Dark Matter Distributions Across Different Galaxy Types

Jaymin Ding, Pradyota Phaneesh, Abhiram Atluri

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Brief History of Dark Matter

Dark Matter has been a focal point of attention since its discovery. Its origin can be traced back to the observations of astronomer Fritz Zwicky in the 1930s. Zwicky noticed inconsistencies between the calculated and observed mass of galaxy clusters, hypothesizing the existence of invisible matter, which he referred to as "dunkle Materie" or Dark Matter.

However, it was not until the 1970s that the concept of dark matter gained significant attention. Vera Rubin, an astronomer, and her colleagues conducted studies on the rotation curves of galaxies. Their observations revealed that stars located at the outer regions of galaxies exhibited velocities higher than expected based solely on visible matter. This behavior suggested the presence of additional mass, dark matter.

Dark matter holds a crucial role in our comprehension of the cosmos, accounting for roughly 27 percent of the universe's total mass. Its gravitational influence also plays a fundamental part in shaping the formation of galaxies, providing the essential framework that governs the construction of the large-scale structures.

Past Research on Dark Matter

This invisible form of matter, aptly named dark matter (DM), exerts a gravitational force on visible matter, including stars and galaxies. When observing a galaxy, the gravitational effects observed, such as the rotational velocity of

the galaxy, cannot be accounted for by visible matter alone. This discrepancy has propelled astronomers to investigate the existence of DM through various astronomical measurements and research.

In 2006, astronomers made a significant breakthrough in the study of dark matter with the observation of the Bullet Cluster. This celestial event involved a collision between two galaxy clusters, and what they found was unexpected. The distribution of visible matter within the Bullet Cluster differed greatly from the distribution of dark matter. This discovery demonstrated that dark matter is not uniformly spread throughout the universe but instead clusters together within large structures.

The Cosmic Microwave Background (CMB) has also provided insights into the existence of DM. Small temperature variations in the CMB can be attributed to the gravitational effects of DM. These variations, once carefully analyzed, can contribute to our understanding of the distribution and influence of DM in the universe.

Gravitational lensing, the bending of light by massive objects, further supports the existence of DM. By observing the distortions in the paths of light rays caused by DM's gravitational pull, astronomers can indirectly detect its presence. Gravitational lensing observations have provided compelling evidence for the clumping and distribution of DM in cosmic structures.

Simulations have played a pivotal role in understanding the effects of DM. These simulations explore different models, including DM that interacts solely through gravitational effects, warm DM with non-negligible free streaming, and DM self-interactions.

While experimental techniques have constrained the parameter space of Weakly Interacting Massive Particles (WIMPs), a proposed candidate for DM, detecting DM directly remains a significant challenge. For instance, Cryogenic Crystal Detectors, like those used in the CRESST experiment in Italy, employ cooled disks of germanium or silicon coated with tungsten or aluminum to detect DM. Despite continuous improvements in sensitivity, definitive detection of DM has yet to be achieved.

As of now, DM is a theoretical form of matter, where ongoing research to uncover its secrets are taking place. By combining observational measurements, simulations, and experimental efforts, researchers try to gain a comprehensive understanding of DM's role in shaping the structure and evolution of the universe.

Our Research Question

The mystery of dark matter has been puzzling scientists for a long time. Ever since the discovery that the outer parts of galaxies were moving at the same speed or faster than the inner parts of galaxies, scientists have been searching for what dark matter could be made of.

Our study aims to find the distribution of dark matter in a galaxy based on the radius, and then compare the distributions for spiral, elliptical, lenticular, and irregular galaxies. We also want to compare the dark matter distributions in field galaxies to those in a cluster.

0.1 How is it Different?

Our research is different because we want to investigate the dark matter distributions across different types of galaxies (spiral, elliptical,...). Rather than directly observing galaxies using large telescopes or measuring the mass of dark matter, we're using data gathered from the SPARC database to do our research. Many researchers also use rotational velocity as their primary indicator of dark matter, however, we will be using mass-luminosity ratio, something which is noticeably more rare in the field.

0.2 How is it Important?

Investigating the distribution of dark matter within galaxies is crucial for understanding the structure of the universe, the formation of galaxies, and the nature of dark matter. While scientists lack a full understanding of dark matter, there is strong evidence supporting its existence. Because of this, further investigation of dark matter, including its distribution, is warranted. Understanding the distribution of dark matter would also provide understanding of astrophysical processes, such as galaxy formation and evolution, and allow testing of theoretical models, including cosmological models. It would also offer a stronger grasp on the formation of galactic halos and gravitational lensing within galaxies.

Even if dark matter is the cause of a misunderstanding of gravity, investigating the distribution of it could help with creating a new idea of gravity's behavior, especially at larger scales. By studying the gravitational effects that cannot be explained by visible matter alone, we can gain insight into potential

modifications to our current understanding of gravity. Thus, investigating the distribution of dark matter within galaxies not only advances our knowledge of astrophysics and cosmology but also contributes to our broader understanding of gravity and its behavior in different astrophysical contexts.

Preliminary Plots

Figure 1: Curve for Galaxy Rotational Velocity vs Dark Matter Halo mass at radius where dark matter density is 200 times the critical density of the universe

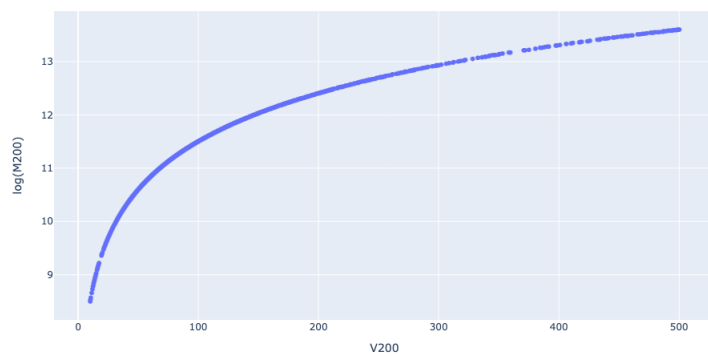
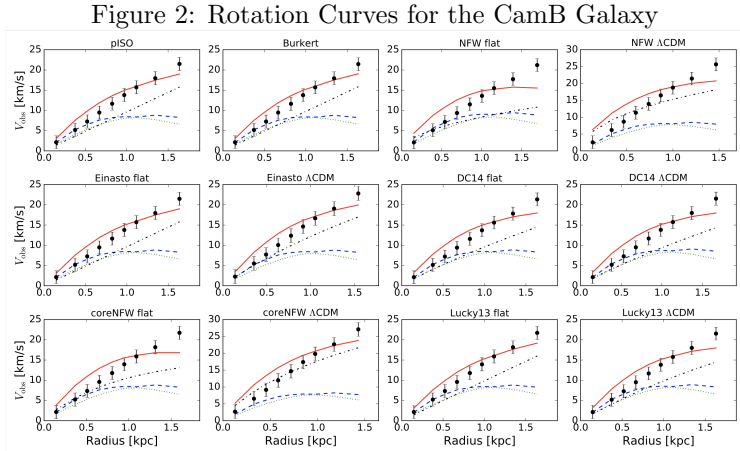


Figure 2: Rotation Curves for the CamB Galaxy



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