Galaxy Pairs in the 2dF Survey I. Effects of Interactions in the Field

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ABSTRACT

We study galaxy pairs in the field selected from the 100 K public release of the 2dF galaxy redshift survey. Our analysis provides a well defined sample of 1258 galaxy pairs, a large database suitable for statistical studies of galaxy interactions in the local universe, \( z \leq 0.1 \). Galaxy pairs where selected by radial velocity (\( \Delta V \)) and projected separation (\( r_p \)) criteria determined by analyzing the star formation activity within neighbours. We have excluded pairs in high density regions by removing galaxies in groups and clusters. We analyze the star formation activity in the pairs as a function of both relative projected distance and relative radial velocity. We found power-law relations for the mean star formation birth parameter and equivalent widths of the galaxies in pairs as a function of \( r_p \) and \( \Delta V \). We find that star formation in galaxy pairs is significantly enhanced over that of isolated galaxies with similar redshifts in the field for \( r_p < 25 \) kpc and \( \Delta V < 100 \) km/s. We detected that when compared to isolated galaxies of similar luminosity and redshift distribution, the effects of having a companion are more significant on the star formation activity of bright galaxies in pairs, unless the pairs are formed by similar luminosity galaxies. In this case, the star formation is enhanced in both components. The ratio between the fractions of star forming galaxies in pairs and in isolation is a useful tools to unveil the effects of having a close companion. We found that about fifty percent of galaxy pairs do not show signs of important star formation activity (independently of their luminosities) supporting the hypothesis that the internal properties of the galaxies play a crucial role in the triggering of star formation by interactions.

Key words: cosmology: theory - galaxies: formation - galaxies: evolution.

1 INTRODUCTION

The actual cosmology paradigm for galaxy formation assumes that structure forms by hierarchical aggregation. In such scenarios galaxy interactions are frequent and have a crucial role in determining galaxy properties. The formation of galaxies in these schemes can be successfully analyzed by using numerical simulations which show that, as the systems are assembled, mergers and interactions can trigger star formation with efficiencies that seem to depend mainly on the internal structure of the systems. By using pre-prepared mergers, Barnes & Hernquist (1996) showed how the gas component experiences torques originated in the companion, increasing its gas density and triggering a starburst during the orbital decay phase of the satellite. These starbursts are fed by gas inflows tidally induced if the axisymmetrical character of the potential well is lost during the interaction. The stability of the systems can be assured by a dominating central mass concentration. A second starburst could be generated at the actual fusion of the baryonic cores. Cosmological hydrodynamical simulations showed that these processes take place in the formation of galactic systems in a hierarchical aggregation scenario in a similar way to that shown by pre-prepared mergers. Tissera (2000) found a correlation between mergers and starbursts. Recently, Tissera et al. (2002, Tis02) showed that the effects of interactions are different at different stages of evolution of the systems being more efficient at higher \( z \) when the systems are in early stages of evolution, and consequently, their potential well could be shallower. If the structure in the Universe formed in consistency with a hierarchical scenario, then, the proximity of a
companion could affect the mass distributions and trigger gas inflows producing an enhancement of the star formation (SF) activity.

In the local Universe, observations show that mergers and interactions of galaxies affect star formation in galaxies (e.g., Larson & Tinsley 1978; Donzelli & Pastoriza 1997; Barton, Geller & Kenyon 1998). It has also been shown that the merger rates (e.g., Woods, Fahlman, Richer 1995; Le Févre et al. 2001; Patton et al. 2002) and the star formation activity of galaxies increase with redshift, suggesting a change in the impact of interactions on the SF process as galaxies evolve. Although the relevance of these violent events on the formation of the structure and their SF history is now widely accepted, many questions remain to be answered. For example, as it has been reported by other authors (e.g., Petrosian et al. 2002), many interacting systems show weak star formation activity suggesting that the particular internal conditions within these systems may be needed to trigger star formation.

