XXIV IAP Colloquium

Is the IGM temperature-density relation inverted?

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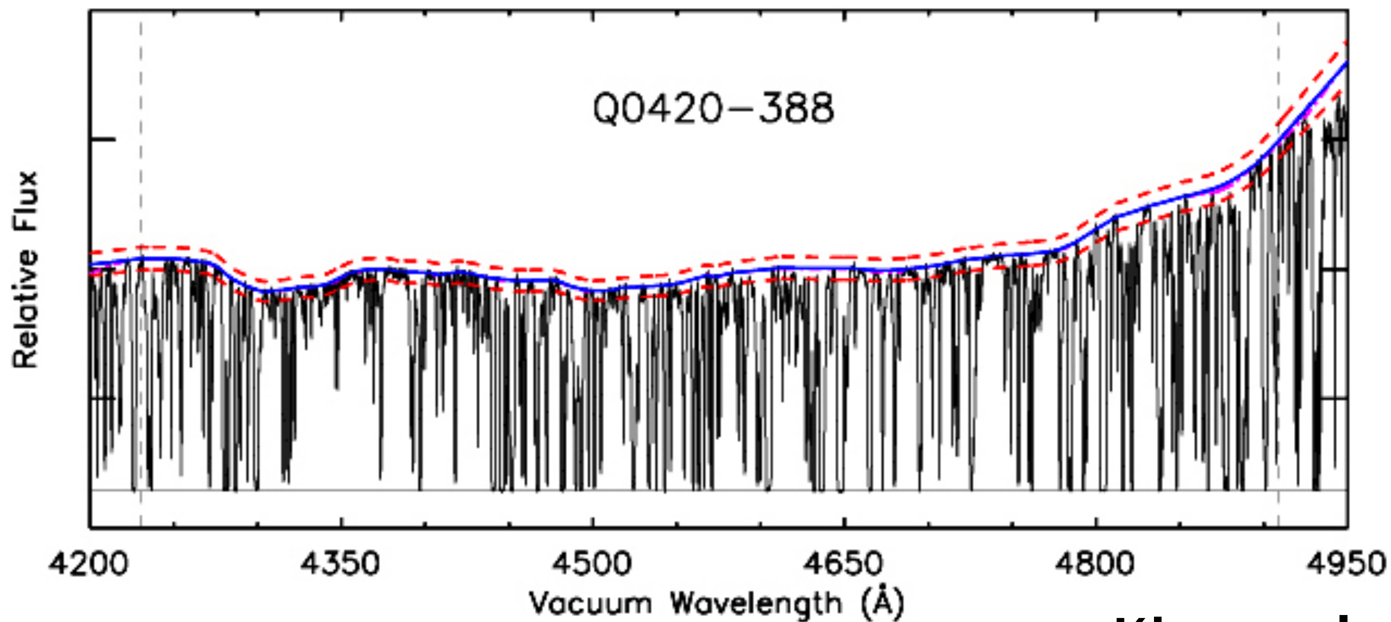
The observational data



Kim et al. (2007)

Set of 18 high resolution VLT/UVES QSO spectra at 1.7<z<3.2 selected from the LUQAS sample (part of ESO LP, **Bergeron et al. 2004**). Total path length Δz=7.83.

- Detailed analysis and removal of identifiable metal lines.
- Characterise impact of continuum placement and noise properties.
- Result: an improved measurement of the Lyα forest flux distribution.

The Lyα forest and the IGM temperature

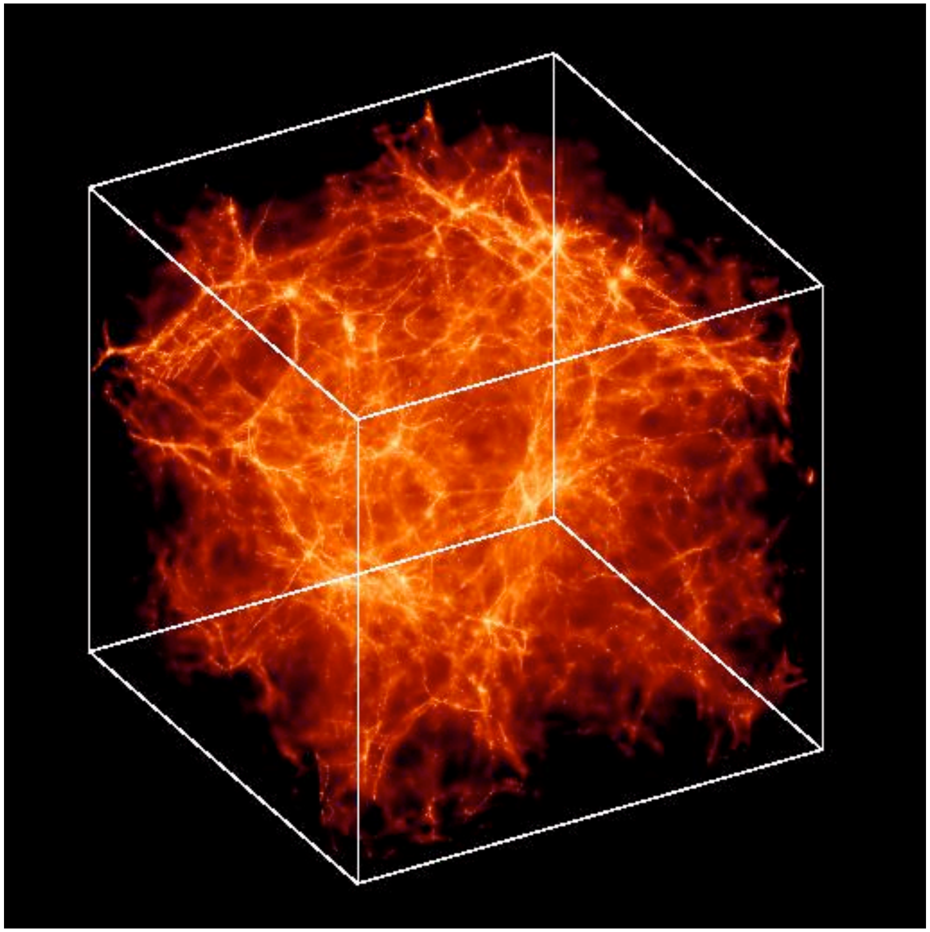
Assuming HI photo-ionisation equilibrium and a temperature-density relation for low density gas, $T=T_0(1+\delta)^{\gamma-1}$ (**Hui & Gnedin 1997**)

