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DWARF AND NORMAL SPIRAL GALAXIES: ARE THEY SELF-SIMILAR?

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RESUMEN

En el presente estudio se ha tratado de comprobar si las galaxias espirales enanas constituyen un grupo diferente a las clásicas o por el contrario no son más que la cola de distribución de éstas. Para ello, lo primero ha sido establecer una lista de todas aquellas galaxias que tienen estructura espiral y pequeño tamaño. Después se ha buscado información acerca del color, luminosidad, morfología y características espectrales de estas galaxias. A partir de esta información se puede concluir que hay indicios más que suficientes para decir que las galaxias espirales enanas difieren de las espirales clásicas en algunas propiedades importantes como son la existencia de un gradiente en metalicidad y la frecuencia de las barras. De todas formas, son necesarias más observaciones de calidad para poder dar una respuesta definitiva.

ABSTRACT

The investigation presented here was focused on clarifying the existence of dwarf spiral galaxies as a separate group from classical spirals. First, a list of spiral galaxies with small sizes was obtained. Information on colors, luminosities, morphologies and chemical content was searched for in the literature for these galaxies. Using this information, it can be concluded that dwarf spirals are not likely to be the tail of the distribution of classical galaxies. On the contrary, significant differences in some of the most important properties of spiral galaxies, such as the metallicity gradient and the bar frecuency, were found. In any case, further and more accurate observations are needed for a definitive answer.

Key Words: **GALAXIES: SPIRALS — GALAXIES: STELLAR CONTENT — INTERSTELLAR MEDIUM: H II REGIONS GENERAL**

1. INTRODUCTION

The idea of an evolutionary track among the Hubble sequence of galaxies, first suggested by Hubble (1926), is brought up now and then (e.g., Mollá & Díaz 2003; Zhang 2003). On the other hand, the interrelation between dwarf and giant galaxies of the same morphological type has been treated so far within a monolithic scheme: dwarf galaxies are merely a scaled version of the giant ones. Kormedy (1985) carried out a careful study on dwarf elliptical galaxies and he concluded that the latter are not self-similar to the giant ellipticals but drastically different in their colors, metal content, and surface-brightness profile. Similar studies were performed for irregular galaxies (e.g., Hunter & Gallagher 1984) and they concluded that size does not make any difference to the properties of irregular galaxies. The small range in size covered by this type of galaxies may be the main reason for this conclusion. So far, no such investigations have been done for dwarf spiral galaxies. Actually, dwarf spiral galaxies have not attracted very much attention. For example, only 12 out of more than 12,000 galaxies cataloged in the Uppsala General Catalog (UGC; Nilson 1973) are classified as dwarf spirals and none in the other most common catalogs such as Tully (1988) or the RC3 (de Vaucouleurs et al. 1991).

Schombert et al. (1995) reported the discovery of a total of six dwarf galaxies with early spiral structure not previously cataloged. The galaxies they studied have distinct bulge and disc components, low surface brightness, high gas mass, blue colors, and non-barred structures. Despite the small size of

TABLE 1

DWARF SPIRAL GALAXIES[a]

Galaxy	α	δ	Distance (Mpc)	M_b	r (kpc)	Type
UGC 17	00 03 43	15 13 06	13 ± 134	−15.98	4.6	S9*
UGC 35	00 05 09	06 15 36	30 ± 11.5	−15.39	6.76	S9
UGC 115	00 10 36	88 20 05	26.4	−16.88	···	dS
UGCA 5	00 18 48	−19 00 28	25.6 ± 17	−16.41	5.51	SXS9*
UGC 191	00 20 05	10 52 48	15.9 ± 0.6	−17.56	3.75	S9
UGCA 6	00 34 11	−30 46 25	19 ± 2.2	−17.39	5.14	SXS9*
UGC 291	00 29 12	33 06 16	48.4 ± 16	−17.11	6.42	S9
UGC 891	01 21 19	12 24 43	9.4 ± 1	−15.32	3.13	SX9*
UGC 990	01 25 24	10 47 49	24 ± 9.8	−15.98	3.1	S9*
NGC 625	01 35 04	−41 26 15	3.9 ± 1.5	−16.32	3.26	SBS9S
UGC 1216	01 44 24	40 41 13	···	···	···	dS
UGC 1249	01 47 29	27 19 59	6.4 ± 15	−17.31	6.44	SBS9
UGC 1491	02 00 43	29 39 08	37.7	−15.10	5.0	S9*
UGC 1865	02 25 00	36 02 16	9.8 ± 2.1	−13.75	4.11	S9*
UGCA 31	02 25 57	−21 25 16	18.4 ± 2.4	−17.26	4.87	SXS9*
UGC 2002	02 32 24	34 29 42	10.1 ± 2.1	−17.38	3.44	S8*
NGC 1051	02 41 02	−06 56 09	15.9 ± 1.5	−17.87	4.83	SBT9P
UGC 2432	02 57 26	10 08 12	5.9 ± 4.3	−13.31	0.94	S9*
NGC 1232A	03 10 02	−20 36 02	20	−16.40	2.71	SBS9
NGC 1311	03 20 07	−52 11 07	5.2 ± 2.4	−15.23	2.28	SBS9?
NGC 1326A	03 25 08	−36 21 43	16.9 ± 7.6	−17.44	4.6	SBS9*
UGCA 74	03 29 32	−17 46 40	18.1 ± 2.3	−17.12	3.98	SBS5P*
UGC 2917	04 05 60	79 50 17	28	−14.75	4.07	S9
UGC 3112	04 43 53	79 59 27	56	−17.66	···	dS
UGC 3212	05 01 02	71 10 33	16.2	−13.58	2.58	S9*
UGCA 103	05 10 47	−31 35 50	10.8 ± 2.3	−17.09	4.63	SXT8*
UGC 3384	06 01 37	73 07 00	14.53	−15.65	3.67	S9*
NGC 2188	06 10 09	−34 06 22	7.9 ± 2.1	−17.49	5.01	SBS9
UGC 3409	06 10 52	64 34 03	18.12	−14.75	3.9	S9
UGC 3461	06 33 15	82 52 15	8.6	−13.45	1.37	S9*
UGC 3475	06 30 29	39 30 14	6.5	−15.35	2.16	S9*
UGC 3566	06 51 33	41 46 19	···	···	···	dS
UGC 3775	07 15 52	12 06 54	20.8 ± 7.7	−15.08	4.68	S9*
NGC 2552	08 19 20	50 00 25	10 ± 3	−17.64	5.04	SAS9S
UGC 4466	08 36 54	77 49 58	19	−14.48	3.8	S9
UGC 4660	08 54 24	34 33 20	29.4	−15.47	5.02	S9
UGC 4612	09 00 18	85 31 56	21.4	−14.96	4.29	S9*
UGC 4776	09 10 08	79 21 37	27.6	−15.79	5.17	S9*
UGC 4948	09 29 19	85 18 13	23.1	−15.64	···	dS
UGC 4984	09 23 40	54 28 57	···	···	···	dS
UGC 5085	09 33 16	42 20 19	···	···	···	dS
UGC 5236	09 46 60	21 43 47	8.7	−13.33	1.63	S9*
UGC 5242	09 47 05	00 57 50	24.76	−16.60	4.86	SBS9*
UGC 5296	09 53 11	58 28 42	20.28	−15.08	3.02	S9*
UGC 5464	10 08 08	29 32 31	11.9 ± 1.5	−14.85	2.39	S9*

TABLE 1 (CONTINUED)