An insight on the nature of interactions can be obtained from studies of close pairs of galaxies in projection. Physical pairs must have similar redshifts, where relative velocities affect distance interpretation and therefore the true relative separations, Yee & Ellingson (1995) and Patton et al. (1996) adopt a minimum projected separation of $20 h^{-1}$ kpc to define close pairs and they find no significant differences between mean properties of paired and isolated galaxies although those which appear to be undergoing interactions or mergers have strong emission line and blue rest-frame colours. A similar result by Zeff & Koo (1989) indicate that in some systems colours correspond to recently enhanced star formation with an overall distribution consistent with field galaxies. Kennicutt et al. (1987) examined the $H_\alpha$ equivalent width, UBV colours and far-infrared flux of a complete sample of local pairs of galaxies and found that these close pairs exhibit a general trend of enhanced star formation and nuclear activity but with a wide dispersion about the mean behavior. Barton et al. (1998) analyzed a sample of approximately 250 pairs of galaxies showing a correlation between their radial and velocity separations and the $H_\alpha$ equivalent width. Although these authors found a clear correlation, their pair sample is still small to carry out a thoughtful statistical study of the effects of interactions and their cosmological evolution.

The 100K public data release (Colles et al. 2001) of approximately 1000000 galaxies of the 2dF Galaxy Redshift Survey (2dFRS) opens the possibility to study galaxy interactions by selecting the largest galaxy pair catalog hitherto constructed and analyzing their properties. The 2dF public data provide the redshift, magnitude and spectral types ($\eta$) of galaxies with $z \leq 0.15$ (Madgwick et al. 2002a, hereafter MZ02). Madgwick et al. (2002b) found a tight correlation between $\eta$ and the birthrate parameter $b$.

In this work, we present a catalog of galaxy pairs in the field constructed from the 2dF public release data and analyze their properties in comparison to isolated galaxies in the field. For this purpose we will exclude those galaxies that belong to groups as defined by Merchán & Zandivarez (2001, hereafter MZ01). Pairs in high density environments will be analyzed in a forthcoming paper. Here, we aim at answering questions such as which type of galaxies are preferentially found in pairs, how the star formation varies among them according to their luminosities, etc. We also intend to statistically determine a critical relative radial velocity and spatial separation for the classification of galaxy pairs. As it has been pointed out in previous works, galaxy pairs can be classified as interacting or close pairs. Interacting galaxy pairs are those that show explicit signs of interactions such as tidal tails. Close pairs are defined according to velocity difference and spatial separation criteria (e.g., Barton et al. 2002; Patton et al. 2002). In this work, galaxy pairs will be statistically selected by applying both a velocity and separation criteria which will be determined according to the star formation activity of neighbouring galaxies.

Because the public release 2dF catalog has different selection effect problems, control samples sharing the same selection effects will be constructed, focusing the analysis on the statistical differences between galaxies in pairs and isolated ones in the 2dFRS as a useful procedure to unveil the effects of galaxy interactions on the star formation process. In Section 2 we will defined the pair selection criteria, field galaxy pair catalog and the comparison samples. Section 3 is focused on the analyses of the star formation properties of galaxies in pairs and Section 4 summarizes the main conclusions.

2 GALAY PAIR CATALOG

The 2dF Galaxy Redshift Survey public data consist of 102326 galaxies observed in the northern and southern main strips of the final planned catalog which will have approximately 250000 galaxies. Despite of the fact that the 2dF public catalog is not complete, we argue that galaxy pair searching is not severely affected by completeness effects. In effect, in spite of the fact that the minimum fiber separation
for 2dF spectroscopy is approximately 25 arcsec, the survey strategy was to repeat the measurements in each field with new fiber positions in order to achieve the highest completeness. Thus, from this point of view there is no bias against small angular separations which would bias the results specially at higher redshifts. Therefore, the inclusion of a pair in our catalog depends mostly on the inclusion of each member in the survey, which were randomly selected within the targets of each field. Therefore, we conclude that there are not significant selection effects on the pair sample which could bias our results on star formation activity.

