Galaxy And Mass Assembly

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The Effect of Group Environment on Feedback and Gas-Fuelling of Local Universe Galaxies: Probing Baryonic Physics in DM Haloes using Herschel and ALMA

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1) Introduction

Direct accretion of gas onto galaxies via cooling and mergers of gas-bearing galaxies are thought to have supplied the gas out of which the stellar populations of local universe galaxies formed. The most fundamental of these processes, direct accretion, is predicted under the Cold Dark Matter paradigm (CDM) to decline as a function of increasing dark matter halo (DMH) mass, due to heating and virialization of the gas in the halos. On smaller scales accretion is expected to be countered/boosted by baryonic feedback processes such as galactic winds driven by star-formation (SF) or AGN activity. Thus, the rate of gas-fuelling and hence the star formation rate (SFR) - both current and integrated over cosmic time - will depend on the dynamical environment.

While fundamental, the baryonic processes influencing gas-fuelling have arguably only been empirically constrained in massive clusters and X-ray emitting groups. The unprecedented density of redshifts furnished by the Galaxy And Mass Assembly (GAMA) deep wide field spectroscopic survey has been used to identify the first statistically significant sample of low mass groups, providing targets for detailed photometric and imaging Herschel and ALMA investigations of obscured star-formation, dust and molecular gas in the wider population of haloes. Here we illustrate the potential of such investigations through a preliminary optical study of the dependence of SF efficiency and current SFR on parent DM Halo mass of GAMA galaxy groups in the local Universe.

2) Galaxy And Mass Assembly

The Galaxy And Mass Assembly survey (GAMA)[1],[2] is an on-going spectroscopic survey with the AAΩ instrument on the AAT which will cover 360 deg^2 to a limiting magnitude of 19.8 in the r band and, in combination with other surveys, compile a state-of-the-art database of ~375,000 galaxies. GAMA has a surface density of redshifts of ~1250 deg^{-2}, 14 times that of SDSS Main, at a spectral resolution of R ~ 1000-1600 at 370-800 nm, roughly twice that of the 2DFGRS, with multiple visits providing unbiased spectral coverage in crowded fields. This positions GAMA in the gap between deep pencil-beam surveys, and shallow wide-field surveys, giving GAMA the unique capability to probe the evolution of large-scale structure from z=0.5.

Multi-wavelength coverage of the GAMA fields is achieved in collaboration with other surveys/ facilities, spanning the Radio(DINGO/ASKAP), FIR(H-ATLAS/HERSCHEL), MIR(WISE), NIR(VIKING/VISTA), Optical(KIDS/VST), NUV/FUV(GALEX), supplying invaluable data for morphological decompositions and independent estimates of SFR.

