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Rotating Halos and Heavy Disks: The Case of NGC 2915

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Abstract. NGC 2915 is a blue compact dwarf galaxy embedded in an extended, low surface brightness HI disk with a bar and two-armed spiral structure. Common mechanisms are unable to explain those patterns and disk dark matter or a rotating triaxial dark halo were proposed as alternatives. Hydrodynamical simulations were run for each case and compared to observations using customized column density and kinematic constraints. The spiral structure can be accounted for by an unseen bar or triaxial halo, but the large bar mass or halo pattern frequency required make it unlikely that the spiral is driven by an external perturber. In particular, the spin parameter lambda is much higher than predicted by current CDM structure formation scenarios. Massive disk models show that when the gas surface density is scaled up by a factor of about 10, the disk develops a spiral structure matching the observed one in perturbed density as well as velocity. This suggests that the disk of NGC2915 contains much more mass than is visible tightly linked to the neutral hydrogen. A classic (quasi-)spherical halo is nevertheless still required, as increasing the disk mass further to fit the circular velocity curve would make the disk violently unstable

1. Introduction and observational properties

NGC 2915 is an isolated blue compact dwarf galaxy whose radio properties are rather extreme, with an HI disk extending to 22 radial scalelengths in the B-band (Meurer et al. 1996). This disk displays a short central bar overlapping the optical emission and a well-developed outer two-arm spiral extending to its edge, both of which can not be reconciled with common formation mechanisms. Bureau et al. (1999) proposed two alternatives: i) the HI disk is embedded in a massive and extended triaxial dark halo with a rotating figure, forcing the bar and spiral pattern at a certain frequency, or ii) (some) dark matter is distributed in a disk closely following the HI distribution, rendering the disk gravitationally unstable. We ran a large number of 2D hydrodynamics simulations aimed at examining both possibilities. The hydrodynamic code used is a simple 2D Eulerian finite difference code on a polar mesh. It is described in full detail in Masset & Bureau (2003) and references therein.

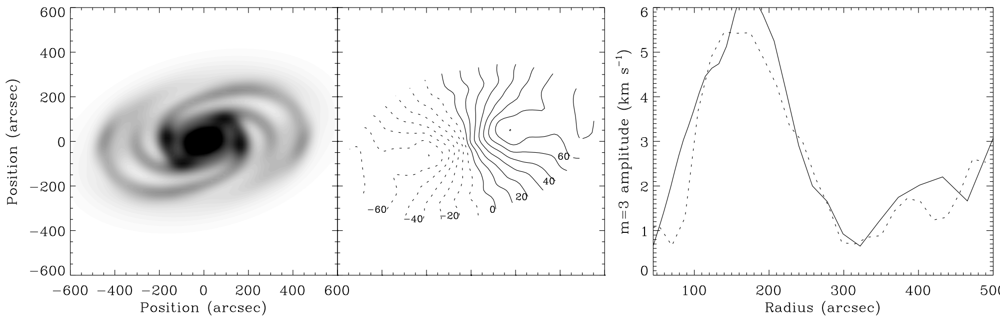

Figure 1. Heavy disk run best match. The left panel shows the beam convolved simulated HI column density (properly scaled), the middle panel the line-of-sight velocity field, and the right panel the radial dependence of the $m = 3$ component of the deprojected line-of-sight velocity (solid line: model, dotted line: observations).

2. External perturber models

We find that the spiral structure of NGC 2915 is best reproduced by a precessing triaxial potential arising from a bar or trixial halo with a pattern speed of about 8 km s^{-1} kpc^{-1}. The bar mass required is however much larger than the mass of the stellar component of NGC 2915 and it is unlikely that a triaxial halo would precess that fast (the dimensionless spin parameter λ implied is very high).

3. Heavy disk runs

We simply scaled up the observed gaseous surface density by a uniform scalar $\lambda_\Sigma \geq 1$, which we varied between 1 and 6, at which value Toomre's Q parameter is approximately unity at $r = 6.5$ and 9 kpc and the disk becomes globally unstable to axisymmetric modes. The goal is to find the range of λ_Σ where a spiral instability develops, leading to the formation of a grand-design spiral structure similar to the one observed and, if possible, to further constrain the value of λ_Σ so that the amplitude of the spiral also matches. We (again) used the observed $m = 3$ amplitude component of the deprojected velocity field as our main constraint. The best match is better than in the external perturber models and is obtained for $\lambda_\Sigma = 4.93$ (see Fig. 1), which amounts to scaling the disk mass of NGC 2915 by a factor ~ 10 due to finite thickness effects.

References

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