The 2dF data comprise information on redshift (z), angular separation, spectral type (η) and blue magnitude (m_0).

The spectral type parameter η are defined by a Principal Component Analysis, PCA, carried out by M02 where it was found to be related to the morphological type and the strength of the absorption-emission features. Madgwick et al. (2002a) suggest four different spectra groups:

Type 1: η < −1.4
Type 2: −1.4 ≤ η < 1.1
Type 3: 1.1 ≤ η < 3.5
Type 4: η ≥ 3.5.

The good correlation found between η and EW(Hα) by M02 supports the interpretation of this parameter as a good indicator of star formation activity.

We have estimated galaxy luminosities by applying the K-corrections derived by M02. The public 2dF data have galaxies with redshift in the range up to z ≈ 0.3, however, for the purpose of defining galaxy pairs we restrict our analysis to z ≤ 0.1 in order to prevent the results for strong biases in galaxy luminosities and unreliable spectral type estimates for distant galaxies.

Contamination by AGN activity could contribute to the emission spectral features and therefore affect our interpretation of star formation derived from the η parameter. However, on the global sense our conclusions should not be greatly affected given the expected good correlation between the star birth rate parameter b and the η parameter in the models analysed by Madgwick et al. (2002b).

As we discussed in the introduction, Barton et al. (1998) presented a sample of approximately 500 galaxies in pairs which were selected to have projected separations r_p < 50 h^{-1} kpc and velocity separations ΔV ≤ 1000 km/s. With this sample they studied the possibility that tidal interactions induced star formation. However, it is not clear from their work, if there are critical spatial and velocity separations which could establish limits for tidal interactions to be effective star formation triggering mechanisms.

We have estimated the stellar birthrate parameter, b = SFR/ < SFR > for each galaxy which provide a useful measure of the present level of star formation activity of a galaxy related to its mean past SF history. This parameter has been found to correlate with the morphological type (Kennicutt 1992) in the sense that late-type spirals and starbursts have larger b values. According to the calibration shown by Kennicutt (1998), systems undergoing strong star formation activity have b > 1.

In order to compute the b parameter we assume a linear correlation between η with EW(Hα) as reported by M02: EW(Hα) = 5.64η + 10.9. The final relation between b and η was obtained by fitting a linear regression of the form b = 0.045EW(Hα) + 0.61 to the high star forming galaxies of Carter et al. (2001). The resulting equation b = 0.25η + 1.06 relates linearly b with η. Our relation reproduce very well the calibration shown by Kennicutt (1998). We notice that the dependence of b on η estimated by Madgwick et al. (2002b) is stronger than the linear one adopted in this paper. It should be taken into account that the birthrate parameter b is linked to models for the star formation history and so the results are reliable on a global or statistical sense. Therefore, the conclusions obtained in this work are not expected to depend crucially on the particular dependence of b on η as far as η provides a useful measure of star formation in galaxies.

For the purpose of analysing how b depends on r_p and ΔV (defined as ΔV = c*(z_1 − z_2), where z_1 and z_2 are the redshift of the galaxies in the pair), we estimated the number of neighbours within concentric spheres centred at a given galaxy. Then, we calculated the mean star formation rate parameter < b > of these neighbours. Three sub-samples were constructed according to the η spectral type of the galaxy centre. Sub-samples I, II and III take as a centre a galaxy with η > 3.5, η > −1.4 and a any η value, respectively. We have adopted η = −1.4 to roughly segregate galaxies between two main types: early and late ones, while η > 3.5 corresponds to systems undergoing strong star formation activity. Sub-sample III has been constructed to compare the two previous ones with the general 2dF survey.

All galaxies with r_p ≤ 1 Mpc and ΔV ≤ 1000 km/s were taken into account. In Fig. 1 for each sub-sample, we show the mean birthrate parameter in r_p bins. Otherwise stated error bars in the figure have been computed trough the bootstrap technique. From this figure we see that, when the central galaxy has η > −1.4 or η > 3.5, the < b > parameter increases, as the further away neighbours are cast out.

