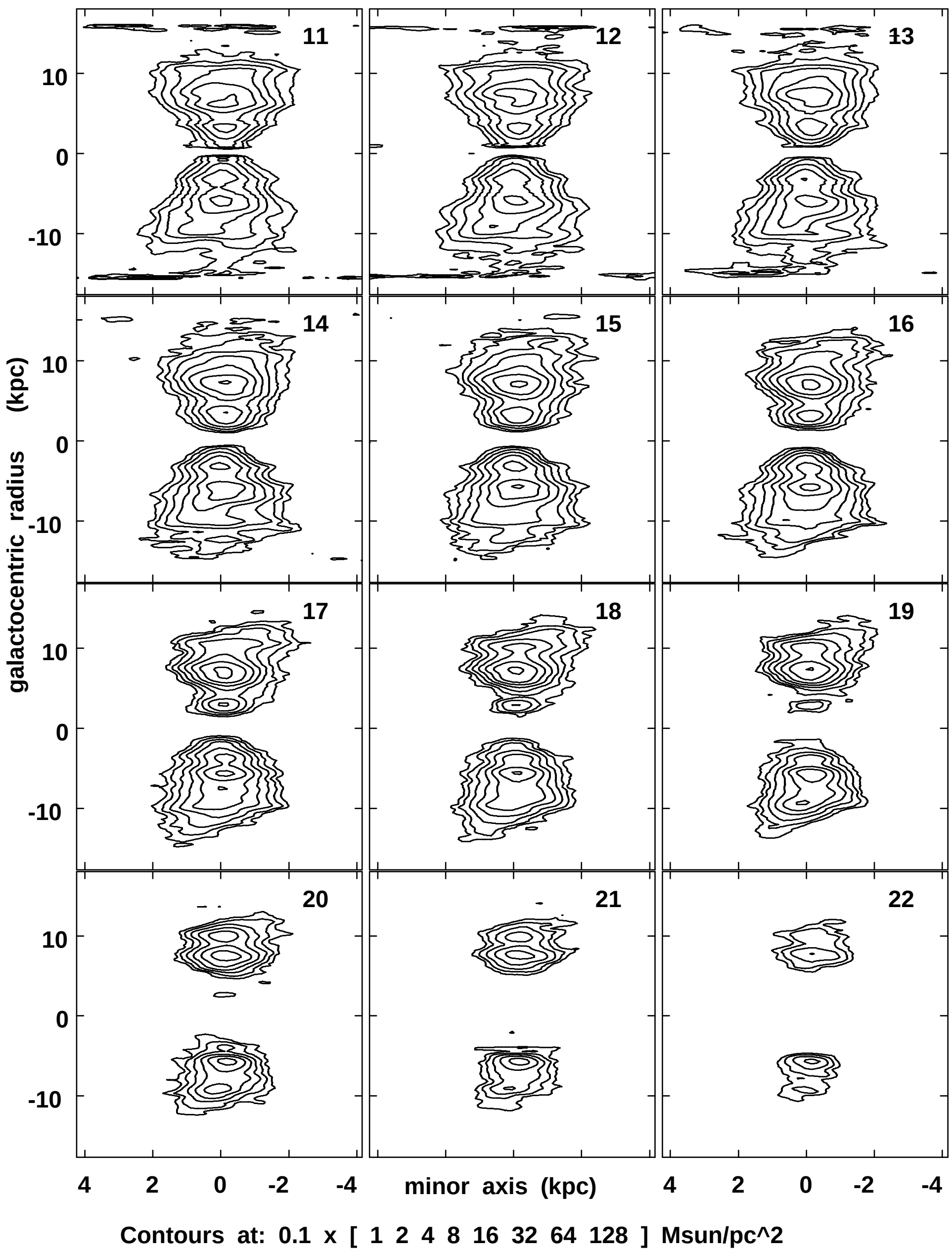

Fig. 34.— Some regridded channels maps (38″ x38″): the major (long) axis coordinate is now *galactocentric* radius. The resolution in this image is roughly 640 pc. The channel numbers, counted w.r.t. the systemic velocity, are plotted in the upper right corner of each panel. The lowest contour plotted corresponds to $\sim$ 5-σ. Like in Fig. 19 of Chapter 3, the channels of the approaching and receding side are combined into one frame. The emission in the channels 11-19 extends to roughly the same galactocentric radius, while the two sides are rather symmetric. The warp can be clearly seen as well.

the local surface brightness as a function of galactocentric radius, is determined. Then, the flux contained in each input pixel is distributed over the appropriate output pixels, conserving flux in the regriding process (some regridded channel maps are shown in Fig. 34).