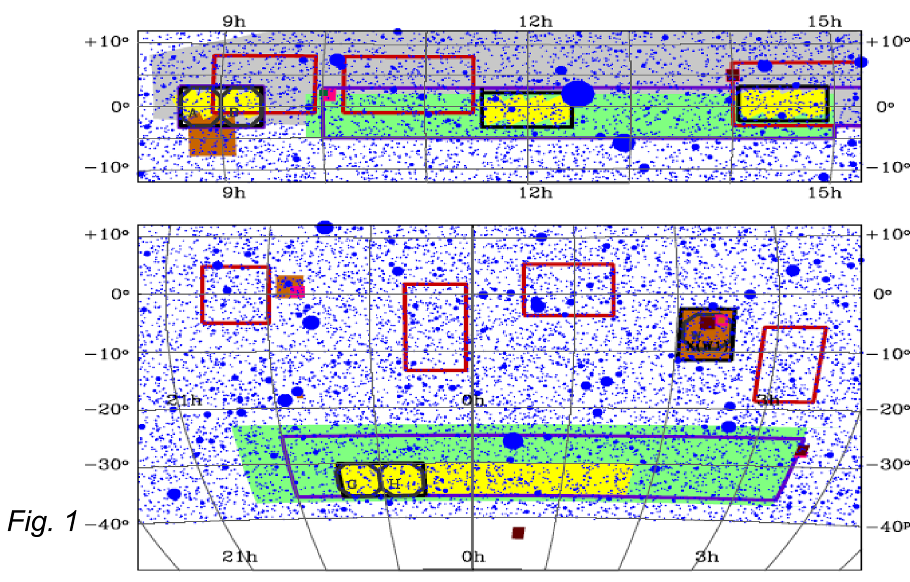

Fig. 1

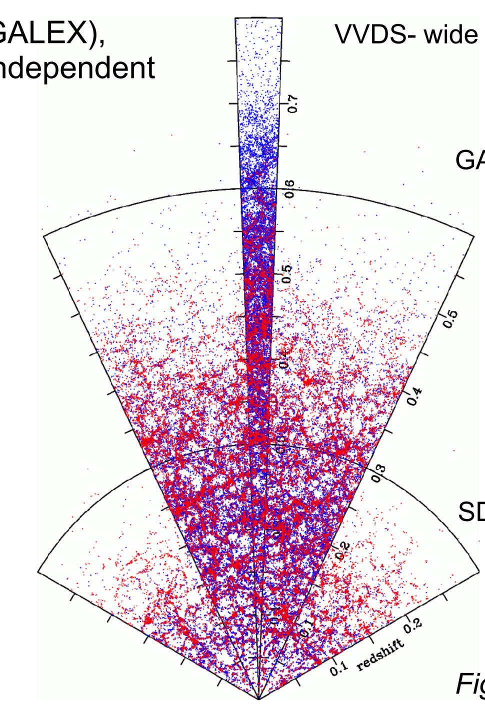

Fig. 2

Fig.1: Map of the sky showing the placement of GAMA fields (black boxes) and demonstrating the overlap with other surveys (e.g. H-ATLAS -yellow shaded areas). The GAMA equatorial fields are now complete. Fig.2: Simulations of a 2 deg thick survey section of 3% SDSS, 50% GAMA, and 50% VVDS-wide, demonstrating GAMAs unique ability to probe the evolution of large scale structure since z = 0.5.

3) GAMA Groups as Environmental Measures

GAMA provides a group catalogue constructed from the spectroscopic data-set using a FoF analysis in spatial and velocity space [3] with unprecedented range in dynamical mass and group multiplicity, sampling the low-mass end of the Halo-mass-function and low multiplicity groups (*Fig.3,4*).

Group dynamical masses can be estimated from the measured velocity dispersion and total stellar masses can be estimated in combination with luminosity functions (LFs) derived from the ancillary photometric data.

