N93-26889

The effects of flaring in HI on the observed velocity field of spirals.

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Abstract

This work is part of a larger project in which we want to determine the shapes of dark halos around spiral galaxies. Rotation curves 'probe' the halos in the radial direction. The derived halo mass distributions are badly constrained though (i.e. van Albada et al., 1985). The local halo densities fully determine the width of the gas distribution once the gaseous velocity dispersion is known. There where the dark halo dominates, the Full Width at Half Maximum (FWHM) of the gas layer is proportional to $(\rho_{halo})^{-0.5}$. Therefore, measuring the width of the gas layer probes the halo density directly.

In a dark halo dominated potential, the FWHM of the gas layer increases linearly with radius. This increase of the thickness of the gas layer is known as 'flaring'. Flaring has been found inside the stellar disk (Rupen, 1991). Beyond the edge of the stellar disk, the analysis is hampered by the onset of the warp. Since the galaxy we are studying, NGC 4244, has no significant warp we hope to extend Rupen's analysis into the halo dominated regime.

The usual method to derive a roation curve from an observed 2-dimensional velocity field is to assume that the hydrogen is distributed in infinitely thin rings (eg Begeman, 1989). For a flaring disk, any line of sight samples many different parts of the galaxy, all having different densities and projected velocities. In order to fully exploit the information contained in the gas distribution, we have to understand the effects of flaring on the observables (the spectrum for each point of the galaxy). We have investigated the effects of a flaring disk on the observed velocity field.

It is is obvious that the largest (kinematical) effects are to be expected for low density dark halos at large inclinations.

For low mass galaxies we expect that the flaring of the HI layer will have a major effect on the observed kinematics.

For galaxy with intermediate $V_{max,halo}$ seen at intermediate inclinations, one *overestimates* $V sin(i)$ typically by a few percent.

For more massive galaxies, any effects arising from the flaring HI layer are minuscule unless the inclination is not too far from 90 degrees.

Introduction

The FWHM of an isothermal gas layer inside the optical disk increases exponentially with distance from the center (Rupen 1991). He shows that (for NGC 4565) the volume mass density decrease is consistent with a constant mass to light ratio for the stars.

We are interested in the flaring of the gas layer beyond the stellar disk. An isothermal gas layer in hydrostatic equilibrium with a dominant dark halo will have a Gaussian vertical distribution. The FWHM of the gas layer is proportional to $(\rho_{halo})^{-0.5}$. For an isothermal halo with $\rho_{halo}(R) \propto 1/R^2$ the FWHM thus increases linearly with radius (under the assumption of a constant gaseous velocity dispersion).

Although very little is known about the shapes of dark halos, there is at least one example (NGC 4650A) where the halo appears to be flattened (Sackett, 1992). The volume density of such a flattened halo is increased with respect to the non-flattened case. Measuring the width of the HI layer will thus set limits on the allowed flattening of the dark halo.

We have constructed a (computer) model which calculates a spectral-line HI cube. Input to this model are the volume mass distributions of the dark and luminous matter and the surface density of the gas. The distribution of the gas is found by solving the equation of hydrostatic equilibrium in the appropriate 'ambient' potential. We use this model to calculated the 'observed' velocity field.

Discussion

To derive the velocity field, some kind of average velocity has to be assigned to each point of the galaxy. One has been doing this by calculating the intensity weighted mean velocity or by making Gaussian fits to to the velocity spectrum at each point. For thin disks either procedure works well, but for thick disks both procedures will return erroneous results. The degree of error depends on the thickness of the hydrogen layer. Indeed for massive galaxies seen at intermediate inclinations, thick disk effects on the observed velocity filed are minimal. The effects of flaring become more significant with increasing inclination and decreasing halo density. To illustrate the effects of a flaring disk, we present in Figure I the side view of a flaring HI layer in an intermediate density dark halo potential seen at an inclination of 70 degrees.

Certainly for less massive galaxies seen at large inclination one needs to derive the thickness of the hydrogen layer, the rotation curve and the total mass distribution simultaneously.

We have used Begeman's (1987) mass model for NGC 3198 to study the effect of flaring in more massive galaxies. We took the rotation curve to be constant for easier interpretation of the calculated velocity field. The very low flaring angle for NGC 3198's dark halo, $\alpha \approx 2.7$ degrees, predicts little or no effects on both the velocity field and the derived rotation curve. This is observed to be true for inclinations of 70 degrees and lower. When inclining the model to 80 degrees, we find that the calculated velocity field shows the characteristic outward curving iso velocity lines (Figure II). The instrinsically flat rotation curve is turned into a slowly rising one Figure III.

We would like to point out that for a falling rotation curve the effects are more severe since not only the gradient in the projection factor, $\cos(\theta)$, but also the gradient in the rotation curve will affect the observed 'average' velocities.

Acknowledgments

We would like to thank Kor Begeman's for his excellent velocity field fitting program and Daniel Puche for implementing it in AIPS.

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Figure I : an edge-on view of a flaring disk

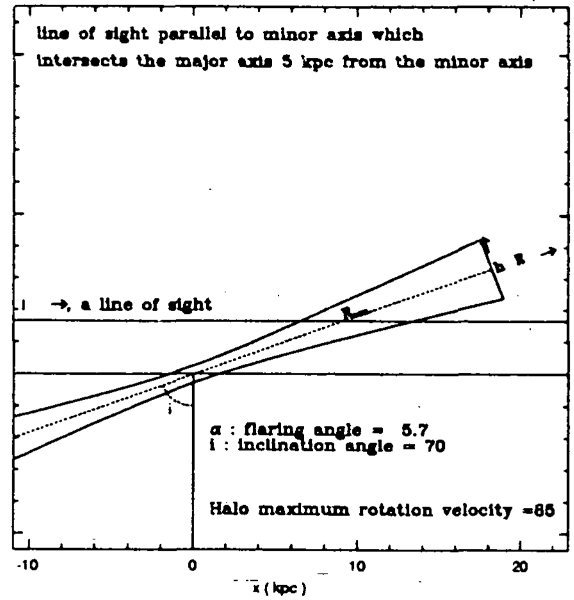

Figure II : Velocity field for 'NGC3918' at i=60

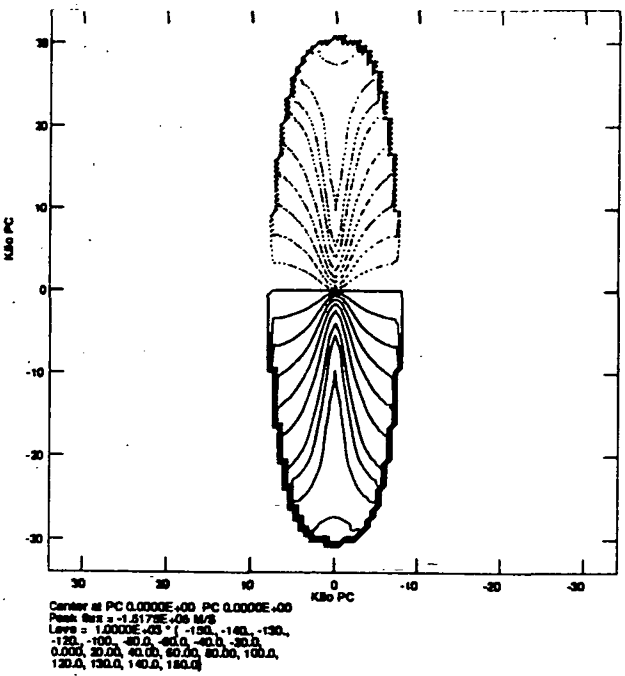

Figure III : Results derived from velocity field