$$\tau = \tau_0 \frac{(1+z)^6(\Omega_b h^2)^2}{T_0^{0.7} H(z)\Gamma(z)}(1+\delta)^{2-0.7(\gamma-1)}$$

e.g. Rauch et al. (1997)

The Lyα forest opacity is closely linked to the IGM temperature (as well as the UV background, baryon fraction, cosmology...)

Hydrodynamical simulations of the Lyα forest with GADGET-2



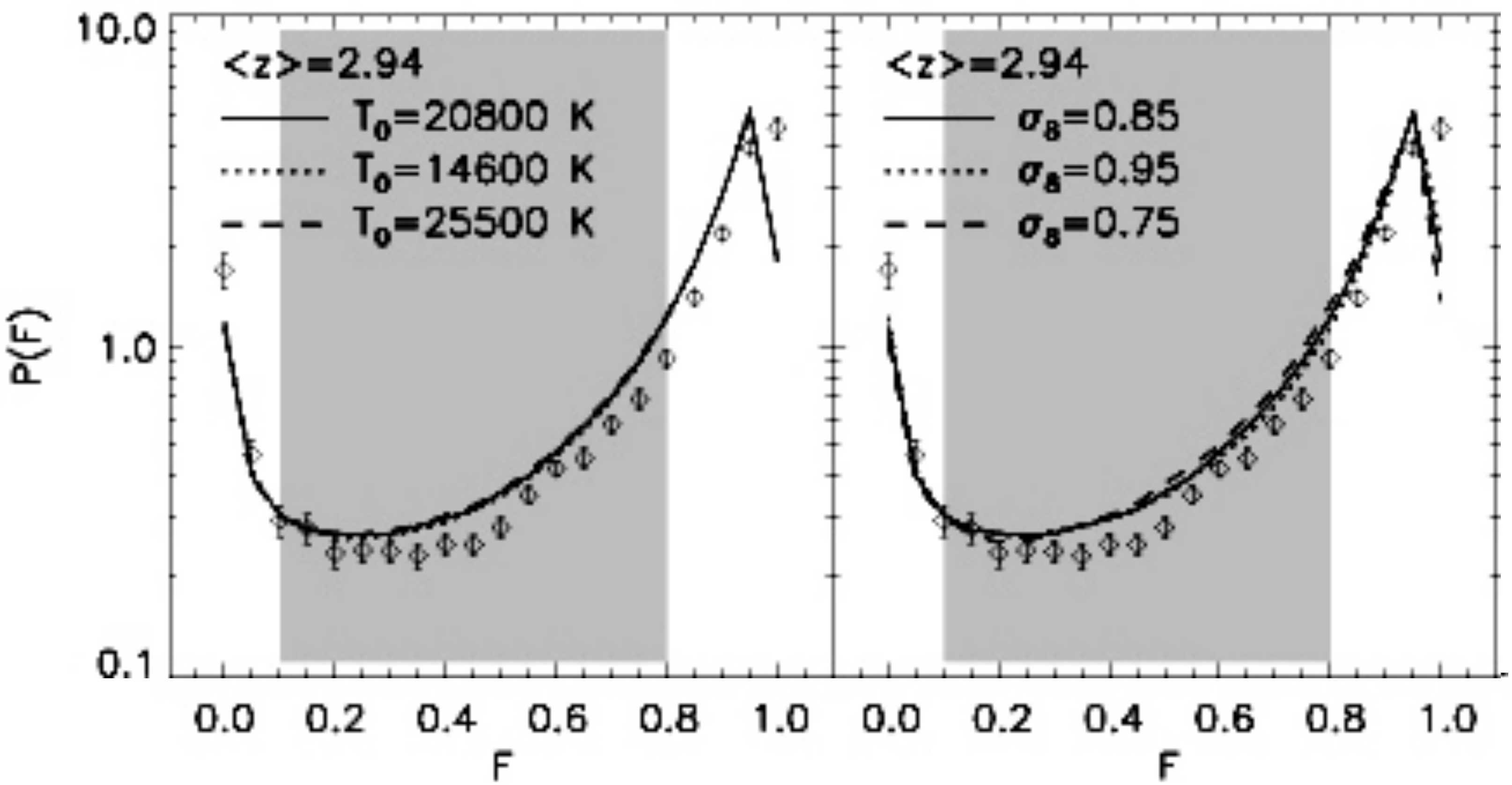
Large set of numerically converged hydrodynamical simulations run with GADGET2 (**Springel 2005**)

