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What do we know for sure about the reionization history?

Apr 24, 2012

KITP DwarfGal12

Slide-by-Slide Outline

(this slide does not count towards the 5 ;))

1. HeII reionization WAS ending at z=3

2. New constraints on patchiness and duration of reionization from kinetic SZ (2 slides!)

3. What does the hydrogen Lyα forest tell us?

4. Constraints on harder sources than stars

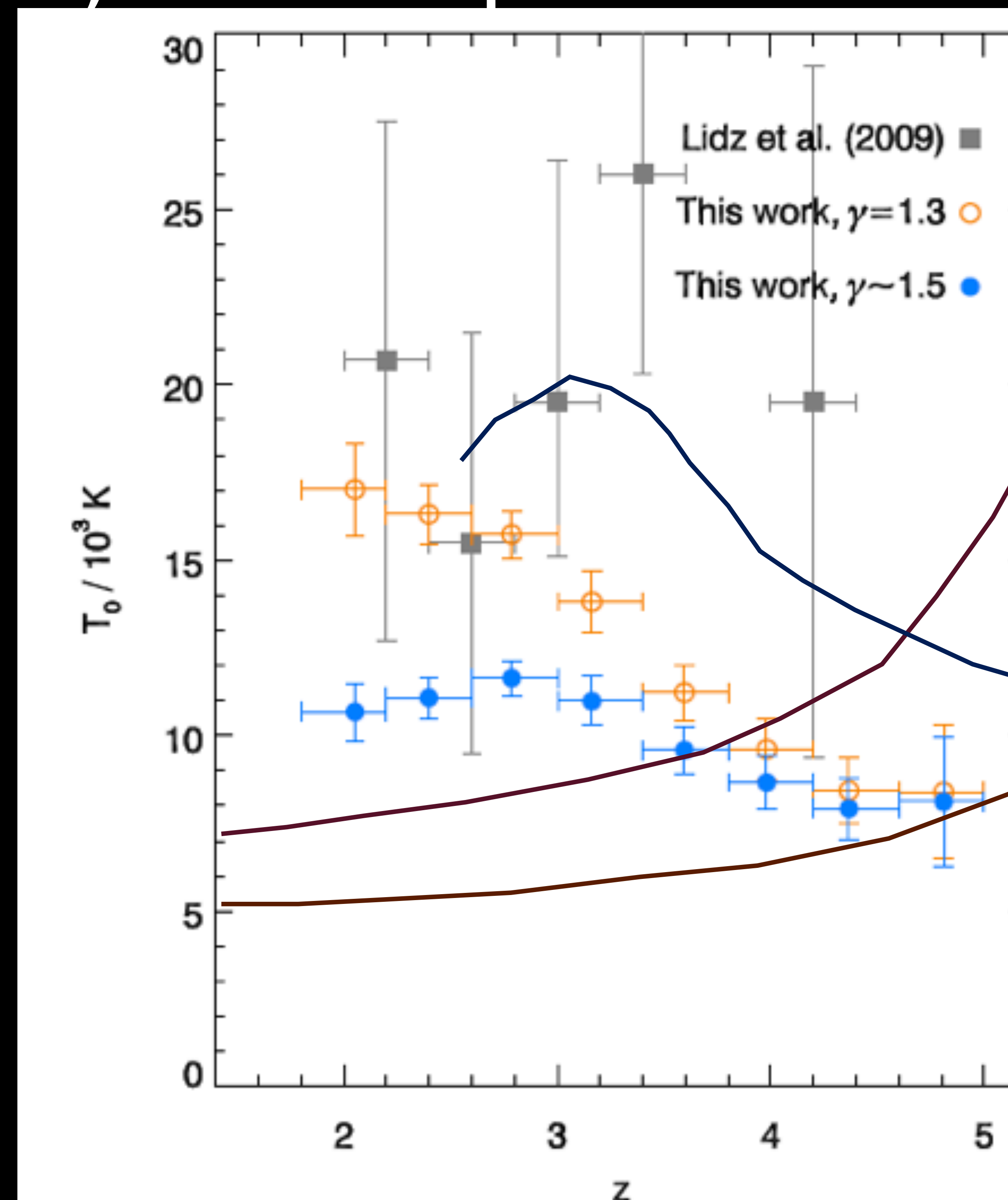
Helium reionization was ending at z=3!

HeII fraction   Temperature

430 cMpc

1) The #s work for quasars

2) IGM temperature



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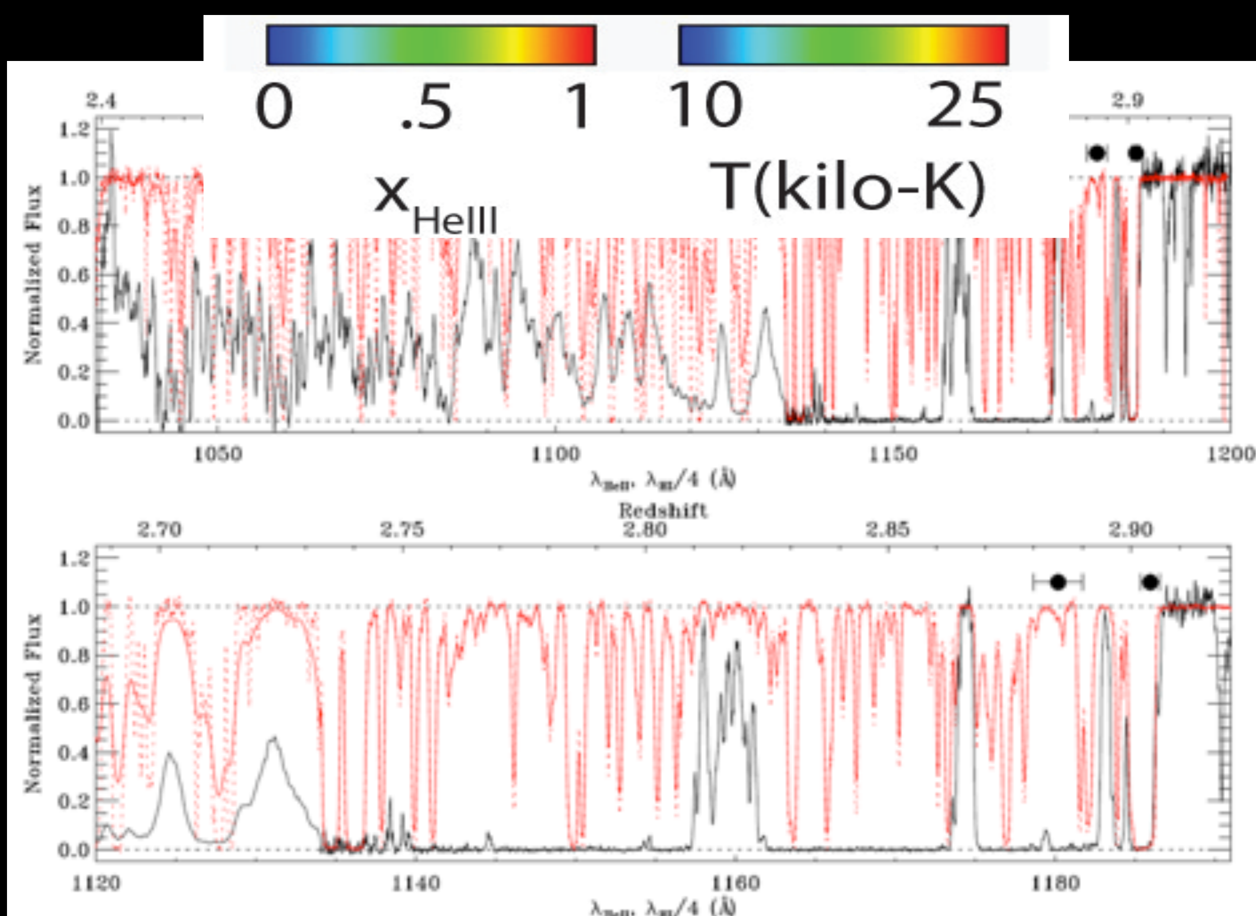

Shull et al (2010); HeII Lya forest for HE 2347; interpretation McQuinn '09

Plot from Becker et al (2010).

