

# AST5220-Milestone II: The Universes Opacity

NILS-OLE STUTZER

## Abstract

*The codes for this paper can be found at:*  
<https://github.com/SagittariusA-Star/AST5220-Milestones>

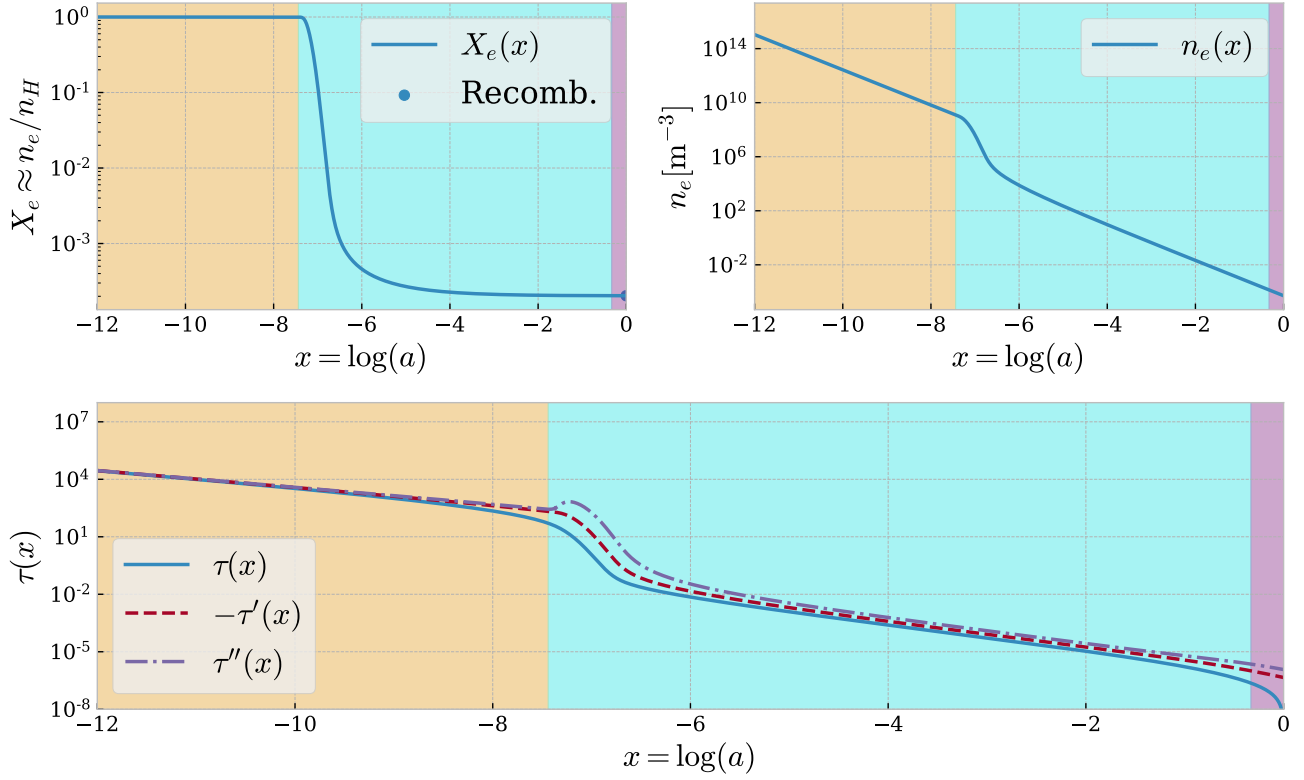
1. INTRODUCTION

2. METHOD

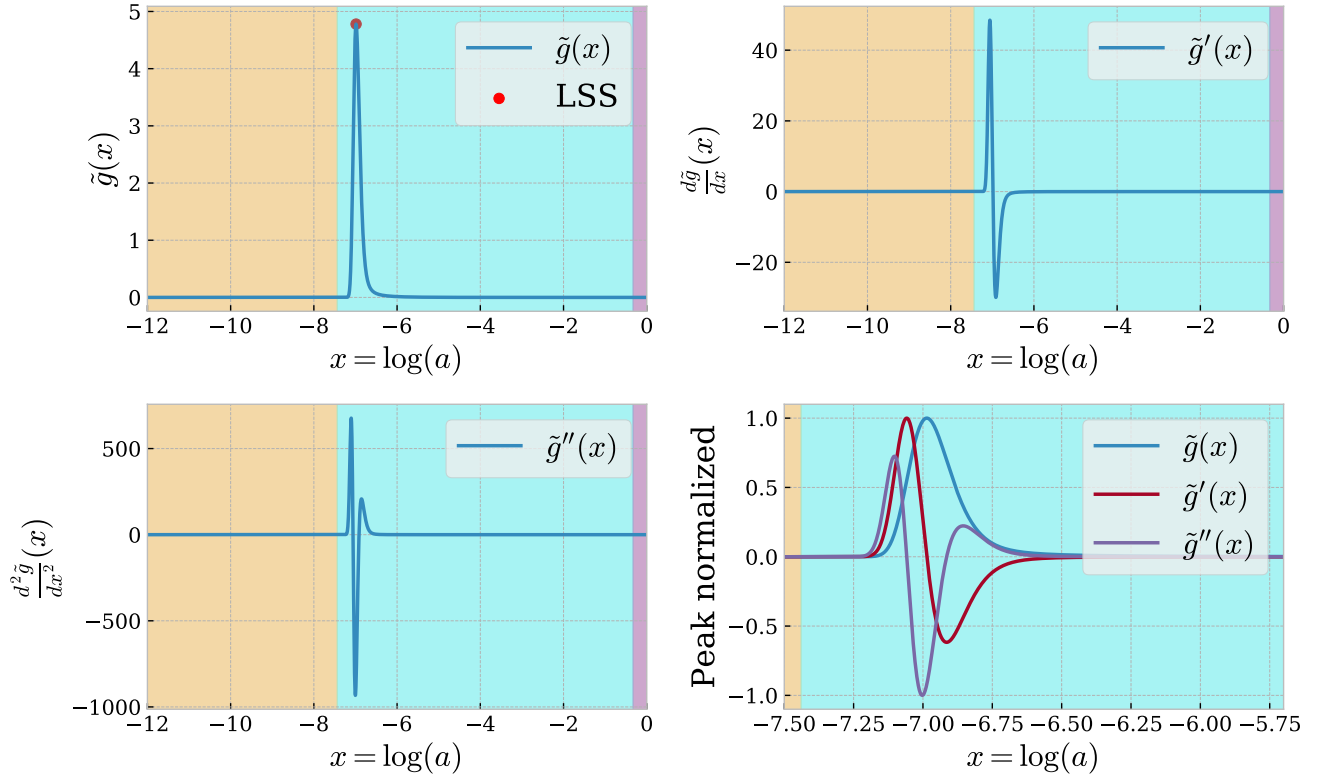
3. RESULTS/DISCUSSION

4. CONCLUSION

REFERENCES



**Figure 1.** **Upper left:** Figure showing the free electron fraction  $X_e$  as a function of the log-scale factor  $x$ . **Upper right:** Figure showing the free electron density  $n_e$  as a function of the log-scale factor  $x$ . **Lower panel:** Figure showing the optical depth  $\tau(x)$  of the universe due to Thomson scattering on free electrons only, as well as the derivative  $\tau'(x)$  and second order derivative  $\tau''(x)$  w.r.t and as functions of the log-scale factor  $x$ . **Note:** The background color in all the plots shows the epoch of dominance for reference. Yellow marks the era of radiation dominance, blue the epoch of matter dominance and purple corresponds to the epoch of dark energy. The color domain is found by checking when the corresponding density parameter is dominant, however, in reality the transitions between each epoch should be smoother than shown.



**Figure 2.** **Upper left:** Figure showing the un-normalized visibility function  $\tilde{g}$  as a function of the log-scale factor  $x$ . The red dot marks the peak of  $\tilde{g}$  and its  $x$  value corresponds to the log scale factor of the surface of last scattering. **Upper right:** Figure showing the un-normalized first order derivative of  $\tilde{g}$  w.r.t. and as a function of the log-scale factor. **Lower left:** Figure showing the un-normalized second order derivative of  $\tilde{g}$  w.r.t. and as a function of the log-scale factor.