WMAP consistent fiducial model

Ω_m=0.26, Ω_Λ=0.74, $\Omega_b h^2$=0.024, h=0.72, n=0.95

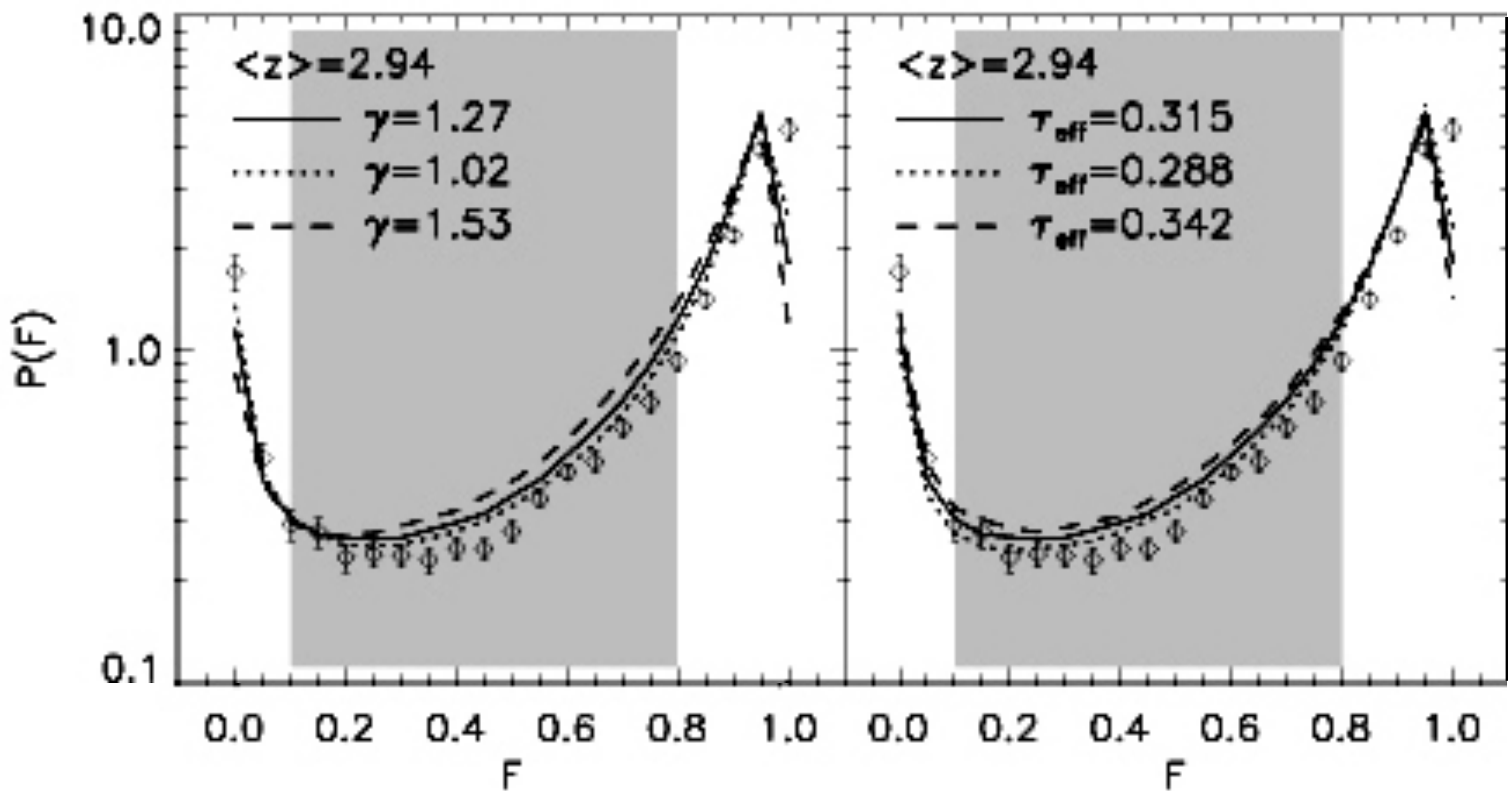
Vary remaining parameters over their observationally established/theoretically expected values and ranges.

Can the standard simulations match the data at z~3?