This result makes evident that the closer neighbours experience the stronger star formation activity. This effect is more significant when the central galaxy is also experiencing strong star formation activity (η > 3.5). We can also observed that neighbours of Type 4 galaxies within 1 Mpc have < b > larger than the averaged one of 2dF galaxies at any r_p.

Similar calculations done for velocity bins within ΔV < 1000 km/s. In Fig. 2 we show < b > as a function of ΔV for the sub-samples constructed by the same criteria mentioned above. We found a velocity cut-off of 350 km/s (vertical dotted line), so that galaxies with ΔV < 350 km/s have < b > significantly enhanced with respect to the those of the total 2dF survey at a 3σ level.

Therefore, according to this analysis, r_p ≤ 100 kpc and ΔV ≤ 350 km/s can be defined as reliable upper limits for the relative radial velocity and projected distance criteria to select galaxy pairs with stronger specific star formation than the averaged galaxies in the 2dF. The signals are more significant when the centre galaxies belong to the spectral Type 4, but it is statistically equivalent to that measured for central galaxies with η > −1.4. Hence these values of relative projected separation and radial velocity may be considered as suitable thresholds for the triggering of star formation induced by interactions.
Figure 2. Mean bithrate star formation parameter \( b \) of galaxies as a function of relative velocity to the target: \( \eta > 3.5 \) (solid line), \( \eta > -1.4 \) (dotted line) and no \( \eta \) restriction (dotted-dashed line) targets are shown. The dotted vertical line depicts the relative radial velocity threshold for galaxy pair identification.

2.1 Field Galaxy Pair Catalog

From the previous analysis we found that a projected distance of 100 kpc and a relative radial velocity of 350 km/s are reliable limits to select pairs with high probability of being an interacting system with enhanced specific star formation activity. Galaxies situated at larger distances and with greater velocity differences do not show statistically significant signs of enhanced SF with respect to the background. With these criteria, we constructed a galaxy pair (GP) catalog from the 2dF public release data. And since, we are interested in studying those pairs that belong to the field (pairs in groups will be discussed in a future paper), we cross-correlated the total galaxy pair catalog with the 2dF group catalog developed by MZ02. The resulting field galaxy pair catalog (FGPC) comprises 1258 pairs with \( z \leq 0.1 \).

In order to properly assess the significance of the results obtained from the FGP catalog we have defined a sample of control galaxies from the 2dF catalog by a Monte Carlo algorithm that selects for each galaxy pair in the FGP catalog, two galaxies in the field (i.e. not included in the FGP catalog and not members of the MZ group catalog) with the same redshift range of the galaxy pair with no restriction in their relative distance. The procedure followed to construct this control catalog assures that it will have the same selection effects than the FGP catalog, and consequently, it can be used to estimate the actual difference between galaxies in pairs and isolated galaxies, in the field, unveiling the effect of the interactions.

For analyzing the spectral type composition of the FGP in comparison with that of general galaxies in the field we defined five combined categories \( (C_i) \) according to the combination of spectral type of the galaxies in the pairs. The first four correspond to GPs that have equal spectral type: \( C1 = (1, 1), C2 = (2, 2), C3 = (3, 3) \) and \( C4 = (4, 4) \). The last spectral category corresponds to pairs composed of galaxies with different spectral types (Table 1).

In Fig. 3a we have plotted the ratio between the fraction of FGPs in the first four spectral categories and of those obtained from the control sample \( \left( F^* = \frac{f_{\text{FGP}}}{f_{\text{CS}}} \right) \). We see that there is excess of C1 and C4 spectral category pairs with respect to the control sample, suggesting a trend for FGP to be composed of two galaxies with similar spectral characteristics, both non star forming or both with significant star formation (see Table 1). We have estimated the mean luminosities of \( \frac{< (L_1 + L_2) >}{2} \) of each category pair and the corresponding to the control sample. In Fig. 3b we show the corresponding ratios of these two samples. We can see that on average, galaxy pairs in C3 and C4 categories are significantly more luminous than their isolated counterparts.