For every channel, for every point on the major axis in the regridded maps, I fit the profile perpendicular to the major axis. Only profiles which have at least three independent points above three four sigma are accepted. Due to inherent asymmetries present in real galaxies, the data is less easily parameterized, in terms of multiple Gaussians, than the CSDD model maps. The peaks arising from the near and far side, originating from rather different positions in the galaxy, are allowed to have different amplitudes, but by an arbitrary 60% only[38]. Furthermore two-component fits are only accepted if the separation between peaks is large enough[39]. The widths of the near and far sides are required to be the same. Because of the large difference between the projected planar widths in the two inclination regimes (Fig. 33) it is imperative to eliminate spurious two-component fits. Therefore, only those two-component Gaussian fits which are more likely (in the χ^2 sense) than the one-component fit are accepted.

The average values of the fitted Gaussian parameters are determined for a selected number of radii, while the errors are calculated by adding (in quadrature) the observational error to the error associated with possible streaming motions (see Chapter 3, Appendix 2.6.1.). Determining thickness and inclination proceeds somewhat differently in the clearly "not edge-on" and the "almost edge-on" regimes. In the not edge-on case I calculate the weighted average of the inclination using Eqn. [(55), Chapter 3] which is then used in Eqn. [(56), Chapter 3] to determine the thickness of the gas layer. In case the two sides of of the CSDD overlap (almost edge-on case) I solve Eqn. [(54), Chapter 3] using a non-linear least squares technique[40]. The square of the difference between the observed and model widths is minimized by varying the inclination and gaseous width [Eqn. (54), Chapter 3], where each data point is weighed by the square of the inverse of its error.

NGC 4244, at $i \approx 85^{\rm o}$, is somewhere in the transition zone between the two regimes: in some channels, at some radii, the near and far side can be separated, while in most cases this is not the case. In Table 6 I describe how to arrive at the thickness and inclination for all usable combinations of number of channels per group. If fewer channels with valid data are found, that particular galactocentric radius is skipped. The final values for inclination and gas layer width are the weighted averages of the values calculated from the two regimes. As discussed above, realistic error estimates are important to arrive at meaningful answers. The systematic effects due to streaming motions can be modelled well (Appendix 2.6. of Chapter 3), but require (in the almost edge-on case) an inclination correction before they can be included in the calculation. This problem is solved by iterating several times.

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[38]This limited range for the ratio of the peaks avoids some of the problems associated with performing multiple Gaussian fits (see Appendix 4.3., and footnote 37).

[39]From simulated data it follows that a composite profile can be fit reliably by two components if the separation between the components is larger than 0.77 $FWHM$, for all the flux ratios considered

[40]The performance of a least squares technique can be greatly improved by imposing physical limits on the to be fitted parameters. For example I limited the inclination to lie in the range $0^{\rm o}$ -$90^{\rm o}$, and the thickness of the gas layer to be positive. A standard LSQ routine (e.g. MRQMIN, Press *et al.* 1990) can be easily modified to include physical limits in the step where a new guess for the solution is calculated: if the new guess exceeds a physical boundary, then the new guess is placed halfway between the old guess and the physical boundary.

Table 6: The action table for the thickness and inclination determination in the almost edge-on (AEO) and not edge-on (NEO) regimes.

#channels in AEO group	action taken for AEO group	#channels in NEO group	action taken for NEO group
≥ 3	AEO procedure	≥ 3	NEO procedure
2	fix i to NEO value, solve eqn. (12,Chapter 3)	≥ 3	NEO procedure
1	fix i to NEO value, solve eqn. (12,Chapter 3)	≥ 3	NEO procedure
≥ 2	AEO procedure	1 or 2	move to AEO group

Chapter 5

CONCLUSIONS

5. Conclusions

5.1. DARK MATTER

The $10h^{-1.5}$% mass fraction of rich clusters (Briel *et al.* 1992; Mushotzky *et al.* 1995) which is in the form of baryons is mostly composed of hydrogen gas, not stars or stellar remnants. The amount of hot intracluster hydrogen is such that the entire DM halos of individual galaxies (6 - $20h$ times the amount of luminous mass in galaxies) might be composed of baryons. In the scenario proposed by Bahcall *et al.* (1995) this gas is not accreted from the general intergalactic medium, but rather, is stripped of the halos of the member galaxies in the process of cluster formation.

The distribution of this hydrogen in the halos of the constituting galaxies remains elusive. X-ray background measurements exclude the presence of a substantial amount of hot gas (10^6 K), while cold gas is unstable and should be forming stars (Hegyi & Olive 1986). Pfenniger & Combes (1994) suggest that the missing mass on galactic scales is composed of cold and dense molecular hydrogen, in thermal equilibrium with the background radiation field: the "clumpuscule" hypothesis. Star formation is inhibited because the interstellar medium is in a dynamical state where the formation of stars (or "Jupiters") is prevented because of frequent collisions between clouds. Such cold molecular hydrogen would be very hard to detect (Pfenniger *et al.* 1994). Because the self-gravity of the gas is so important (Paper I; Chapter 2), the thickness of the gas layer is strongly affected by the presence (or absence) of a massive molecular disk.