Galaxy	α	δ	Distance (Mpc)	M_b	r (kpc)	Type
UGC 5571	10 19 42	52 03 57	8.83	−12.77	1.51	S9*
UGC 5629	10 24 13	21 03 01	14.1	−13.66	2.64	S9*
UGC 5666	10 28 21	68 24 43	2.7 ± 1.9	−16.83	5.18	SBS9
UGC 5675	10 28 30	19 33 46	14.7	−12.92	3.98	S9*
UGC 5692	10 30 34	70 37 14	2.4	−13.62	1.13	S9*
UGC 5716	10 31 43	25 18 30	17.04	−14.61	3.19	S9*
UGC 5740	10 34 46	50 46 06	11.3 ± 2.6	−15.25	2.85	SX9
UGC 5848	10 44 22	56 25 14	16.3 ± 5.3	−16.29	4.95	S9*
UGC 5889	10 47 22	14 04 10	5.1 ± 2.5	−14.46	1.66	SXS9
UGC 6122	11 03 32	11 07 07	20.5	−15.64	3.5	S9*
NGC 3510	11 03 43	28 53 06	7.9 ± 1.5	−15.82	4.57	SBS9
UGC 6205	11 09 59	46 05 44	18.87	−16.53	4.99	S9
UGC 6251	11 13 26	53 35 42	18.1 ± 5.7	−16.40	4.79	SXS9
UGC 6266	11 14 33	43 14 09	29.29	−15.40	5.36	S9
UGC 6304	11 17 49	58 21 05	23.51	−15.40	4.72	S9
UGC 6344	11 20 23	57 44 28	25.8	−15.12	4.11	S9
UGC 6377	11 21 53	41 13 46	27.3	−15.45	···	dS
UGC 6566	11 35 43	58 11 33	16.24	−14.60	2.53	SB9
NGC 3769A	11 37 50	47 52 53	17	−16.43	2.65	SB9
UGC 6682	11 43 09	59 06 21	23.8 ± 6.1	−17.43	5.6	S9
UGC 6713	11 44 25	48 50 07	17.05 ± 5	−16.24	3.67	S9
UGC 6757	11 46 59	61 30 08	···	···	···	dS
UGC 6840	11 52 07	52 06 29	17 ± 3	−16.95	4.6	SBT9
UGC 6921	11 56 42	48 20 02	8.3 ± 4.4	−16.59	1.5	SBS9*
UGC 6956	11 58 25	50 55 02	17 ± 4.8	−16.32	5.53	SBS9*
UGC 7007	12 01 33	33 20 29	8.9 ± 1.4	−13.51	2.25	S9*
UGC 7185	12 11 27	02 55 32	17.29	−16.66	2.95	SAT9*
UGC 7382	12 19 53	27 37 15	30.8	−18.53	3.56	S
UGC 7490	12 24 25	70 20 01	11.4 ± 4.9	−17.34	5.34	SA9
UGC 7599	12 28 28	37 14 01	3.5 ± 0.2	−12.89	1.01	S9
UGC 7713	12 33 48	15 10 05	16.8 ± 13	−16.87	4.99	SXS9
UGC 7781	12 36 38	06 37 17	16.8 ± 2.5	−17.22	5.60	S9
UGC 7780	12 36 42	03 06 28	19.23	−15.82	4.75	S8*
UGC 7730	12 39 06	64 34 01	37.3	−16.94	5.95	S9
UGC 7861	12 41 53	41 16 26	8.2 ± 0.08	−16.73	2.61	SXT9P
UGC 7913	12 44 34	−02 19 09	21.2	−17.06	4.45	SXS9
UGCA 294	12 44 38	28 28 19	9.7 ± 2.9	−14.90	1.02	S0
UGC 7971	12 48 23	51 09 53	8 ± 1.8	−16.16	2.6	S9*
UGC 8048	12 55 39	−00 15 49	14.86	−13.86	3.20	S9
UGC 8074	12 57 44	02 41 33	21.7 ± 9.5	−17.21	3.79	S9
UGC 8188	13 05 50	37 36 18	4.4 ± 0.12	−15.28	3.85	SAS9
UGC 8285	13 12 33	07 11 03	17.5 ± 5.5	−16.66	4.32	S8*
UGC 8588	13 35 42	45 55 47	26.4 ± 7.1	−17.38	4.94	S9*
UGC 8601	13 36 30	47 44 12	···	···	···	dS
UGC 9018	14 05 33	54 27 39	6.4 ± 6	−14.72	1.54	SAS9
UGC 9570	14 51 36	58 57 12	29.4	−15.89	···	dS

TABLE 1 (CONTINUED)

Galaxy	α	δ	Distance (Mpc)	M_b	r (kpc)	Type
UGC 9597	14 55 00	30 49 26	23.14	−15.27	4.75	S9*
UGC 9762	15 11 41	32 38 35	36.3 ± 6	−15.88	5.28	S9*
UGC 9875	15 30 47	23 03 57	23 ± 3.6	−15.03	4.5	S9*
UGC 9902	15 34 33	15 08 00	22.6	−14.98	3.00	SB8?
UGC 9938	15 37 12	30 04 37	22.1 ± 2.8	−16.04	4.44	S9*
UGC 10031	15 45 45	61 33 21	18.2 ± 6.2	−14.36	4.10	S9*
UGC 10058	15 50 24	25 55 21	34.4 ± 5.7	−15.91	5.48	SBS9
UGC 10266	16 11 56	48 53 50	79.1	−17.55	···	dS
UGC 10310	16 14 49	47 10 08	12.22	−16.91	5.01	SB9
UGC 10609	16 52 57	69 52 56	17.06	−14.83	2.72	S9*
UGC 10791	17 14 38	72 23 56	17.73	−16.46	3.81	S9*
UGC 10808	17 19 51	28 19 00	14.6 ± 25	−13.98	1.9	S9*
UGC 11111	18 05 18	23 06 20	31.9	−15.99	3.52	S9*
IC 4710	18 28 38	−66 58 54	8.9 ± 1	−17.63	4.7	SBS9
UGC 11331	18 39 00	73 36 34	20.74	−16.98	4.56	S9*
UGC 11820	21 49 28	14 13 52	17.1 ± 2.4	−14.70	4.96	S9*
UGC 12082	22 34 11	32 51 44	13.9 ± 3.2	−17.03	5.3	S9
UGC 12212	22 50 30	29 08 18	14.7 ± 2.8	−15.11	3.3	S9*
UGC 12732	23 40 40	21 61 41	12.4	−17.05	5.44	S9
UGCA 442	23 43 45	−31 57 22	3.3 ± 0.3	−14.06	1.7	SBS9

[a]Column 1 lists the name of the galaxy while the coordinates (2000) are given in columns 2 and 3. The distance, with the uncertainties when obtained, is listed in column 4. The absolute magnitude and the optical size are given in columns 5 and 6. Finally, in column 7 the morphological type as it stands in the RC3 is given.

their sample they claimed that they belong to a new group of galaxies.

Dwarf spiral galaxies will play a major role in many problems of the utmost importance due to their small sizes and lack of dynamical complexity. Examples are: the origin of nitrogen (e.g., Dufour 1986), the flat abundance gradient for low-mass spirals (Mollá & Roy 1999) and barred galaxies (e.g., Edmunds & Roy 1993), the star-formation triggering mechanisms, and the dark matter content in small galaxies. In addition, a significant population of dwarf spiral galaxies will increase the number of satellites of external galaxies and diminish the disparity between hierarchical cosmological model predictions (Navarro, Frenk, & White 1996) and observations.

The main goal of the present investigation is to elucidate whether dwarf spiral galaxies are scaled-down versions of the classical spirals or, on the contrary, have distinct properties, as is the case for dwarf ellipticals. Comparison with classical spirals and irregular galaxies will be useful for understanding the influence of the size of the galaxy on some of the previously outlined problems. As the existence of spiral arms may have influence on those properties, we will refer to dwarf spirals as those disc galaxies with well-defined spiral shape (arms). In order to have a sample as similar to the classical spirals as possible, galaxies with a thick disc but no spiral arms, like IC 2574, will not be considered spirals.

