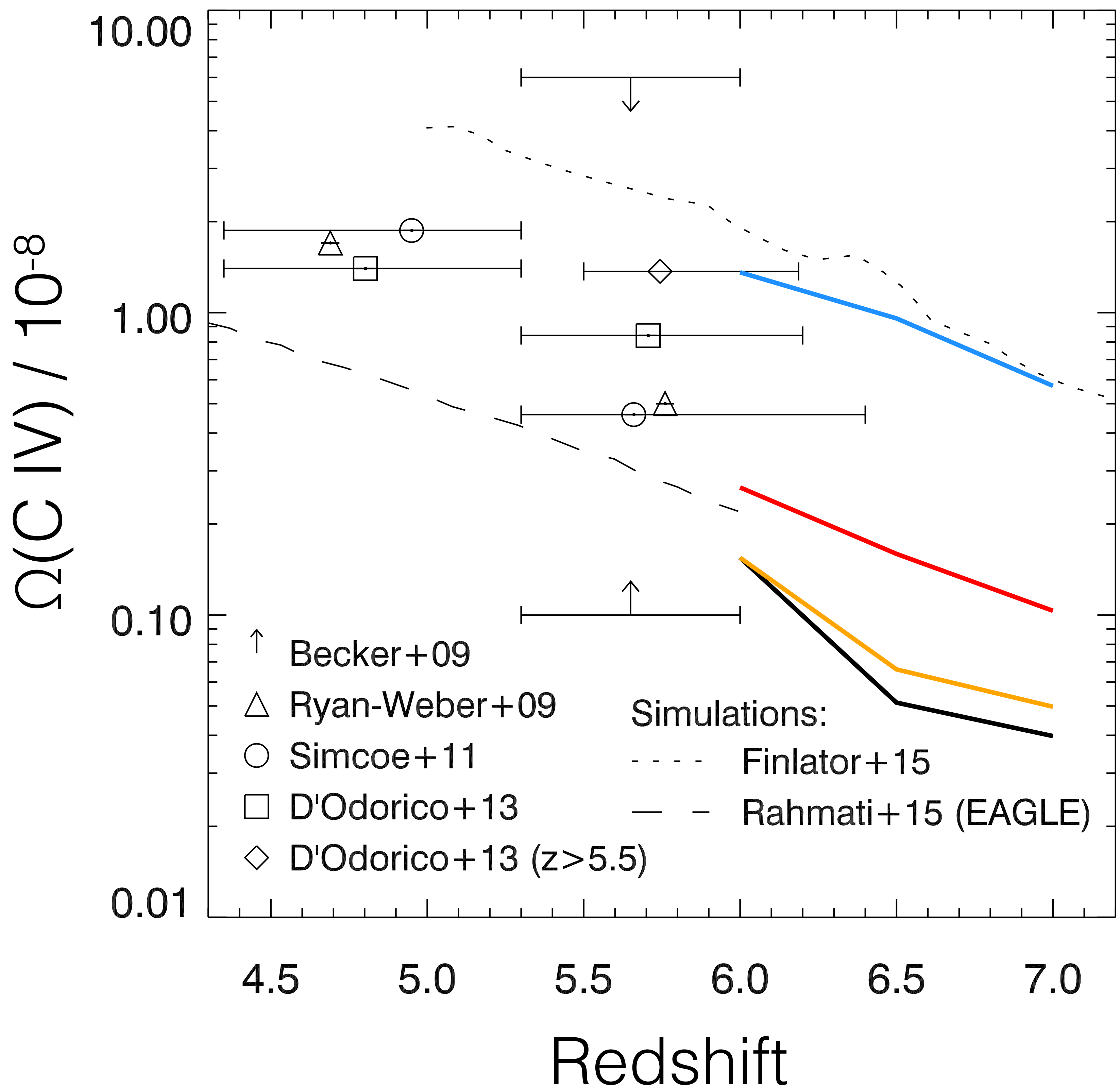
