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Analyzing Dark Matter Distribution in Spiral Galaxies Using Rotation Curves

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Introduction

One of the most profound discoveries in modern astrophysics is the realization that the majority of the universe's mass is not visible but composed of a mysterious substance known as dark matter. While dark matter does not emit, absorb, or reflect electromagnetic radiation, its presence is inferred from gravitational effects on visible matter, such as stars and gas in galaxies. Among the most compelling pieces of evidence for dark matter is the study of galactic rotation curves—plots showing the orbital velocity of stars as a function of their distance from the galactic center. In spiral galaxies, these rotation curves deviate significantly from what is predicted by Newtonian mechanics when considering only luminous matter. Instead of declining beyond the visible edge of the galaxy, they remain flat or even rise, implying the existence of an unseen mass component. This essay examines how rotation curves are used to analyze the distribution of dark matter in spiral galaxies, explores modeling techniques, and discusses their implications for our understanding of cosmic structure [1].

Description

Rotation curves are constructed by measuring the Doppler shifts of spectral lines emitted by stars and interstellar gas at different radial distances from the galactic center. For spiral galaxies, which are characterized by rotating disk structures, these measurements reveal how the orbital velocity of matter varies with radius. According to classical gravitational theory, if mass were concentrated primarily in the central bulge of a galaxy, the rotational velocity V(r)V(r)V(r) should decrease with distance However, observations from galaxies such as NGC 3198 and M33 show that the rotation curves remain remarkably flat out to large radii, inconsistent with the visible matter distribution. To account for this discrepancy, astrophysicists propose that galaxies are embedded in massive dark matter halos, which extend far beyond the visible edges of the galactic disk. These halos provide the necessary gravitational pull to sustain the observed orbital velocities at large distances. The mass distribution of the dark matter halo is modeled using density profiles such as the Navarro-Frenk-White (NFW) profile, the pseudo-isothermal profile, or the Burkert profile. Each of these profiles assumes different core behaviors—cuspy or cored—and can be tested against observational data. The fitting process involves subtracting the luminous mass contribution (from stars and gas) from the total dynamical mass inferred from the rotation curve to isolate the dark matter component.

One of the major strengths of rotation curve analysis is its ability to probe the radial structure of dark matter in individual galaxies. For instance, Low Surface Brightness (LSB) galaxies, which are faint and diffuse, tend to be dominated by dark matter at all radii, making them ideal laboratories for testing halo models. In contrast, high surface brightness galaxies often show more baryonic dominance in the inner regions. Comparative studies across galaxy types have revealed a surprising universality in the shape of rotation curves, leading to proposals like the "Radial Acceleration Relation" (RAR), which empirically links total acceleration to the visible matter distribution. This has even fueled alternative theories like Modified Newtonian Dynamics (MOND), though dark matter remains the prevailing explanation supported by cosmological simulations.

Numerical simulations, such as those from the ΛCDM model, predict the hierarchical formation of dark matter halos and the large-scale structure of the universe. These simulations are used to create synthetic rotation curves which can be compared with observations to test the validity of dark matter models. Discrepancies, such as the "core-cusp problem" or "missing satellites problem," have led to refinements in dark matter theories, including the idea of self-interacting dark matter or warm dark matter candidates. Observational advances through high-resolution spectrometry and 21-cm line mapping have improved the precision of rotation curves, further sharpening our ability to distinguish between competing models [2].

Conclusion

Analyzing rotation curves in spiral galaxies offers one of the most direct and convincing methods for probing the distribution and nature of dark matter. The discrepancy between observed rotational velocities and those predicted by visible matter underscores the necessity of a dominant unseen mass component enveloping galaxies. Through careful modeling of these curves, astronomers can constrain the shape, density, and extent of dark matter halos, enriching our understanding of galactic dynamics and the universe's composition. As observational techniques and computational models continue to improve, rotation curve analysis remains a cornerstone in the ongoing quest to unravel the enigmatic properties of dark matter, a key player in shaping the cosmos from the smallest galactic structures to the largest cosmic webs.

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Conflict of Interest

None.

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References

1. Zhang, Sheng, Zhihao Zhang, Yifan Si and Bo Li, et al. "Gradient hydrogen migration modulated with self-adapting S vacancy in copper-doped $ZnIn_2S_4$ nanosheet for photocatalytic hydrogen evolution." *ACS Nano* 15 (2021): 15238–15248.

2. Ren, Gaoyang, Junjie Zhao, Zhen Zhao and Zhenyu Li, et al. "Defects-induced single-atom anchoring on metal-organic frameworks for high-efficiency photocatalytic nitrogen reduction." *Angew Chem Int Ed* 63 (2024): e202314408.

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