Spiral Density Wave Theory

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[1] The spiral structure was a stationary pattern rather than an evolving winding of material spiral arms. Suppose that there was a force that perturbed the orbits of stars away from mean shapes that are circles. In an inertial frame, each star would follow a perturbed epicyclic path that would not close in a frame with zero angular speed. But in a frame that rotated at some pattern speed Ω_p, the orbits might close, having a two-lobed oval.

1 Hypothesis of Quasi-Stationary Spiral Structure

Consider the dynamics and self-gravitation of the matter in a disk of infinitesimal thickness. Introduce a cylindrical coordinate system (r, φ, z) where the galactic center is located at $r = 0$, and the midplane of the galactic disk is at $z = 0$. The gravitational potential of the galaxy in the midplane of the disk can then be modeled as the sum of a stationary axisymmetric part (due to a bulge, disk, and halo) and a nonstationary and nonaxisymmetric part (due to the spiral gravitational perturbation),

$$V(r, \varphi, z = 0, t) = V_0(r) + V_1(r)e^{i(\omega t - m\varphi)} \ ,$$

where the spiral perturbation is small relative to the axisymmetric reference state and therefore can be Fourier-analyzed in time t and angle φ, with the physical quantity being the real part of the complex perturbation..

References

[1] F. H. Shu. Six Decades of Spiral Density Wave Theory. ARA&A, 54:667–724, September 2016.