Comments on Properties of Gas Rich Dwarfs Galaxies in the Range of Radio Frequencies (B-Band)

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Abstract

In this project we analyze data of a large sample of gas rich dwarfs galaxies including; Low Surface Brightness Galaxies (LSBGs), Blue Compact Galaxies (BCGs), and dwarfs Irregulars (dIr). We then study the difference between properties of these galaxies in the range of radio frequencies (B-band).

The data are available in HIPASS catalogue and McGaugh's Data Page.

We depended also NASA/IPACExtragalactic Databes web site http://ned.ipac.caltech.edu in the data reduction.

We measured the gas evolution (HI mass), gas mass-to-luminosity ratio, and abundance of the elements such as the oxygen abundance for these galaxies.

Our results show a big discrepancy between the behavior of LSBGs at low and high luminosity ranges. We find that the LSBGs have higher HI masses than other samples of BCGs. BCGs are forced to stem from LSBGs or from dlrs according to their gas to light ratio vs total luminosity value.

Key words: galaxies, Low Surface Brightness Galaxies, galaxies evolution, gas rich galaxies

Introduction

Dwarf galaxies are important to our understanding of galaxy formation and evolution, because they are the smallest star-forming units at the time of galaxy´s formation. The key to the star formation history of any galaxy and to its subsequent evolution is its gas supply. Whether the gas supply is converted completely into stars immediately after formation, as in elliptical, or whether the gas supply remains dispersed until a dynamic event increases the number of cloud collisions, as in a tidally induced starburst, the gas mass fraction, f_g, is the primary parameter for quantifying the evolutionary state of a galaxy. A galaxy's chemical and photometric evolution closely follows the gas consumption rate. [1]

Historically, gas-rich galaxies have been divided into two types, disk galaxies and dwarf galaxies. Disk galaxies are brighter and higher in surface brightness and have dominated our studies of the star formation process. In contrast, dwarf galaxies are fainter and lower in surface brightness, making their detection and inclusion in galaxy catalogs problematic. In the last decade, new galaxy catalogs have widened our range of central surface brightness to include new extremes in low stellar densities (i.e., LSB). The common interpretation is that these systems have had, in the past, very low rates of star formation, and thus there is the expectation that LSB galaxies should be rich in gas compared to their stellar mass. [2]

Dwarf galaxies are typically low in density, so division by central surface brightness (based on fits to the galaxy's profile) can be used as an indicator of dwarfness. There is some physical reasoning to support the idea that all LSB galaxies should be dwarf systems. To produce low stellar densities would require very low past star formation rates and, hence, low total stellar mass and luminosity. Low surface brightness does not necessarily mean low stellar densities, but the colors of LSB galaxies rule out any highly unusual connection between luminosity and mass which is parameterized by, [3]

$$\Upsilon_* = M_*/L \qquad (1)$$

M_* is the stellar mass and L is the total luminosity of a galaxy.

That means the low optical density is indeed low stellar density. Or, conversely, we might expect a dwarf galaxy of low mass to have low mean density which, in turn, inhibits star formation to produce a LSB object. One could argue that initial conditions, such as the amplitude of the density perturbation in the early universe from which the galaxy will form, produces a necessary connection between a dwarf galaxy and a LSB galaxy. Unfortunately, the discovery of large Malin galaxies destroyed the notion that all LSB galaxies are dwarfs. In fact, most LSB disk systems are comparable in size to the ordinary spirals that make up the Hubble sequence.

Gas rich dwarfs

The gas rich dwarfs have a significant fraction of their baryonic matter is in the form of gas (mostly neutral hydrogen). They are divided into Low Surface Brightness Galaxies (LSBGs), Blue Compact Galaxies (BGCs), and dwarfs Irregulars (dIs). In the following I listed the main characteristics of gas-rich dwarfs. [4]

LSBGs

It is a commonly used criterion to set the limit between (LSBGs) and High Surface Brightness galaxies HSBGs galaxies at surface brightness $\mu_B > 23.5$ mag*arcsec^2. [4]

Observations show that LSBGs typically have low HI surface densities, approximately 3 times lower than in normal late-type galaxies. This results in a reduced efficiency in production of massive molecular clouds and low star formation efficiency per gas mass fraction.

LSBGs thus are more gas rich than their high surface brightness counterparts but less evolved. The stellar population can roughly be characterized by their broadband colours ranging from very red (B-V~1.2) to very blue (B-V ~ 0.2). Luminosities range from M_B = -13 to -20 plus a few rare cases of real giants like Malin I (M_B ~ -22). [4]

The extremely blue LSBGs, are chemically unevolved and hence useful as templates in studies of early star and galaxy formation. The low chemical abundances also make them valuable in the determination of the primordial helium content. It has sometimes been argued that some of the blue LSBGs are genuinely young systems or of intermediate age.