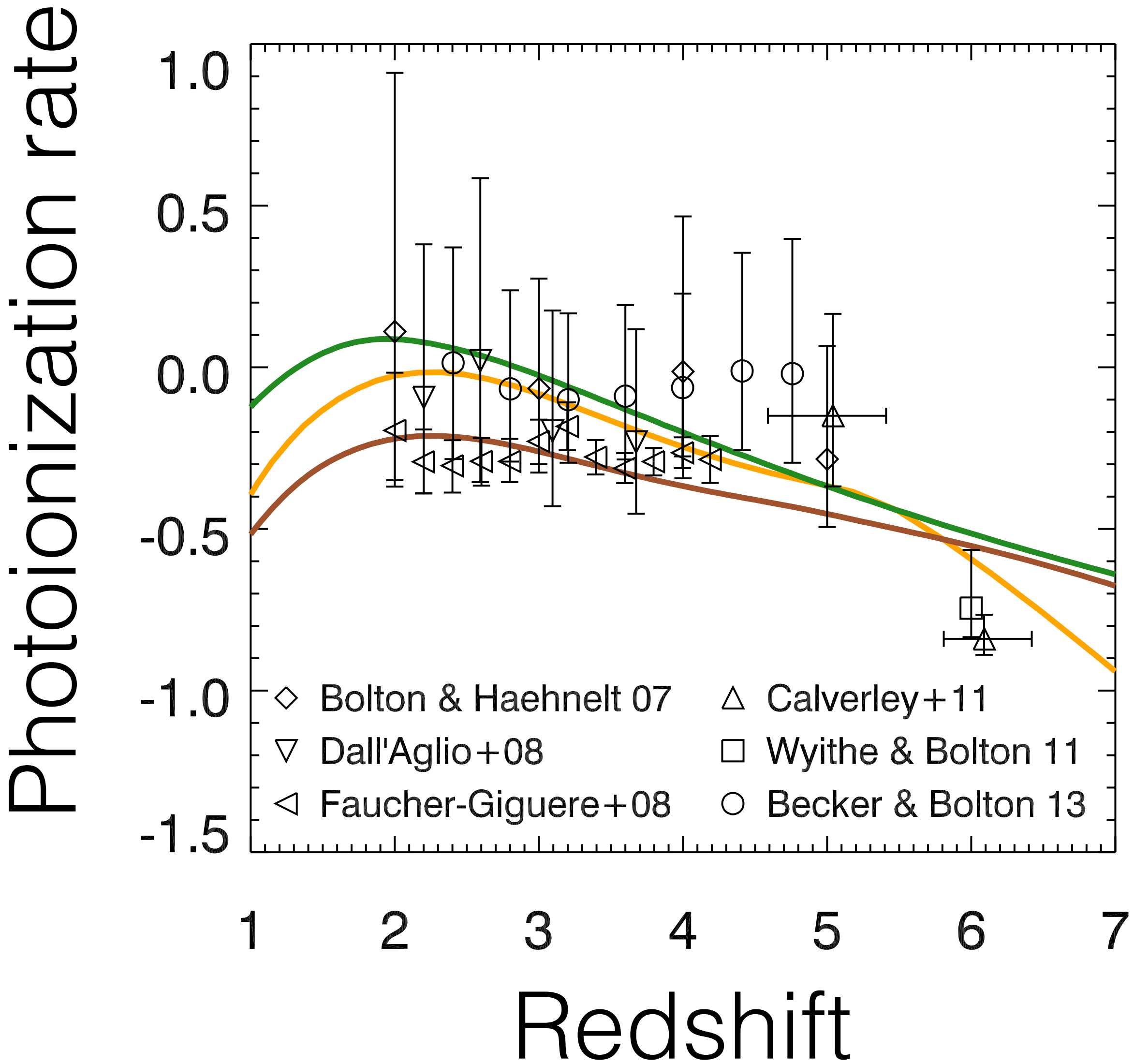