### Table 1. Spectral composition of galaxy pairs: Percentages of spectral type categories.

| Catalog | C1 | C2 | C3 | C4 | C5 |
|---------|----|----|----|----|----|
| FGP     | 22 | 7  | 6  | 5  | 59 |
| CS      | 7  | 10 | 6  | 3  | 74 |
| FGP/CS  | 3.14 | 0.7 | 1  | 1.7 | 0.80 |

Note: FGP: field galaxy pairs; CS: control sample.

In Fig. 3b we have divided these relations by the corresponding of the control catalog. Error bars correspond to standard Poisson deviations.

3 STAR FORMATION IN GALAXY PAIRS

The final FGP catalog allows a detailed study of the possible effects of the interactions. For these galaxies, we have estimated the \( < b > \) as a function of \( r_p \) and \( \Delta V \) where \( r_p \)
and $\Delta V$ are the projected distance and the relative radial velocity, respectively, between members of a pair.

Fig. 4 shows $\langle b \rangle$ in bins of $r_p$. It can be seen that the star formation efficiency increases for closer galaxy pairs. A similar behaviour is found for the relative radial velocity (Fig. 5). Power laws provide good fits to the data. The following relations for the mean $b$ parameter and the equivalent width have been obtained from these fittings:

1. $\langle EW \rangle = (4.10 \pm 0.50)r_p^{-0.40 \pm 0.02}$
2. $\langle EW \rangle = (1.30 \pm 0.50)\Delta V^{-0.30 \pm 0.16}$
3. $\langle b \rangle = (0.63 \pm 0.01)r_p^{-0.23 \pm 0.02}$
4. $\langle b \rangle = (0.40 \pm 0.31)\Delta V^{-0.14 \pm 0.09}$

where $r_p$ and $\Delta V$ are given in Mpc and km/s and $EW$ in Amstrong. Errors have been estimated by applying the bootstrap technique (100 random samples). Note that the dependence on the projected distance is more significant than on the velocity separation. These relations have been confronted with Barton et al. (1998) data finding a good agreement with their observations for the dependence on projected distance.

In order to assess the importance of interactions on SF activity compared to isolated galaxies, we have computed the mean $b$ parameter for the galaxy pair control sample, $\bar{b} = 1.32$. This value has been depicted in Fig. 4 and in Fig. 9 (dashed lines) where it can be appreciated that only galaxies in very close pairs show significantly higher mean star formation activity than that of isolated galaxies in the field.

Complications related to the physical interpretation of redshift space identified pairs where $r_p$ and $\Delta V$ provide only lower limits for the true galaxy separations should be always considered. Also, transient properties, interlopers and interactions which have not undergone a close approximation difficulties a straightforward interpretations of the mean values of the starbirth rate parameter. Taking into account these caveats, we have calculated the fraction $f^*$ of star forming galaxies with $b > \bar{b}$, and show them in the small windows of Fig. 4 and in Fig. 9. The dashed lines represent the corresponding fractions for the control sample. As it can be appreciated the proximity in projected distance correlates with an increase in the fractions of galaxies undergoing strong star formation activity until they exceed the mean fraction of the control sample. Note that although we find no excess of $b$ in FGP with respect to those of isolated ones as a function of the relative radial velocity, there is a tendency in the fractions of pairs with $b > \bar{b}$ and small $\Delta V$. These results point out the existence of a large number of pairs that, although satisfying the general constrains of velocity and spatial separations do not exhibit enhanced SF with respect to isolated galaxies.

