Faint companions in the close environment of star–forming dwarf galaxies: possible overlooked starburst triggers? *

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Abstract

Using the NASA Extragalactic Database, we have searched the close environment of 98 star–forming dwarf galaxies (SFDGs) from field– and low density environments for companion galaxies. Most of the found companions are dwarf galaxies, previously disregarded in environmental studies of SFDGs. Using a subsample at low redshifts, $cz < 2000$ km s^{-1}, i.e. less biased against dwarf companions, we find that 30 % of the SFDGs have close companions within a projected linear separation s_p <100 kpc and a redshift difference of $\Delta cz < 500\,\mathrm{km\,s^{-1}}$. This fraction must be considered a lower limit, given the incompleteness of the available data sets and the non-negligible frequency of HI clouds in the vicinity of SFDGs, so that the majority of SFDGs should not be considered isolated.

The redshift differences between companion candidates and sample SFDGs are typically $\lesssim$ 250 km s^{-1} and concentrated towards lower values. This is similarly observed for dwarf satellites of spiral galaxies and suggests a physical association between the companion candidates and the sample SFDGs. SFDGs with a close companion do not show significant differences in their Hβ equivalent widths and $B-V$ colours as compared to isolated ones. However, the available data do not allow to rule out close dwarf companions as an influencing factor for star formation activity.

1 Introduction

Comparative studies of gas–rich dwarf galaxies with current or recent strong star formation (SF) suggest that they form one and the same physical class of objects (Papaderos et al. 1996, Marlowe et al. 1999). In the following, we shall therefore unify Blue Compact Dwarf Galaxies (BCDs), HII galaxies, etc. using the term “Star–Forming Dwarf Galaxies (SFDGs)” (cf. Vílchez 1995). Starbursts or episodes of strongly enhanced star formation (SF) are considered frequent in gas-rich dwarf galaxies, and are principal evolutionary drivers of such objects. The frequency of local dwarfs implies numerous less evolved, i.e. gas–rich, probably starbursting dwarfs at higher redshifts, possibly contributing significantly to the star formation rate (SFR) density (see e.g. Guzmán et al. 1997). While internal regulation processes were put forward to explain their strong SF activity (cf. Papaderos et al. 1996 and references therein), SFDGs were also suggested to be influenced by interaction with their environment. Studies assessing this hypothesis revealed that SFDGs

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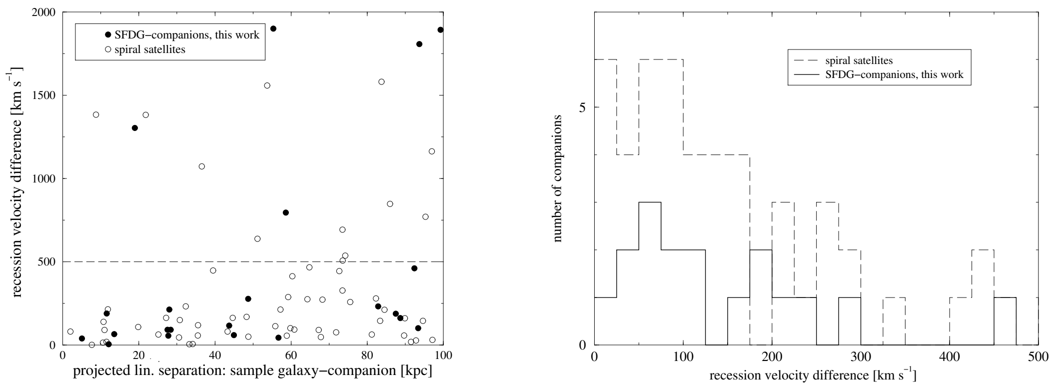

Figure 1: **left** Recession velocity difference vs. projected linear separation of putative companions of SFDGs (filled symbols). Open circles show the distribution of companions (not restricted to dwarfs) we found around field spiral galaxies from the sample of Kennicutt & Kent (1983). **right** Distribution of the recession velocity differences between the sample SFDGs and the putative companions. The dashed histogram represents the spiral companions shown in the left panel of this figure.

