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Galaxy interactions increase star formation rates

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Abstract

We investigate the influence of galaxy-galaxy interactions on the star formation by studying a sample of almost 1500 of the nearest galaxies, all within a distance of 40 Mpc. We calculate the relative enhancement of the massive star formation rate (SFR), as measured from far-IR emission, and the specific star formation rate (SSFR), which is the former quantity normalised by the stellar mass of the galaxy. We do this for each galaxy by normalising by the median SFR and SSFR values of individual control populations of similar non-interacting galaxies. We find that both the SFR and the SSFR are enhanced in interacting galaxies, and more so as the degree of interaction is higher. The increase is, however, moderate, reaching a maximum of a factor of 2.2 for the highest degree of interaction (mergers). We argue that this study based on a representative sample of nearby galaxies should be used to place strong constraints on studies based on samples of galaxies at larger distances, beyond the local Universe.

1 Introduction and sample

Galaxy-galaxy interactions and mergers are fundamental for our understanding of how the Universe has evolved since the Big Bang. Mergers between dark matter haloes and/or luminous galaxies are thought to increase the mass of the haloes and galaxies, and shape the galaxies from more irregular, clump-like structures to the generally smooth and/or disk-like bodies that we observe at the current epoch. One general assumption is that interactions and mergers stimulate star formation, leading to enhanced star formation rates (SFRs).

We know that this happens from objects with the highest SFRs, such as (Ultra-) Luminous InfraRed Galaxies, or (U)LIRGs, which are almost without exception interacting or merging galaxies. It is less clear, however, whether a galaxy-galaxy interaction or merger is always accompanied by a significant increase in the star formation activity, in other words,

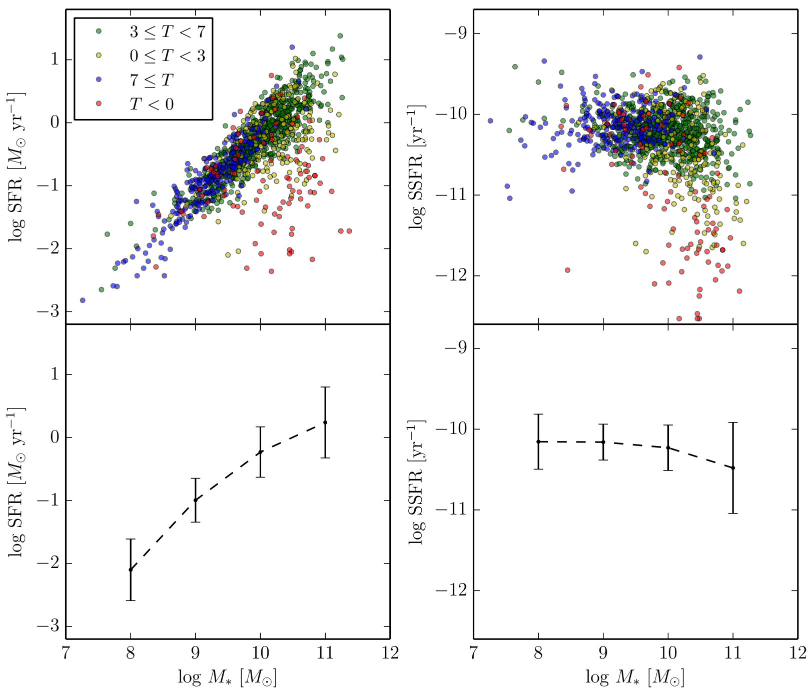

Figure 1: Log of the SFR (*left* panels) and the SSFR (*right* panels) as a function of stellar mass. *Top* panels show the individual galaxies, colour-coded by galaxy morphological type, while the *lower* panels show the median values, with the $1\,\sigma$ spread indicated by the error bars. The dashed line connects the points. From [2].

whether interactions and mergers lead to statistical enhancements of the SFR, and by how much. Various observational results indeed show this, but find a rather limited increase in the SFR, of factors of a few (e.g., Knapen & James 2009), and this is also found from numerical simulations, e.g., those by Di Matteo et al. (2008).

In this paper, we study the statistical behaviour of the SFR and the specific SFR (SSFR, which is the SFR normalised by stellar mass) of a sample of some 1500 galaxies in the very local Universe, within a distance of 40 Mpc. The galaxies form part of the *Spitzer* Survey of Stellar Structure in Galaxies (S^{4}G, Sheth et al. 2010). From the S^{4}G mid-infrared imaging we derive the stellar mass (Querejeta et al. 2015), we use *IRAS* infrared fluxes to determine the SFR (also from Querejeta et al. 2015), and we use the classification of Knapen et al. (2014) to identify the interaction or merging properties of the galaxies.

This sample is unique because it covers galaxies down to stellar masses of around $10^8\,\mathrm{M}_\odot$ and of all morphological types, from elliptical to irregular, for which we have reliable estimates of the SFR, and excellent measures of the total stellar mass.

2 The "galaxy main sequence"

In Fig. 2 we give a basic overview of our data in the form of what is commonly known nowadays as the "galaxy main sequence": a plot of SFR as a function of stellar mass (left panels). In the right panels, we also plot the SSFR as a function of stellar mass. There are no new results in these plots, but they do highlight a number of features of our sample galaxies. First, while the SFR rises with stellar mass, the SSFR does not (in fact, it seems to be lower in higher-mass galaxies). Second, there is a population of galaxies which clearly deviates from the "main sequence", and which have relatively low SFR and often even SSFR. These are mostly ellipticals and early-type spirals. Third, galaxies of different morphological types preferably lie in different parts of the plots.