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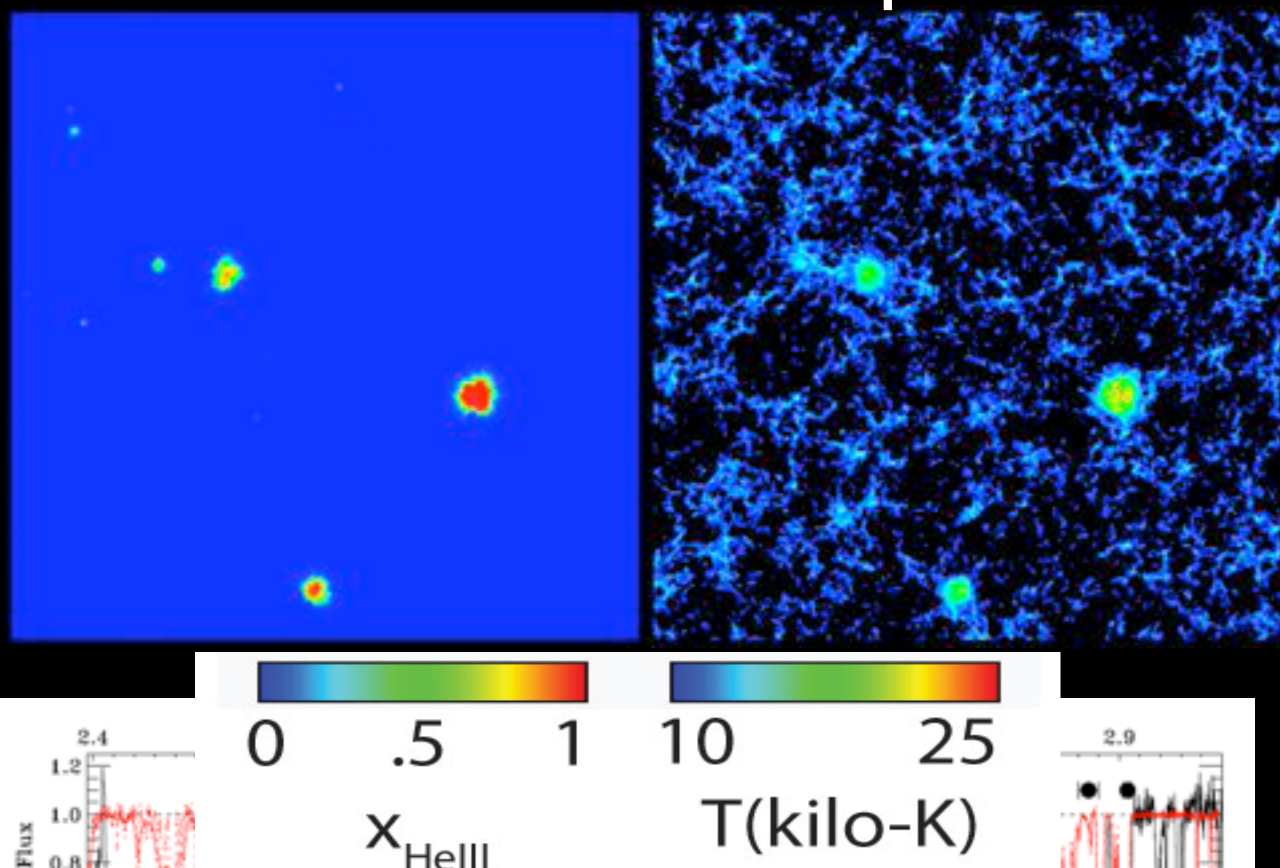

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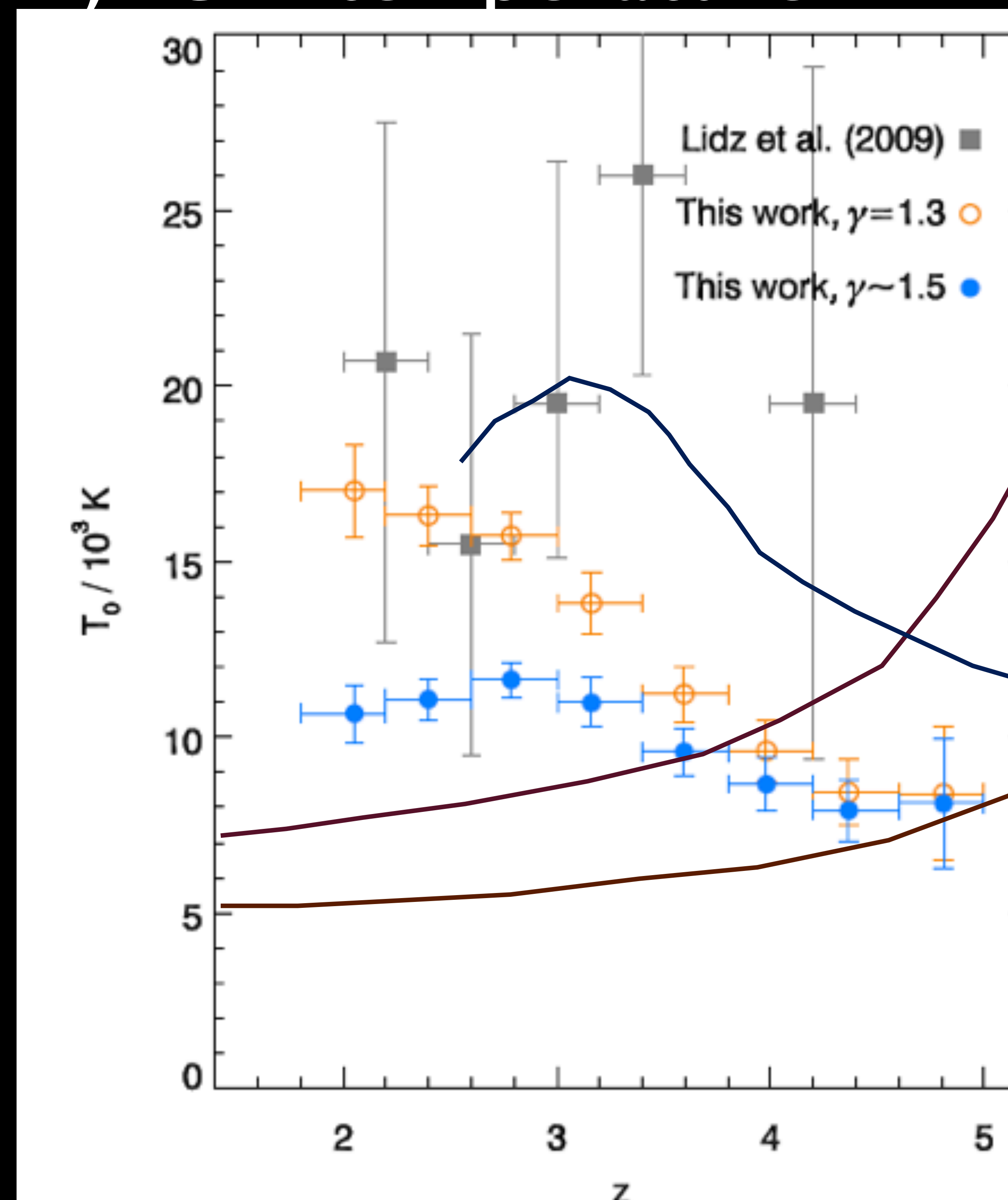

