The Spitzer Interacting Galaxies Survey: The Behaviour of Cold Gas in Mergers

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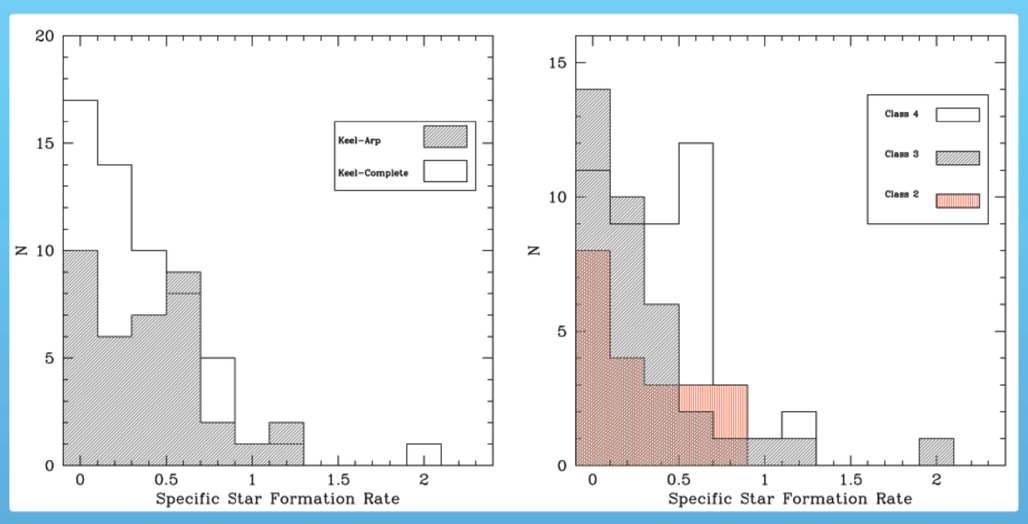
Introduction

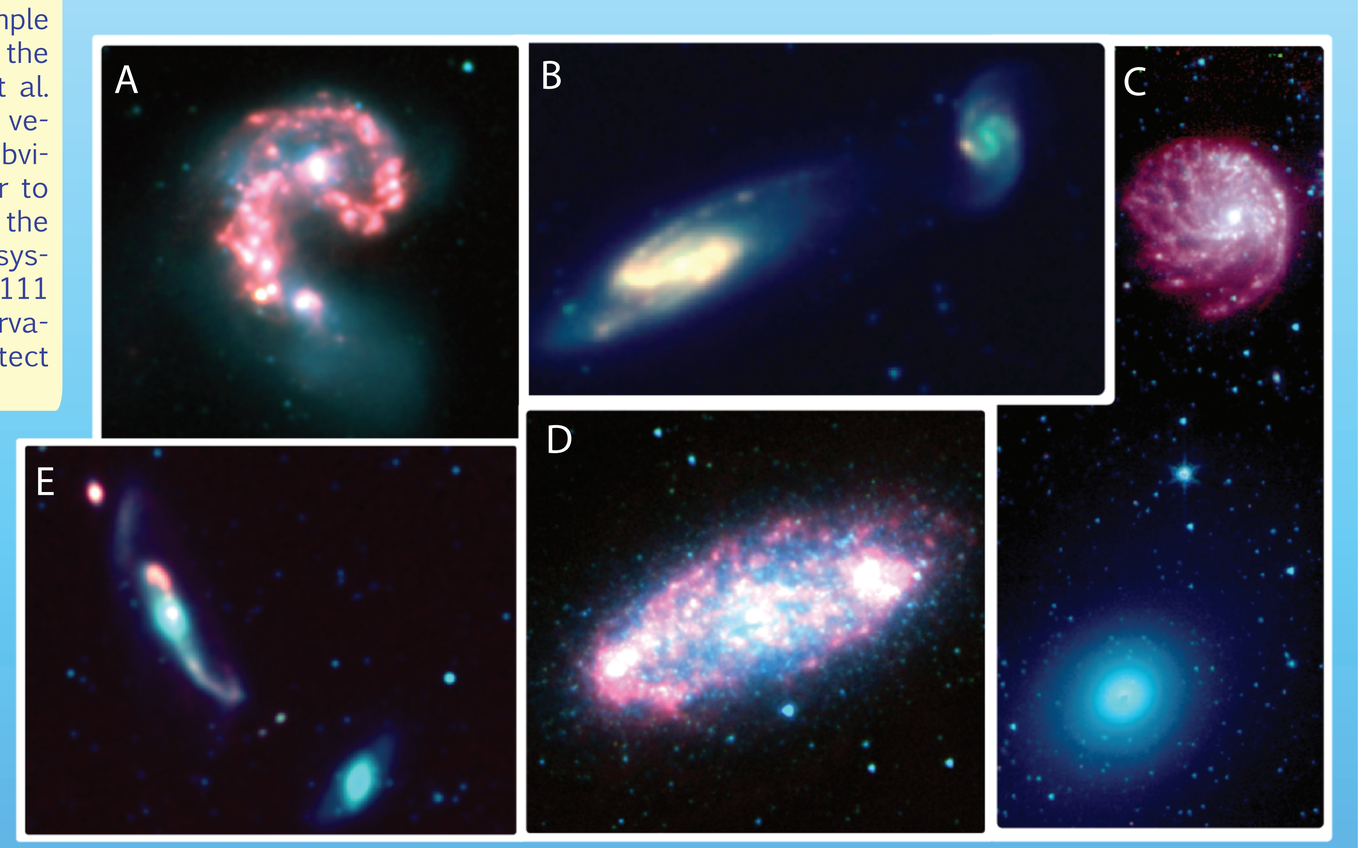
It is widely believed that very few galaxies exist today that have not been formed or shaped in some way by an interaction with another system. These interactions play a major role in the evolution of galaxies by triggering star formation and nuclear activity. However, the parameters that influence this enhanced activity are poorly understood. To address these issues we have undertaken a Spitzer study of 111 nearby interacting galaxies. Our goal is to investigate, using this large statistically meaningful sample, how these interactions induce galactic activity either in the form of widespread star-formation or AGN activity. By characterising this behaviour we can gain understanding of: how interactions trigger star-formation, how large concentrations of gas and dust in the central regions may promote or hide AGN activity and, if and how star-forming and AGN activity relates with the parameters of the interaction.