In the next section all the dwarf spiral galaxies are presented, as well as the criteria for such classification. A comparison of the luminosities and sizes between dwarfs and classical spirals is also presented. The study of the dynamics, colors, and chemical properties is presented in § 3. Finally, some conclusions are outlined in § 4.

2. THE SAMPLE OF DWARF SPIRAL GALAXIES

As already mentioned, a review of some of the most used catalogs (UGC, RC3, Tully 88), gave only 12 galaxies classified as dwarf spirals. One reason for this small number may be the great number of subclasses of the spiral systems. So, dwarf spiral galaxies

TABLE 2

CANDIDATE DWARF SPIRAL GALAXIES[a]

Galaxy	α	δ	Distance (Mpc)	M_b	r (kpc)	Type
UGC 417	00 39 28	04 10 34	...	...	...	dw
UGC 1740	02 16 05	43 29 24	...	...	...	dw
UGC 2139	02 39 23	36 23 53	...	...	...	dw
UGC 2301	02 49 38	38 15 41	...	...	...	dw (B?)
UGC 2524	03 05 15	05 14 02	11.6	−13.03	...	dw
UGC 3305	05 26 48	54 23 46	96	−19.62	...	dw (B?)
UGC 3491	06 38 77	75 24 16	51.4	−16.93	...	dw
UGC 4333	08 20 37	52 31 07	31.46	−15.68	...	dw (B?)
UGC 4378	08 25 29	69 53 59	26.7	−14.08	...	dw (B?)
UGC 4497	08 38 49	67 21 58	52.7	−17.29	...	dw
UGC 5983	10 52 16	36 35 39	...	...	...	dw (dE?)
UGC 7160	12 10 05	70 24 11	28.1	−15.31	...	dw
UGC 7642	12 30 13	02 37 29	21.83	−16.97	3.32	S?
UGC 8439	13 25 14	43 16 03	16	−17.83	4.32	S?

[a]Column 1 provides the name of the galaxy while the coordinates (2000) are listed in columns 2 and 3. The distances are given in column 4. The absolute magnitude and the optical size, when obtained, are listed in columns 5 and 6. Finally, column 7 contains the morphological type with comments from the most recent images.

may be common, but listed under other morphological types.

In order to extract them, the most common catalogs were inspected. First, all the galaxies classified as Magellanic spirals (Sm) in the UGC were selected. To get a more complete and updated sample, a cross-correlation with the Tully catalog (1988) was carried out, adding to the sample those galaxies of types 9 and 10 that were not listed in the UGC. All the known dwarf irregulars and interacting systems were eliminated from this sample and NED[1] was used to contrast the data. All those galaxies that do not present a spiral structure in the available images were disregarded. 247 galaxies were finally selected, plus the 12 original dwarf spirals. So, the first sample, hereinafter the main sample, consists of 259 late-type spiral galaxies.

The next step was the selection from this main sample of only those galaxies that are really dwarf systems. The definition of dwarf galaxies, as discussed in Hidalgo-Gámez & Olofsson (1998), is not well established. The most common definition is based on the absolute magnitude, considering all those galaxies with $M_v > -16$ as dwarf (e.g., Bingelli 1993). Other authors have used other bands and other values of the absolute magnitude as definition of dwarf galaxies (e.g., $M_b = -17$ in Hidalgo-Gámez & Olofsson 1998 or $M_b = -18$ in Taylor, Kobulnicky, & Skillman 1998). If the absolute magnitude is determined from the expression

$$-M_b = 5(\log D - 1) - m + A_B \quad ,$$

where D is the distance to the galaxy and A_B the Galactic extinction (Schelgel, Finkbeiner, & Davis 1998), the uncertainties in the absolute magnitudes are very large because distance determinations are normally not very accurate. This is especially true for this sample, where the distances to most of the galaxies are measured with no primary distance indicators.

In this investigation a definition of dwarf galaxy based on two parameters, the absolute magnitude (M_b) and the optical radius (r), will be considered. Otherwise, using only the absolute magnitude as a definition, galaxies with optical radius of 10 kpc or more might be classified as dwarfs (see Figure 1). A galaxy will be considered a dwarf when its optical radius is approximately 1/3 of the typical optical radius of a normal galaxy. The Milky Way can be considered as a typical spiral galaxy, with an optical radius of 15 kpc (Robin, Creze, & Mohan 1992;

[1]NED is operated by the Jet Propulsion Laboratory, California Institute of Technology, under contract with the National Aeronautics and Space Administration.

Ruphy et al. 1996). Then, a spiral galaxy is a dwarf only if its optical radius is 5 kpc or smaller, defined as in Hidalgo-Gámez & Oloffson (1998). Using this radius as the limiting size and with the help of Fig. 1 (see § 2.1) a limiting magnitude of −18 was chosen. Therefore, a spiral galaxy will be considered a dwarf when its size is smaller than 5 kpc and its luminosity lower than −18. A few galaxies were selected even though they do not fulfil both requirements simultaneously: they were included in the final sample because the uncertainties in their distance determinations were so large that the value of both M_b and r might change drastically. For three galaxies there is no information on the uncertainties but variations in their distance determinations of less than 1 Mpc justifies their inclusion in the sample.

The final sample (hereafter the dSpiral sample) consists of a total of 111 galaxies which are listed in Table 1. The first column gives the name of the galaxy. Columns 2 and 3 are the 2000 coordinates. The distance, in Mpc, is presented in column 4. When more than one source is used for the distance determination, a weighted value is given. The uncertainties correspond to variations in the distance determination by different authors and not to uncertainties in the distance itself. Column 5 presents the absolute magnitude. The optical radius, in kpc, is presented in column 6. Finally, column 7 gives the morphological type after RC3 (de Vaucouleurs et al. 1991), a list updated and widely used in literature.

Before going any further we would like to comment on the galaxies classified as *dw* in the UGC. They are small galaxies with no clear structure. The low resolution of these galaxies in the photographic plates inhibited a further classification by Nilson. Upon inspection of the newest images available in the literature none of them show any clear spiral arms, although some resemble spiral galaxies at large inclination. Only one galaxy is suspected to be elliptical, but it cannot be confirmed yet. They are listed in Table 2, along with two galaxies classified as S? in the RC3 (UGC 7642 and UGC 8439), but since their spiral structure is not clear they are not considered in the following. High-quality images will elucidate whether they are spirals or spheroids.

2.1. *Distribution of Sizes and Luminosities*

The main sample can be divided into two: the dSpirals and all those galaxies which are not dwarfs. The latter are referred to as the comparison sample because they will be useful for testing some of the properties of the dSpirals.

Fig. 1 shows the well-known relationship between the absolute magnitude and the size (Holmberg 1975) for all the galaxies in the main sample. Those galaxies finally selected as dwarf spirals are represented as crosses, while stars stand for galaxies in the comparison sample. Considering all the galaxies, a trend is clear between these two parameters, but at low luminosities the dispersion in magnitudes is small, increasing to more than five magnitudes at the upper, non-dwarf, end. This behaviour is reflected in the regression coefficients, which are $r_l = -0.61$ for dwarf galaxies and $r_l = -0.4$ for non-dwarfs. Among the latter are galaxies with low luminosity ($M_b < -16$) and very large size ($r > 10$ kpc). They should not be considered as dwarf systems but as low surface brightness galaxies. Also, there are few systems with very small sizes but large luminosities and they could be considered as the spiral counterpart of the Blue Compact Irregulars. Finally, the existence of very large galaxies ($\log r > 1.5$) which do not follow the general trend is quite noticeable.