typically reside in regions of lower density of luminous galaxies (Salzer 1989, Telles & Terlevich 1995). Interactions with luminous galaxies, given their typically large distances, were therefore not considered a general trigger mechanism for starburst activity in SFDGs. This scenario was also abandoned in view of comparisons between SFDGs with and without — generally relatively distant — luminous companions (Campos–Aguilar & Moles 1991, Telles & Terlevich 1995). On the other hand, mixed evidence for differing properties of SFDGs in void, field and cluster environments (Vílchez 1995, Vennik et al. 2000), although controversially discussed, calls for an assessment of alternative environmental factors. In this respect, it appears interesting that Lindner et al. (1996) attributed the apparent extreme isolation of some distant BCDs to the observational bias against faint companions. A significant influence of a low mass companion close to a SFDG appears possible, since the tidal forces it exerts scale only with the first power of its mass, but with the third power of its distance. An alternative scenario is the triggering and fueling of a starburst by infall of gas–rich companions onto a SFDG (e.g. Hensler et al. 1999). Observational results suggest that such yet uncatalogued, optically faint objects, down to extragalactic HI clouds with no optical counterpart, are frequent around SFDGs (e.g. Taylor et al. 1995, Pustilnik et al. 1997). We present a first study of the frequency, properties and possible influence of such companions in the close environment of SFDGs. For a detailed description of this work, see Noeske et al. (2001).

Table 1: Companion search results for subsamples within different redshift intervals

cz^a [km s^{-1}] range (1)	sample size (2)	non isol. (3)	no. of comps. (4)	dwarf comps. (5)
unconstrained	98	16	18	15
$cz < 2000$	42	13	15	14
$2000 \leq cz < 4000$	12	2	2	1
$cz \geq 4000$	44	1	1	0

[a] redshifts correspond to Virgo infall corrected distances, assuming $H_0 = 75\,\mathrm{km\,s^{-1}\,Mpc^{-1}}$; (1) redshift interval of respective subsample; (2) no. of sample galaxies in subsample; (3) no. of sample galaxies in subsample with at least one possible companion; (4) no. of possible companions found for the respective subsample; (5) no. of dwarf galaxies among possible companions

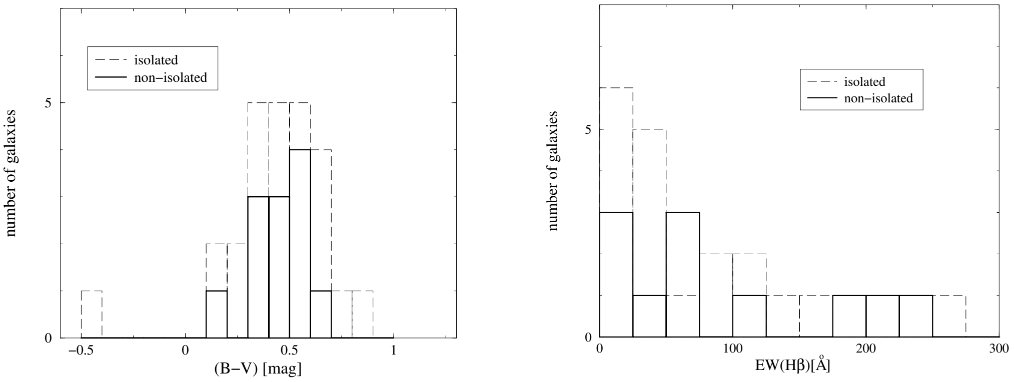

Figure 2: Distribution of the **left:** $B-V$ colours and **right:** Hβ equivalent widths $EW(\mathrm{H}\beta)$ for the isolated (dashed line) and the non–isolated (solid line) subsample of SFDGs. The comparison is restricted to the subsample at close distances, i.e. at redshifts $cz < 2000\,\mathrm{km\,s^{-1}}$.

2 The SFDG sample and companion search catalog

We selected all dwarf HII galaxies from the University of Michigan Lists IV and V, studied in detail by Salzer et al. (1989). As these objects are relatively distant (mostly $cz > 2000\,\mathrm{km\,s^{-1}}$), we included a number of well–observed BCDs at smaller distances (Cairós 2000) to be less biased against low–luminosity companions. None of our objects resides in a group or cluster environment. To search for companion objects, we chose the NASA Extragalactic Database (NED), one of the deepest online catalogs to date. Its inhomogeneous completeness does not hamper our study, as one still cannot extrapolate even beyond a sharp limit (cf. Section 3.2). We searched for extragalactic optical sources with the additional requirement of a known redshift, so that the companions' properties and distribution could be studied. Spectrophotometric data from the NED and different literature sources were compiled for both the sample SFDGs and the found companions. Distances were calculated from NED redshifts, using Tully (1988) to correct for Virgo Cluster infall.