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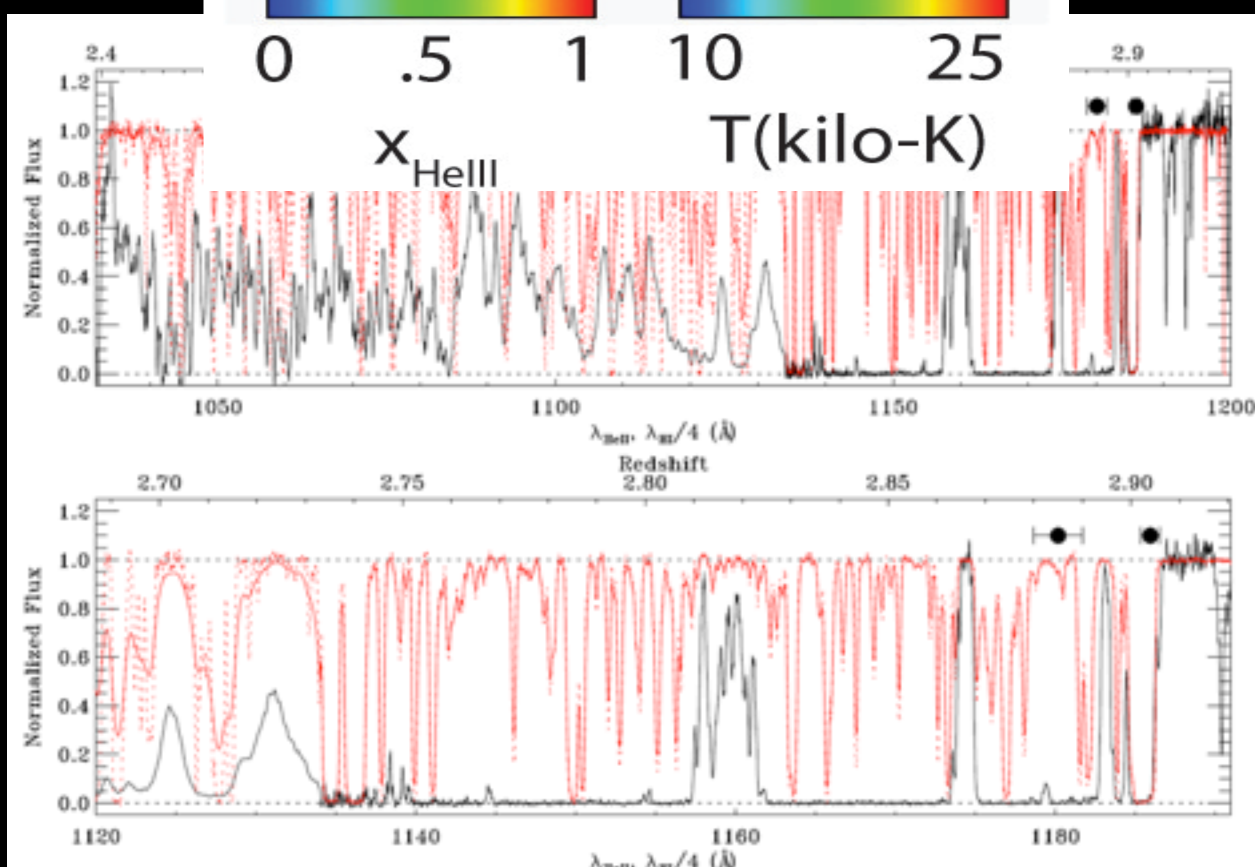

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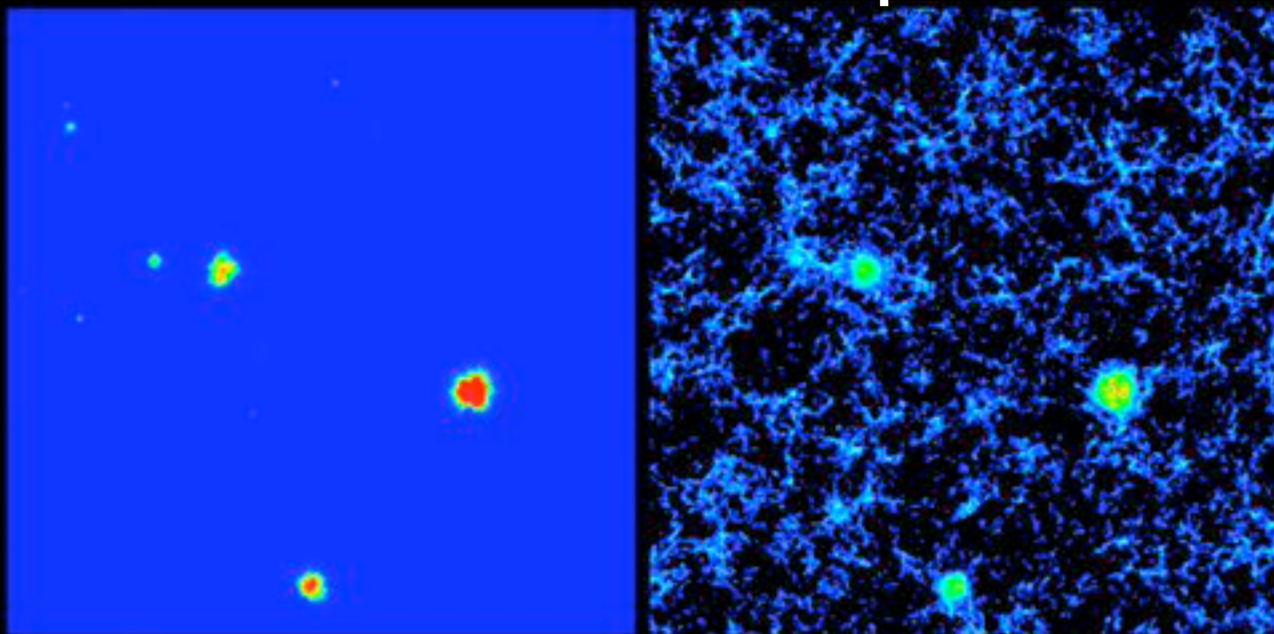