The weaker dependence of the mean birth rate parameter $\langle b \rangle$ on the relative velocity may have several sources. Firstly, an overall rms uncertainty of $\pm 85$ km/s is derived by repeated observations in the 2dF survey and by comparison with other redshift catalogs. This large scatter implies a large observational error in the relative velocity of a pair of galaxies in the catalog $\approx 120$ km/s. Therefore, this observational uncertainty should be considered as the main cause of the weaker dependence on relative velocity. There are, however, other issues to be considered, since there can be several pairs with large spatial separations but with small radial velocity differences. Hence, for a given relative velocity bin, contributions of pairs with different orbital position are canceled out. This is reflected in the lack of large $b$ values for any relative velocity bin (notice however, that the global mean $b$ values for all $r_p$ in Fig. 4, and all $\Delta V$ in Fig. 5 are equal). In the case of projected separation bins, there is also a contamination by small $r_p$ and large $\Delta V$ although the enhancement of star formation with spatial separation is strong enough to override this contamination.

In order to visualize how $\langle b \rangle$ depends on the combination of orbital parameters we have estimated $b$ as a function of $r_p$ by considering pairs by different velocity separations (Fig. 6). As it can be clearly seen the signal increases as pairs with larger $\Delta V$ are excluded from the calculations. A similar behavior is observed for the fractions ($f^*$). Those are systems with large relative distance observed with a small projected separation. From this figure we may infer that as the galaxies orbit into each other or experience a close encounter, the star formation activity of the system increases. In spite of the uncertainty in $\Delta V$ due to measurement errors, we note that the larger star formation activity for pairs with quoted values as small as $\Delta V < 50$ km/s.

The most significant difference between the star formation activity of galaxies in pairs and those of the control sample is obtained when the analysis is restricted to pairs with $r_p \leq 25$ kpc. This sub-sample shows the strongest signal of enhanced SF as illustrated in Fig. 4 where we have plotted the $b$ parameters as a function of the relative radial velocity. The dashed lines depict the mean $\langle b \rangle$ and $f^*$ for the corresponding control sample. Confronting this figure with Fig. 6X we can conclude that pairs with small $r_p$ have a statistically significant increase of their star formation rate when restricted to small relative velocities. In consequence, we define a subsample of close pairs by imposing the restrictions: $r_p < 25$ kpc and $\Delta V < 100$ km/s, hereafter close GP (CGP) sample. This set of galaxies exhibits the the higher star formation efficiency.

### 3.1 Dependence on Luminosity

An analysis of the dependence of the SF activity on the luminosity of the galaxies in pairs could help to understand how SF activity is regulated between pair members. Several observational works have found evidence that in an interacting pair, the fainter galaxy seems to be more affected (e.g. Donzelli & Pastoriza 1997). Recently, Colina et al. (2001) found that Ultra Luminous Infrared Galaxies could be related to the merger of structures with different luminosities in the range $0.3 - 2L^*$. Arguments related to the stability properties of the galaxies have been used to explain these observations. Numerical simulations show that disc galaxies with a small or with a lack of bulge component (e.g, Mihos & Hernquist 1996; Domínguez-Tenreiro, Tissera & Sáiz 1998; Tissera et al. 2002) tend to be more susceptible to the effects of tidal interactions which can trigger gas inflows and star formation. According to Tissera et al. (2002) these systems would be in early stages of evolution where their bulges are being built up, and consequently, on average, they would be smaller (or fainter).

We can use this large galaxy pair catalog for investi-
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Figure 4. Mean $b$ parameters estimated in projected distance bins for galaxies in interacting pairs. The dashed horizontal lines represent the mean $b$ parameter for the control sample. The small box correspond to the fraction $f^*$ of galaxies with $b > \bar{b}$.

Figure 5. Mean $b$ parameters estimated in relative radial velocity bins for galaxies in interacting pairs. The dashed horizontal lines represent the mean $b$ parameter for the control sample. The small box correspond to the fraction $f^*$ of galaxies with $b > \bar{b}$.