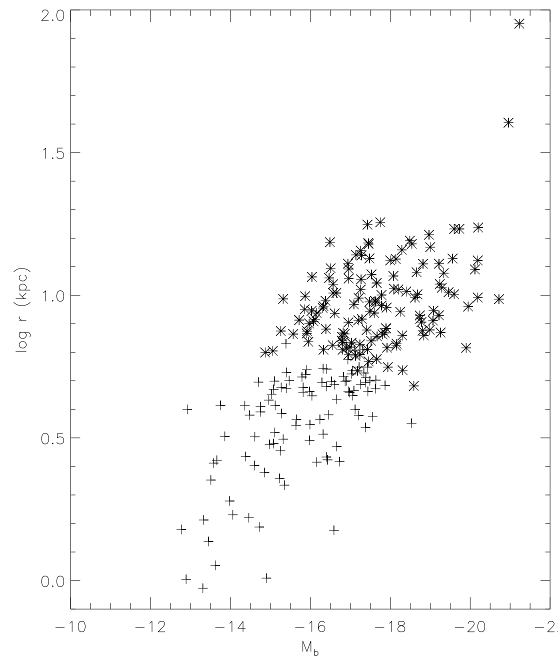

Fig. 1. The M_b vs. r relationship. Genuine dwarf spiral galaxies are represented as crosses while stars depict those galaxies in the main sample which were finally rejected as dwarfs. The regression coeficients are −0.61 and −0.4, respectively. This might indicate that most of those galaxies rejected as dwarf spirals are really non-dwarf systems.

A comparison between the main sample and the dSpirals is enlightening. Figure 2 shows the luminosity distribution of the main sample (solid line) and dSpirals (dashed line). The first one resembles

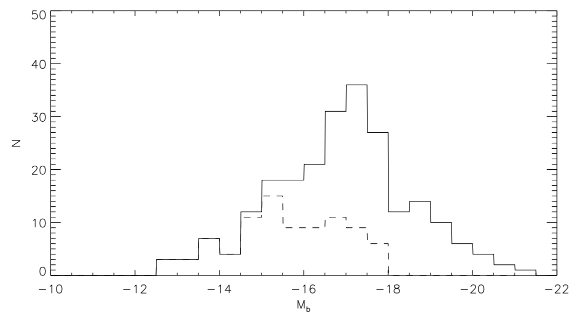

Fig. 2. Histogram of the M_b for dwarf spiral galaxies (dashed line) and for the main sample (solid line). The distributions look rather different, with the former resembling a Gaussian distribution with a peak at -17 mag, and the dwarf systems showing a broad distribution over 3 mag.

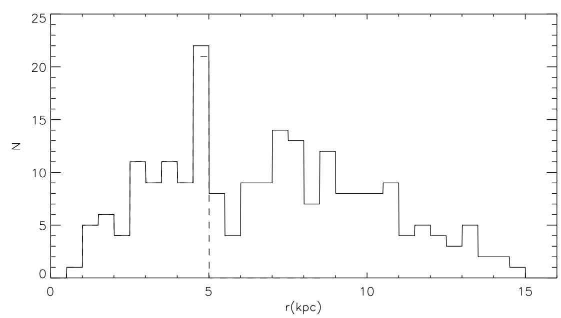

Fig. 3. Histogram of the size distribution for the main sample (solid line) and for the dSpirals (dashed line). The most striking feature is the large peak at 4.5 kpc. The distributions for dSpirals and the main sample are identical between 0 and 5 kpc.

a Gaussian distribution, with a peak at -17 mag and a FWHM of 2 mag, with a deficiency of bright galaxies as well as very dim ones. dSpirals, on the contrary, show a broad distribution with a width at the maximum luminosity of more than 3 mag. The size distribution for these two samples is presented in Figure 3. There are no differences among them up to $r = 5$ kpc, as expected. The most interesting feature is the large peak at $r = 4.5$ kpc. As the only restriction imposed on the main sample was for them to be late-type spirals, this peak may be an indication that there exists a preferred size for this type of galaxies. The probability of such a preferred size arising from a random distribution is 0.1% from a χ^2 test. A deeper study of the dynamics that might cause this effect is beyond the scope of this paper.

Another interesting comparison is that between dSpirals and a sample of nearby dwarf irregular (dI) galaxies from Hidalgo-Gámez & Olofsson (1998). Irregulars are both fainter and smaller than spirals. One might think the reason for this difference is the different definition of a dwarf galaxy for irregulars: $M_b < -17$ and $r < 3$ kpc. This explanation may work for the luminosity distribution (Figure 4) which shows a strong deficiency of galaxies brighter than -16 in the dI sample, while both types of galaxies follow a similar distribution at the faint end. But the size distribution (Figure 5) cannot be accounted for by it. There is a real lack of very small spiral galaxies: only 10 dwarf spirals have radii smaller than 2 kpc while 33 out of 46 dI do so. The fact that there is a breaking radius at 3 kpc is very interesting. Because this is the largest allowed radius for dwarf irregulars, the lack of dI systems larger than this value is not surprising, but the dramatical decrease in the number of dSpirals for lower radii is. This might be an indication that spiral structures are not very stable at small sizes as they dissolve into a featureless structure. One caveat about this interpretation is the different distance range covered in these two samples, which might have some influence on the result. In order to check this, only those dSpirals with distance up to 5 Mpc were considered. There are only seven of them. While the luminosity distribution is flat, in the sense that all the range between -13 to -16 is covered, 4 out of those seven galaxies have radii smaller than 2 kpc. It can be concluded that part of the missed spiral galaxies with very small sizes are not detected in the surveys. However, this explanation cannot account for all the galaxies. It should be remembered that 72% of the galaxies in the sample of irregulars have sizes smaller than 2 kpc, while only less than 57% of those in the spirals sample do so. Unless dwarf spirals are much more common that dwarf irregulars, which does not seems to be the case (e.g., in the HDF the most abundant type of galaxies have irregular form and blue color, see van der Bergh 1996), the lack of very small spiral systems is real. Moreover, the existence of large irregular galaxies with bars and faint spiral arms, like LMC, or well defined disc as IC 2574, works in the direction of a dilution of spiral structure at small sizes.

3. DWARF AND LARGE SPIRALS: ARE THEY SIMILAR?

From the analysis of the absolute magnitudes and sizes of the dSpirals, dI and the main sample it can be concluded that the dSpiral galaxies are not similar to the classical spirals or to the dwarf irregulars. As said before, both parameters are sensitive to distance. Therefore, less questionable parameters, such

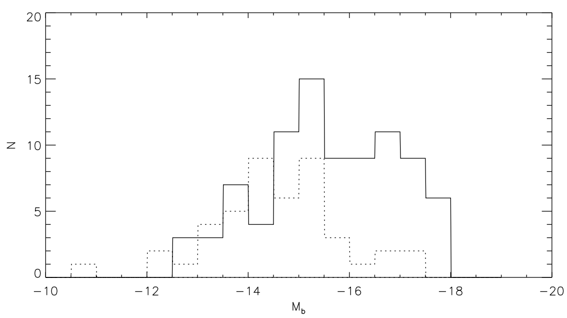

Fig. 4. Histograms of the luminosity distribution for dSpirals (solid line) and nearby dwarf irregulars (dotted line). The distribution is similar, with a broad peak in both samples. The main differences are the absence of low luminosity dSpirals and the maximun value of M_b, which are -15 and -14 respectively. The average values are -15.83 ($\sigma = 1.4$) and -14.58 ($\sigma = 1.3$), respectively. When only the nearby dSpirals are considered, the averaged M_b is -14.67.

as the colors, the number of barred galaxies, or the metal content, have to be studied in order to obtain a more reliable answer.