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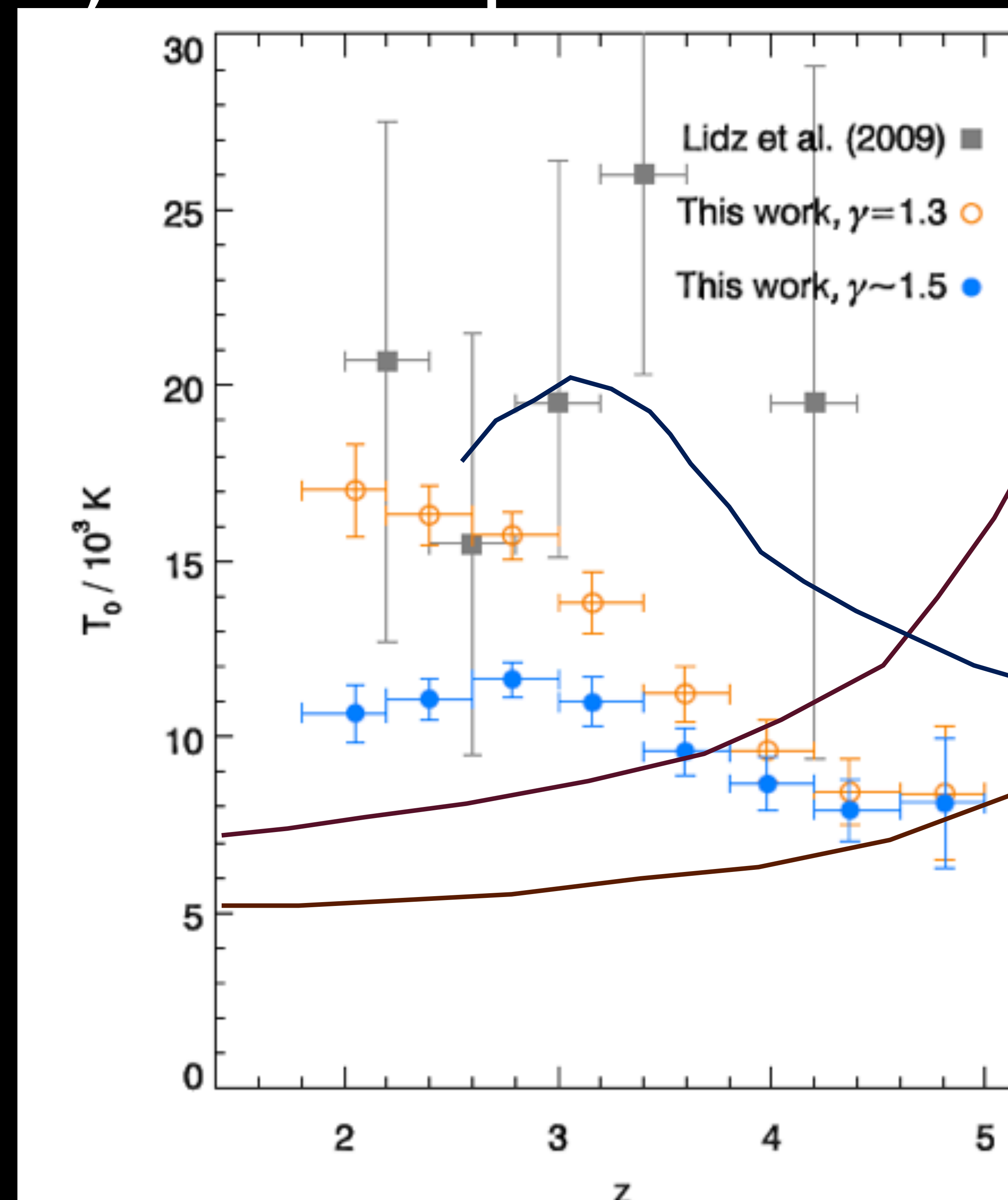

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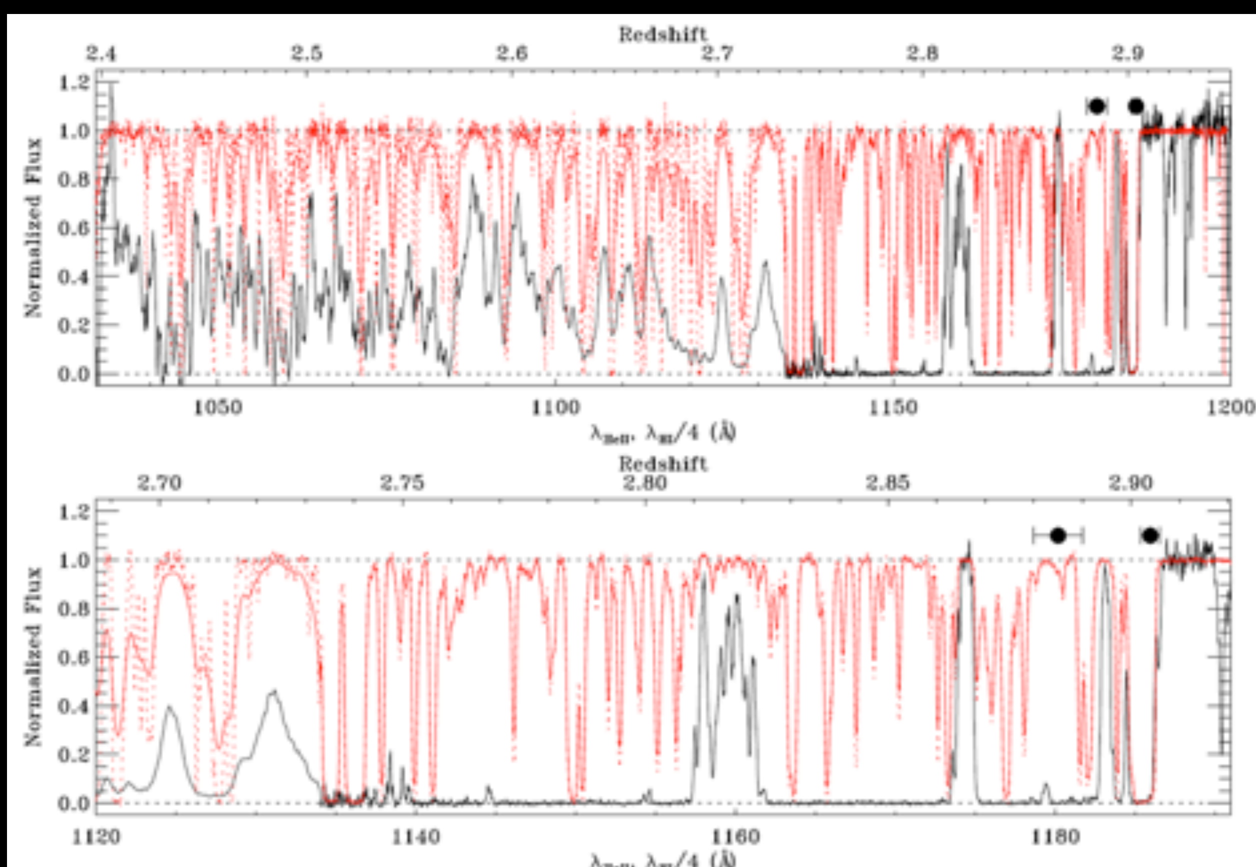

