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To: EDGES Group

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Subject: Tests of the levels of Lyman alpha which lead to a flattened absorption profile

The possible detection of a flattened absorption signature discussed in memo #222, if real, is more likely to be the result of the spin temperature reaching and saturating on the kinetic temperature rather than the presence of a large optical depth.

To test the level of coupling needed to flatten the absorption I have modeled an absorption assuming

1] $T_{cmb}$ = 2.75 (1+z)

2] $T_k$ = red curve from Figure 7 of Prober et al 2015 plus rise at z < 16 as in Ciardi et al. 2010 Figure 2 total.

3] $y\alpha, eff$ from Ciardi et al. 2010 with $Ly\alpha$ from Holzbauer and Furlanetto 2012 figure 2.

4] $\tau(z)$ from memo 221

5] $T_{spin} = \left(T_{cmb} + y\alpha, effT_k\right) / \left(1 + y\alpha, eff\right)$

Where Tcmb – CMB temperature

Tk = kitnetic temperature

$y\alpha, eff$ = coupling efficiency to Tk

$Ly\alpha$ = Lyman alpha flux erg $s^{-1}$ $cm^{-2}$ $Hz^{-1}$ $sr^{-1}$

The absorption profiles were computed from 50 to 100 MHz using the Lyman alpha intensity from Holzbauer and Furlanetto 2012.

Figure 1 shows the signatures for $M_{min}=10^7$ M⊙ (the thick curve) and $M_{min} = 10^8$ M⊙ (the thin curve).

Reducing the intensity by a factor of 10 eliminates the flattening. Deeper absorption would be obtained with lower kinetic temperature and a narrower range of redshift would result from a steepening of the Lyman alpha intensity as well as a shift of the maximum z from 10 to about 13. A lower kinetic temperature might result from an earlier decoupling from the CMB due to reduced Compton scattering (see Loeb and Furlanetto 2013 Figure 2.5.

Figure 2 shows the effect of lowering the kinetic temperature from 5 to 3 k at z=20 in the thick curve and the thin curve shows the added effect of steepening and shifting the Lyman alpha intensity.

Pober, Jonathan C., Zaki S. Ali, Aaron R. Parsons, Matthew McQuinn, James E. Aguirre, Gianni Bernardi, Richard F. Bradley et al. (2015), PAPER-64 Constraints on reionization. II. The Temperature of the z= 8.4 intergalactic medium." The Astrophysical Journal 809, no. 1: 62.

Loeb, Abraham, Steven R. Furlantetto (2013), The First Galaxies in the Universe, Princeton University Press.

Holzbauer, Lauren N., and Steven R. Furlanetto (2012), Fluctuations in the high-redshift Lyman-Werner and Lyα radiation backgrounds. Monthly notices of the Royal Astronomical Society 419, no.1: 718-731.

Ciardi, Bennedetta, Ruben Salvaterra, and Tiziana Di Matteo (2010), Lyα versus X-ray heating in the high-z intergalactic medium. Monthly Notices of the Royal Astronomical Society 401, no. 4: 2635-2640.