It is important to keep in mind when comparing different studies in the literature that while the shape of the "main sequence" is the same, the range in stellar masses is often different. For example, there are studies of the "local" Universe, often based on SDSS data, which start around $\log M_* = 10$ and where the "main sequence" is dominated by galaxies with such high masses that they are virtually absent in the nearby Universe as defined in our current study.

3 Star formation enhancement by interactions

We can use the SFR and SSFR values derived for our galaxies to study whether interactions and mergers enhance them statistically. For this, we use the classification of Paper I, where we visually inspected all galaxies found to have a close companion in order to assign them an interaction class. We used three classes, namely A. mergers, B. highly distorted galaxies, and C. galaxies with minor distortions, whereas class 0 indicates galaxies with a close companion (see [4] or [3] for the exact criteria for the presence of companions) and class N includes all galaxies without close companions.

To see whether, and by how much, interactions between galaxies change the SFR and SSFR, we must compare the interacting galaxies with a control sample. The control values of SFR and SSFR are calculated separately for each galaxy by determining the median values of all the SFRs and SSFRs of all non-interacting galaxies which resemble a certain galaxy, in the sense that they are within ± 1 in numerical morphological type and within ± 0.2 in $\log(M/\mathrm{M}_\odot)$ in stellar mass. For each of the galaxies we then divide the SFR and SSFR by the median value of the SFR and SSFR of their respective control group of galaxies. The size of this control group varies from 7 to 265, with most interacting galaxies having control groups of near 100 (mean: 113, median: 105).

The results are shown in Fig. 2, in terms of individual (top panels) and median (lower panels) SFRs (left) and SSFRs (right panels) normalised in all cases to the control values for each galaxy. The first thing to note is that the spread in enhancement of both SFR and SSFR is huge in all classes, including in the control class (N). Second, the median values for the control sample (class N) are indeed unity, confirming that our method to calculate the (S)SFRs normalised by control galaxies is valid.

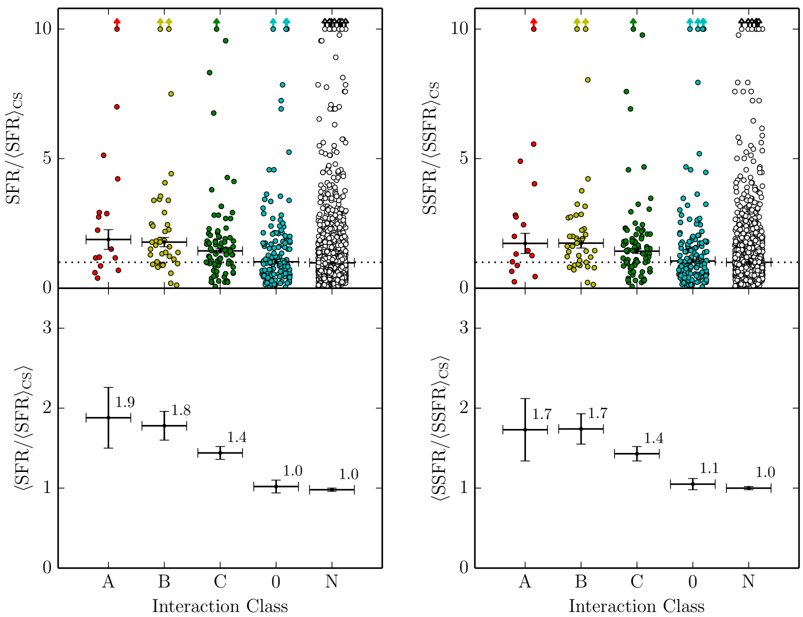

Figure 2: The SFR (*left* panels) and SSFR (*right* panels) enhancement, defined as the (S)SFR of a galaxy normalised by the median (S)SFR for its control population, separated by interaction class (where A is the most extreme class, of mergers, and N contains those galaxies which are neither interacting nor have a close companion). Values larger than 10 are indicated by lower limits. Median values per class are indicated with their $1\,\sigma$ uncertainty in both top and lower panels, but are amplified in the lower panels where the values are indicated next to the data points. From [2].

Third, the median SFR and SSFR enhancements are higher than unity in interacting galaxies, but only moderately so. Even for the most extreme of our categories (A, mergers) the median SFR enhancement is below a factor of 2. The median SSFR is enhanced by very similar factors in all classes. And a fourth conclusion we can reach from Fig. 2 is that the median enhancements in both SFR and SSFR increase with interaction class. The highest enhancements are found in the closest interaction stages (A, B, C, in that order).

4 Conclusions

We have studied whether, and by how much, interactions and mergers in galaxies increase their SFRs and their SFRs normalised by their stellar mass (SSFRs). For this, we have used a sample of almost 1500 of the nearest galaxies which form part of the S^4G survey and for which we could determine the overall SFR and stellar mass and, from detailed inspection of their images, whether they show some or significant evidence for interactions, or are merging.

By defining a matched control sample for each galaxy in our sample, we find that both the SFR and the SSFR are enhanced in a statistical way in interacting galaxies, and more so as the degree of interaction is higher. The increase is, however, moderate, reaching a maximum of a factor of just below 2 for the highest degree of interaction (mergers). In addition, galaxies with the highest and lowest measured SFRs and SSFRs can occur in all classes, including the extreme ones of mergers or isolated galaxies.

Many studies of the role of interactions between galaxies are based on samples of galaxies at larger distances, beyond the local Universe. We argue that our study, which is based on a representative sample of the nearest galaxies, should be used to place strong constraints on such higher-redshift studies.

Acknowledgments

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