The Effects of Dark Matter in the Epoch of Reionization

Mpho Kgoadi

University of the Witwatersrand

Abstract

Many theories have been proposed about the nature of dark matter but perhaps the most studied is the WIMP (Weakly Interacting Massive Particle). In this work we present an argument for studying the properties of dark matter in the Epoch of Reionization (EoR) using the redshifted 21 cm background.

Introduction

- The early Universe went through two major phase changes; Recombination and Reionization.
- The first billion years of the Universe is poorly constrained
- Gunn-Peterson trough shows the Universe is fully ionized at z $\sim$ 6
- Evidence of reionization include quasars, CMB and 21 cm observations
- Sources include stars, AGNs and other exotic sources
- What about dark matter ?

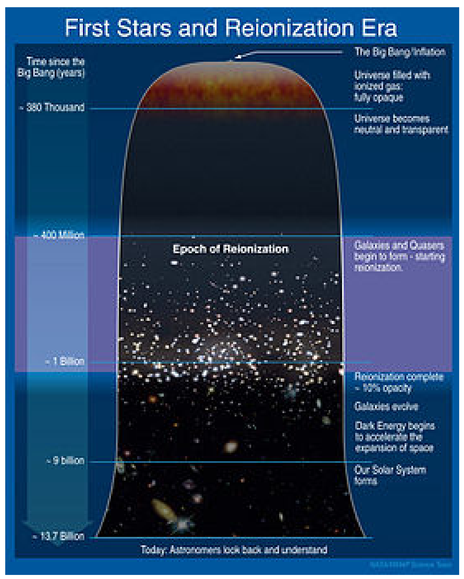


Figure 1:The history of the Universe

21 cm physics

- The 21 cm line is caused by the hyperfine splitting of the hydrogen ground state
- Spins align/oppose (triplet/singlet)
- This leads to an energy separation which corresponds to a wavelength of 21 cm
- The most important observable is the brightness temperature given by

$$T_b \approx 27 x_{HI} \left(\frac{\Omega_b h^2}{0.023}\right) \left(\frac{0.15}{\Omega_m h^2} \frac{1+z}{10}\right)^{1/2} \left(\frac{T_s - T_R}{T_s}\right) \text{ mK}$$

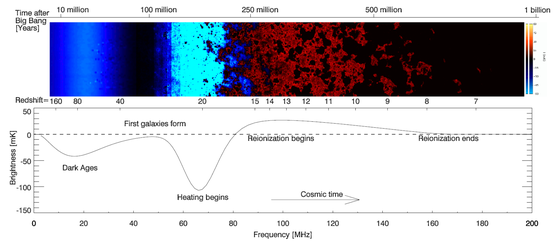


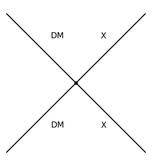
Figure 2:The 21 cm cosmic hydrogen signal

Dark Matter

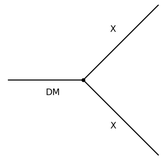
We assume a general case of particle dark matter

m_{DM} Particle mass

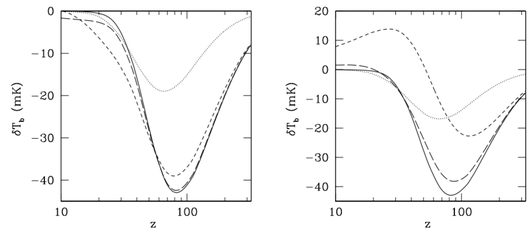
$\langle \sigma V \rangle$ Annihilation 'rate'



Γ Decay rate



Previous work shows substantial heating effects



DarkHistory

- Darkhistory uses updated efficiency functions
- It includes structure boost from halo formation
- It makes the temperature constraint calculations significantly more streamlined, self-consistent, and accurate

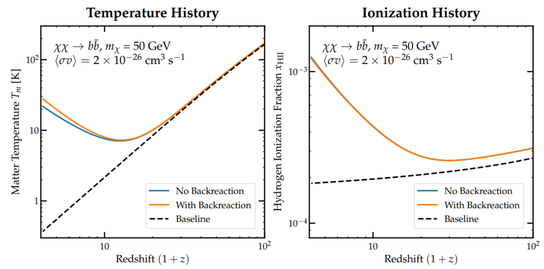
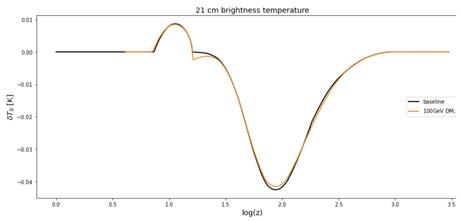


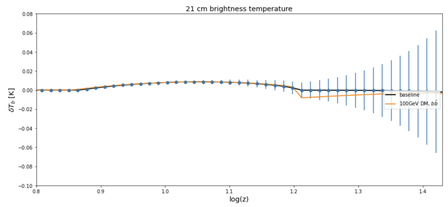
Figure 3:Temperature and Ionization history from DarkHistory

Results

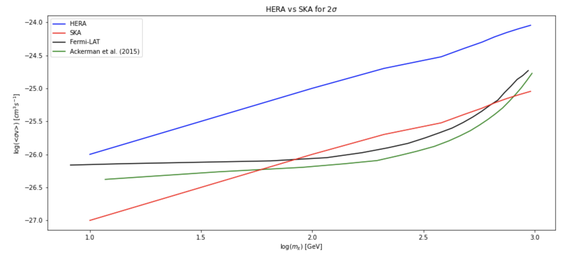


- Effect of DM on heating reduced
- Radically alters z $\sim$ 15 behaviour
- Due to reduced heating efficiency

Can Interferometers measure the global signal ?



For WIMP mass of 100 GeV we get $\langle \sigma v \rangle = 4 \times 10^{-26}$ cm^3 s^{-1}



Conclusion

- EoR is a great probe of exotic energy injection
- This requires precise modelling of energy deposition
- Previous results were highly over-estimated
- DarkHistory lets us start to correct this
- Early results are promising

Challenges and future work

- The sensitivity impact on interferometers
- Extend analysis to single dish experiments
- Sharp features from DarkHistory
- Incorporate all Lyman- sources

References

- Marcos Valdes, A Ferrara, M Mapelli, and E Ripamonti. Constraining dark matter through 21cm observations.
- Hongwan Liu, Gregory W Ridgway, and Tracy R Slatyer. Darkhistory: A code package for calculating modified cosmic ionization and thermal histories with dark matter and other exotic energy injections
- Jonathan R Pritchard and Abraham Loeb. 21 cm cosmology in the 21st century.Reportson Progress in Physics, 75(8):086901, 2012.

Contact Information

Kgoadimpho16@gmail.com