Unveiling star-formation in the Universe's most typical environment

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Galaxies in the early Universe were very different to the ones we see today. The first galaxies were relatively simple systems, irregular conglomerates stars and gas. As the Universe evolved, so did these galaxies, changing into the diverse array of complex structures we see nearby, including our own Milky Way. There are various factors that drive these evolutionary processes, such as a galaxy's local environment (where it lives), the rate at which it is forming stars and its structure (spiral arms, bars, bulges). It is the varying contribution of these factors over cosmological timescales that determine a galaxy's properties at the current time.

To first order the most dominant mechanisms that shape the galaxies we see today are the merger of two or more galaxies into a larger system and the formation of new stars from available gas reservoirs. However, these processes are not mutually exclusive, as interactions between galaxies can strongly affect their star formation rate (SFR). In order to understand the formation mechanisms of galaxies, we must explore how these processes contribute to galaxy evolution processes over cosmological timescales.

This project has explored all of these three fundamental processes: mergers, star-formation and the effect of galaxy interactions on star-formation, using data from the Galaxy and Mass Assembly Survey – an impressive dataset of ~250,000 galaxies observed using the world's best telescope to probe emission over a board range of wavelengths.

Mergers – We have accurately measured the rate at which galaxy are merging in the local Universe and how these mergers are redistributing stellar material, leading to observed global distribution of stars in galaxies (the stellar mass function). Previous studies exploring merger rates have been encumbered by low completeness; essentially only observing a relatively small fraction of galaxies. With GAMA we have observed ALL galaxies to a low stellar mass limit, allowing us to now fully parameterise the effect of mergers in the redistribution of stellar mass.

Star-formation – The rate at which galaxies are forming stars is one of the key fundamental measurables in the Universe. There are various different methods for measuring this SFR each targeting emission from different physical processes occurring within the galaxy (Fig1). However, each of method is limited by largely unknown corrections and assumptions that need to be applied to convert an observed emission to a true SFR – primarily due to the effect of dust scattering. In addition, different observables only accurately predict SFRs for specific galaxy types and/or specific epochs and environments. This leads to different methods predicting vastly different SFRs. If we wish to understand the relative important of star-formation in galaxy evolution, we must ensure consistency in SFR estimates across all galaxies, epochs and environments. The GAMA sample gives us a unique opportunity to study SFRs using thirteen different observables, covering a diverse array of astrophysical processes (Fig1). We have derived SF using all of these methods and recalibrated each SFR to produce the same results across the full sample; providing all of these calibrations to the wider astronomy community. One of these calibrations is based around the radio continuum, which is laying the foundations for future studies with the Square Kilometre Array - Australia's flag-ship astronomy project. Using these new SFRs we have then explored the global evolution of star formation in the Universe, and how galaxies are evolving via the conversion of gas into stars.

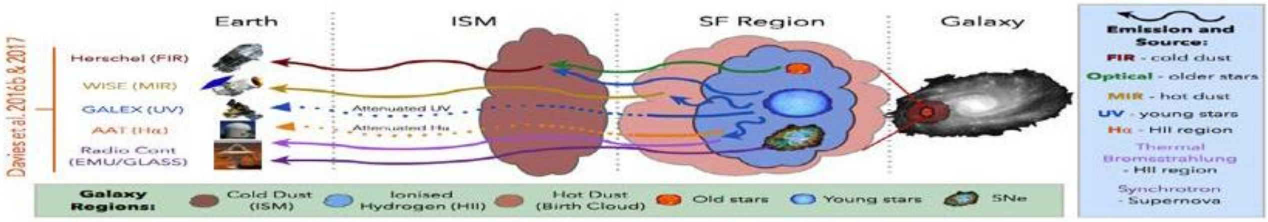

Figure 1: *Measuring SF in galaxies is problematic, UV emission is produced in young stars and heats the surrounding ionised hydrogen (HII), hot dust close to the stars and colder dust in the Inter-stellar medium (ISM), which then scatters (attenuates) some fraction of the emission. HII regions then emit optical line (i.e. Hα) and thermal Bremsstrahlung emission, where the line emission is also attenuated by dust. Both the hot and cold dust re-radiate some of this emission in the mid-(MIR) and far-infrared (FIR) respectively. Lastly, the young stars end their life as supernovae (SNe) and emit synchrotron radiation. All of these processes can give different measurements of the star formation rate. In Davies et al. (2016b, 2017) we measured emission from ALL of these processes and compared their predictions for the rate at which galaxies are forming new stars.*

Effect of galaxy interactions on SF – By compiling a unique sample of mergers and SFR diagnostics for the GAMA sample we have the ideal dataset for studying the effect of galaxy interactions on SF. Exploring these processes, we find that galaxy interactions primarily enhance SF, and that this process is strongest when the two interacting galaxies have similar mass. However, when the galaxies have vastly different masses, the smaller galaxy has its SF suppressed – potentially due to a lack of gas supply. This is an important, previously undocumented, process, which can explain the formation of non-star-forming low mass galaxies in over-dense environments.

By combining these studies we can build a complete picture of how mergers and SF are driving galaxy evolution in the local Universe. The next fundamental challenge is to probe the evolution of these processes to earlier times. We are undertaking a new spectroscopic survey of 2Million galaxies (WAVES) to continue and expand this project into the coming decade.