Disk Galaxy Rotation Curves and Dark Matter Halos

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Contents

1 Introduction

The kinetics of celestial bodies can tell us a lot about their properties, of which the mass is best determined. In the solar system the motion of larger bodies follows the laws of keplarian motion and thus the same was expected for stars in galaxies. Consequently astronomers around the world were puzzled when the first, reliable observations of galactic rotation curves did not fit this model [RF70]. With more precise measurements the results of the first observations were cemented and the theory of dark matter, non-luminous matter which spread out far beyond the luminous matter, arose [RFT80]. This non-luminous matter, often called Dark Matter, which is thought to have such a huge impact on the kinematics of galaxies, remains a mystery, as it has not been observed until today.

2 Early Observations of Galaxy Rotation Curves [RF70, RFT80]

- 1970 observation of 67 HII regions in Andromeda with DTM image-tube spectrographs + observation of [N II] $\lambda 6583$ emission in the center. Rotational speeds from the Doppler shift
- 1980 rotation curves for 21 Sc Galaxies using the Kitt Peak 4m RC spectrograph with a Carnegie image tube
- The 1970 Andromeda and the 1980 Sc observations show similar velocity curves
- Velocities in disk beyond the nucleus "surprisingly similar"
- No expected drop in rot. velocity for larger R
- Steep drop in radial velocity for small R (nucleus)
- Conclusion: there must be a large amount of non-luminous matter extending beyond the luminous matter —> Dark Matter

3 Connecting Rotation Curves to the Distribution of Dark Matter in Halos [PSS96, NFW96, NFW97]

- Persic, Salucci, Stel
  - Large (1100) Sample of rotation curves + photometry
  - Statistical analysis of the data
  - Strong dependence of profile and amplitude of rotation curves on the luminosity
  - —> Mass ratios for Dark and Luminous matter
  - Universal rotation curve only dependent on luminosity
- Navarro, Frenk, White
  - N-body simulations for SCDM & CDMΛ cosmological models
  - halos formed by dissipationless hierarchical clustering
  - Denser halo in low mass galaxies
  - introduce the NFW DM-halo profile as result of the simulations

4 Dark Matter Candidates

4.1 Fuzzy Dark Matter[HBG00]

- Particles so light (m˜10^{-22}eV) that the wave properties can suppress cusps in DM halos
- non-thermally produced
- utilizes non-equilibrium statistical field theory

4.2 Primordial Black Holes[KSFM17, KS12]

- Small black holes with a mass between 10^{20}g and 10^{27}g
- Massive but tiny
- Form during the QCD phase transition in the early Universe by cosmic string loops, bubble collisions or large density perturbations.
- If all of the Milkyways DM consists of PHB —> About 10^{25} PHBs in MW
- Distinct signature so possibly falsified or confirmed in near future

5 Conclusion

- Rotation curves do not follow keplarian motion
- Rotation curves are similar for most spiral galaxies
- RCs strongly indicate that a DM halo must exist
- The DM halos extend can be calculated using NFW profile
- It is largely unknown what dark matter is but PBH and FDM are possible candidates to explain the observations

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