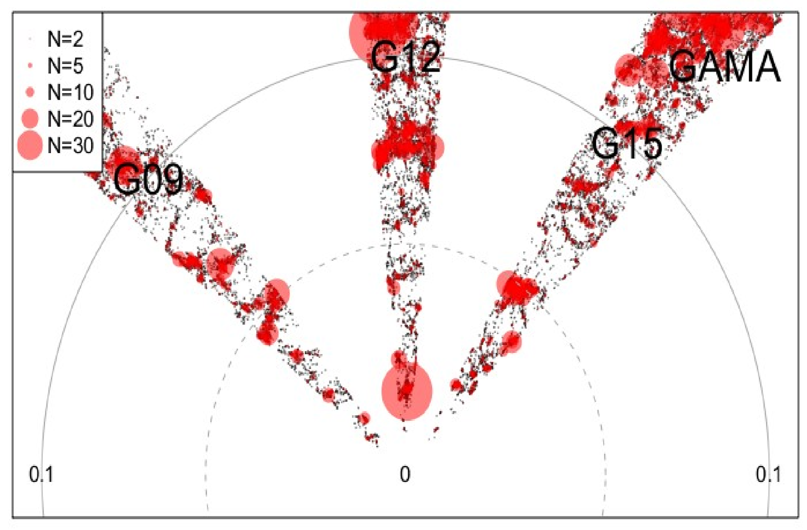

Fig. 3

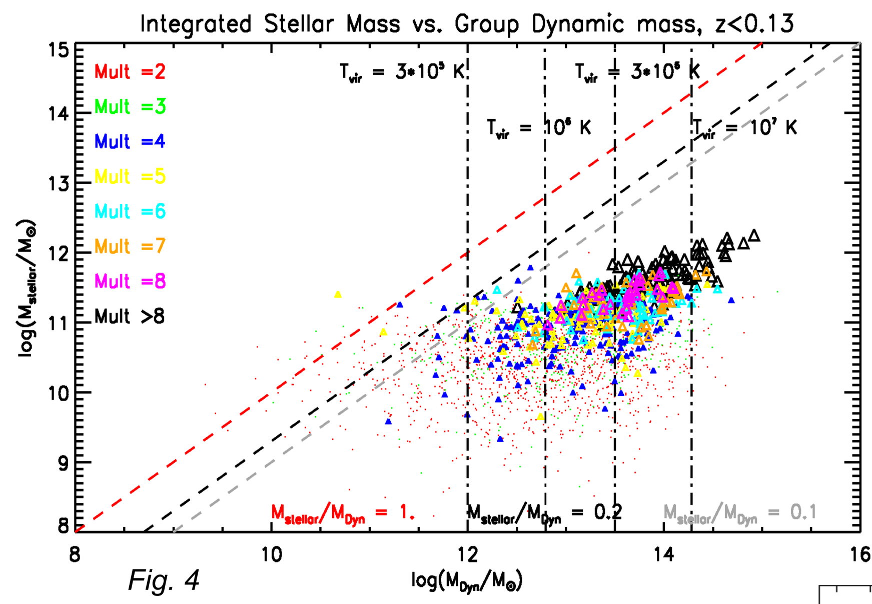

Fig. 4

Fig. 3: Distribution of low z GAMA galaxies in RA and redshift. Groups are shown as red circles. Even at low redshift filamentary structure and the positioning of groups at its nodes is clearly in evidence.

Fig. 4: Group stellar mass (extrapolated from summed r-band flux via LF) vs. group dynamical mass (derived from velocity dispersion). Data is preliminary; in particular groups with multiplicity <4 are subject to scatter and systematic uncertainties in M_{Dyn} . T_{vir} following van den Voort et al., 2010.

Preliminary analysis (*Fig. 4*) shows a strong tendency for the ratio of group stellar mass to group dynamical mass to increase with decreasing group dynamical mass over a range down to $\sim M_{Dyn} = 10^{12} M_{\odot}$.

These early results are qualitatively in agreement with expectations that intergalactic gas with higher virial temperature in groups of larger DMH-mass condenses into stars less efficiently (*Fig. 5*).

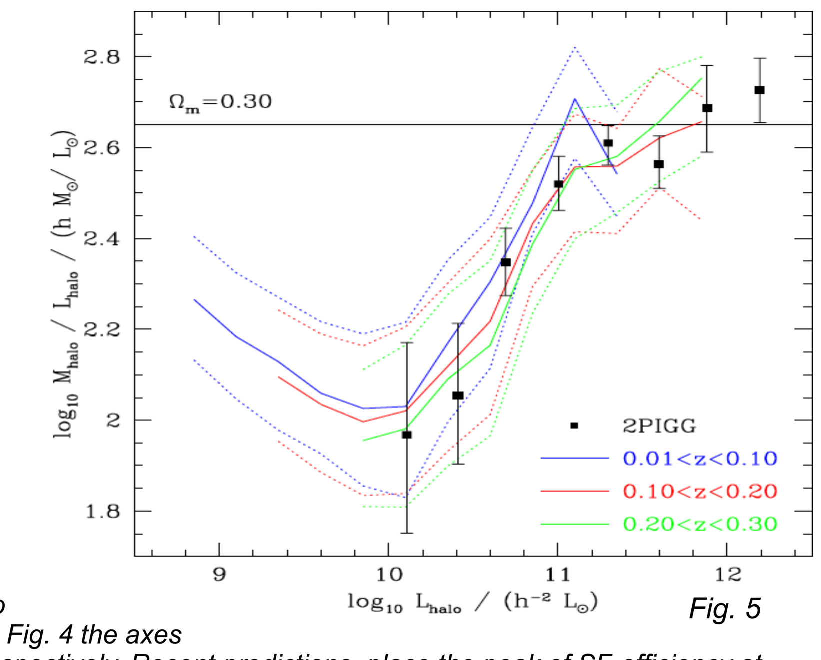

Fig. 5

Fig. 5: Model predictions of group dynamical mass-to-Light ratio as function of group luminosity compared to Data as measured by 2PIGG [4]. For comparison with Fig. 4 the axes must be transformed to stellar mass and halo mass respectively. Recent predictions place the peak of SF-efficiency at $\sim M_{Dyn} = 10^{12} M_{\odot}$ with lower mass halos having lower efficiencies due to feedback.

4) Star Formation and Gas Content ; HERSCHEL and ALMA

Preliminary estimates of group SFRs, as derived from H_{α} emission line data, referenced to total group stellar mass also show a decrease of the group specific SFR (GSSFR) with increasing group dynamical mass (*Fig.6*).