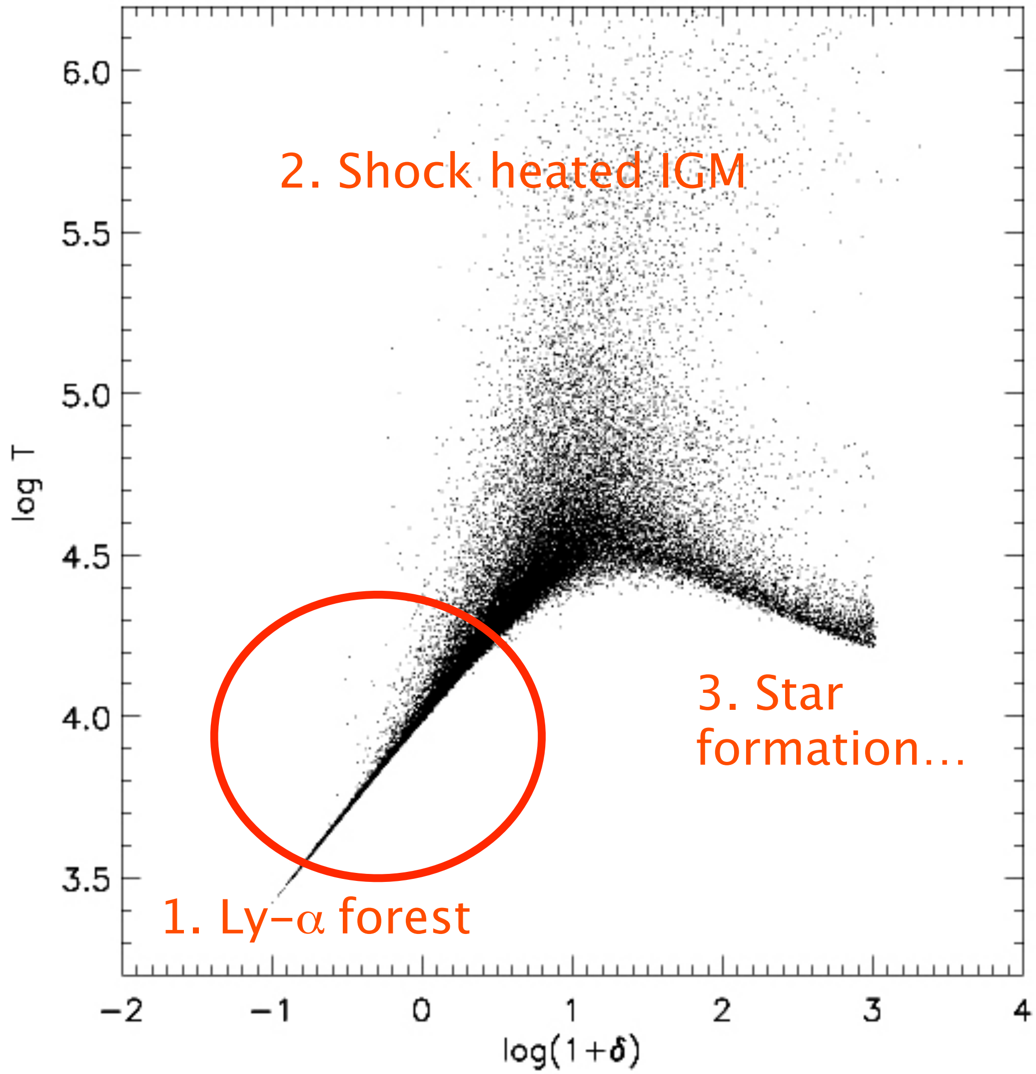
Bolton et al. (2008)

Can the standard simulations match the data at z~3?



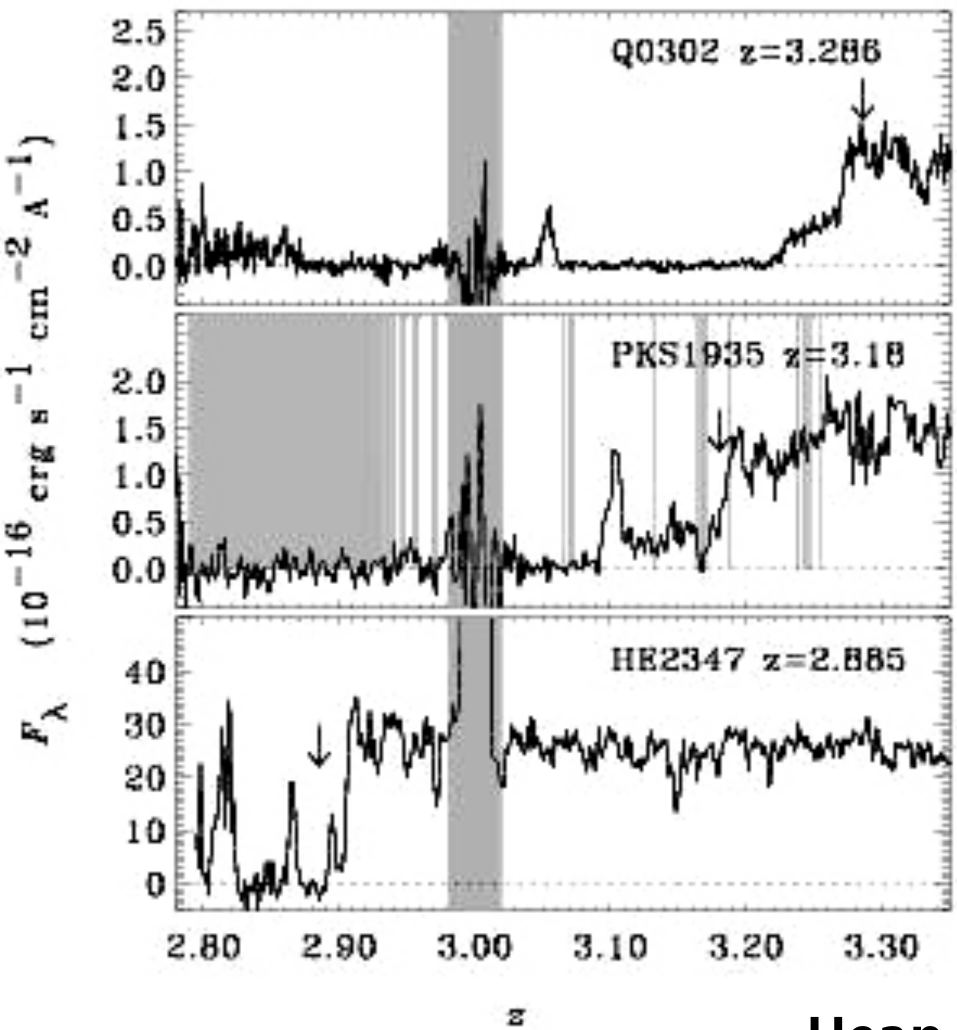
Bolton et al. (2008)

The thermal state of the optically thin IGM at z~3



See e.g.
Hui & Gnedin (1997)
Valageas et al. (2002)