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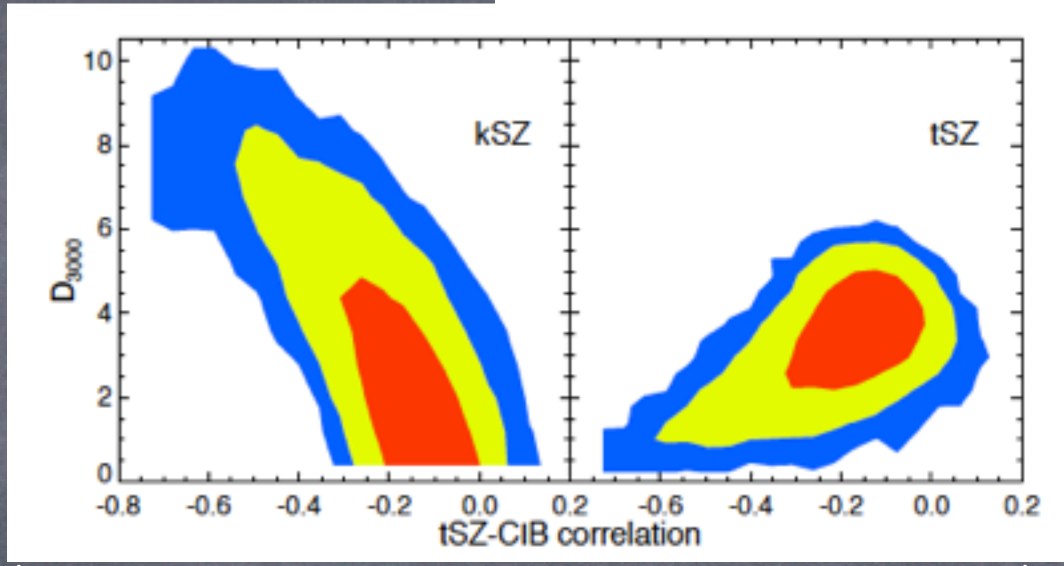
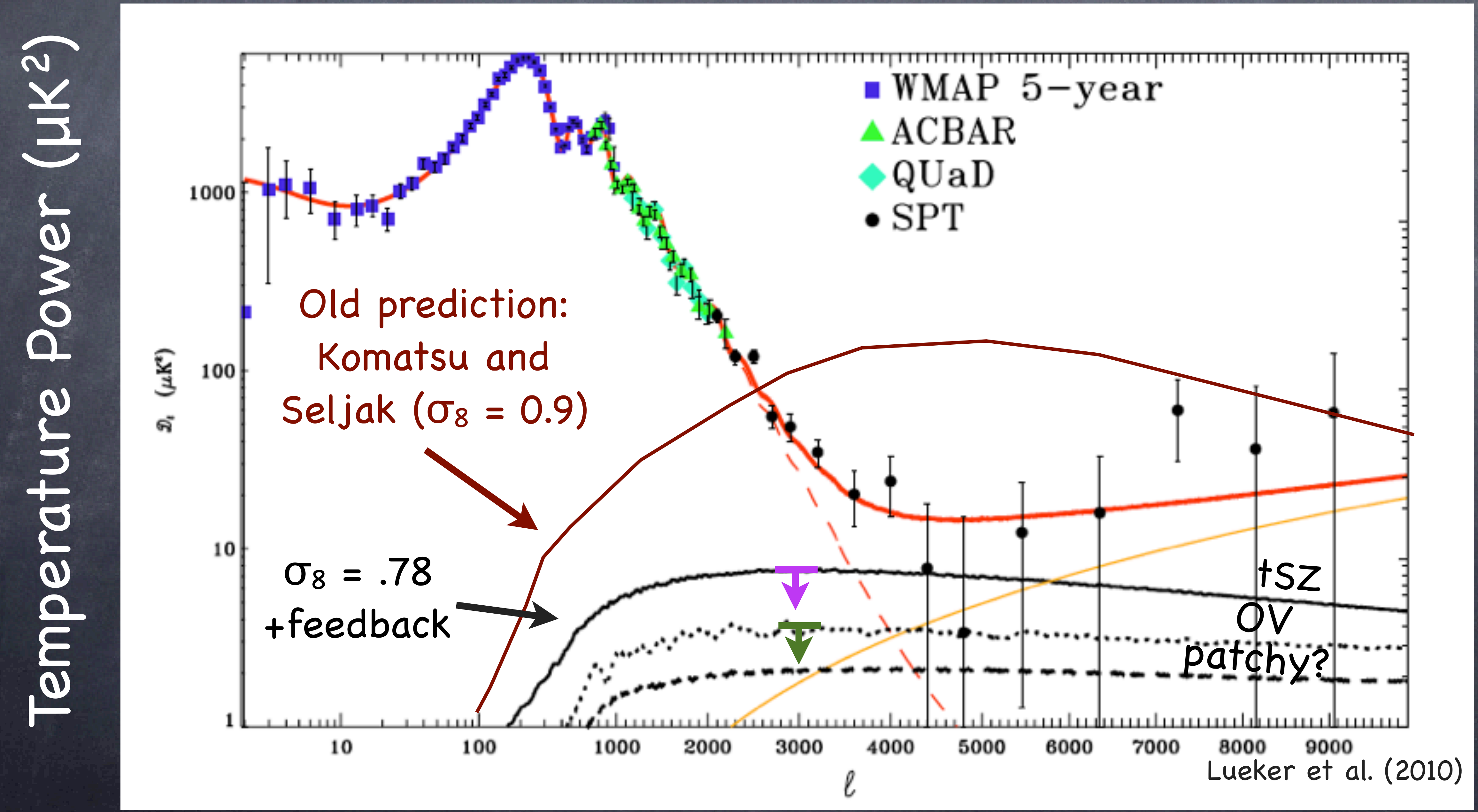
The Kinetic SZ Effect

Reichardt et al '12



(reason for this degeneracy I find not intuitive)



Kinetic SZ Measurements limit duration/patchiness

Arrows show SPT bounds subtracting 2 μK^2 OV (which is very conservative)

