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Spiral Galaxy Gravitation Potential Yielding Rotation Curve

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Introduction

For decades, astronomers have been concerned with the rotation curves highlighted by the circular motion of stars, or more precisely characterised by the spectroscopic observation of the motion of neutral hydrogen and other gases in the disc regions of spiral galaxies. The orbital speeds reported in the disc portions of spiral galaxies are substantially slower than those predicted by Newton's law of gravitation. A two-component model of spiral galaxies' gravitation potential has been proposed, combining a spherically symmetric component with a second component that observes planar radial symmetry on the galactic plane and vanishes beyond the galaxy's effective radius outside an annular disc. It is demonstrated that such a model for potential satisfying the Poisson Equation will result in a rotation velocity curve that is flat over distance from the galactic centre towards the galaxy's edge. This link is shown as a result of classical understanding of gravity and specific symmetry of the gravitational potential without any extrinsic requirement of dark matter in many spiral galaxies, as observed experimentally in many spiral galaxies.

The rotation curves (orbital speed vs radial position from nucleus) of the most luminous galaxies are modestly declining in the regions outside the star-bearing disc, coming down from a broad maximum in the disc. The rotation speeds of galaxies of intermediate mass are typically virtually flat along the disc radius. Lower-luminosity galaxies typically have orbital velocities that increase monotonically across the disc.

However, flat rotation curves must be interpreted with caution. The existence of dark matter haloes is a very important topic, and we should proceed with caution before accepting data that has such a profound impact on our understanding of matter in the Universe. As a result, efforts were made to simulate observed rotation curves using as little mass as feasible in the dark matter haloes.

Spectroscopic measurements of emission lines such as Hα, HI, and CO lines from disc objects, specifically population I objects and interstellar gases, are used to determine the rotation of spiral galaxies. The velocity dispersion in these lines is negligibly small in comparison to rotational velocity, implying that the pressure term in the virial theorem is negligible, allowing the dynamical balance between gravitational and centrifugal forces to be utilised to compute mass with adequate accuracy. Bulge kinematics employing velocity dispersion and rotation also use absorption lines. The dynamical technique is particularly important for determining the mass of dark matter and black holes, which cannot be determined using surface photometry with a mass-to-luminosity (M/L) ratio.

In the literature, rotation curves have been widely employed as tracers of the mass distribution in spiral galaxies. The relationship between the shape of the rotation curve and the amount of bright (baryonic) and dark matter (DM) in a galaxy can reveal a lot about how galaxies arise and evolve.

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