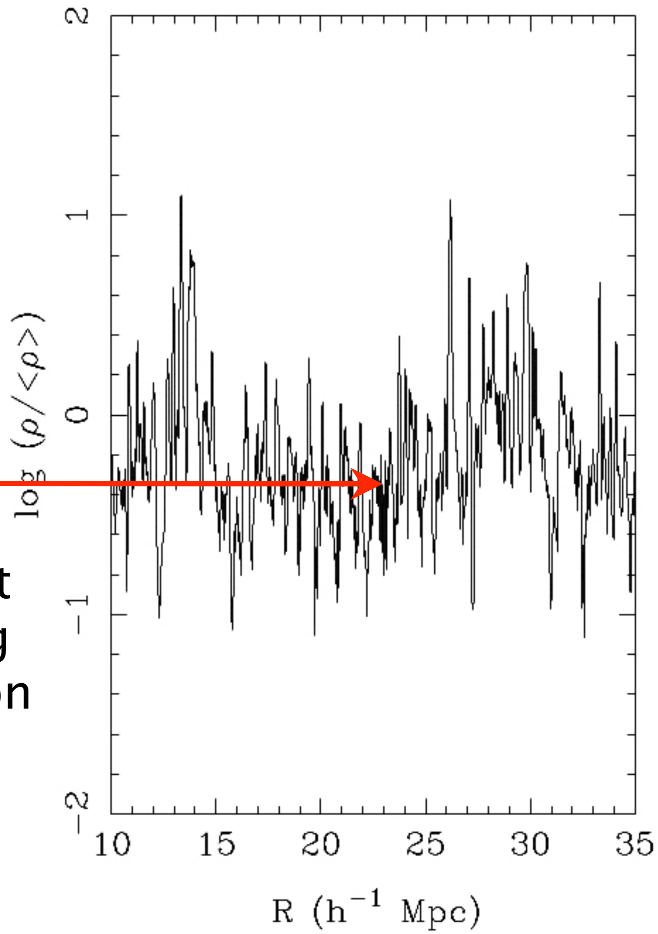
The He II Gunn–Peterson trough



Heap et al. (2000)