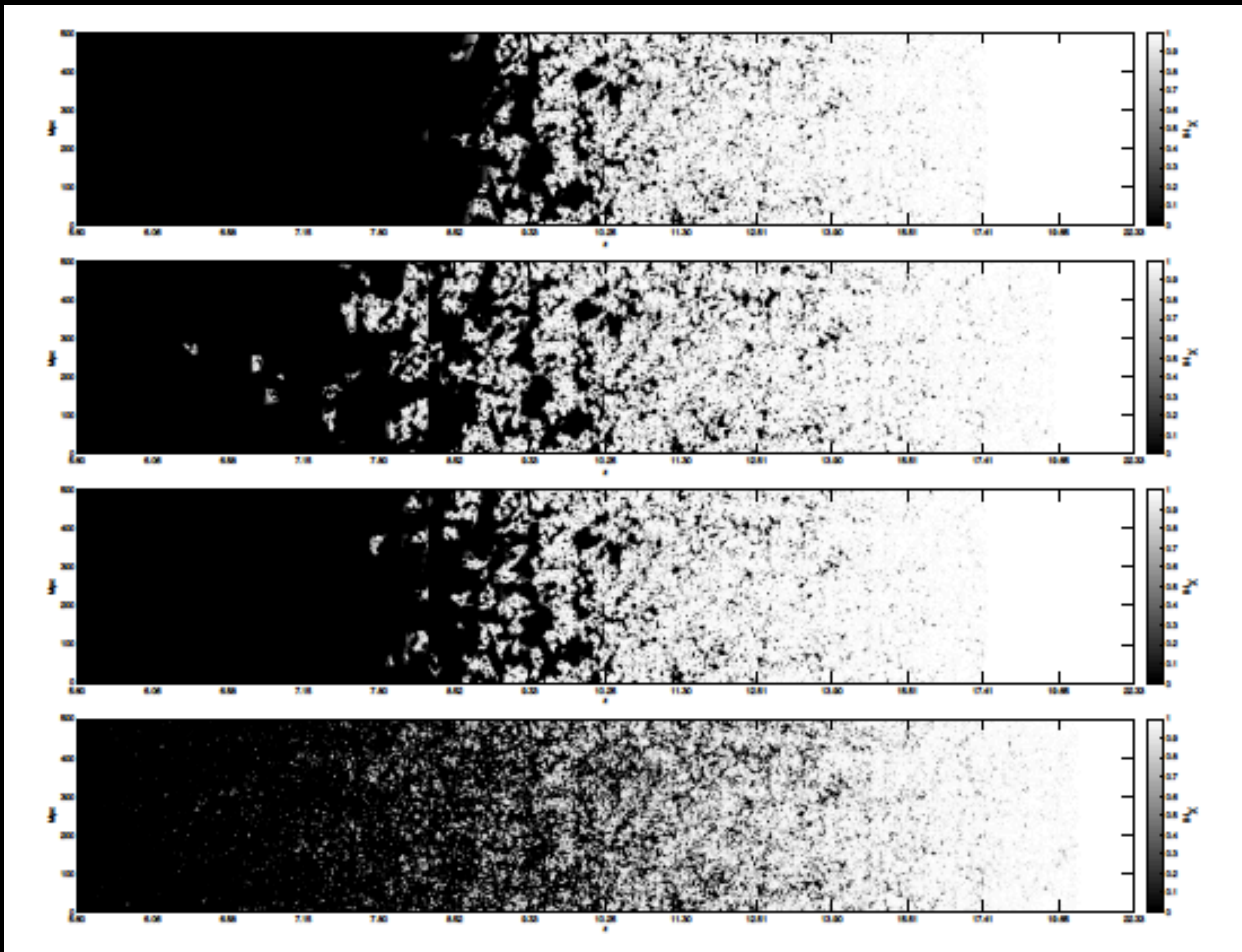
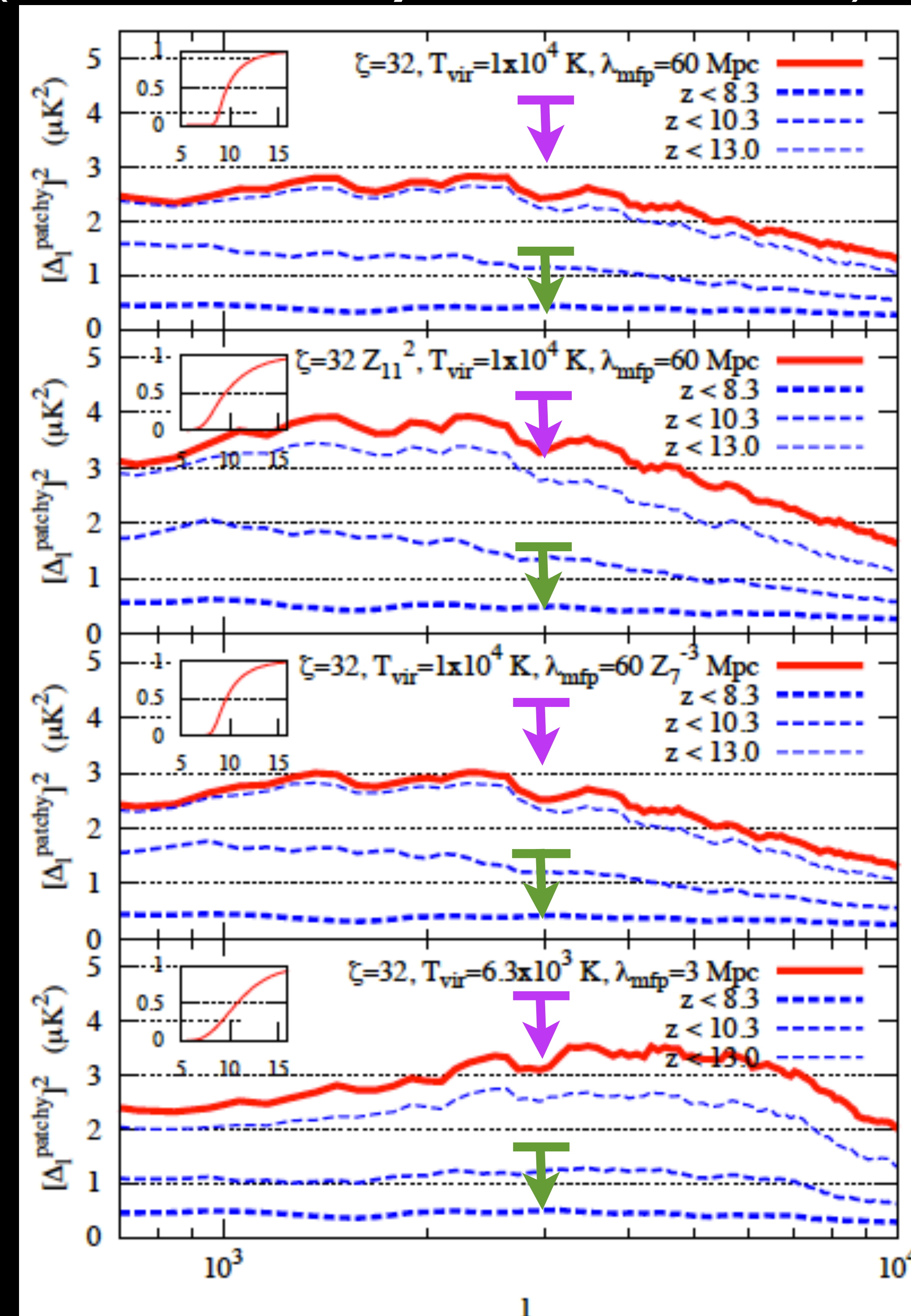
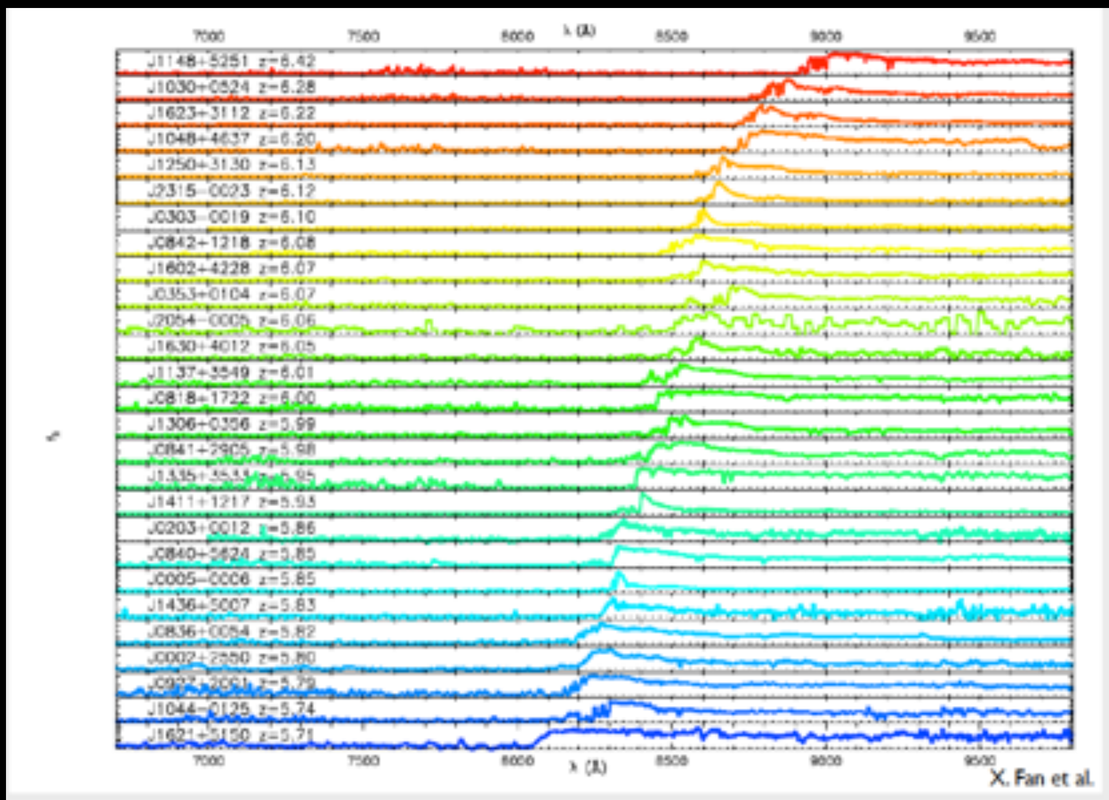