BCGs

BCGs have quite similar hydrogen masses and chemical abundances as LSBGs but with the main difference that the BCGs have a higher central surface brightness, up to ~ 4 times that of the LSBGs. Luminosities ranges from M_B = -12 to -21.

BCGs are characterized by compact appearance (barely distinguishable from stars on the photographic survey plates where they were first classified), high gas content, blue colour and low chemical composition (as all the dwarfs they are metal-poor).

These properties are typical of unevolved systems, those that have experienced few starbursts in their life. Therefore they are an important link with the early epoch of galaxy formation. [4]

There are two main types of BCGs:

1. Low luminosity, quiet regular, rather ordered rotation (low mass) ⟹ may be more related to normal irregulars

2. Luminous, more irregular, chaotic rotation, (more massive) ⟹ may steam from mergers

Dwarfs Irregulars

dIr are characterized by their diffuse size and have a range of luminosity M_B = -11 to -19. They show a little organized rotation, characterized by a slope in the rotation curve not as steep as in the BCGs. The mass in fact is not so centrally concentrated being the dlrs very diffuse, with an asymmetrical appearance on the sky: the stars lye in disorganized patches in a relatively large fraction of the disk. As all the dwarfs, dlrs turned to be dark matter dominated.

Mostly, they are not satellites of larger systems. In the Local Group, about a dozen of dlrs were found. Usually they are found in the local field and in nearby clusters and groups. [4]

Data reduction and discussion

We have included a sample of 217 galaxies classified as Irregular, 331 LSB galaxies and 288 galaxies classified as BCGs galaxies. All these galaxies were observed with the Nancay radio telescope in 1995 and 1996, and available in the HIPASS catalogue and McGaugh's Data Page.

Our samples of the galaxies have been reduced using NASA/IPAC Extragalactic Database NED. We obtained the distance r in Mpc, absolute magnitude in B-band M_B in mag., HI flux f(HI) in Jy km/s, for each galaxy in the sample. Depending values of r, M_B, f(HI), we calculated gas mass M(HI), luminosity L_B of the galaxies, M (HI)/ L_B, and oxygen abundance, as it will be explained in the following sections.

The obtained results are ASCII table containing five columns and 836 rows of the samples of the galaxies. The five columns are the galaxy name, M(HI), L_B, M (HI)/ L_B, and oxygen abundance.

The output results can be read into your favourite plotting program for further analysis. Our results have been plotted using MATLAB program.

The mass-luminosity relation

Gas evolution of the galaxies can be explained through studying the cool atomic gas HI, and the gas abundance. HI mass (M(HI)) of the galaxies define by, [5]

$$HI\ mass = 2.356\ x\ 10^5 r^2 f(HI) \quad (2)$$

Figure 1 shows the relation between M(HI) in solar units versus M_B for our sample.

We can see clearly that all the dwarfs seem to follow a general tendency: the B-magnitude scales with the HI mass, since during a galaxy's aging the gas is used up to fuel the star formation and by the time the luminosity slows down, unless an event as an instantaneous burst or a gas infall or supernova explosion occurs.

There are many important properties of the gas-rich dwarfs can derive from analyzing their positions in the log (M (HI)) vs M_B diagram.

For example, one can estimate the range in blue luminosity and in the HI mass: the dIrs seems to have the lowest values for both the ranges, while the LSBGs the highest.

The LSBGs also seem to be scattered more than other types of dwarfs as if they can embody variegated evolution scenarios.

One can see also, most of BCGs are at the high luminosity tail, while the different type of galaxies seems to merge at the high luminosity end.

The cool atomic gas HI

The M (HI)/ L_B value represents the gas mass-to-luminosity ratio, a measure of the relative HI content. [5]

L_B gives the ratio between the galaxy luminosity and the solar luminosity, it is given by, [4]

$$L_B = 10^{\left(0.4\left(M_{B,solar} - M_{B,galaxy}\right)\right)} \quad (3)$$

The absolute magnitude of the sun $M_{B,\odot} = 5.48$

Depending values of $M_{B,galaxy}$ which they obtained from NED, we calculated L_B for all the galaxies in our sample.

In gas rich galaxies, HI mass typically accounts for the majority of the gas content and its distribution is centered on the optical position of the galaxy, usually extending well beyond the optical system (mostly in LSBGs and dlrs).