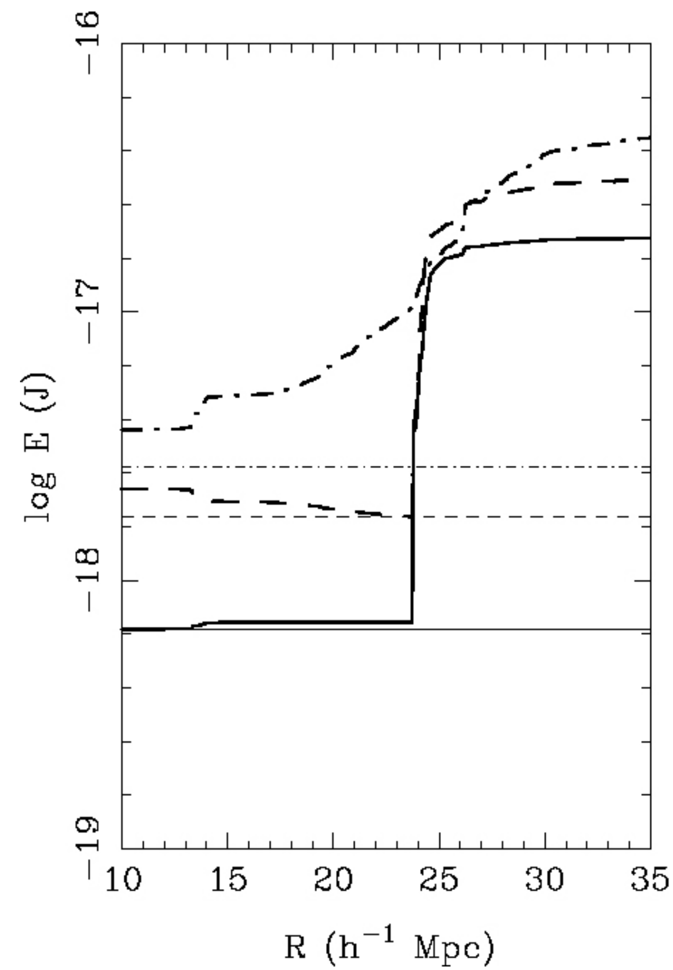
Radiative transfer effects…

Incident ionising radiation



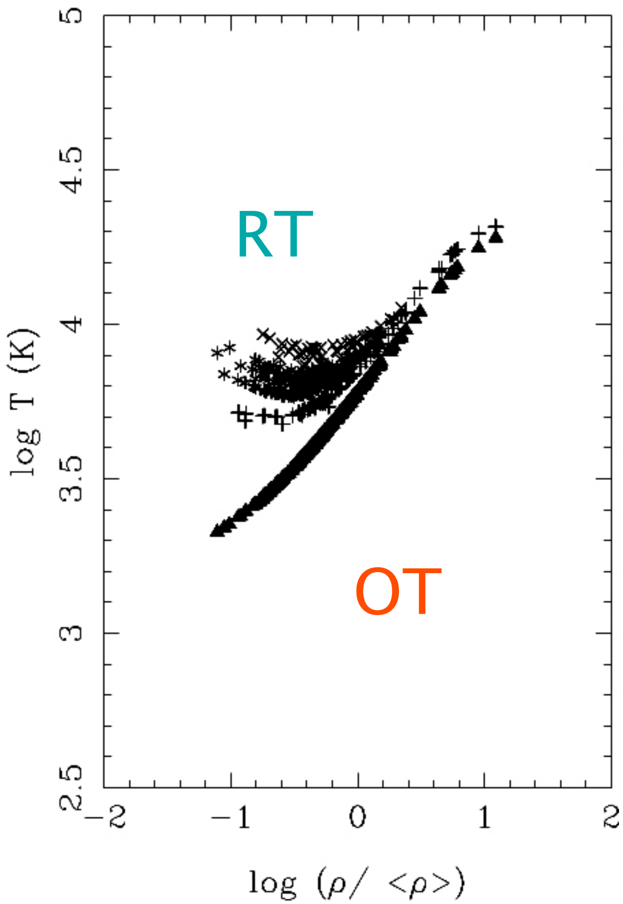
Optically thick IGM

$\sigma_\nu \sim \nu^{-3}$



Bolton, Meiksin & White (2004), see also **Abel & Haehnelt (1999)**

can blur/invert the temperature-density relation.

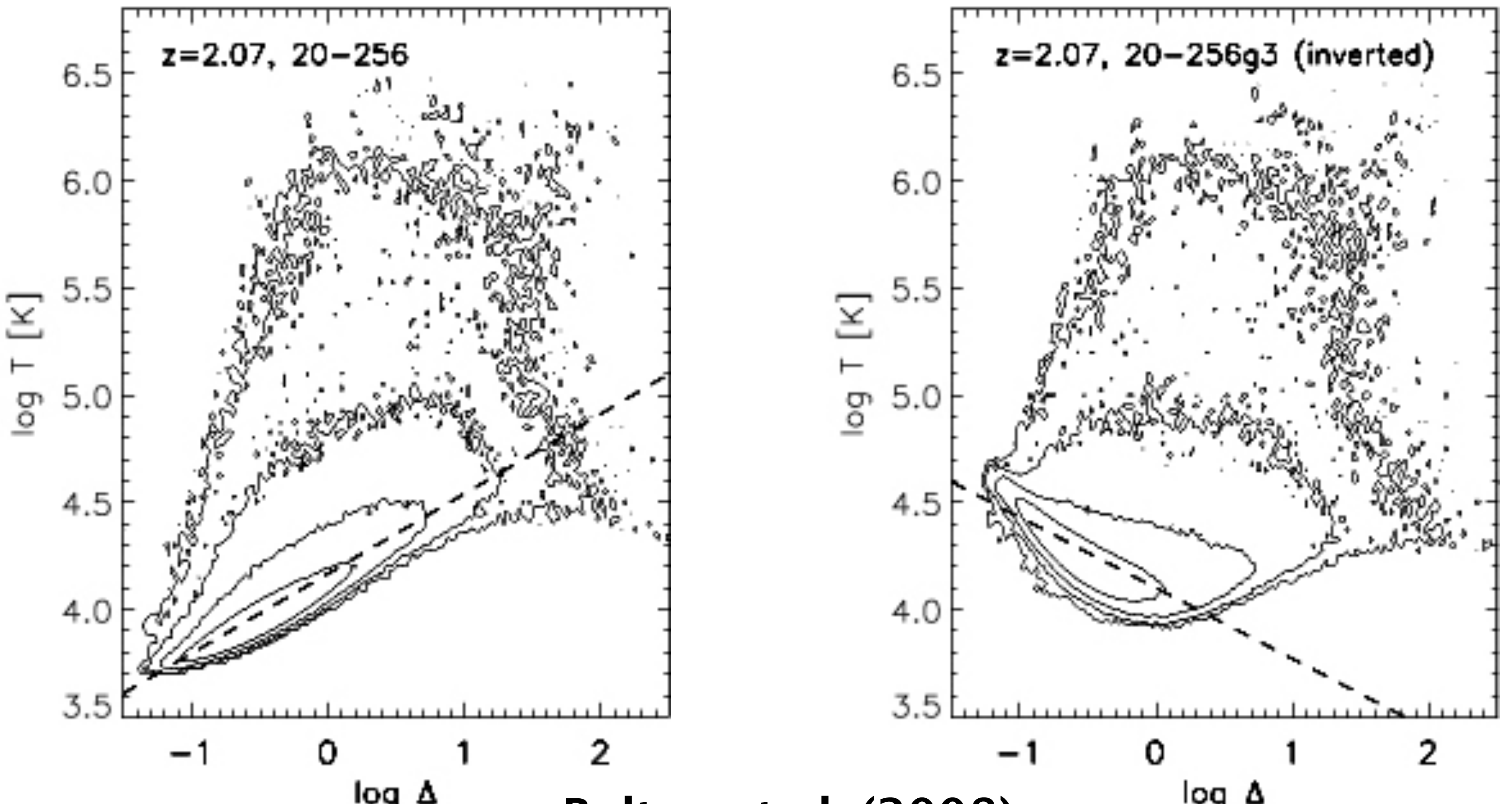


Bolton, Meiksin & White (2004)

