Star Formation in Close Pairs selected from the Sloan Digital Sky Survey

B. Nikolic, H. Cullen and P. Alexander
Cavendish Lab., Cambridge CB3 0HE, UK

1. Introduction

The most intensely star-forming galaxies in the local Universe, as discovered by the IRAS mission, contain a high fraction of morphologically disturbed or interacting systems (Sanders & Mirabel, 1996); at luminosities greater than 3 10^{12} $L_\odot$ they are universally classified as interacting/merging/post-merger (*ibid*). Interacting/merging galaxies selected on the basis of peculiar optical morphologies also appear to have enhanced star formation relative to the general population (Larson & Tinsley, 1978).

We have begun investigating the external factors which may influence the rate of star formation in galaxies, starting with the effects of tidal interactions. To gauge the magnitude of these effects, we have taken care to select an objective and complete sample with as little bias as possible towards star forming systems. Tidal influence on each of the galaxies in our sample is quantified by identifying and measuring the distance to the nearest companion, using a photometric technique with good completeness characteristics.

2. Methods

- Our primary sample is a complete volume (z<0.1) and luminosity limited (M_r<-20.45) sub-sample of the SDSS `Main Galaxy Sample' (MGS).
- We have calculated star-formation rates for all of the members of the primary sample from extinction and aperture corrected Hα luminosities. For those galaxies detected in the IRAS all-sky survey, we have also calculated far infrared-derived star-formation rates.
- Mass-normalised star-formation rates were derived using galaxy stellar masses estimated from *z*-band luminosities
- Nearest companions were identified using the algorithm illustrated in Figure 1.
- We use the *r*-band concentration index, *C* = Petrosian half-light/ Petrosian 90%-light radius, as a proxy to galaxy morphology.

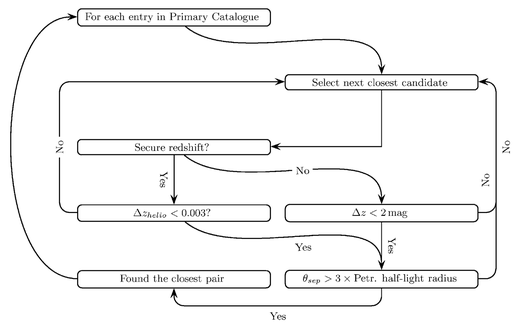

Figure 1: Schematic representation of the algorithm used to select nearest companions.

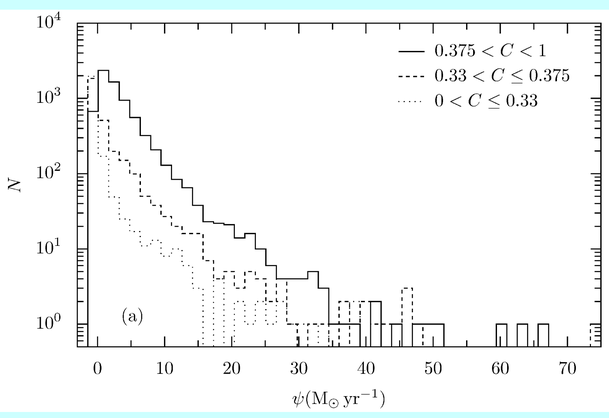

Figure 2: The distribution of star-formation rates of galaxies in three morphologically classified sub-samples.

3. Results: Hα

- The distribution of star-formation rates in the volume limited sample is shown in Figure 2.
- Some of the low-redshift galaxies in our sample with close companions are illustrated in Figure 3. Although generally accurate, it can be seen that our algorithm does not identify very close companions or merging galaxies.
- We find that there is an anti-correlation between SSFR and projected separation to the nearest companion in the range $0 < r_p < 50$ kpc in the late-type, mixed-type and early-type morphological sub-samples (Figure 4).
- The anti-correlation appears to extend to larger separations in the late-type sub-sample.
- Kolmogorov-Smirnov test confirms, at a formal confidence level greater than 99.9%, the difference in distributions of SSFR between galaxies with close companions and isolated galaxies.
- Our data do not indicate that the morphological type or mass (within the factor of six that we probe) of the companion galaxy has an effect on the triggering of star formation.