The key to the star formation history (SFH) of any galaxy and its subsequent evolution is the gas supply and its density. Whether the gas supply is immediately converted into stars, whether it remains dispersed until a dynamic event increases the number of gas clouds collision, the gas mass fraction is the primary parameter for quantized the evolutionary state of a galaxy. [6]

The neutral density peaks coincide with regions of star formation, being its necessary fuel.

The general law describing the relation between the SFR and the neutral density is the Schmidt law and it is define by, [3,7]

$$\Sigma_{SFR} = A\, \Sigma_{gas}^{N} \quad (4)$$

Where $\Sigma_{SFR}$and Σ_{gas} are the surface densities of SFR and gas.

A is simply assumed to be constant, and N is a power index.

SFR = density n where n = 1-2

Figure 2 explained the relation between M (HI)/ L_B versus M_B, it seems clear that low luminosity LSBGs have a higher M (HI) / L_B and so differ significantly from the BCGs and dIrs having the same range in luminosity. They have as well as higher HI mass at fixed luminosity and lower star formation efficiency (SFE) if the SFR is considered as a measure of the blue luminosity. The opposite seems to happen at high luminosity: LSBGs and BCGs seem to have similar HI mass and SFE.

In this figure, one sees BCGs mainly distributed in the central area where most of the dwarfs seem to lie. In the surroundings, there are LSBGs and dIrs: most of dIrs lies along a line placed at.

Oxygen abundance

The oxygen abundance is used to test the metallicity content of dwarf galaxies, since the Fe abundance is very little and not useful for this purpose, because in the early stages of a galaxy the abundance of O is higher than Fe. The galaxy's progress might be measured by the mass of stars formed and by the metals produced. In fact the chemical abundance can be used as a "clock" for galactic aging and in some cases (as in the dwarfs) it can tell us if the galaxy is passing through a SF period. [8]

The metallicity of a galaxy is controlled mainly by:

• Stellar evolution and nucleosynthesis.
• Star formation history.
• Outflows and inflows.
• Mergers and interactions.
• ISM mixing.

Figure 3 shows the relation between oxygen abundance (12+ log (O/H)) and M_B. Oxygen abundance can be calculated using the equation, [9]

$$12 + \log(O/H) = 12 + 0.196 y_o + \log(\log\left(\frac{1}{\mu}\right)) \qquad (5)$$

μ is the relative baryonic gas mass fraction = (gas mass)/(gas mass + stellar mass).

In the previous figure one can see that masses of dIrs are mostly low enough. Luminous BCGs which lie on the right side of dIrs distributions in the figure have to stem from LSBGs because it would be necessary to increase the luminosity quite a lot and there is not enough fuel for this in dIrs, even mixing lots of them.

BCGs have the highest metallicity value at the same mass. The BCGs seem to retain better the metals, as if they can avoid outflows. This unexpected property may be explained by:
• High compactness
• Presence of dark matter, who enhance the gravitational field
• Round morphology, this may prevent the gas to flow out in the polar direction

Conclusions

In the different types of gas rich dwarfs galaxies there are different HI morphologies:
• In the LSBGs, the ratio (M (HI)/ L_B is quite big ~ 1) but their SFR is quite low.
• The BCGs are very compact object; the gas is concentrated in the central region where the SFR reaches high values.
• The dlrs lie in an intermediary situation: they have a more extended HI component than BCGs (but not as much as LSBGs) and thus have lower SFR (than BCGs).
• dIrs have a lowest range in blue luminosity and in the HI mass, while the LSBGs have the highest value for both the ranges. That means the majority of the gas content and its distribution is centered on the optical position of LSBGs.
• BCGs have a higher brightness and that may be due to a more centrally concentrated stars forming region: just a true sign of an increased star formation activity.
• BCGs have also the highest metallicity value at the same mass as it is clear in figure 3. This property may be explained by presence of dark matter, which enhances the gravitational field.

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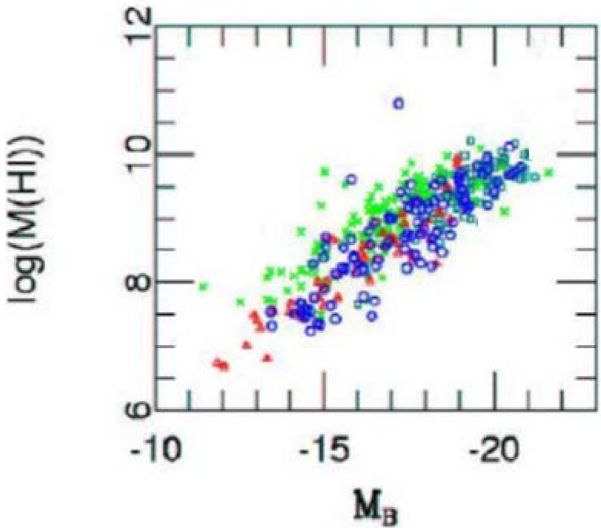