Here I present initial results from analysis of the IRAC data and discuss our current HI study of a subsample of these systems.

The Spitzer Interacting Galaxies Survey (SIGS):

The aim of this programme is to investigate an unbiased, comprehensive sample of galaxies that is statistically meaningful. To achieve this we have used the "Keel-complete" optically selected catalog of interacting spiral galaxies (Keel et al. 1985). This sample is selected on the basis of galaxy separations and relative velocities, rather than morphology, leading to the inclusion of galaxies without obvious signs of interaction (e.g. systems in an early stage of interaction). In order to investigate the effect of strong tidal interactions we have additionally included the members of the “Keel-Arp” sample, which contains more optically disturbed systems. We further impose a cut of $V_{sys} < 4000$ km s^{-1}. This selection results in 111 galaxies within 50 systems. All of these galaxies have IRAC, IRS and MIPS observations which allow us to map the star-formation throughout the galaxies and detect and measure AGN activity.

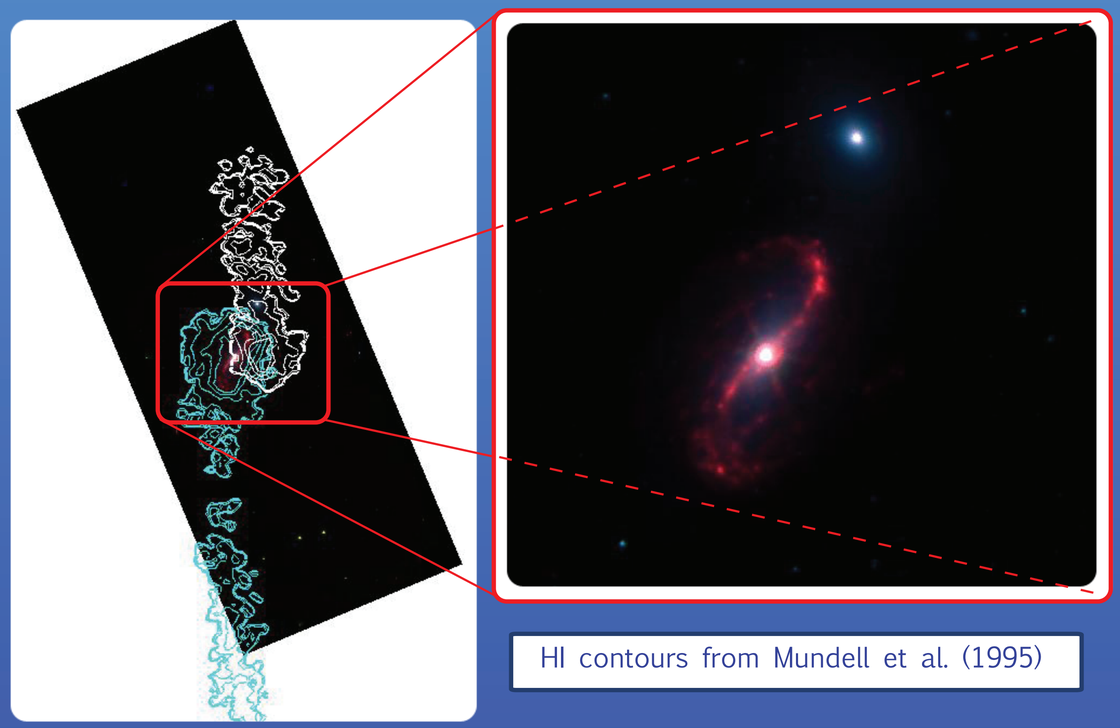




Above: True colour images of a selection of galaxies from SIGS displaying the wide range of interacting systems. A) The Antennae, B) Arp 290, C) Arp 114, D) NGC 2976, E) NGC 3800 & NGC 3799. Colours represent IRAC bands Non-stellar (8μm-renormalised 3.6μm), 4.5μm, 3.6μm.

Above left: From the IRAC photometry we have derived specific star-formation rates (SSFR) based on the non-stellar 8μm fluxes. The histogram in the left hand panel above presents the SSFR for both the Keel-Complete sample (open histogram) and the Keel-Arp sample (shaded). From this it can be seen that the Keel-Arp sample has a relatively higher SSFR than the Keel-Complete sample. Given that the Keel-Arp sample was selected to provide more strongly interacting galaxies this result is unsurprising, nonetheless, it does confirm that systems with disturbed morphologies do indeed host more enhanced star-formation.