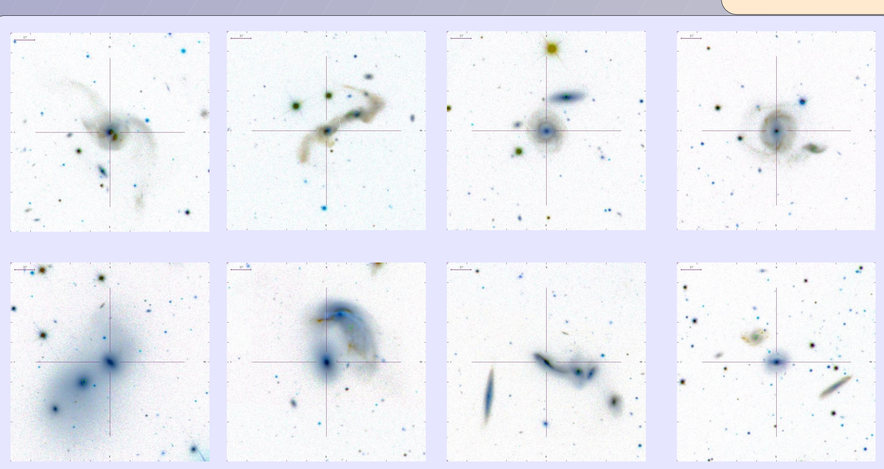

Figure 3: Montage of some of the galaxies in our sample at low redshift (z<0.04) and with companions at projected separations closer than 30 kpc. Cross denotes the primary galaxy and the green triangle denotes the companion identified by our algorithm.

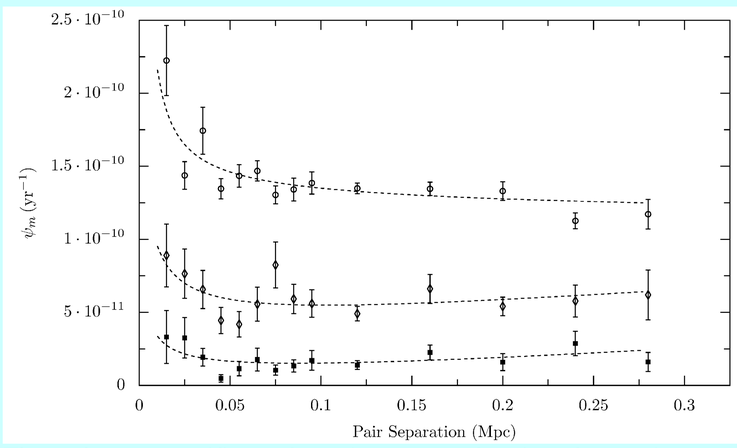

Figure 4: Mean specific star formation rate as a function of separation to the nearest companion for three morphologically classified sub-samples (from top to bottom): Late (C > 0.375), mixed (0.33< C < 0.375) and early (C < 0.33).

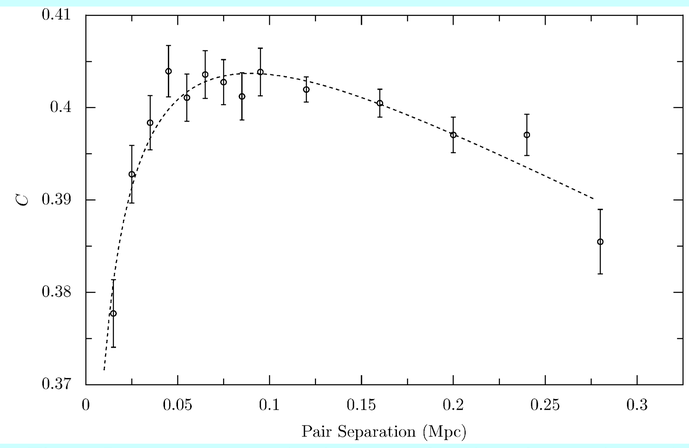

Figure 5: Mean concentration index as a function of separation to the nearest companion.

4. Results: Far-infrared

- We compare in Figure 6 the dependence on companion separation of Hα and far-infrared derived star-formation rates for the subset of galaxies detected by IRAS. There is clearly broad agreement between the two very different measures of star-formation.
- In order to account for the possibility that both the companion and primary galaxies contribute to the measured far-infrared flux, we have indicated two normalisations in Figure 6: normalisation by just the mass of the primary galaxy, as was done for all other plots; and, normalisation by the sum of the masses of the primary and companion galaxies. The latter normalisation appears to agree better with the Hα star-formation rates.
- SDSS imaging of the eight most luminous infrared galaxies in our sample is shown in Figure 7. All but one show signs of interaction or merger; however, as was expected, only half have been correctly identified as such by our algorithm.