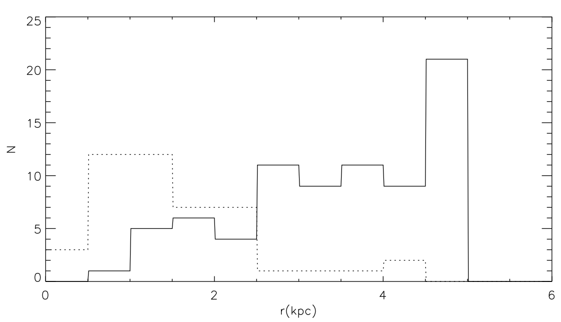

Fig. 5. Histograms of the size for dSpirals (solid line) and nearby dwarf irrgulars (dotted line). The lack of large irregular systems is because of the definition of dwarf irregulars but the absence of very small spiral systems is real.

3.1. *Dynamics*

Bars are global, transient perturbations in a spiral galaxy. When a disk becomes unstable, the most likely instability is a bar (Binney & Tremaine 1987). Galactic discs are generally unstable to bar instabilities which can be formed within a few dynamical timescales. After the work of Ostriker & Peebles (1973) there is a consensus about the importance of bars for the understanding of the dynamics of the central regions and its connection with the dark matter content (e.g., Debattista & Sellwood 2000; Athanassoula 2002). Moreover, Bournaud &

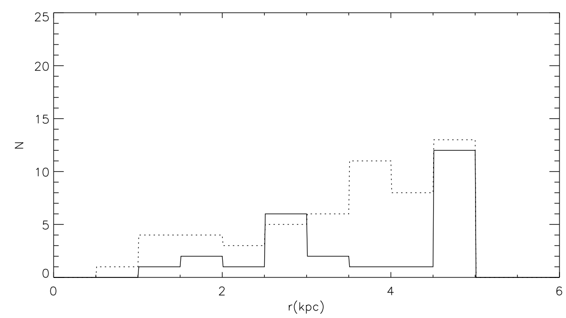

Fig. 6. Histograms of the optical size of barred dSpirals (solid line) and non-barred (dotted line). Again, the distributions are very different. Barred galaxies peak at $r = 4.5$ kpc (50%), while non-barred present a large range in sizes, with the majority of the galaxies ranging between 2 and 5 kpc.

Combes (2002) concluded that probably all spiral galaxies host at least one bar during their lifetime. It is crucial therefore to look at the percentage of barred dwarf spiral galaxies.

Almost half of all known spiral galaxies are barred. Considering the classification from the RC3, 30% of the spirals are strongly barred and 25% are mixed (or weakly barred). Recently, Eskridge et al. (2000) obtained a much larger percentage of barred galaxies from near IR images. They concluded that only 27% of the galaxies in their sample (186 classical spirals) are not barred. For the dSpirals, the percentage of barred galaxies is less than 17%, with another 10% of weakly barred galaxies. Comparing the values in the optical bands only, as there is no information on the near IR for dwarf spiral galaxies, dwarf barred galaxies are less common than their normal/giant counterparts. The differences cannot be accounted for as a result of misclassification of the dwarf galaxies because the same source, RC3, was used for both samples.

Now, galaxies in the comparison sample are useful in order to see whether there is any trend as to the size. 32 out of the 136 galaxies in this sample are strongly barred systems according to the RC3, while only 15 are weakly barred. These figures correspond to 23% and 11%, respectively. They are intermediate between those of classical and dwarf spirals.

The size distribution for barred and mixed galaxies and for non-barred galaxies is shown in Figure 6. It is clear from this figure that barred galaxies have a tendency to be larger than non-barred system, with average values of 3.72 and 3.39 kpc, respectively. Again, there is a strong peak at 4.5 kpc, with half of the barred systems having sizes in this

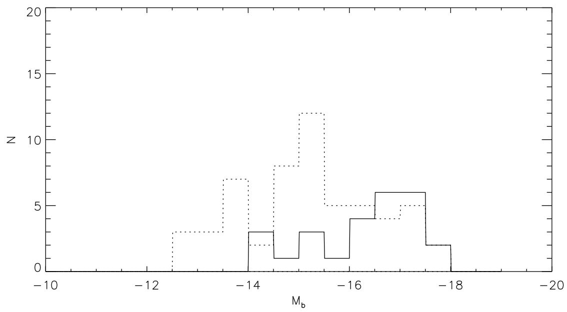

Fig. 7. Histograms of the absolute magnitude of dwarf barred spirals (solid line) and non-barred dwarf spirals (dotted line). Barred systems are more luminous, especially due to the lack of very faint barred galaxies. The dimest barred galaxies are 2 mag brighter than the non-barred ones.

range. Moreover, there is another peak at 3 kpc with only four galaxies between both peaks. On the contrary, non-barred galaxies show a decrease towards smaller sizes. Also, a significant number of them are small systems ($r < 3$ kpc). However, there are still eight barred galaxies with $r < 3$ kpc. There are differences in the luminosity distribution as well (Figure 7). Barred galaxies are more luminous ($< M_b > = -16.33$) than non-barred ones ($< M_b > = -14.58$). While non-barred galaxies spread towards low luminosities, the faintest barred ones are brighter by 2 magnitudes. The same behaviour is observed among the non-dwarf systems, with barred galaxies being more luminous and bigger than the non-barred ones as well as covering a lower range in both parameters. The larger luminosities can be explained by the large number of H II regions in barred galaxies, which then will have larger blue luminosities. Concerning the radii distribution, it might be that in order to have a bar structure the galaxy size cannot be an arbitrary one, and that certain values are preferred.

The susceptibility of galactic discs to global non-axisymmetric instabilities is measured through the X_m parameter (instability requires $X_m < 1$). The response of the disc to these modes is non-linear and is usually investigated with N-body simulations. For a first approach, it is enough to assume that $X_m \propto \kappa^2 R/2\pi m G\Sigma_d$ where R is the radius, Σ_d the disc surface density, κ the epicyclic frequency and $m = 2$ for bar modes. The exact rate of growth depends on the Toomre parameter Q. A hot disc with $Q \leq 2$–2.5 is stable against bar instabilities even without a dark halo (Athanassoula & Sellwood 1986). However, since only discs with spiral structure are considered the Toomre parameter is expected to be similar for both dwarf and normal galaxies. Interestingly, if dwarf spiral galaxies are dominated by a dark matter halo with a radial distribution $\rho_{\rm DM,dwarf}(r)$, related to the dark distribution of a normal spiral by a transformation $\rho_{\rm DM,dwarf}(r) = \rho_{\rm DM,normal}(\lambda r)$, with $\lambda > 1$, and their surface density is self-similar $\Sigma_{\rm d,dwarf}(R) = \xi\Sigma_{\rm d,normal}(\lambda R)$, with $\xi \leq 1$, the susceptibility parameter for the dwarf spiral is a factor of order $(\xi\lambda)^{-1}$ smaller than for a normal spiral. According to this rough estimate, dwarf spirals require a surface density a few times lower (~ 5) than normal spirals in their central parts for bar stability.

TABLE 3

AVERAGE VALUES OF THE H I MASS AND SURFACE DENSITY[a]

	M(H I)	Σ_g
Barred Normal	3.17 ± 0.20	11.22 ± 0.20
Barred Dwarf	0.90 ± 0.14	14.64 ± 0.14
Non-Barred Normal	3.95 ± 0.07	9.23 ± 0.07
Non-Barred Dwarf	0.66 ± 0.07	13.66 ± 0.07

[a]The units are 109 $M_\odot$ and $M_\odot/{\rm pc}^2$.

Ostriker & Peebles (1973) suggested that halo-to-disk mass ratios of 1–2.5 (interior to the disk) lead to stability. It is known that dwarf galaxies, both irregular and elliptical, are dark matter dominated. An example is DDO 154 where 90 % of the mass is in the dark halo. However, recent studies by Athanassoula (2002) suggest that the halo can stimulate the growth of the bar due to halo resonance stars. It appears that dwarf spiral galaxies may shed light on this.