In addition to comparing the two samples we have further categorised the systems based on an empirical scheme of optical classification (e.g. Dopita et al., 2002). Here a scale of 1-5 has been used; where 1 indicates an isolated systems through to 5, which represents a system at the point of merging/merger remnant (e.g. Arp 220 or NGC 7252). The distribution of SSFR between these classes is shown in the right hand histogram. Due to the nature of our selection we only have systems ranging between 2 to 4 on this scale. What can be seen in this plot is that the distributions between classes 2 & 3 are largely similar. However, a larger fraction of class 4 galaxies have higher SSFR compared to the other systems. This suggests that mild interactions are not sufficient to trigger vigorous star-formation. In further work the IR SFRs will be more reliably calibrated by the inclusion of the 24μm MIPS data (e.g. Calzetti et al. 2007).



HI contours from Mundell et al. (1995)

The Behaviour of Cold Gas

Observations of HI emission from galaxies provide information about the large-scale cold gas within each system and as such provide an excellent tracer of galaxy interactions due to the dissipative nature of the gas, which responds in a highly non-linear way to small deviations from axial symmetry. Further, by observing this emission (in conjunction with IR and CO data) it is possible to determine a relationship between SFR and gas density (Kennicutt 1998).

To investigate the behaviour of cold gas in interactions we have constructed a subsample of 6 galaxy pairs from SIGS. All of these systems have been selected to contain one gas-rich and one gas-poor system (defined as a damp merger), thereby allowing us to cleanly observe the HI emission arising from the gas-rich system. With these observations we can more easily trace the flow of the gas, which will then be compared with simulations. With these data we can also investigate the spatially resolved star-formation gas density relation, which has been observed to vary in merging galaxies (Boquien et al. 2011), thought to be caused by gas turbulence and fragmentation.

Left: IRAC image of Arp 94, one of our damp merger systems, with VLA HI contours overlaid. From this image it can be seen that NGC 3227, the spiral galaxy in this pair, is associated with kpc-scale plumes extending to the north and south of the system, while the early-type galaxy, NGC 3226, has no neutral hydrogen emission associated with it at all. The tidal features observed are thought to be a consequence of the interaction between these two galaxies.

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