Fig. (1): HI mass vs absolute blue magnitude. The symbols correspond to: dlrs (red triangles), BCGs (blue circles), LSBGs (green crosses)

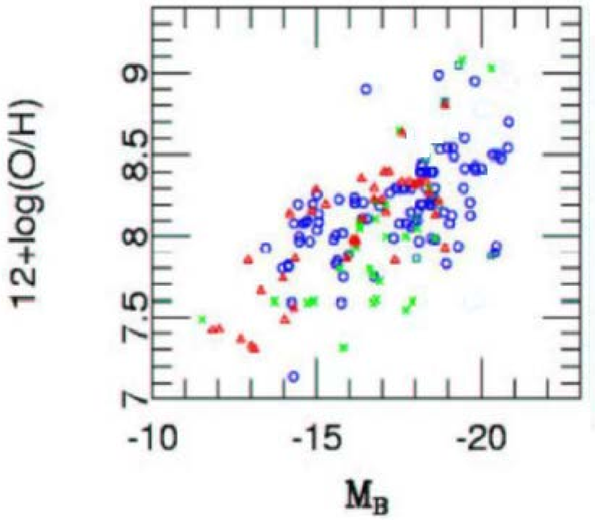

Fig. (2): Gas to light ratio vs absolute blue magnitude. This diagram roughly shows the stellar mass. In the area with M (HI)/ LB ≤ 0 and MB ≤ -18. The symbols correspond to: dIrs (red triangles), BCGs (blue circles), LSBGs (green crosses)

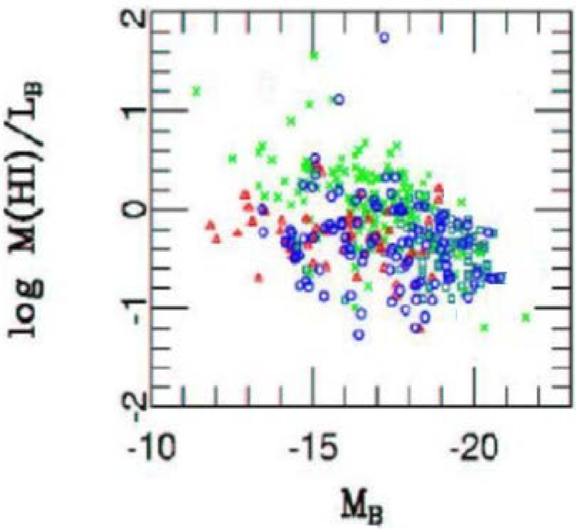

Fig. (3): Oxygen abundance vs absolute blue magnitude. The symbols correspond to: dIrs (red triangle), BCGs (blue circles), LSBGs (green crosses)

تعليقات على خصائص المجرات الاقزام الغنية بالغاز ضمن مديات الترددات الطيفية الراديوية المعروفة B-band

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الخلاصة

في هذا العمل حللت بيانات لانموذج مكون من مجرات اقزام غنية بالغاز التي تشمل مجرات واطئة في اضاءتها السطحية و مجرات زرقاء مندمجة و مجرات اقزام غير منتظمة الشكل. اذ درس الفرق بين خصائص هذه المجرات في مديات الترددات الراديوية.
كما ان هذه المجرات موجودة في: HIPASS catalogue and McGaugh's Data Page
اعتمد موقع (NASA/IPAC Extragalactic Database NED) في تحليل البيانات. كما قيس
HI mass ، و نسبة كتلة الغاز الى الاضاءة، ووفرة العناصر مثل الاوكسجين في هذه المجرات ايضا.
اظهرت النتائج وجود تفاوت كبير مابين سلوك المجرات الواطئة السطوع في مديات اللمعان الواطئة و العالية. اذ استنتج ان كتل الغازات HI mass في المجرات LSBGs اعلى مما هو عليه بالنسبة الى المجرات BCGs فضلا عن ان هذه المجرات هي من اسلاف المجرات LSBGs او dIr اعتمادا على العلاقة بين كتلة الغاز الى الاضاءة السطحية في مديات اللمعان المختلفة.

الكلمات المفتاحية: المجرات، المجرات الواطئة الاضاءة السطحية، نشوء المجرات، المجرات الغنية بالغاز