Mimicking RT effects on the IGM thermal state

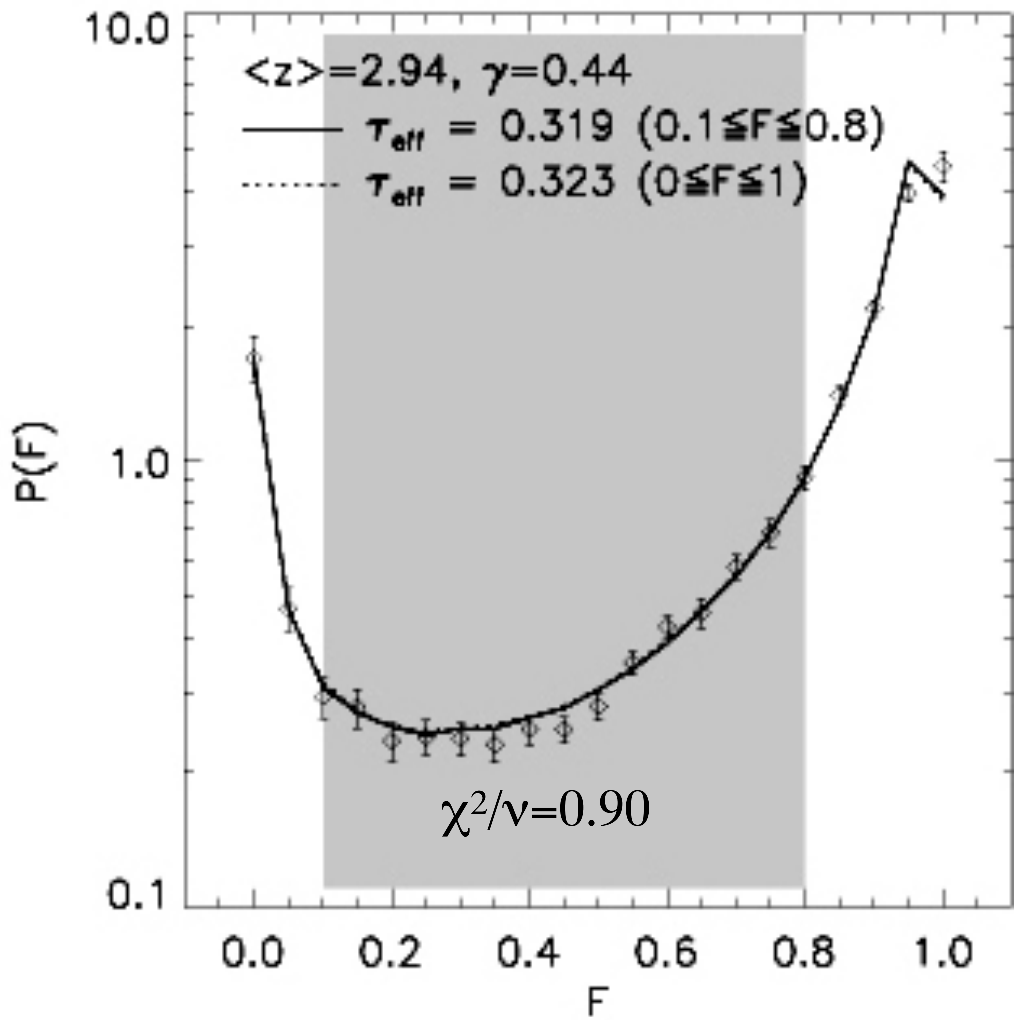
Standard T−ρ relation
(Optically thin, spatially uniform UVB)

Inverted T−ρ relation
(May mimic He II reionisation effects on the IGM)



Bolton et al. (2008)

Evidence for an inverted T−ρ relation?



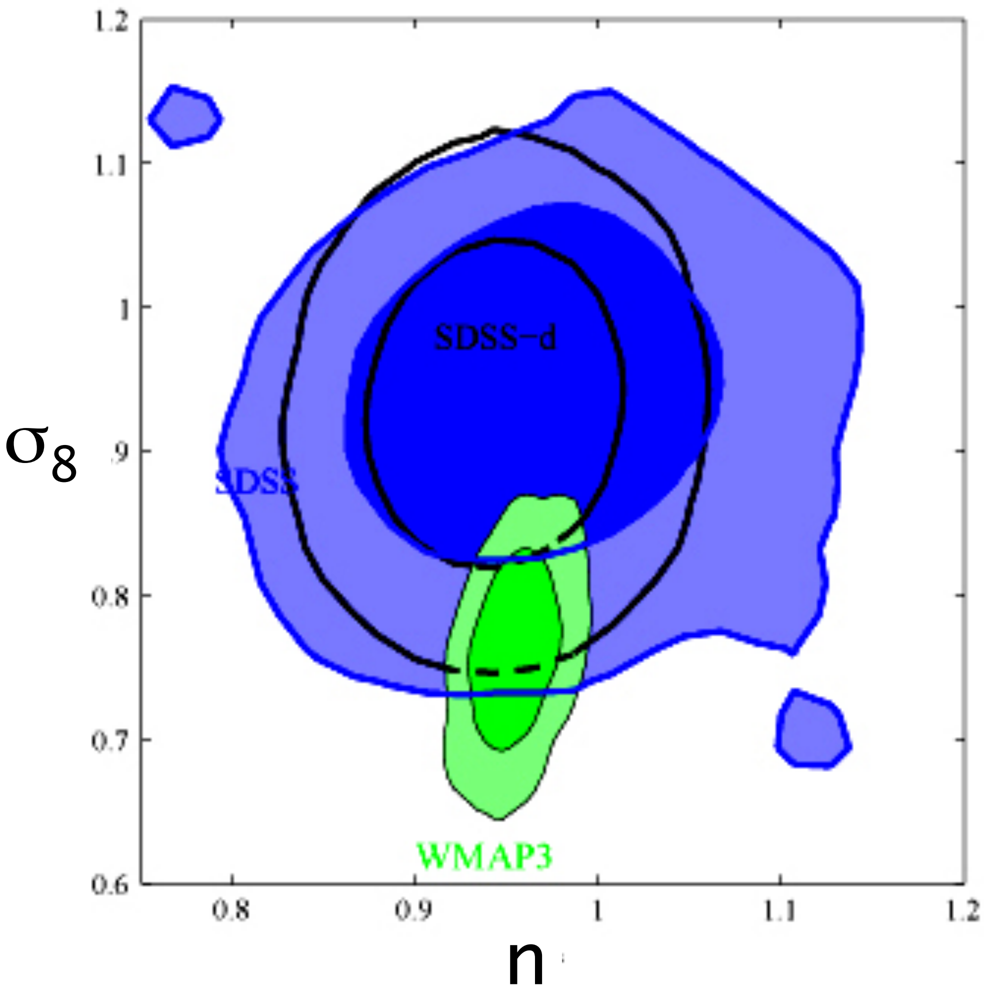
$$n_{HI}\Gamma_{HI} \propto T_0^{-0.7}\Delta^{2-0.7(\gamma-1)}$$