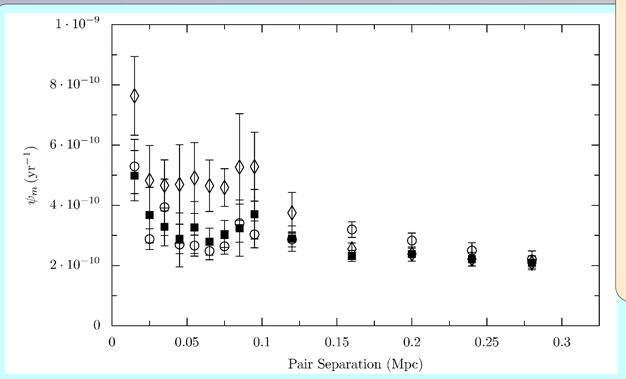

Figure 6: Mean specific star-formation rate as function of pair separation for the sub-sample detected by IRAS. Open circles: H-alpha derived SSFR; open diamonds: FIR derived SSFR, normalising by the mass of the primary galaxy only; filled squares: FIR derived SSFR, normalising by masses of both the primary and companion galaxy if within 90 arcseconds.

5. Results: light profiles

- The relationship between the concentration index and the separation to the nearest companion is shown in Figures 5. Galaxies with companions closer than 50 kpc have on light-profiles which are on average significantly more concentrated in the nucleus.
- Inspection of imaging of some of these galaxies suggests that they have normal disk components and that the observed effect may be due to nuclear starbursts.
- Some or all of the observed enhancement of star formation in mixed- and early-type galaxies with close companions may in fact be due to this effect.

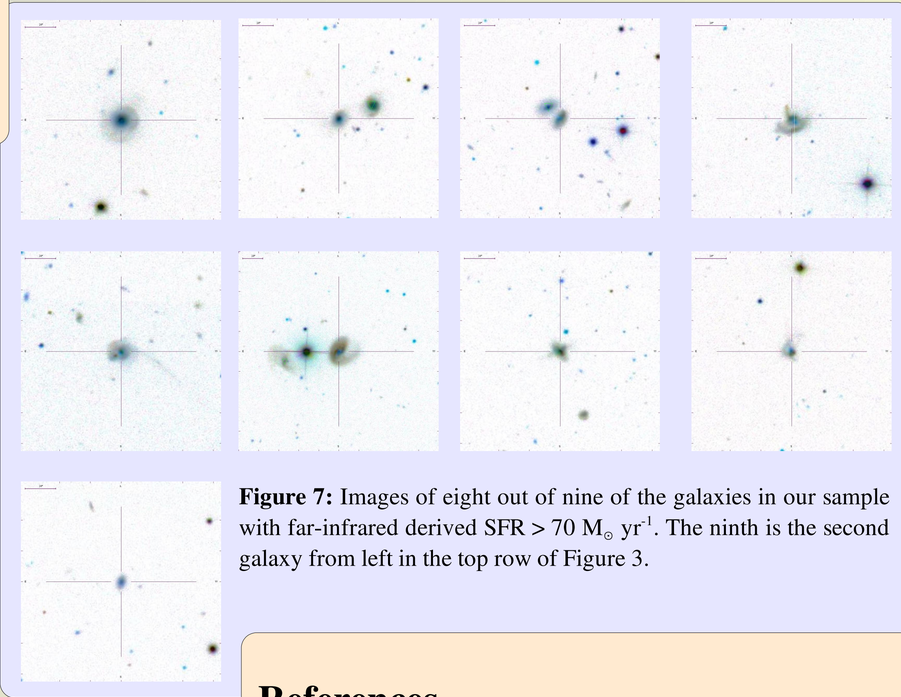

Figure 7: Images of eight out of nine of the galaxies in our sample with far-infrared derived SFR > 70 $M_\odot$ yr^{-1}. The ninth is the second galaxy from left in the top row of Figure 3.

6. Discussion & Conclusions

- We confirm previous findings (Barton et al 2000, Lambas et al 2003) that galaxies with close companions have moderately enhanced star formation compared to isolated galaxies.
- At least as far as it's discernible with the concentration index, this enhancement is present in galaxies across the morphological spectrum.
- A tight relation between the concentration index and separation to the nearest companion is observed which we interpret as due to triggering of nuclear starbursts. Under this assumption, the observations suggest that 50 kpc is the approximate length scale at which tidal triggering occurs.
- The observed enhancement of star formation in galaxies with close companions is equally reflected in optical spectra and far-infrared emission. Although the coarse resolution of IRAS doesn't allow us to investigate in detail, our data suggest that significant star formation occurs in both of the galaxies involved in interaction.
- We do not find any statistical dependence on the morphology or mass of the companion galaxy.

References:

Sanders & Mirabel, ARA&A, 34:749, 1996
Larson & Tinsley, ApJ, 219:46, 1978
Lambas et al, MNRAS, 346:1189, 2003
Barton et al, ApJ, 530:660, 2000

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