Figure 6. Mean $b$ parameters estimated in projected distance bins for galaxies in FGP catalog for three different maximum relative radial velocity limits: $\Delta V < 350$ km/s (solid line), $\Delta V < 100$ km/s (long-dashed line) and $\Delta V < 50$ km/s (dotted line). The dashed horizontal line represents the mean $b$ parameter for the control sample. The small box correspond to the fraction $f^*$ of galaxies with $b > \bar{b}$.

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For this purpose we estimate the mean birth rate parameter in luminosity bins for galaxies in the FGP catalog and those in the control sample. We then define the star formation excess $\beta$ as the ratio between these two $b$ parameters. Hence, $\beta$ yields the excess of star formation in galaxies in pairs with respect to any isolated galaxy in the field with the same selection effects and redshift distribution. This point is crucial for the understanding of the following reasonings since we are always assessing the effects of having a companion on the SF activity by comparing to isolated galaxies with the same redshift distribution. In this Section we also add the constrain of luminosity range.

In Fig. 5 we show $< \beta >$ vs log $< L/L_\odot >$ for the FGP and the CGP samples ($r < 25$ kpc and $\Delta V < 100$ km/s). As it can be seen the total FGP sample shows the same level of SF activity than isolated galaxies in the field ($\beta \approx 1$), while the CGP sample has a larger star formation enhancement with respect to isolated galaxies ($\beta \geq 1.5$). In the small box, we show the fraction of galaxies ($F^*$) that are experiencing larger SF activity than the corresponding mean in the control sample, in each luminosity interval, over the corresponding fractions of the control samples. This calculation was carried out for both the complete and the close galaxy pair samples. It can be appreciated from this box a significant increase in the fraction of star formation galaxies in pairs with respect to isolated ones as a function of luminosity. This trend is washed out when mean $b$ values are estimated since there is a large percentage of non star-forming pairs. Owing to the fact that the larger difference between the star formation of galaxies in pairs and that of isolated ones is detected for bright galaxies, we have to consider the possible presence of AGN as well as starburst associated to interactions. Note that we are always measuring the SF excess respect to isolated galaxies. In absolute mean values, faint galaxies have a higher $b$ parameter.
3.2 Pairs formed by similar and different luminosity galaxies

In this section we analyse FGPs according to the relative luminosity of their member galaxies. For FGPs and galaxies in the control sample, we estimate the ratio of luminosities $L_2/L_1$ of the faint over the bright member. As shown in Fig. 8, we found that FGPs are composed of galaxies with relative luminosities similar to those of any isolated pair of galaxies in the field (with the same redshift distribution), except for a weak tendency for some excess of pairs of galaxies composed with different luminosities. The bootstrap error analysis indicates that this excess has a statistical significance. This is likely to be due to the effects of the interaction, where it could be argued for truncated star formation owing to the tidal perturbation of the more massive companion.

We define two sub-samples according to the relative luminosity of galaxies ($L_2, L_1$) in pairs. We adopt $L_2/L_1 = 0.5$ as a threshold to split the FGP catalog into two subsamples of dissimilar ($L_2/L_1 < 0.5$) and a similar ($L_2/L_1 \geq 0.5$) galaxy luminosities in pairs (this choice divides the sample into subsamples with roughly the same number of members). Assuming that all interacting pairs might eventually give origin to a merger event, this luminosity ratio can be also interpreted as a threshold to split the data into major and minor merger candidate sub-samples. We then calculated the $< \beta >$ parameter as a function of luminosity for these two sub-samples restricted to the subsample of close galaxy pairs defined by $r_p < 25$ kpc and $\Delta V < 100$ km/s. While for the minor merger candidate sub-sample, we found no excess, a mean $\beta \approx 2$ is detected for the major merger candidate one. However, in both cases, we found no dependence on luminosity.