Underdense regions, associated with flux near the continuum level become hotter and more highly ionised.

Overdense regions become cooler and more neutral.

Bolton et al. (2008)
and see also
Becker et al. (2007)

Systematic uncertainties in modelling the flux power spectrum?



Viel, Haehnelt & Lewis (2006)

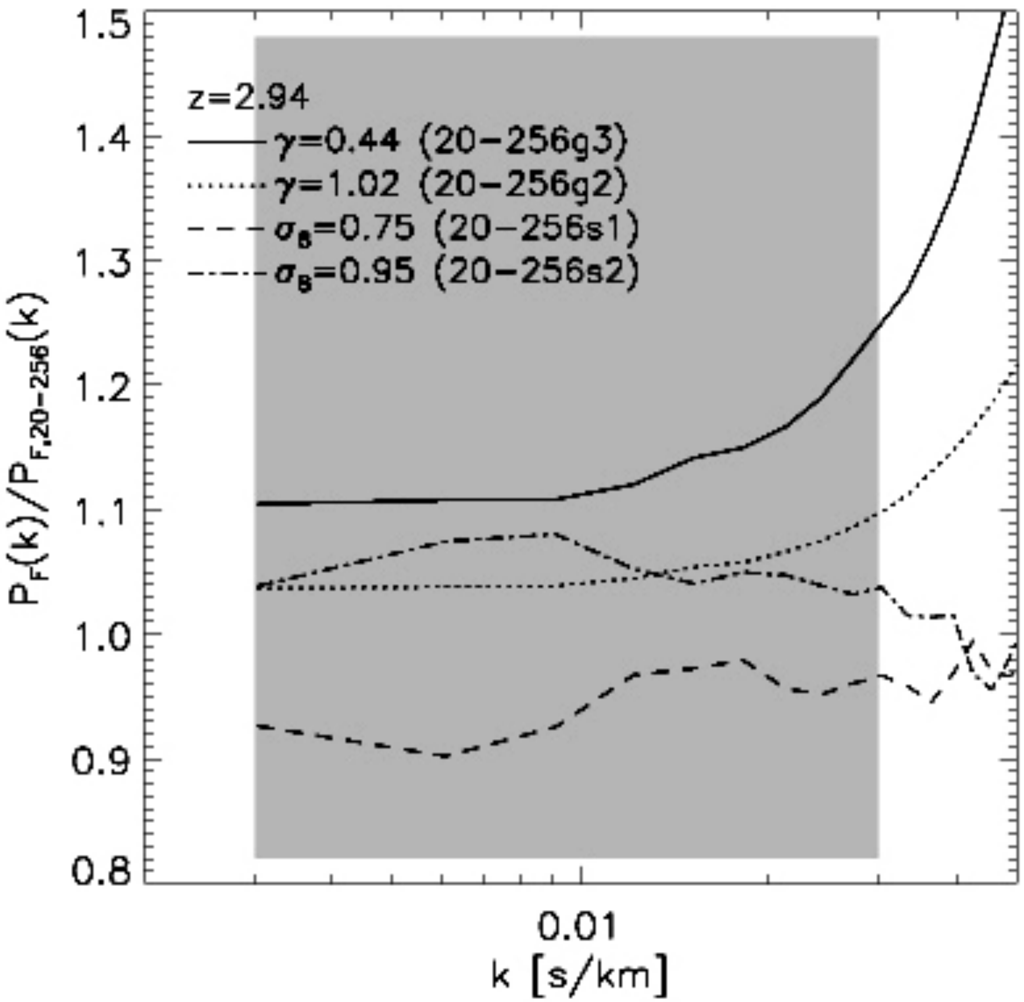
WMAP 3

$$\sigma_8 = 0.76 \pm 0.05, n = 0.96 \pm 0.02$$

WMAP 3 + SDSS Ly-α

$$\sigma_8 = 0.86 \pm 0.03, n = 0.96 \pm 0.02$$

Implications for cosmology with the Lyα forest



Bolton et al. (2008)

Inverted γ increases power at the scales relevant for measuring the matter power spectrum

Colder, more neutral material in the overdense regions associated with the most prominent lines increases the fluctuations in the transmission.

Acts in the same way as a larger σ_8!

Conclusions

• Is the IGM temperature-density relation inverted? Perhaps, but the real situation may be somewhat more complex.

• The data are indeed consistent with voids in the IGM which are significantly hotter than usually assumed (**Bolton et al. 2008**).

• Radiative transfer effects during He II reionisation by quasars may provide the missing physics which improves the agreement of simulations with the data.

• This also has important implications for cosmological parameters derived from the Lyα forest. Hotter voids can mimic the effect of larger σ_8

• Further investigation is needed - more detailed simulations of HeII reionisation and a full analysis of other statistics are required...