The Star Formation Distribution in Interacting Galaxies

Scientific Justification (max 1200 words)

Galaxy interaction is a fundamental process that has played a pivotal role in galaxy evolution throughout cosmic history. It induces severe morphological disturbance (cite), the formation of tidal features (cite), large increases in star formation (cite) which often leads to quenching (cite) and, it has been argued, leads to the ignition of nuclear activity in the galactic core (cite). However, how the underlying parameters of an interaction (the mass ratio, relative sizes, impact parameter, etc) influence which processes occurs or which tidal features form is poorly understood.

A recent project which attempted to understand this was that of the Galaxy Zoo: Mergers project (cite). This was a citizen science project which utilised a highly efficient N-body simulation to constrain fourteen underlying parameters of a sample of sixty major interacting galaxies. This project was successful in parameterising each of them, and was able to recover their merger history. However, we have been developing new software to mirror this process automatically. This will allow us to apply their constraining methodology to a much larger sample, without having to wait years for the citizen scientist outputs.

The code we have developed (cite, in prep link) is conducting a flux and morphological matching in order to fin the best fit underlying parameters of these sixty interactions (and their errors). However, there is a key component of an interaction we are missing: that of the velocity. By not knowing where the tidal features are moving, we get multiple degenerate best fit solutions from our models: particularly in the orientation of the interaction. Attaining this information on a subset of our sample (fourteen systems) would allow us to quantify the improvement our method can attain.

A preliminary investigation into the improvement of our algorithm for parameterising interacting galaxies is shown in Figure 1 for the Heart (J155308.62+540950.4) interacting system. This is one of four of our interacting galaxy sample which has existing IFU data from MaNGA (cite). The Figure shows contours of increasing probability for the best fit parameters of the system. While there is no appreciable improvement in the sizes and masses of the system, there is significant improvement in position, velocity and orientation of the interaction. In fact, in the orientation of the system, we completely break the degeneracy existing in it when no velocity information is available. This allows us to select a single peak in parameter space of our best fit model, significantly improving its applicability in the field.

A second question we will answer with this proposal is that of where / if a starburst occurs in an interaction at all. Often, this question is attempted to be answered with simulations of varying resolution (such as Illustris (cite specific paper) or EAGLE (cite specific paper on interaction). However, there is much debate as to when in the interaction or even where in the galaxy a starburst takes place. Is it primarily at the start of the interaction (cite), during it or only upon coalescence (cite)? When the increase in star formation begins, does gas rush to the core of the galaxy and only cause a starburst there (cite), or are there significant increases in star formation in the galactic disk and tidal features (cite)? The simple fact of the matter is, **direct observations localising star formation in interacting galaxies is very difficult to come by and, therefore, the answer remains elusive**.

Preliminary work on this has been conducted using a subset of interacting galaxies from the O’Ryan et al (2023) catalogue. This is a large catalogue of interacting galaxies, that we then cross matched with the COSMOS2020 catalogue for photometric information. Those overlapping examples were broken down into four separate stages of interaction: stage 1 - approaching, stage 2 – contact made (disturbance visible), stage 3 – past contact (tidal features formed), stage 4 – coalescing and their total stellar masses and star formation rates investigated. The results from this (shown in Figure 2) indicates that star formation enhancement occurs primarily in the third and fourth stages of interaction. **However, it is important to note that these only answer one of our two questions and is also purely based on photometric fitting of these galaxies.**

The eleven systems we propose (shown in Figure 3) to observe are of a variety of stages of interaction with similar mass ratios and gas content. Two systems are in stage 1 and 2 while three are in stage 3 and 4. Often, the interactions themselves are so large that observing the primary and secondary of the interaction must be done with two separate observations. This is specific to stage 2 and 3 primarily as the two galaxies are fully separate and distinct. We elect to add an additional system to stages 3 and 4 as our preliminary results indicate this is where we should observe our star formation enhancement, and the power will be localising them.