In order to check whether surface density is the key parameter, it has been obtained for all the galaxies in both the comparison sample and the dSpirals. Using the m_{21} parameter from the RC3 and related equations the following equation can be used to obtain the H I mass

$$\log(M\ ({\rm H\,I})) = 12.336 - 0.4\, m_{21} + \log(1+z) + 2\log D\ ,$$

where D is the distance in Mpc and z the redshift. The surface density was obtained dividing this mass by $\pi\ r^2$, with r the optical radius. Two important caveats appear: this is only the H I surface density, and it is averaged over the total optical size of the galaxy and not only for the central parts, where bars are formed. The averaged values of both the M(H I) and the gas surface density, Σ_g, are presented in Table 3 for barred normal and dwarf galaxies and for non-barred ones. The largest differences are found between the normal and the dwarf systems, while very similar values are found for barred and non-barred systems of both groups. These values are a factor of 2 larger than in the solar neighboorhoud, 6 $M_{\odot}/\mathrm{p}c^{2}$ (Binney & Tremaine 1987).

In order to match the results on the surface density with the frecuency of bars, the stellar surface density in dwarf galaxies should be lower than in normal galaxies. Five of the galaxies in Table 1 have been investigated by van Zee, Haynes, & Salzer (1997) as part of a sample of quiescent galaxies. They concluded that the star formation rates are low for all the galaxies in their sample. This is specially true for the dwarf spirals which have rates of 0.1 $M_{\odot}$/yr or less, in agreement with the conclusions from a quick inspection of Hα images taken by the author. If dSpirals are quiescent galaxies the number of stars that have been formed during their lifetime might not be large since the amount of gas is considerable (see Table 4). This is supported by the comparison of the gas surface density between dSpirals and dI. The latter has an averaged Σ_g almost three times larger than the largest values for dSpirals. It can be concluded that dSpirals do not form as many stars as dI galaxies do.

These results should be taken with caution because the central density of the total mass may be very different from the values tabulated here for dwarf spirals. It might be that the central density for dSpirals is lower than in normal galaxies and thus that they are more stable to bar formation. But if dwarf spirals have large dark matter content, like the dwarf irregulars, the lack of barred galaxies among them is easily explained.

Moreover, if interactions and gas accretion are important for the triggering and maintenance of bars (Bournaud & Combes 2002), there should be fewer dwarf barred spirals because they are isolated systems (see next subsection). Anyhow, a deep study of the dark matter content and total masses distribution is needed in order to clarify this issue.

Finally, the absence of barred galaxies may be a mere problem of misidentification when the distance increases. Van den Bergh et al. (1996) found that only 0.3% of the distant objects in the HDF are barred, and that this is not a result of the low signal-to-noise in the data. A similar conclusion is obtained here, with the average redshift for barred systems being 0.55 while it is 0.95 for the non-barred ones. Then, either bar structures are formed during the recent history of spirals or they become difficult to identify from a mere visual inspection at large distances. Deep images in the optical and near-infrared with Fourier analysis, as those performed by Barazza, Bingelli & Jerjen (2002), will elucidate this question. But if dwarf spiral galaxies are mainly non-barred systems, then they will be of the utmost importance for understanding the formation and evolution of bar structures.

3.2. *Spatial Distribution and Colors*

In the study of six dwarf spiral galaxies by Schombert et al. (1995) it was concluded that these galaxies are not localized in rich clusters. A first inspection of the sample presented here allows a similar conclusion. Only one of the galaxies in Table 1 belongs to the Virgo cluster, UGC 7781. This is in agreement with the conclusion by Iglesias-Páramo et al. (2002) and by Sandage, Bingelli, & Tammann (1985) that there are no spiral galaxies in the Virgo cluster with $M_v < -18$. None of the galaxies in Table 1 are located in the neighborhood of the Coma cluster or any other rich cluster. Moreover, out of seven dSpiral galaxies closer than 5 Mpc to the Milky Way, none is in the Local Group. In addition, when compared with the UM Galaxies (Lee et al. 2000), dSpirals show a tendency to avoid companions and crowdy fields.

One explanation is that, as opposed to spiral structure in very massive galaxies (M > 10^{10} $M_{\odot}$) which is stable to chaos induced by cluster formation and galaxy encounters, low-mass small galaxies can be disrupted by galaxy perturbations. These encounters will heat the stellar disc diluting the spiral arms into a thick disc. The scaleheight of the disc increases substantially and no spiral features remain. These gravitational encounters are common in rich clusters (Moore et al. 1999). Therefore, inside rich groups and clusters, bars and spiral structures in small galaxies might be transient structures, with very short lifetimes. An increase in the star formation rate, together with a dilution of the spiral arms, may change these dwarf spirals into dwarf irregular galaxies. Moreover, the stripping of the gas of the galaxies will transform them into dwarf ellipticals. This is the simplest explanation for the small number of dwarf spiral galaxies as compared with classicals in clusters.

Recently, Barazza et al. (2002) have discovered bars and spiral patterns in a few dwarf galaxies previously classified as dE and dS0. If this is confirmed, it might indicate that the transformation of dSpirals into dwarf ellipticals could be occur more often than previously thought. The main caveat is that a similar trend of avoiding crowdy fields is found for the comparison sample, which is composed of larger and more massive (in gas, at least) galaxies.

Another conclusion by Schombert et al. (1995) is that the colors of their sample are very blue, even bluer than normal early-type classical spirals. The (B-V) color from the RC3 has been found for 39 galaxies in the dSpiral sample and the averaged value is 0.48, which is very similar to other gas-rich dwarf galaxies (e.g., van Zee et al. 1997). Blue colors might be an indication of an important population of recently formed stars. But as said in the previous subsection, the star formation rates, when determined, are very low.

Although Schombert et al.'s sample of galaxies contains early type spirals and most of the galaxies in Table 1 here are late-type, properties like colors, star formation rates and spatial distribution are more similar between these two samples than between dwarfs and classicals of the same type.

3.3. *Abundance Gradients*

One of the most important and characteristic properties of spiral galaxies is the existence of a gradient in metallicity, specially for Sc and Sd types (Zaritsky, Kennicutt, & Huchra 1994). This gradient is observed for most chemical elements and both in the gas and in the stellar metallicity (Edvardsson 1998; Venn et al. 1998; Henry 1998). Also, the gradient is less steep for barred galaxies (Martin 1992; Edmunds & Roy 1993). Unlike them, there are no differences in the metal content for most of the dwarf irregular systems (e.g., Roy et al. 1996, but see Hidalgo-Gámez, Masegosa, & Olofsson 2001 for a different opinion). The study of this property in the dSpiral galaxies will be crucial in order to achieve a definitive conclusion.

Information on spectral lines was searched for in the literature for the galaxies in the dwarf spiral sample. Line ratios provide information about the density, the ionization level, the excitation level, and shocks, in addition to the chemical abundances.

For only eight of the dwarf spirals in Table 1 there exists some of this information in the literature. They are UGC 7971 (Hunter & Hoffman 1999), UGC 5675 (McGaugh 1994), UGC 6921 (Gallagher & Hunter 1989), NGC 2188 (Domgönger & Dettmar 1997), UGC 191, UGC 891, UGC 5716, and UGC 11820 (van Zee et al. 1997). The galaxy UGC 10310 (DDO 204) is now added to them. It was observed by the author the night of July 7th, 1995 with the CAFOS spectrograph on the 2.2 m telescope at Calar Alto Observatory (Spain). The night was clear and stable with a seeing of 1 arcsec.

