CTA200: Final Project

# Power Spectra Calculations for Different Dark Matter Models Using the CLASS Code in Python

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## 1 Introduction and Method

In this report, I investigate the matter power spectrum and the Cosmic Microwave Background (CMB) angular power spectrum in the context of both the Cold Dark Matter (CDM) model and the Warm Dark Matter (WDM) model. By utilizing the Cosmic Linear Anisotropy Solving System (CLASS) code, a widely used numerical solver for cosmological perturbations, I obtain accurate and reliable predictions of these observables. My study aims to provide a better understanding of the distinguishing features of the CDM and WDM scenarios.

I consider two dark matter models for our analysis, the Cold Dark Matter (CDM) model, and the Warm Dark Matter (WDM) model. These models are characterized by distinct particle properties, which in turn influence the formation of large-scale structures and the evolution of the Universe. For the Cold Dark Matter model, I use cosmological parameters derived from the Planck 2018 results, which provide comprehensive and precise constraints on various cosmological observables (Planck Collaboration, 2018). Due to the absence of a well-established source for the Warm Dark Matter model parameters, I have manually selected and input the relevant parameters, guided by existing literature and theoretical considerations.

I employ the CLASS code for each model, generating the matter power spectrum and the CMB angular power spectrum. I compare the results obtained for the CDM and WDM models to identify key differences in their respective signatures. I discuss the physical implications of my findings, focusing on how the distinct power spectra from the CDM and WDM models.

## 2 Result and Analysis

The CMB angular power spectrum describes the temperature fluctuations in the Cosmic Microwave Background radiation as a function of angular scale across the sky. Figure 1 presents the CMB angular power spectrum for the Cold Dark Matter model, showcasing the characteristic three peaks in the spectrum. These peaks arise due to the interplay between gravitational forces and radiation pressure during the early Universe, leading to acoustic oscillations in the photon-baryon fluid. The first and highest peak corresponds to the largest scale of structure formation in the universe, which is the scale at which matter and radiation were tightly coupled, also known as the sound horizon. The second and third peak represent the first and second overtone of the acoustic oscillations in the photon-baryon fluid.

The matter power spectrum describes the distribution of matter density fluctuations in the universe as a function of spatial scale (or wavenumber). Figure 2 demonstrates the Matter power spectrum for the Cold Dark Matter model. At larger scales (with smaller k values), density variations in the universe are small, and the distribution of matter can be described using a Gaussian distribution (a bell curve). At smaller scales, which indictaes a higher k value, the process of gravitational collapse becomes more complex and non-linear.

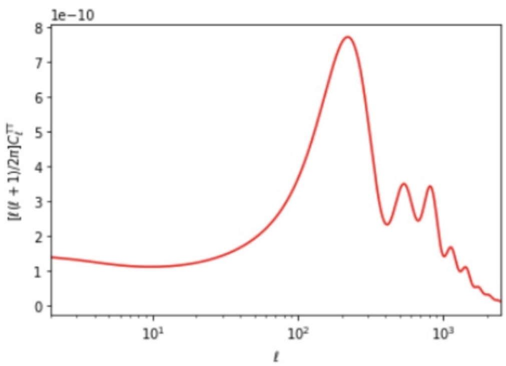


Figure 1: Cosmic Microwave Background (CMB) angular power spectrum for cold dark matter model

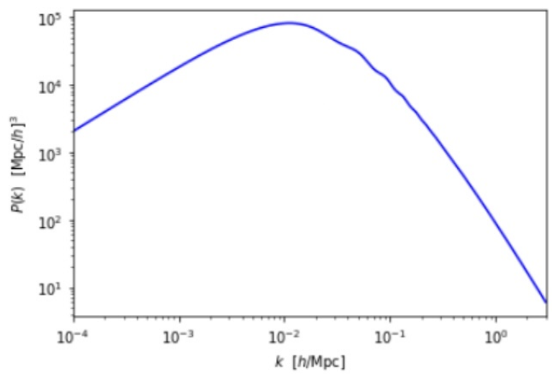


Figure 2: Matter power spectrum for cold dark matter model

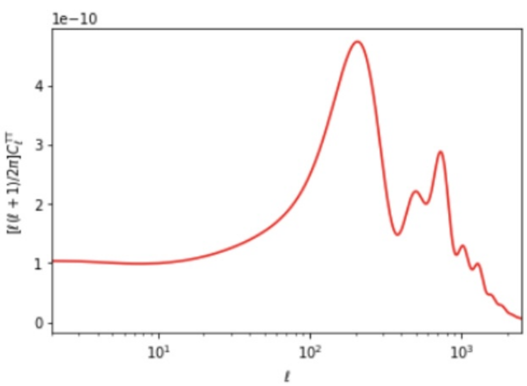


Figure 3: Cosmic Microwave Background (CMB) angular power spectrum for warm dark matter model

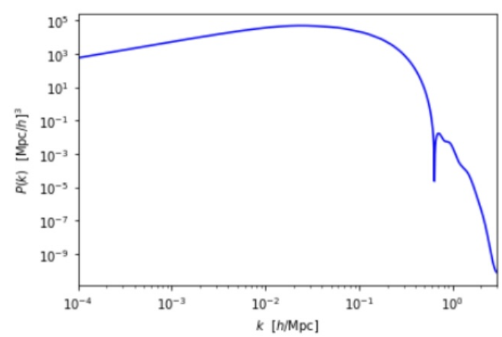


Figure 4: Matter power spectrum for warm dark matter model

Given the less reliable parameters for the Warm Dark Matter model, it is important to note that the resulting plots may not provide as much information as desired. In my analysis, Figure 3 displays the angular power spectrum for Warm Dark Matter, revealing more fluctuations compared to the Cold Dark Matter model. Figure 4 presents the matter power spectrum for Warm Dark Matter; however, a comprehensive physical interpretation of this plot is still under development. The differences observed between the Cold and Warm Dark Matter models highlight the need for further investigation and refinement of the Warm Dark Matter model parameters.

## References

[1] Planck Collaboration. (2018). Planck 2018 results. VI. Cosmological parameters. arXiv preprint arXiv:1807.06211.