3 Results and Discussion

3.1 Companion selection criteria and distribution of the companions

Figure 1 (left) shows that almost all of the companions have low redshift differences ($\lesssim 500\,\mathrm{km\,s^{-1}}$) to the sample SFDGs. Subsequently, a projected linear separation $s_p < 100\,\mathrm{kpc}$ and a redshift difference corresponding to $\Delta cz < 500\,\mathrm{km\,s^{-1}}$ were adopted as companion selection criteria, values below which tidal forces have been estimated to be significant (Campos–Aguilar et al. 1993, Pustilnik et al. 2001) and for which pairs of normal galaxies and SFDGs show likely signs of interaction. The rising frequency of companions towards lower redshift differences (Figure 1, right) is reminiscent of what is observed for binary galaxies (Schneider & Salpeter 1992) as well as for dwarf companions of normal spiral galaxies (Zaritsky et al. 1997; cf. also Figure 1 left & right for spiral companions of any luminosity). It is hence very likely that the companions we find are physically associated with the sample SFDGs, rather than random encounters. The independence of Δcz on s_p found for spiral companions has been attributed to the dynamic dominance of a massive DM halo (Zaritsky et al. 1997). A similar scenario appears tempting for SFDG companions, if a larger dataset can prove that they also show no correlation of s_p and Δcz, as suggested by Figure 1 (left).

3.2 Companion properties: invisible distant dwarfs

Table 1 (first row) shows that the majority (>80%) of the found companions are dwarf galaxies ($M_B > -18$ mag). As expected, these are almost solely found for the nearest subsample ($cz < 2000\,\mathrm{km\,s^{-1}}$) due to their intrinsic faintness. From this closest, i.e. least biased subsample, one obtains a fraction of ~30% of SFDGs with at least one close companion. We emphasize that this is a lower limit, given the incompleteness of our search catalog. Unfortunately, as both the faint end of the galaxy luminosity function, and the frequency of purely gaseous companions are still poorly constrained, a meaningful extrapolation below this limit does not appear reasonable to date. The average companion is as blue as the sample SFDGs ($\overline{B-V} = 0.44$ mag), and by 0.72 B mag (median) brighter than its 'mother' galaxy. This probably reflects a selection effect, as preferably the brightest companions – nevertheless dwarfs – with active SF are catalogued in the NED.

3.3 Close dwarf companions as possible starburst triggers?

Objects with and without found companions ('isolated' and 'non–isolated') are partly separable only for the nearest ($cz < 2000\,\mathrm{km\,s^{-1}}$) subsample. These galaxies were compared with respect to $B-V$ and $EW(\mathrm{H}\beta)$, observables which are available for most of the sample and trace the relative SF activity on respective timescales of $\sim 10^7$ and $\sim 10^8$ yr. The distributions for the isolated and non–isolated SFDGs of the nearest subsample are shown in Figure 2. Kolmogorov–Smirnov tests yield high probabilities for equal parent distributions ($B-V$: 0.90, $EW(\mathrm{H}\beta)$: 0.45), whereas the respective sample means are compatible within the sample standard deviations. These results can neither prove the hypothesis of purely internal triggering of SF, nor disprove an external influence of close companions, due to the low number statistics and the large intrinsic scatter of the data. The picture is further blurred by the incompleteness of the companion search, i.e. a poor separation of isolated and non–isolated sample objects. In addition, the time window to detect a starburst through *strongly* changed SF tracers is narrow for SFDGs, $\sim 10^7$ yr after its onset. The presence of dwarf companions in the close environment of SFDGs readdresses the question of environmental influences on their SF activity, a scenario which had been abandoned before due to the general lack of luminous companions. To obtain decisive answers, large samples and deep search catalogs will be required, as well as advances on the part of theory on interacting dwarf galaxies.

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