

# Figures from De Domenico & Insolia 2012

October 23, 2018

I have implemented the continuous loss approximation for UHECR proton energy losses during propagation based on the parameterisation in [1]. Here I summarise the results of reproducing a few of the figures from the original paper as a consistency check.

## Figure 2

The losses of UHECR protons can be found by solving the following equation

$$\frac{dE}{dz} = -\frac{E}{L_{\text{loss}}(z, E)}. \quad (1)$$

$L_{\text{loss}}$  is loss length in Mpc, given by

$$L_{\text{loss}}(z, E) = \frac{dz}{dt} \frac{1}{[\beta_{\text{rsh}}(z) + \beta_{\pi}(z, E) + \beta_{e^{\pm}}(z, E)]}, \quad (2)$$

where the  $\beta$  terms are the loss rates of the different processes, as defined in [1]. The original and created figures are shown in Figure 1.

## Figure 4

Following the notation of the original paper, the survival probability and flux of UHECR protons is given by (see Equations 10 and 11 in [1])

$$\omega_{\text{GZK}}(z, E_f) = \frac{s-1}{E_f^{-s+1}} \int_{E_i(z, E_f)}^{\infty} E^{-s} dE = \left[ \frac{E_i(z, E_f)}{E_f} \right]^{1-s} \quad (3)$$

$$\Omega_{\text{GZK}}(z, E_f) = \frac{\int_z^{\infty} dz' \int_{E_i(z', E_f)}^{\infty} E^{-s} dE}{\int_0^{\infty} dz' \int_{E_i(z', E_f)}^{\infty} E^{-s} dE} \quad (4)$$

The original and recreated figures are shown in Figures 2 and 3. Good agreement is found. **However, it should be noted that it is necessary to use  $\omega_{\text{GZK}}$  and not  $\Omega_{\text{GZK}}$ , as described in the paper.** The same calculation for  $\Omega_{\text{GZK}}$  results in a different shape for the plotted quantities.

## References

- [1] De Domenico, M. & Insolia, A., 2012. *Influence of cosmological models on the GZK horizon of ultrahigh energy protons*. Journal of Physics G: Nuclear and Particle Physics, 40(1), p.015201.

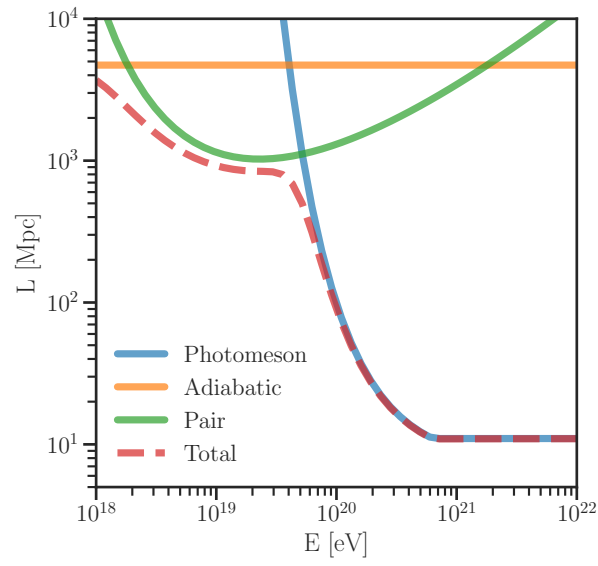
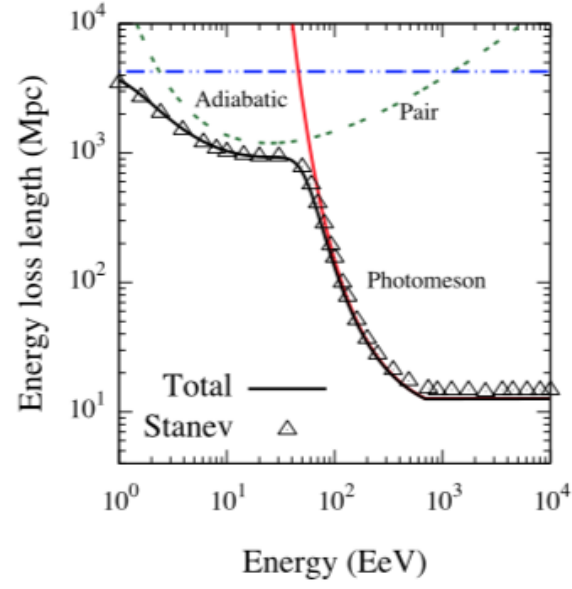


Figure 1: Comparison of Figure 2 from [1]. The original is shown on the top with the recreated underneath.