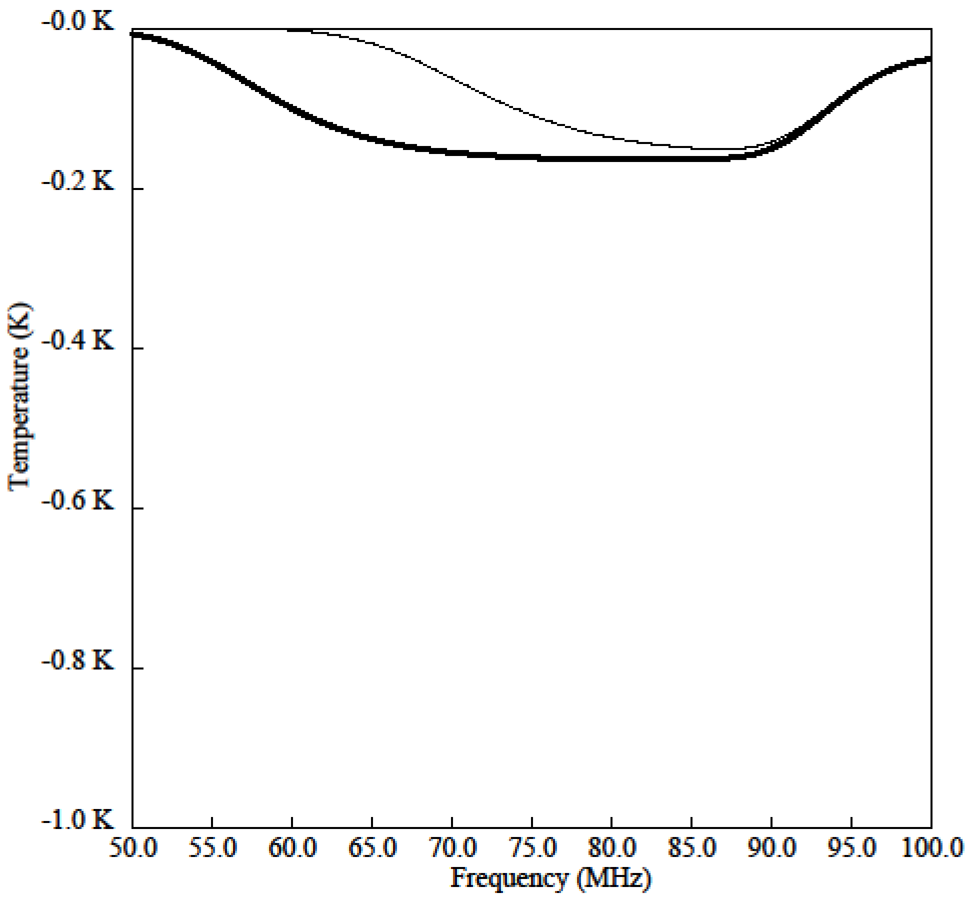


Figure 1. Absorption model using kinetic temperature from Prober et al. 2015 and Lyman intensity from Holzbauerand and Furlanetto 2012. Thick curve for $M_{min}=10^7\ M_{\odot}$ and thin curve for $M_{min}=10^8\ M_{\odot}$.

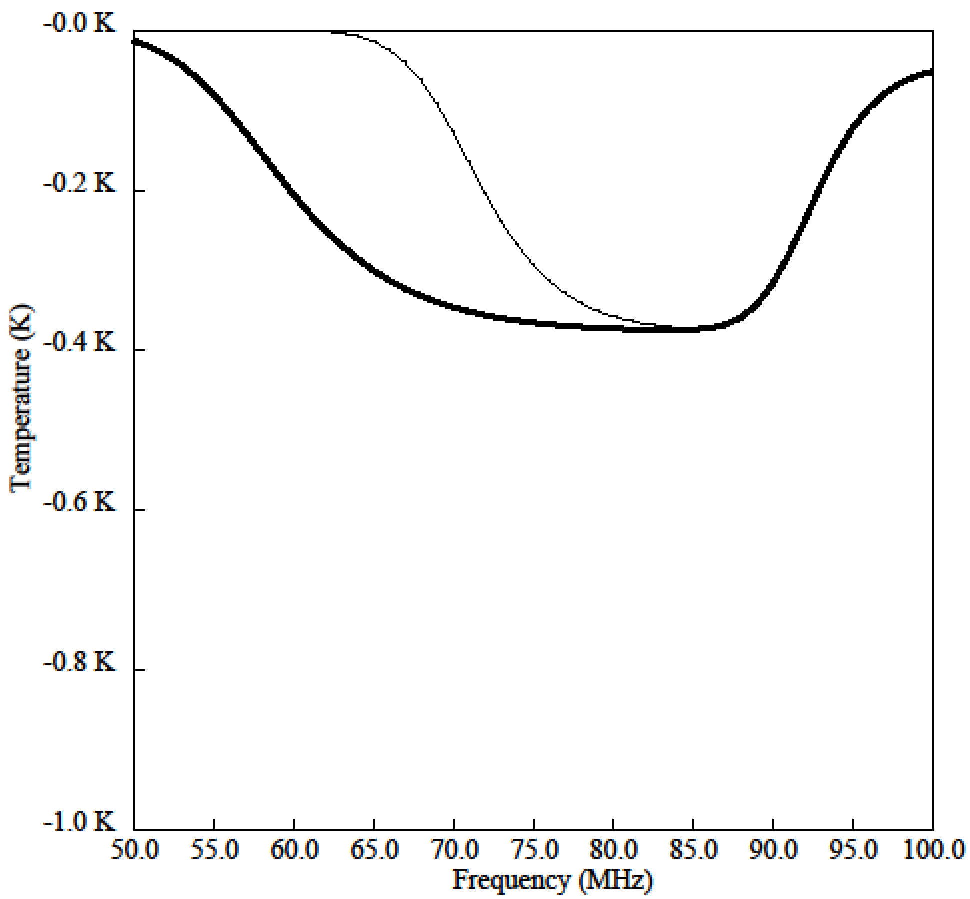


Figure 2. Thick curve for lower $T_k$ and thin curve for added change to Lyman alpha intensity see text.