Dark matter vistas in the light of 21cm cosmology and some aspects of gravitational lensing

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Abstract

The 21cm signal has become a vital tool in cosmology, offering insights into the early and late formative stages of the Universe, particularly during the era of galaxy and star formation, known as the cosmic dawn. This thesis investigates various cosmologically significant parameters using the global 21cm signal during this epoch. The 21cm line, arising out from the hyperfine transition of neutral hydrogen, is essential in this study.

The EDGES collaboration reported a 21 cm differential brightness temperature of $T_{21} = -500^{+200}_{-500}$ mK at $z = 17.2$, indicating a gas temperature significantly lower than expected in the ΛCDM model. This discrepancy suggests mechanisms such as increased background radiation or gas cooling might be at play. This thesis explores dark matter models, particularly the Inert Doublet Model (IDM) and Elastically Decoupling Dark Matter (ELDER), to explain this observation.

For IDM, we constrain parameters related to energy injection and relic density, focusing on the velocity-averaged annihilation cross-section. Our findings indicate that IDM dark matter influences the 21cm signal, particularly through annihilation and baryon-dark matter collisions, affecting the temperature profile and resulting in notable fluctuations in T_{21} at specific redshifts.

In two-component dark matter scenarios, IDM and generic dark matter coexist, influencing the 21cm signal through distinct mechanisms. We identify constraints on generic dark matter mass to align with EDGES observations, highlighting the intricate balance between heating and cooling effects in this dual framework.

ELDER dark matter, characterized by self-interactions, further modifies dark matter dynamics and structure formation. This thesis examines how these self-interactions impact the 21cm signal, offering insights into the nature and behavior of dark matter in the early Universe.

Additionally, gravitational lensing by neutron stars can amplify the 21cm signal, enhancing detection capabilities with radio telescopes like the uGMRT. Our research reveals that neutron stars with specific characteristics can significantly affect the 21cm signal, providing a method to estimate the position and size of these stars using the signal-to-noise ratio.

This study offers comprehensive insights into dark matter interactions, gravitational lensing effects, and their collective impact on the 21cm signal, enriching our understanding of cosmic evolution and the nature of dark matter.

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