Dissipationless galaxy formation simulations tend to produce triaxial DM halos (e.g., Frenk *et al.* 1988; Warren *et al.* 1992), with an intrinsic flattening distribution peaked at $q_\rho = c/a = 0.5$ ($\pm$ 0.15). In these simulations the dark matter is 100% non-baryonic and interacts only gravitationally. Adding 10% baryonic matter (gas) and including gasdynamics to these simulations produces more oblate halos while q_ρ remains unchanged (Katz & Gunn 1991; Udry & Martinet 1994; Dubinski 1994). Those 10% baryons are then converted into the stars we observe today. Significantly flattened halos suggests that the process of galaxy formation is more dissipational, which might occur if a larger fraction of the initial density perturbations are baryonic.

We thus have the situation that baryonic dark matter and non-baryonic dark matter scenarios predict halos with different flattenings.

5.2. THE SHAPE OF DARK HALOS

In Chapter 2 (Paper I) we have seen that the thickness of the gas layer is a sensitive probe of the shape of the DM distribution. The thickness of the gas layer depends, to reasonable approximation, on the total amount of dark mass which is co-spatial with the gas layer. Thus, the gas layer will be thinner in flatter halos with larger midplane densities.

Four ingredients are essential for the determination of the shape of the dark halo: the thickness of the gas layer, the velocity dispersion of the gas, the surface density of the gas, and the rotation curve. In the ideal, case where the gas layer extends well into the halo, these measurements would be sufficient for the determination of the shape of the dark halo [via Eqn. (45), Chapter 3]. However, in a more realistic case, like NGC 4244, the gas layer does not extend much beyond the optical disk, so that the stellar mass distribution plays some role as well (Fig. 11, Chapter 2). The global approach, outlined in Chapter 2, is specifically designed to deal with the situation in which the relative importance of the three components (stars, gas, and halo) contributing to the total potential is radially varying. However, this self-consistent manner of modelling the thickness of the gas layer requires an azimuthally symmetric galaxy.

The method presented in Chapter 3 produces an azimuthally averaged value for the thickness of the gas layer, and is hence suitable for comparison with the model flaring curves. The H I surface density, as determined from the total H I map, is an azimuthal average as well (Chapter 3, Sec. 3.4.1.). The velocity dispersion as determined from the H I spectral line observations is not an azimuthal average, but is determined on the major axis of the galaxy (Chapter 3, Sec. 3.4.2.).

From the comparison of the thickness measurements with the model flaring curves we infer that the dark halo of NGC 4244 is significantly flattened. Taking the uncertainties in the gaseous velocity dispersion and inclination into account I determine the value for the axial ratio of the dark matter distribution: $0.1 \leq q_\rho \leq 0.5$, with a most likely value of 0.2. The largest source of uncertainty is the gaseous velocity dispersion (Chapter 3).

Compared to the values predicted ($q_\rho = 0.5 \pm 0.15$; Dubinski, 1994) from the galaxy formation scenarios, the axial ratio of NGC 4244 is rather small. It would be interesting to see whether flatter halos result if these galaxy formation simulations use larger gas fractions. Consistency with the clumpuscule hypothesis (Pfenniger *et al.* 1994) requires a dark matter velocity dispersion about 1.4 times larger than the velocity dispersion of the H I . The largely unknown physical state of this dark molecular disk precludes us from confirming or falsifying the clumpuscule hypothesis.

Since the flaring can be determined at lower inclinations as well, possibly at inclinations as low as 60^o , the shape of dark matter halos surrounding many galaxies of different Hubble types can be determined. It will then be possible to gauge the significance of the highly flattened dark halo of NGC 4244, and place more stringent constraints on the process of galaxy formation and the nature of dark matter.

6. Future Work

As argued above, it is crucial to determine the shape of dark halos for a representative sample of galaxies. These determinations are most easily made for systems with regular extended H I envelopes at inclinations larger than 60^o . Coincidentally, similar requirements were imposed to select galaxies for the more traditional rotation curve studies. A large number of systems are thus available for study. The resolution of the VLA in C-array configuration is good enough to resolve the thickness of the gas layer to distances of about 15 Mpc. I plan to observe a number of these galaxies. As the bulge-to-disk ratio varies significantly along the Hubble sequence, the conspiracy-of-shapes theory (Sackett *et al.* 1994) can be better tested.

In conjunction with additional optical and near-IR observations, flaring measurements might be useful in determining the mass-to-light ratio of stellar disks. Near-IR observations are required to determine the exact mass distribution of the stellar disks. Accurate, high-resolution stellar absorption line studies can be used to probe the vertical distribution of the stars (a sech^2 distribution has a lower face-on velocity dispersion than an exponential distribution; van der Kruit 1988). With the more detailed description of the total potential (Chapter 2) it might even be possible to distinguish flat dark halos from round dark halos in the inner parts of galaxies (Chapter 3, Fig. 6). Among the sample of nearby galaxies for which sensitive, high resolution

H I observations exist (kindly made available to me by Robert Braun) some good candidates may be found.

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