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Bloated Dwarfs: The Thickness of the HI Disks in Irregular Galaxies

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Abstract. Somewhat counterintuitively, the gas disks of (dwarf) irregular galaxies, such as the LMC, are thicker than those of normal disk galaxies, both in relative as well as in absolute terms. In retrospect, this is easily understood. The velocity dispersion of the gas throughout galaxy disks (regulated by star forming activity) is similar (6–9 $\mathrm{km\,s^{-1}}$) in dwarf galaxies and in spirals. The gravitational potential of irregulars is considerably smaller, though, with as a result a thicker or puffed–up gas disk. We will explain several methods which can be used to derive the scaleheight of the gas in irregular galaxies. The larger scaleheight we encounter has consequences for the escape of metals to the halo as a result of supernova explosions within OB associations. It also increases the cross section of irregular galaxies, increasing the probability for intercepting lines of sight towards QSOs.

1. Introduction

There is growing evidence that the neutral gas disks of gas rich dwarf Irregular (dIrr) galaxies are thick, both in a relative sense (as compared to their overall dimensions) as well as in an absolute sense. This has some important consequences, especially given that dwarf galaxies were supposedly more numerous at large lookback times (forming the building blocks of today's galaxies). For example, thick disks imply a larger cross section for intercepting light coming from distant objects, giving rise to QSO absorption lines.

Another reason to be interested in the thickness of the neutral gas disks is that it defines the maximum size superbubbles (created by multiple supernova explosions within OB associations) can attain before breaking out into the halo. And in the case of break out, enriched gas is less likely to escape into the IGM or intracluster medium, as shown by Silich & Tenorio–Tagle (2001; see also Mac Low & Ferrara 1999).

Table 1. Relation between superbubble diameters and scale height

Galaxy	h [pc]	D_{max} [pc]	Reference
M 31	125	300	Brinks & Bajaja (1986)
M 33	125	300	Deul & den Hartog (1990)
LMC	180	360	Kim et al. (1999), Padoan et al. (2001)
IC 2574	350	800	Walter & Brinks (1999)
DDO 47	500	1000	Walter & Brinks (2001)
Holmberg II	625	1100	Puche et al. (1992)

Lastly, tracing the gas perpendicular to the disk allows one to trace the gravitational potential in the z–direction and offers one of the few ways to determine the three dimensional shape of the Dark Matter (DM) dominated halo.

In this contribution we will present two independent methods which are now used routinely to estimate the thickness of the neutral gas, as traced by HI, of dIrr galaxies. We will summarise the results obtained thusfar of a sample of dIrr galaxies for which good HI data have been published. And finally we will put these results in a wider context.

2. Methods

There exist several direct and indirect methods to measure the thickness of the HI layer of a (dwarf) galaxy.

1. *Direct observations of the HI distribution in an edge–on (dwarf) galaxy.* Although this seems straightforward, there are complications. The HI gas layer might be warped and/or flaring which, seen in projection, would create the impression of a thick HI disk. To compound the problem, it is expected that some HI ends up in a galactic fountain, in which case gas can be found at up to a few kpc distance from the disk, at least in spiral galaxies (NGC 891: Swaters et al. 1997; NGC 2403: Fraternali et al. 2001).

2. *Fit a detailed model which is compared with the observed three–dimensional (position, position and velocity) HI data.* This approach was used in the case of NGC 4244 (Olling 1995, 1996).

3. *Derive the spectral correlation function (SCF) in close to face–on galaxies.* This method has been successfully applied to the LMC (Padoan et al. 2001). It relies on observations at high linear resolution (of order 20 pc) and requires close to face-on objects in order to work.

4. *Based generally on HI data, derive a model of the mass distribution in the disk of a dwarf galaxy. Combined with the observed velocity dispersion, predict the scaleheight of the gas, assuming hydrostatic equilibrium.* This is a poor man's approach to the method listed under item 2 but has the advantage that it can be applied to dIrrs observed at lower resolution.

5. *In a statistical sense, measure the size distribution of cavities in the neutral gas layer (HI shells and superbubbles), postulating that the size set by a convenient cut–off in the diameter distribution corresponds to the full width of the HI layer.*

3. Thickness of Dwarfs

HI observations are a great tool to determine the kinematics of a dIrr galaxy. Assuming the gas to be in circular rotation, a rotation curve is derived which in turn determines the mass distribution in the disk midplane. Using the relation linking the scaleheight to the velocity dispersion by van der Kruit (1981), this then leads to an estimate for the disk thickness. Table 1 summarizes the 1σ scaleheight derived for several dIrr galaxies according to this method.