TABLE 4

LINE INTENSITIES NORMALIZED TO Hβ[a]

Galaxy	[O II]/Hβ	[O III]/Hβ	[N II]/Hβ	12+ +log(O/H)
UGC 191 1	2.98	4.06	0.14	8.12
UGC 191 2	3.20	3.20	0.23	8.10
UGC 191 3	3.46	2.94	0.22	8.14
UGC 5675 a3	3.48	2.70	···	7.7 or 8.45
UGC 5675 a1	5.70	1.78	···	7.8 or 8.3
DDO 204 a	0.2	3.7	···	7.5
DDO 204 c	0.19	2.0	···	7.1
UGC 11820-1	3.83	2.79	0.13	8.2
UGC 11820-2	3.33	2.95	0.16	8.12
UGC 11820-6	3.34	1.83	0.11	7.87
NGC 3985	2.45	0.57	···	7.2 or 8.9
NGC 2188	3.36	3.00	···	7.7 or 8.45
DDO 150	···	5.35	···	···
UGC 891	4.55	1.88	0.22	8.2
UGC 5716	2.64	3.78	0.09	8.3

[a]In column 1 is given the most common name of the galaxy; column 2 shows the intensity of the [O II]λ3727 Å line; the intensity of the [O III]λ5007 Å line is given in column 3, that of [N II]λ6583 Å is shown in column 4. The oxygen abundance, determined from the R_{23} and/or the N_{23} indicators (except for UGC 191) is shown in column 5.

Grisms number 8 and 9 were used to obtained the spectrum of the blue and the red lines, covering a wavelength range between 2000 Å and 8000 Å. The integration time was one hour in both grisms.Two standard stars (BD 33 2642 and LDS 749) were observed in order to calibrate the flux, and the wavelength calibration was performed using HgHeRb lamps. One single slit position passing throughout the galaxy and covering three H II regions was obtained. The data reduction was performed with the software package MIDAS.

Only four of the former galaxies have abundance determinations at more than one location and only in UGC 191 was the forbbiden oxygen line [O III]λ4363 Å detected. For the other three galaxies, UGC 5716, UGC 11820, and DDO 204, the chemical indicator R_{23} (Pagel et al. 1979) can be determined from the information available. This indicator presents large uncertainties and its reliability is under debate (Díaz, Edmunds, & Terlevich [2002] astro-ph 0211593). Moreover, the abundances of two of these galaxies are bivaluated due to the lack of information on their nitrogen content. The oxygen abundances of each region are listed in Table 4 along with the intensity of a few of the most interesting lines.

Only UGC 11820 and DDO 204, which is the sole barred galaxy of the four, show differences larger than 0.1 dex, but the [O II]λ3727 Å line in the latter galaxy is very weak and has large uncertainties (more than 50%). Considering all the uncertainties, it can be concluded that only UGC 11820 out of the four shows important differences in its oxygen abundance. This result is not surprising because no metallicity gradient was found for a few classical, large, late-type spirals, e.g., NGC 1313 (Mollá & Roy 1999). They concluded that low-mass galaxies seem to have flatter abundance gradients. In agreement with these results, UGC 11820 is the galaxy with the largest $M(HI)$ of the four.

It should be kept in mind that the gradients for classical spirals are relatively small (e.g., 0.07 dex/kpc for the Milky Way [Henry 1998]). Assuming a typical radius of 5 kpc for dwarf galaxies from Fig. 1, the differences in metallicity might be no larger than 0.35 dex between the innermost and the outer parts. Variations of this order of magnitude might be masked by the uncertainties in the abundances. Thus, gradients in the abundances are not easy to detect in small-size systems.

Usually, spiral galaxies have higher values of their metal content than irregulars, even at the outer parts of the disk (Dutil 1998). The oxygen content can be determined for all the dSpirals with spectral information using the bright-line method (Pagel et al. 1979). For those galaxies whose R_{23} indicator could not be obtained, the N_{23} parameter, defined as log[N II]/[O III] (Edmund & Pagel 1984), was used for determining the chemical abundances. Three galaxies have an abundance degeneracy because of the lack of nitrogen lines (see Table 4). The average oxygen abundances of this subsample is 8.1. If the upper branch is considered for the degenerate galaxies, the average oxygen content for the dSpirals is 8.28, similar to the LMC metallicity. However, their metal content is very similar to that of a sample of dI (Hidalgo-Gámez & Olofsson 2002).

3.4. *More on Dwarf Spirals*

Dwarf galaxies tend to have larger OB associations than spiral galaxies (Bomans 2001). This is true when scaled to the galaxy size, therefore, dwarf spiral galaxies must show some evidence of larger OB associations. The values of the excitation parameter, defined as the intensity of the [O III]λ5007/Hβ, and the ionization parameter, [O III]/[O II], averaged for the dSpirals with spectral information, are presented in Table 5. Values of these parameters for the dI sample, late-type spirals from McCall et al. (1985) and four classical spirals such as M31 (Galarza et al. 1997), M33 (Kwitter & Aller 1981), M51 (Díaz et al. 1991), and M101 (Torres-Peimbert et al. 1989) are also shown. Both the excitation and the ionization parameters are smaller for the dSpirals sample than for the dIs. Actually, they are closer to the values for giant, classical spirals. The excitation and ionization are also smaller in the dSpirals than in the late-type spirals. These values might be due to a selection effect because only late-type galaxies of high ionization, (meaning that the intensity of the line [N II]λ 6583 Å is lower than the intensity of the line [O III]λ5007 Å) were selected from McCall et al.'s sample. These low values of both the ionization and the excitation in the dSpirals might indicate a deficiency of massive stars in spirals as said, but also may be an indication of older star formation events in these galaxies. It is not easy to know which effect is prevailing because the other parameter that might help, the equivalent width of Hβ, also has a twofold meaning. However, despite the differences in the excitation and ionization values, all the galaxies are excited by the same mechanism because they all lie on the same locus on the well known log[O II]/Hβ vs. log[O III]/Hβ diagnostic diagram.

Another important problem where dwarf spirals might help is that of the origin of nitrogen. This element is a secondary element in classical spirals, produced by low mass stars (Vila-Costas & Edmunds 1993), while it is primary in irregular galaxies with a typical value of log[N II]/[O II] = −1.5 (Garnett 1990). Only four galaxies, with a total of eight H II regions, have simultaneously determined intensities of [N II] and [O II]. In Figure 8 is shown the diagram log(N^+/O^+) vs. O/H for dwarf spirals including also dI and some of the late-type spirals from McCall et al. When only one type of galaxies is considered (e.g., dSpirals) a scatter diagram is obtained (r_l = 0.01). But if all the galaxies are put together, a positive correlation is found. The main reason is that while the three types of galaxies shown in Fig. 8 have similar oxygen abundances, nitrogen shows important differences. In addition, the averaged values for the N/O ratio are slightly larger (−1.23) in the late-spirals while the dIs show lower log(N/O), −1.62. Despite the small number of data points in Fig. 8, the correlation can be explained using the chemical evolutionary models of dwarf galaxies with strong bursts (see Figs. 4 and 6 in Pilyugin 1992). According to chemical models (ibid), a lower value of the N/O ratio means a younger star formation event: oxygen is already released from the massive stars while nitrogen is still locked into the low mass

TABLE 5

SPECTRAL PROPERTIES[a]

Type	[O III]/Hβ	[O III]/[O II]	[N II]/Hβ	[S II]/Hβ	EW(Hβ)
dSpirals	3.08	1.07	0.17	0.10	58
dI	3.91	2.32	0.07	0.13	115
late Spirals	3.56	1.50	0.37	0.23	118
M31	0.99	0.33	···	0.31	···
M33	2.88	1.41	···	0.04	···
M51	0.16	0.17	···	0.07	···
M101	2.25	1.26	···	0.08	···

[a]Properties like the ionization, the excitation and the shock contribution can be determined from line intensity ratios. Column 1 gives the type of the galaxies while the excitation and ionization parameters are shown in columns 2 and 3, respectively. Column 4 gives the intensity of [N II]λ6583 Å normalized to Hβ; the intensity of the [S II]λ6716 Å normalized to Hα is presented in column 5. Finally, in column 6 are shown the values of the equivalent width of the Hβ line, when available. All t values are averaged when more than one galaxy is considered.

stars. From the locations of the dSpirals in this diagram it can be concluded that either the star formation events in these galaxies are not recent or the number of massive O stars from which the oxygen is released is not large, in agreement with the star formation results.