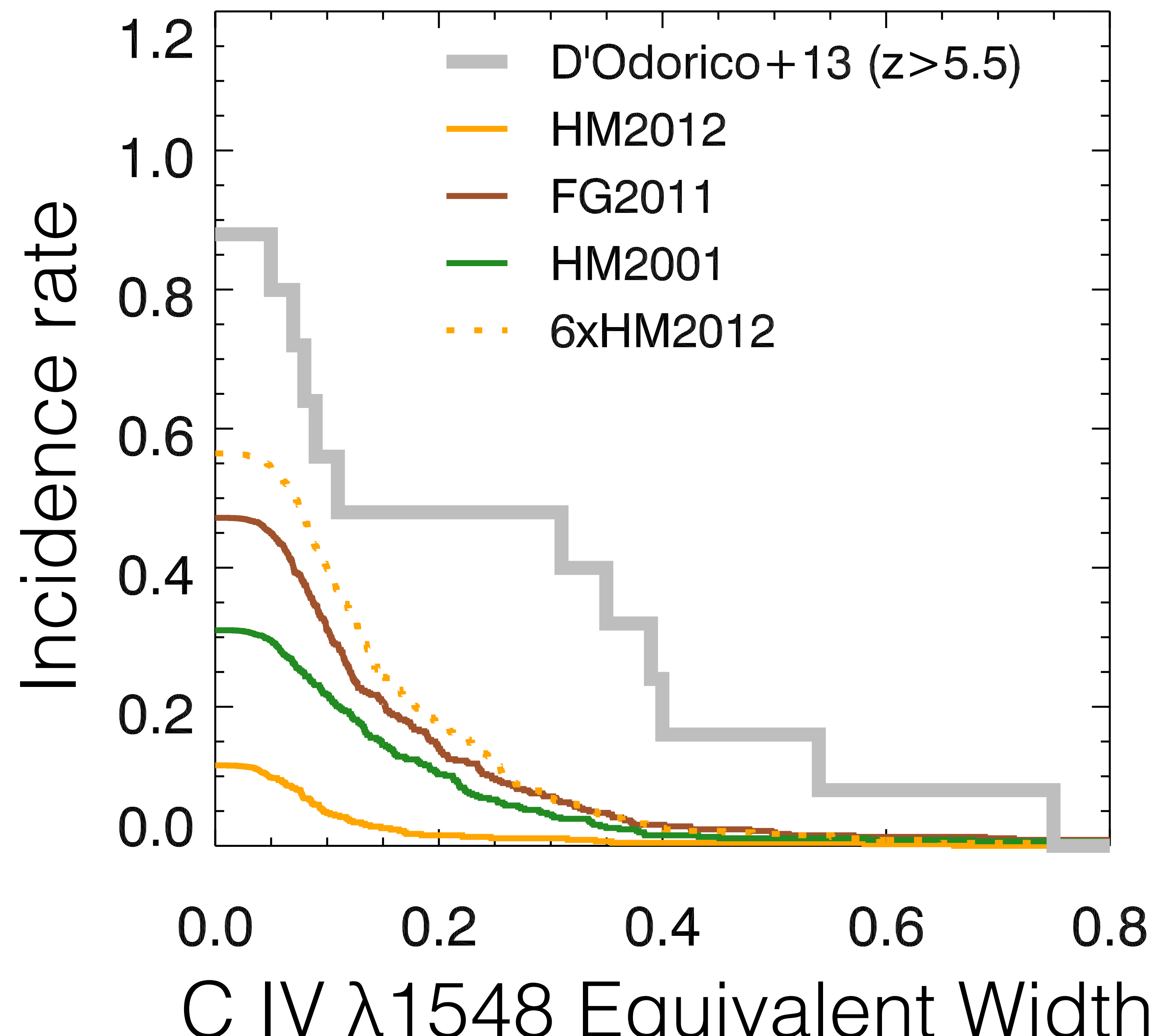