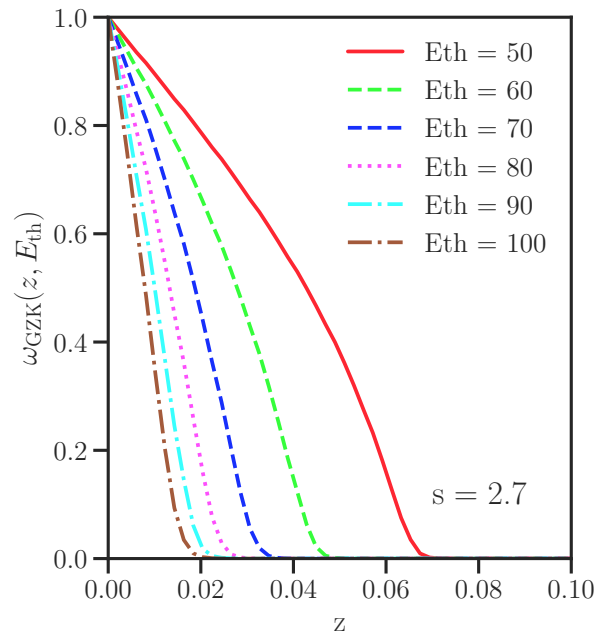
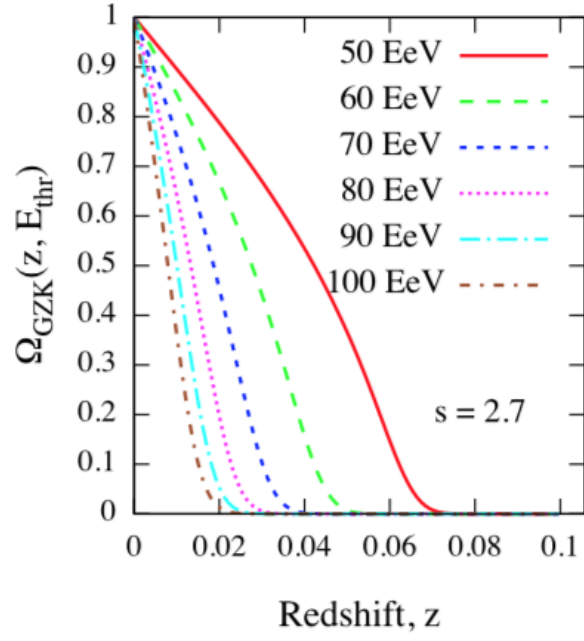


Figure 2: Comparison of Figure 4a from [1]. The original is shown on the top with the recreated underneath.

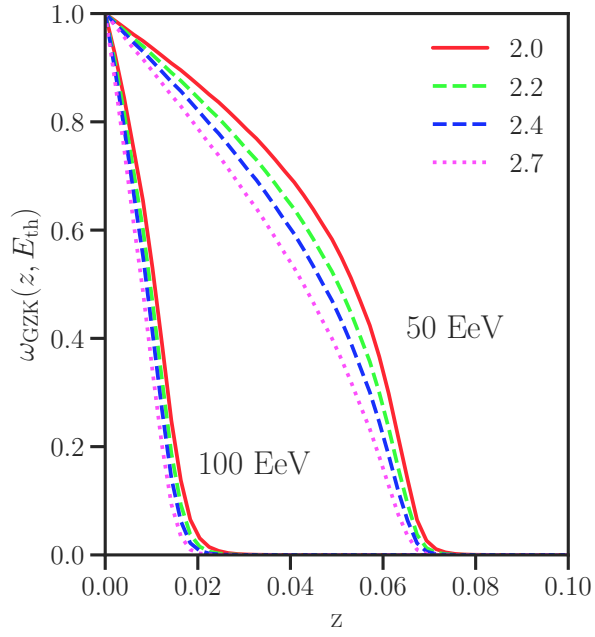
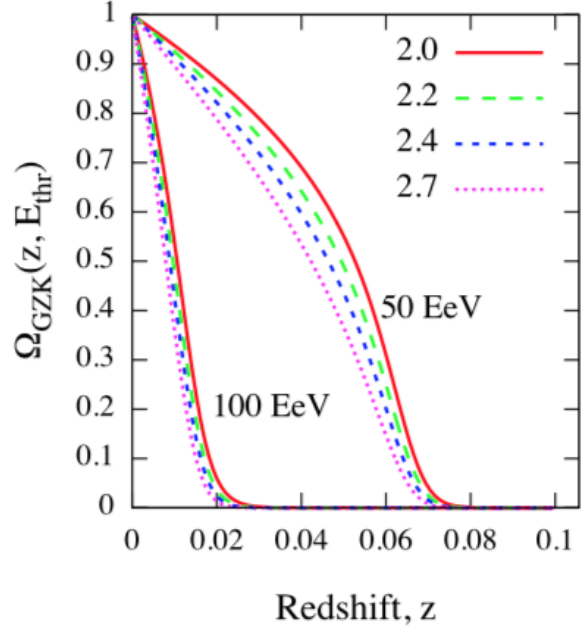


Figure 3: Comparison of Figure 4b from [1]. The original is shown on the top with the recreated underneath.