In order to shed light on the importance of galaxy luminosity and the strength of the interaction we have also investigated the dependence of the SF excess on projected distance for the fainter and brighter galaxy members in minor merger candidates ($L_2/L_1 \leq 0.5$). For this purpose we have estimated the $< \beta >$ parameter as a function of $r_p$ for the faint and bright components of CGPs as shown in Fig. 10. It can be appreciated from this figure the similar
behavior of the mean SF enhancement with respect to the control sample of the two components. However, when fractions are estimated for the bright (dashed) and faint (solid) components we found that the former shows a clear excess. At a given luminosity, brighter components of dissimilar luminosity pairs have a larger probability to have enhanced SF when compared to isolated galaxies and from larger projected distances.

As similar analysis was performed for the major merger candidate sub-sample. In this case in order to classify them in bright and faint luminosity pairs we estimated the mean luminosity of the pair and adopted a threshold of log \((L_1 + L_2)/(2L_\odot) = 9.5\). For these two sets, we estimated \(<\beta>\) as a function of projected distance. The results are plotted in Fig. 11 from where it can be appreciated that the two samples exhibit a similar trend in mean SF enhancement as a function of \(r_p\) which is found to be higher than that of minor merger candidates. The small box shows the ratio between the fraction of galaxies with \(b > \bar{b}\) and those corresponding to the control sample. In this case, we found that both components of major merger candidates have a similar probability to have enhanced SF activity. However, we note that the fractions are larger than those of the corresponding control sample only for close encounters \((r_p \leq 25 \text{ kpc})\).

This analysis suggests that the effects of interactions on the SF activity is more important in the brighter components of pairs with different luminosities. For galaxies with a similar luminosity companion, both objects show a larger star formation activity than isolated galaxies.

It should be stressed that these results do not contradict observations where the faint member of interacting pairs has on average a larger star formation activity since these studies lack a proper confrontation to isolated galaxies (see Bergvall et al. 2003 for the first observational works that used this approach).

4 DISCUSSION AND CONCLUSIONS

We carried out a statistical analysis of 1258 galaxy pairs in the field with \(z \leq 0.1\) selected from the 2dF public release data. Our study is centred on the star formation enhancement of the pair members with respect to isolated galaxies in the field with the same redshift distribution and luminosities by analysis the dependence of the mean birth rate parameters and the fractions of star forming galaxies. Particularly, the latter results to be an important tool to unveil the effects of having a companion since it is less affected by interpolers, non SF pairs, etc.

We can summarize our results in the following main conclusions.

1. We detect a significant correlation between the star birth rate parameter \(<b>\) and both, projected spatial separation \(r_p\) and relative radial velocity \(\Delta V\) for galaxy pairs. For \(r_p < 25\text{kpc}\) and \(\Delta V < 100\text{ km/s}\) we obtain a substantial star formation enhancement with respect to the isolated control sample. The \(\Delta V\) dependence is less pronounced although we find a systematic increase of star formation activity for decreasing relative velocity.

2. A significant percentage of galaxies (\(\approx 45\%\)) which satisfy the pair selection criteria but that have negligible star formation has been found. This result suggests that it is not only proximity that may be playing a role in triggering star formation.
formation but the internal structure of the galaxies could also be a crucial factor as it has been found in numerical simulations.

3. There is no an overall dependence of the mean star formation enhancement $< \beta >$ on luminosity for galaxy pairs at $z \leq 0.10$. A nearly constant value $< \beta > \simeq 1.2$ for the total FGP catalog and $< \beta > \simeq 2$ for the close GP subsample have been measured. However, the fractions of galaxies in pairs that have a higher SF activity than the corresponding averaged one of isolated galaxies, show a clear excess for the bright members.

4. We divide the close pair sample in minor ($L_2/L_1 < 0.5$) and major ($L_2/L_1 > 0.5$) merger candidates according to their relative luminosities. We found that bright components in minor merger candidates show higher probability to have enhanced SF by tidal interactions than isolated galaxies and from larger projected distances than the faint components. In the case of major mergers both components show comparable star formation enhancements and with a similar projected distance dependence.

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