$$\Omega_{\mathrm{C\,IV}} = \frac{H_0\, m_{\mathrm{C\,IV}}}{c\, \rho_{\mathrm{crit}}} \int N f(N) \mathrm{d}N$$

Why are we not finding C IV in the simulations?

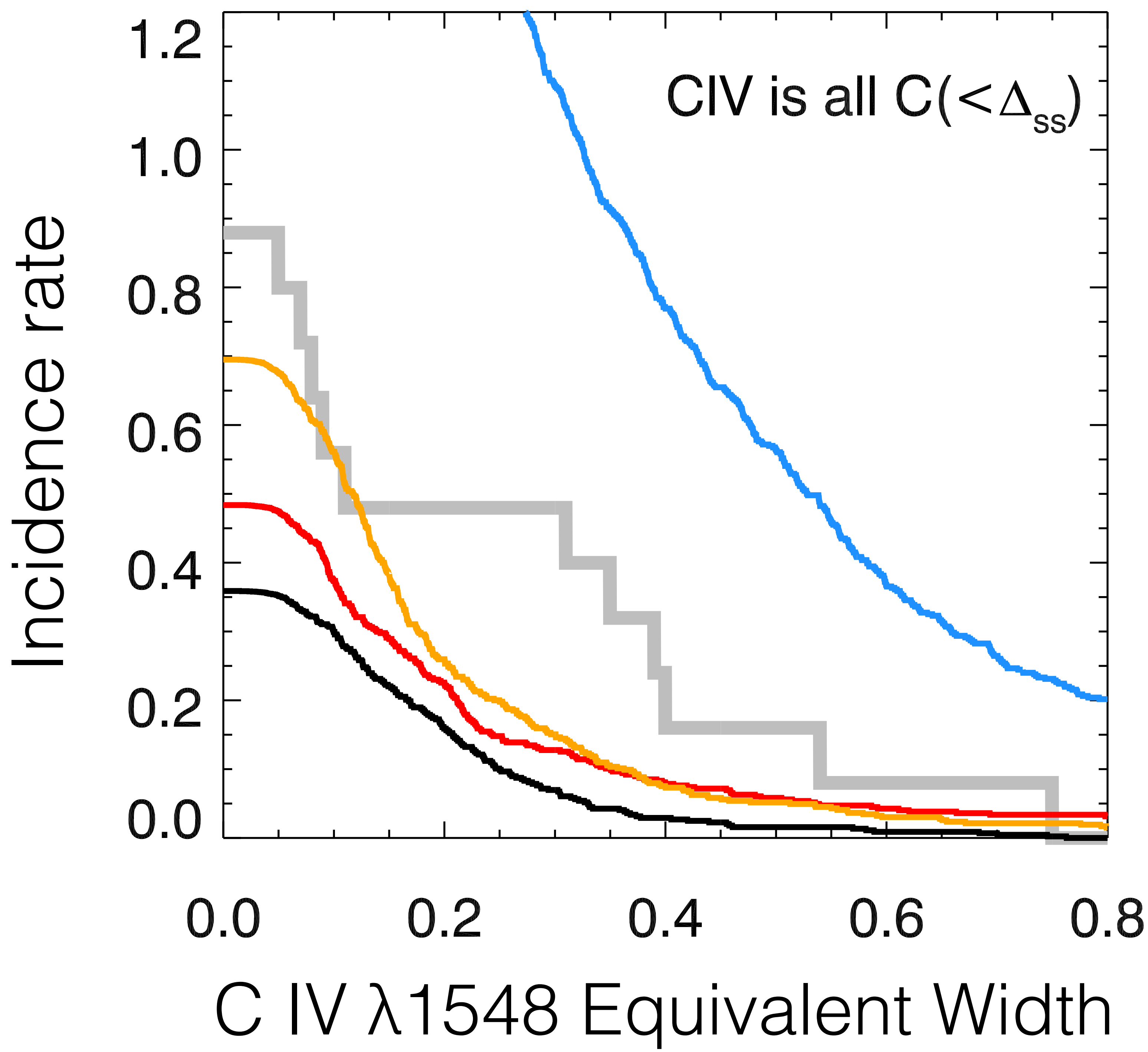
- Temperature of the gas not right? (Too hot?)
- Need a harder/locally amplified UV background?
- Winds not enriching the IGM out to low enough densities?





Choosing a different UVB (harder/higher amplitude) helps, but doesn't produce the strong absorbers

What if all carbon in non self-shielded gas was C IV?



Even for this extreme test, most models struggling

- The IGM appears to be enriched efficiently early on (predominantly by the small/faint galaxies that are believed to drive reionization?)

- Low-ionization absorbers reasonably robust to choice of feedback scheme/hydro-solver

- Do we need stronger/more efficient winds particularly in low mass galaxies? Are the simulations not implementing the correct wind physics?