Figure 1. Slices through our ionization fields with thickness 1.1 Mpc. The top panel corresponds to $\{\zeta, T_{\rm vir}, R_{\rm mfp}\} = \{32, 10^4\ {\rm K}, 60\ {\rm Mpc}\}$. The middle two panels illustrate the impact of temporal evolution in our astrophysical parameters: $\{\zeta, T_{\rm vir}, R_{\rm mfp}\} = \{32[(1+z)/11]^2, 10^4\ {\rm K}, 60\ {\rm Mpc}\}$, and $\{\zeta, T_{\rm vir}, R_{\rm mfp}\} = \{32, 10^4\ {\rm K}, 60\,[7/(1+z)]^3\ {\rm Mpc}\}$, from top to bottom. The bottom panel corresponds to an extreme scenario with a small mean free path, $\{\zeta, T_{\rm vir}, R_{\rm mfp}\} = \{32, 6.3\times10^3\ {\rm K}, 3\ {\rm Mpc}\}$. The models have τ_e= 0.087, 0.086, 0.085, and 0.098, consistent at 1σ with *WMAP*, and $[\Delta^{\rm patchy}_{l3000}]^2$= 2.4, 3.3, 2.5, and 3.1 μK^2 (*top to bottom, respectively*). The vertical lines that are sometimes evident (such as in the second panel at $z \approx 8.3$) owe to how the snapshots are stacked (see



See Mesinger, McQuinn & Spergel '12 for more details (also see Zahn et al '12)

HI Lyα forest gives lower bound on z_{rei} & constrains ionizing production rate



Currently ≥47 z > 5.7 QSOs known (many faint)

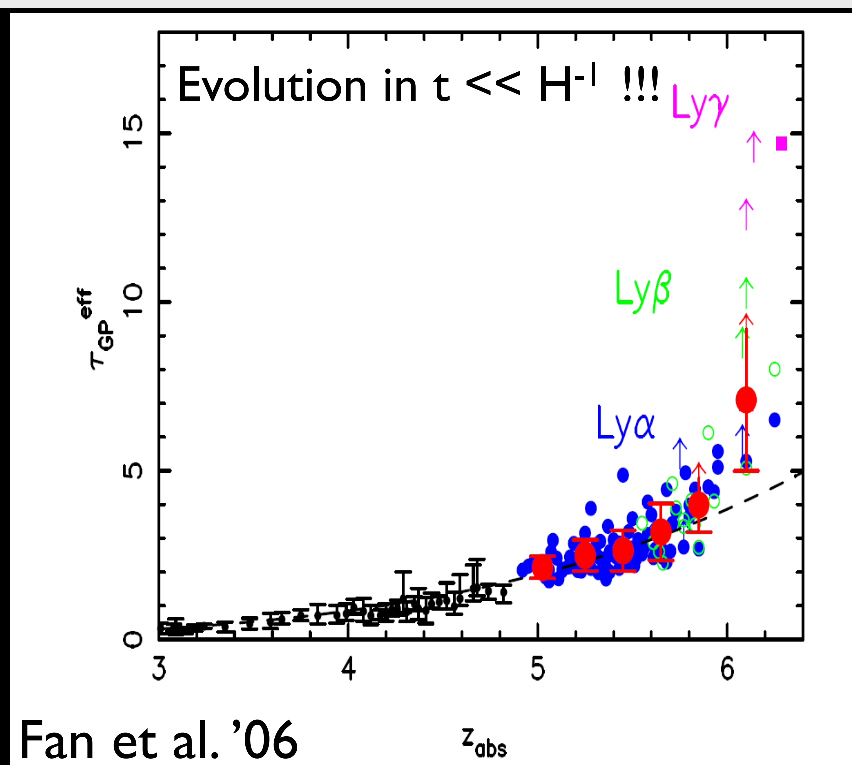
Does quick evolution necessarily mean percolation of HII regions?

Not necessarily

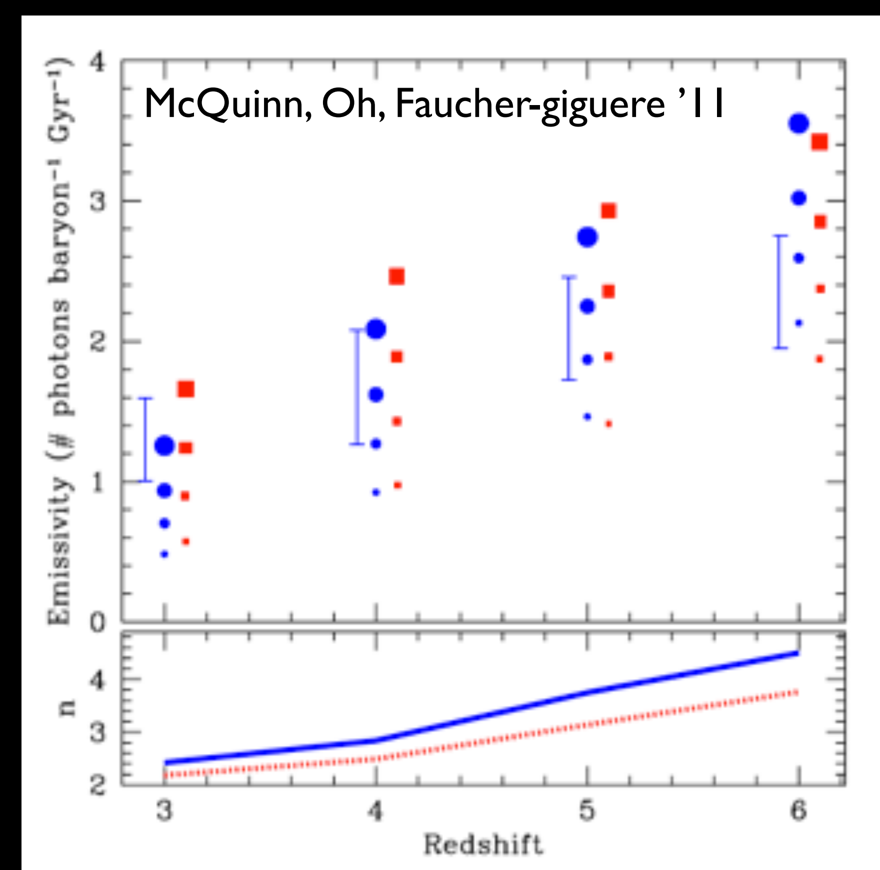
$$\Gamma \approx \frac{\sigma_{\rm LL}(3\beta - 3 + \alpha)}{3+\alpha}\epsilon\,\lambda \propto \Delta_i^{(7-\gamma)/3} \propto \epsilon^{\frac{7-\gamma}{9-3\gamma}} \propto \epsilon^{1/(2-\beta)}$$

ε is escaping emissivity, λ is m.f.p., γ is p.l. index of density PDF, and β is p.l. index of the column density distribution

-log(mean Lyα Transmission)