The evolution of the diameter of shells created by multiple supernova explosions in the bloated ISM of dIrr galaxies has been investigated, e.g., by Silich & Tenorio–Tagle (1998). The shell expands through the overpressure generated by the hot (coronal) gas deposited by multiple SNe until it reaches a diameter comparable to the width of the neutral gas layer. Any further SN will cause the supershell to break–out, venting coronal gas in to the halo at which moment the pressure inside the superbubble will drop and the shell, after entering the snowplough phase, will eventually stall. Assuming that the largest shells have reached this phase, their diameter should be an independent measure for the thickness of the disk. In thick disks, these shells are, ideally, spherical bubbles for which projection effects, i.e., the inclination of the disk, play no role.

A complication arises when neighbouring superbubbles physically overlap and merge to form a larger supershell (see for example some numerical results on the interaction of supershells by Santillán et al., 2002). Kim et al. (1999) show rather convincingly that in the LMC the giant shells (in their terminology) have not merged and suggest an HI layer thickness of 360 pc, or a scaleheight of 180 pc. They assume that all larger, supergiant shells are due to mergers. In Table 1 the diameter of the estimated largest HI superbubble (not due to a merger of giant shells) in dIrr galaxies is given. For comparison the same data on two regular spirals, M 31 and M 33 are included.

4. Discussion and Conclusions

From the above we can draw the following conclusions regarding the thickness of the neutral gas layer of dwarf galaxies. As was shown by Walter & Brinks (1999) the energy input of an evolving OB association is, to first order at least, independent of host galaxy. The O and B stars which explode as SNe deposit each a canonical 10^{51} erg of mechanical energy into the ISM. This energy is what maintains the velocity dispersion of the gas near the sound speed of a neutral medium with temperatures of 5000–8000 K, i.e., corresponding to velocity dispersions ranging from 6–9 $\mathrm{km\,s^{-1}}$. Because the mass surface density in the plane of a dwarf galaxy is down as compared to larger spirals, the scaleheight, h, is up.

Because of this larger scaleheight, for similar HI column densities, the HI volume density, n_{HI}, is down. Moreover, the gravitational pull towards the plane is reduced, hence HI shells in the ISM of dwarf galaxies can grow to larger dimensions. As shown in Table 1, the dynamically derived scaleheight correlates well with the scaleheight estimated on the basis of the largest diameter of single HI supershells, the ratio being close to the expected 2.35 for a gaussian z–distribution. In absolute terms, dwarf galaxies are 2–5 × thicker than spirals. Their aspect ratio is 1:5 rather than 1:100

If the picture painted above is correct, we expect the stellar disk of dIrr galaxies to be also thicker than in spiral galaxies and therefore that truly thin dwarf galaxies are the exception rather than the rule. This seems to be corroborated by an analysis of the Flat Galaxy Catalogue (Karachentsev 1999).

As dwarf galaxies are DM dominated (van den Bosch & Swaters 2001) but at the same time possess a thick gas disk, this argues against a strongly flattened halo. It also renders less attractive the idea of a sizeable amount of very cold (and hence difficult to detect) gas in an extended disk concomitant with the HI, as proposed by Pfenniger et al. (1994).

If, as seems plausible, a bit of star formation is able to puff up the gas layer of dwarf galaxies, this brings the volume density of gas atoms down and effectively inhibits further star formation, possibly explaining why dIrr galaxies are young objects as far as their star formation history is concerned, having undergone only a few massive events of star formation over a Hubble time.

References

Brinks, E., & Bajaja, E. 1986, A&A, 169, 14

Deul, E.R., & den Hartog, R.H. 1990, A&A, 229, 362

Fraternali, F., Oosterloo, T., Sancisi, R., & van Moorsel, G. 2001, ApJ, 562, L47

Karachentsev, I.D. 1999, Astron. Lett., 25, 318

Kim, S., Dopita, M., Staveley–Smith, L., & Bessell, M.S. 1999, ApJ, 118, 2797

Mac Low, M.–M., & Ferrara, A. 1999, ApJ, 513, 142

Olling, R.P. 1995, AJ, 110, 591

Olling, R.P. 1996, AJ, 112, 457

Padoan, P., Kim, S., Goodman, A., & Staveley–Smith, L. 2001, ApJ, 555, 33

Pfenniger, D., Combes, F. & Martinet, L. 1994, A&A, 285, 79

Puche, D., Westpfahl, D., Brinks, E., & Roy, J.–R. 1992, AJ, 103, 1841

Santillán, A., Franco, J., & Hernández, L. 2002 in ASP Conf. Proc., Galaxies: The Third Dimension, ed. M. Rosado, L. Binette & L. Arias (San Francisco: ASP), in press

Silich, S., & Tenorio–Tagle, G. 1998, MNRAS, 299, 249

Silich, S., & Tenorio–Tagle, G. 2001, ApJ, 552, 91

Swaters, R.A., Sancisi, R., & van der Hulst, J.M. 1997, ApJ, 491, 140

van den Bosch, F.C., & Swaters, R.A. 2001, MNRAS, 325, 1017

van der Kruit, P. C. 1981, A&A, 99, 298

Walter, F., & Brinks, E. 1999, AJ, 118, 273

Walter, F., & Brinks, E. 2001, AJ, 121, 3026