Finally, the effect of density waves in the interstellar medium of spiral galaxies can be studied. Density waves might excite shocks in the medium. As the [S II]/Hα ratio is related to shocks (Evans & Dopita 1985), it is expected that spiral galaxies would have a large value for this ratio. The values are shown in Table 5 and the plot log[O III]/Hβ vs. log[S II]/Hα is presented in Figure 9. Except for M31, dSpirals and classical spirals have similar values of this ratio, which are smaller than those for the late-type spirals. The most striking feature is that only six dSpirals have larger values of the [S II]/Hα than the rest of the galaxies. Actually, four of them, in addition to M31 at the top and two dIs and one late-type at the bottom, show an upper envelope following the well-known anticorrelation between these two parameters (Martin 1997). Moreover, there is a lower limit at 0.03 in log[S II]/Hα, and all the galaxies lie in the same place on the diagram. For all the samples, the [S II]/Hα ratio always has low values, shocks are not needed and pure photoionization models explain them. If size were the key parameter, all the classical spirals, especially M101, should be in a very different place on the plot, which is not the situation. Another important parameter might be the metallicity because this ratio is metallicity dependent (Dopita & Sutherland 1993), and the late-type as well as both dwarf samples have lower metal

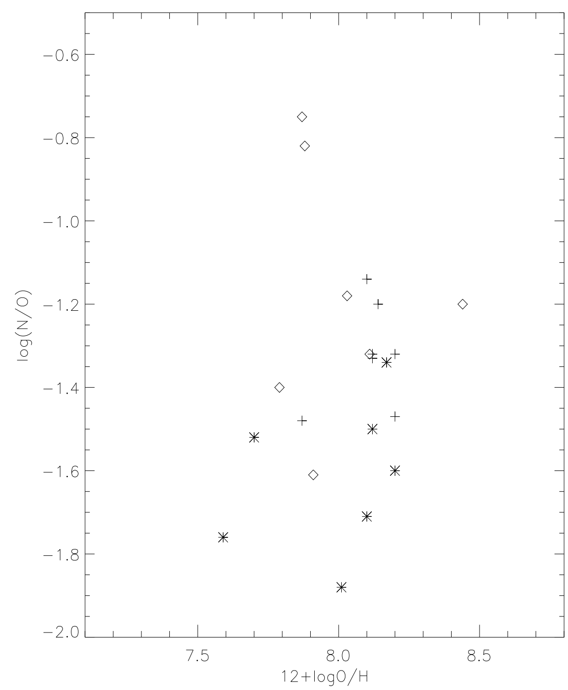

Fig. 8. The N^+/O^+ vs. the oxygen abundance for gas-rich galaxies. Crosses stand for dSpirals, stars for dIs and romboids represent McCall's spirals. An average value of −1.5 could be established with a large dispersion for all the galaxies, with dIs having the lowest values and the late types the largest. Only two of the McCall's galaxies do not fit into this trend.

content. Again, the location of all the data points cannot be explained, especially for the classical spirals which are metal-rich but lie on the same place

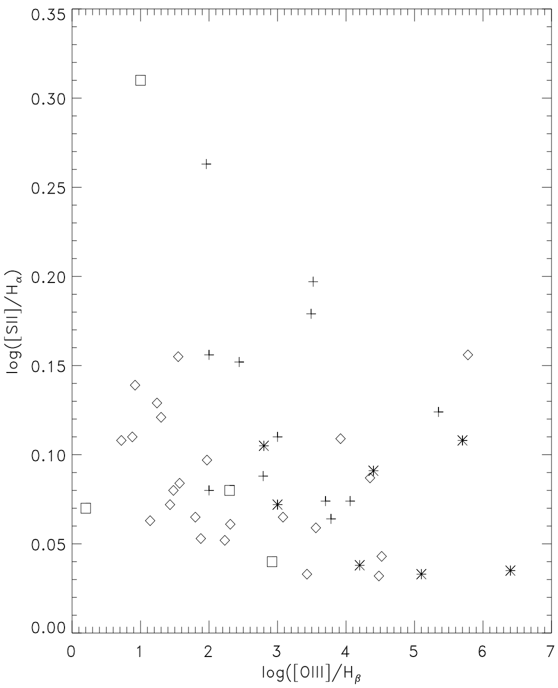

Fig. 9. The [S II]λ6716/Hα vs. the excitation. Symbols as in Fig. 8, but open squares are classical spirals. Two features are clear in this figure: a lower limit at log[S II]/Hα = 0.03 and an upper envelope running from 0.3 to 0.1.

as the late-types and dwarfs. It must be kept in mind that for classical spirals this ratio is integrated over the galaxy and the effect of shock waves may be diluted.

4. CONCLUSIONS AND FUTURE WORK

Spiral galaxies with small radii and small luminosities do exist, contrary to the conclusion reached by Edmunds & Roy (1993) that there is no spiral structure for $M_B < -17$. In the present work we have obtained a sample of more than 100 galaxies which are both small and spiral. Many more dwarf spiral galaxies may be hidden at intermediate/large redshift. They are likely to be found outside rich clusters and they might have low surface brightness. These may be the main reasons why they have not yet been found.

In this investigation we have compared the main properties of spiral galaxies of both sizes: large and dwarf. Also, a comparison with dwarf irregular galaxies has been undertaken. The spectral characteristic of all of them are very similar. As discussed in Hidalgo-Gámez & Olofsson (2002), the spectral features of the different types of gas-rich galaxies are very similar although their sizes, luminosities, and star formation histories differ. This is confirmed here: classical giant spirals, like M101 are found to have similar values of the excitation, ionization, and [S II]/Hα to dwarf irregulars and dwarf spirals. The main differences between the large and the small spiral galaxies concern the origin of nitrogen, the abundance gradient and the oxygen abundance. As in dwarf irregulars, nitrogen seems to be primary also in dwarf spirals. The lack of abundance gradients in dSpirals can be explained by the difficulties of measuring small differences in the abundances (smaller than 0.2 dex). The lower oxygen abundances can be explained by the small sizes of the OB associations.

Another important difference concerns the number of barred systems in dwarf and normal spirals, with a deficiency in the former. Two reasons could be invoked. Either it is more difficult to detect bars in small, dim and distant objects, or the deficiency might be real, because the larger amount of dark matter in dwarf galaxies prevents bar formation. In addition, barred galaxies do not show a broad range in sizes but peak at 3 and 4.5 kpc, while non-barred systems have no preferred radii. Althougth barred galaxies are brighter than non-barred ones, there are no preferred values of M_b.

Finally, dwarf spirals are larger and more luminous than dwarf irregulars. Moreover, there seems to exist a transition radius: larger systems develop relatively thin discs and spiral arms, whereas smaller galaxies do not show any of the typical spiral structures.

According to the differences between classical and dwarf spirals, the latter seem to be more similar to dwarf irregular galaxies than to the classical spirals, not only in their metal content but also in their colors and dark matter content.

Although more observations are needed for a complete answer to all the questions raised in this study, there is enough information to conclude that dwarf spirals are not a mere continuation of the classical spirals into smaller sizes. Instead, they seem to be more related to dIs than to classical spirals.

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