Lya forest measures this since $x_{HI} = \alpha n_e / \Gamma$



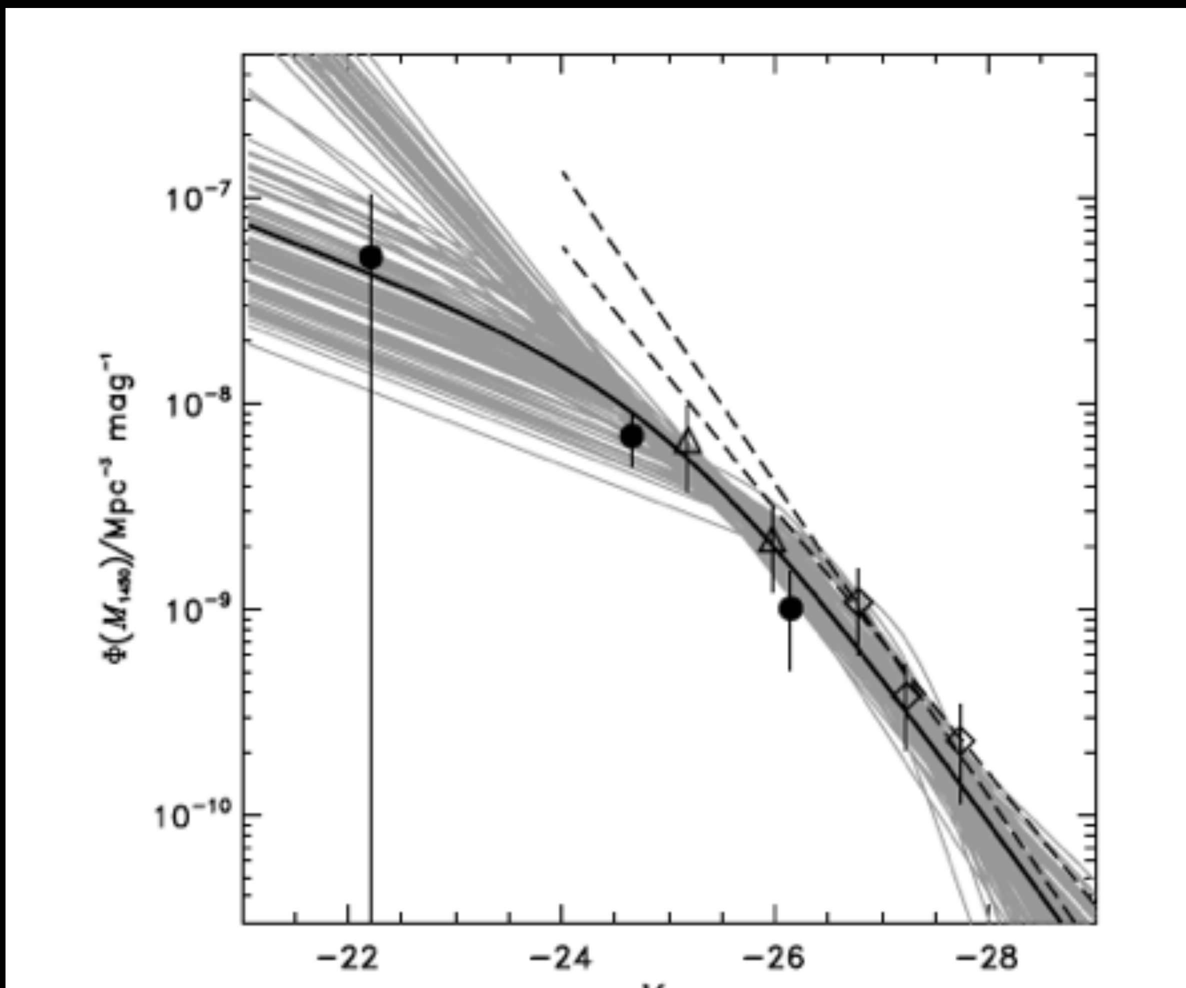
3.5-4.5 in sims

See also Miralda-escude '03, Bolton & Haehnelt '07

HI Reionization by AGN/X-rays?

(Does it have to be 100% dwarf galaxies?)

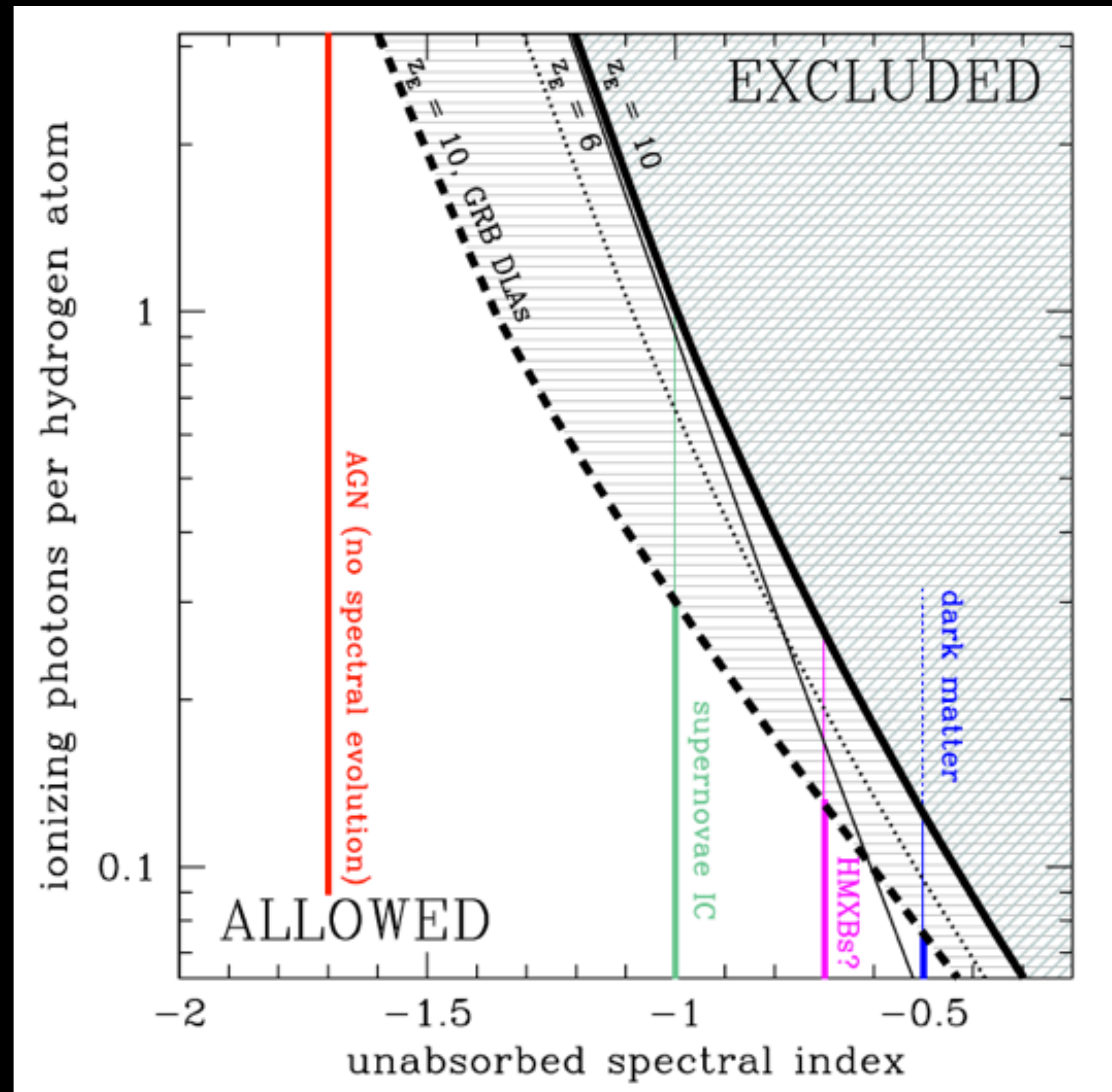
Luminosity Function :



Willott '10; Canada France high-z quasar survey has recently strongly limited parameter space of AGN

Find quasars can contribute < 10%

Diffuse Soft X-ray background: $n_i = \frac{4\pi}{c}\int_{13.6\,\mathrm{eV}/(1+z_E)}^{E_{max}/(1+z_E)} dE\,\frac{I_E}{E}$



in prep; see also Dijkstra et al 2004

Thank you!