It is important to note that using WEAVE gives us a unique opportunity to investigate where and when a star burst occurs in interacting galaxies by looking at the most massive, fully constrained samples in the local universe. The large Field-of-View required to view these systems with an IFU (**and only available with WEAVE**) means that a full star formation or velocity map of these entire systems has never been created. With the closes system being at z = N, we will be able to achieve a huge resolution of Xpc / fibre. We will be able to map exactly where star formation is occurring in these systems, and exactly how the tidal features are moving in three dimensional space.

We believe this is an excellent pioneering use of WEAVE, to demonstrate that it can break boundaries even with well studied and understood systems. We will publish two papers from the results of this observing run. The first will be on the degeneracy breaking ability of adding velocity information to our parameterising software, and conducting a full parameterisation of all systems observed. The second will be a paper on studying precisely where and when star formation is enhanced in major, wet interacting systems.

Figure 1 Caption:

Probability distribution of the best fit parameters for the Heart (J155308.62+540950.4) interacting galaxy system. This is a stage 4 system, and one of the interacting systems proposed to be observed. Shown on the left hand side is the initial probability distribution of numerous parameters of the interaction with no velocity information available. On the right hand side is the same, but with velocity information available. AS can be seen, with velocity information from IFU data, we have a significant improvement on our constraints for the velocity, position and orientation parameters. In fact, we completely break degeneracy in the orientation parameters.

Figure 2 Caption:

Preliminary results from an upcoming work investigating the effect of interaction stage on numerous galactic parameters. In this example, we show the change in total star formation rate and stellar mass in an interacting system with stage. As can be seen, the total star formation is significantly higher in galaxies of the same mass at stages 3 and 4 compared to stages 1 and 2. This implies that the star formation enhancement expected to occur in interaction only begins to take effect once the two systems have passed each other, tidal features are forming and they exhibit severe morphological disturbance or the beginning of coalescence.

Figure 3 Caption:

The targets proposed to be observed in this observing run. In total, there are 16 targets over eleven different interacting systems. Due to the very large FoV of all WEAVE LIFUs, we are able to observe the all of these systems (except Heart) for the first time with IFUs. For six of the systems, the FoV is expected to be so large that the entire system will be covered with one observation. However, for the remaining five systems, we must observe the primary and secondary with different exposures.

Notes on what I want to write here:

1. The primary aim of this project is to get velocity information throughout these interacting galaxies.
   1. Talk about constraining interaction.
   2. Talk about the Galaxy Zoo Mergers project.
   3. Talk about my code, and how that’s working.
   4. Provide an example of how adding velocity information to this approach could seriously improve statistics.
   5. Relate to how Euclid / WEAVE, providing spectroscopic and velocity information through their surveys will make using my code even better.
2. A secondary, easy result, is to investigate where star formation is occurring at different stages of the interaction.
   1. We know interactions cause starbursts.
   2. So, where do they happen?
   3. Will compare the star formation occurring in the galactic core compared to that in the tidal features.
   4. Due to the size of each target, we will get extremely high resolution maps of the star formation happening within them.
      1. Calculate this to see.

Technical Justification (max 1200 Words)

Notes on what I want to write here:

1. Basically, primary reason I want to use WEAVE here is the massive Field of View.
   1. The colossal FOV of the LIFU means that for the first time we can capture the entire system of these very local systems.
   2. Because these systems are so local, and so large in size, have not got IFU data for any of the given ones (besides Heart, used as comparison).
2. Extremely large, local galaxies will be an excellent use of WEAVE to show how we can get to the sub-kpc measurements of galaxy emission.
3. Each galaxy is a very bright one, with the dimmest target having a V band magnitude of 18 magnitude (double check this).
   1. Therefore, to get the outer edges of the disks should be easy.
   2. Tidal features will be no dimmer than mu = 21 mags/arcsec^2.
4. Can achieve a SNR of 50 with just two hours of exposure on each target.
5. Hence, asking for 32 hours exposure for full 16 targets. This is a total of 11 interacting systems that will be fully observed.