Under the assumption of a steady state between gas-fuelling from the IGM and gas consumption through SF in the group member galaxies, *Fig. 6* shows the dependence of SF efficiency on halo mass is continuing at the present epoch. This might indicate that stars are condensing out of gas that has passed through the virial shock ("warm accretion") though the data exhibit large scatter. This scatter may have a physical origin or may be due to dust attenuation effects which are known to introduce a large uncertainty to SFR estimates derived from optical measurements.

The use of submm measurements of a subset of luminous galaxies detected in the HERSCHEL-ATLAS survey [5],[6],[7], in combination with the GAMA UV – NIR photometry and morphological decompositions [9], already allows fully self-consistent radiation transfer modelling of the galaxy SEDs ([10],[11], see inset box), yielding attenuation-corrected instantaneous SFRs for such galaxies. Deeper pointed observations will be able to extend coverage out to less massive star-forming galaxies present in the GAMA spectroscopic sample.

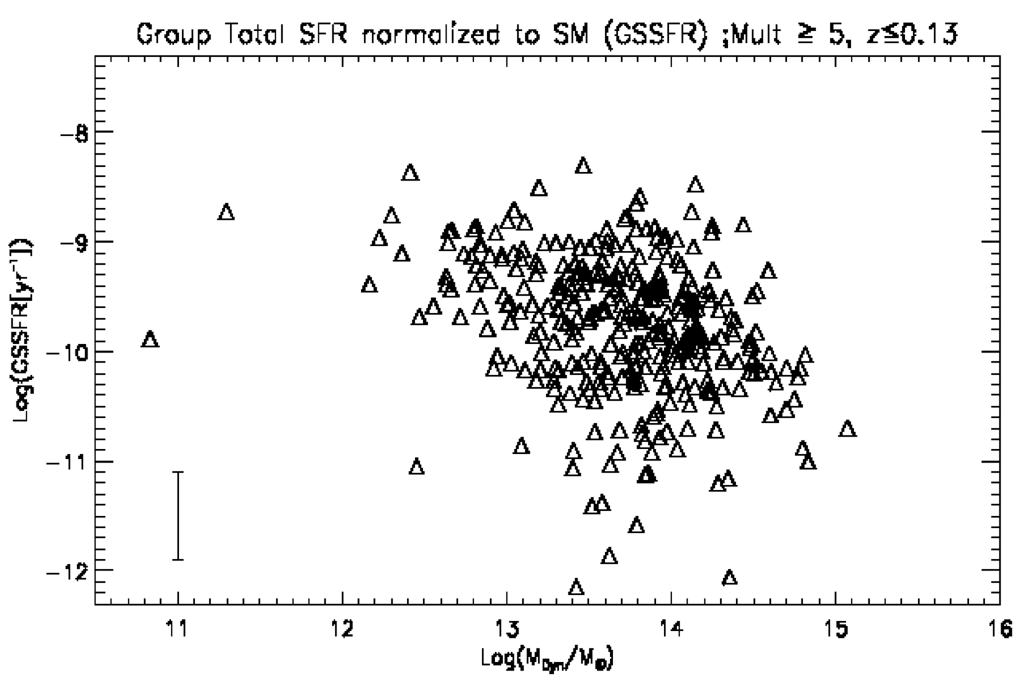

Fig. 6: Preliminary estimates of total group SFR normalized to group stellar mass, as derived from GAMA year 1&2 Hα emission lines. Groups with larger dynamical mass show lower GSSFR. Scatter may partially be due to dust attenuation and sample incompleteness. An initial attempt at correction using Balmer decrement, Cardelli et al. extinction law, and Case B recombination has been made [13]. This is expected to improve using radiation transfer methods, when FIR data becomes available.

Radiation Transfer modelling

Attenuation by dust intrinsic to galaxies of the emission at UV and optical wavelengths is a major source of errors in the determination of SFRs and SF histories of galaxies form both broad-band and spectroscopic data.

Using the multi-wavelength and morphological information available in GAMA in combination with an empirically constrained multi-component model of typical, "normal" SF galaxies (*Fig. I1*) allows a fully self-consistent de-reddening via radiation transfer modelling of the UV - FIR SED [10],[11],[12], and subsequent extraction of the instantaneous SFR, as well as independent extraction of the SFH.

Preliminary results of attenuation corrections using a crude application of this method (as discussed in [12]) are encouraging, resulting in a tightening of the NUV-r – SSFR correlation in *Fig. I2*. The method already yields a tighter correlation than corrections using the Balmer decrement.

FIR data is essential for this approach, so any SPIRE and PACS data complementing H-ATLAS for low-luminosity sources will be invaluable.

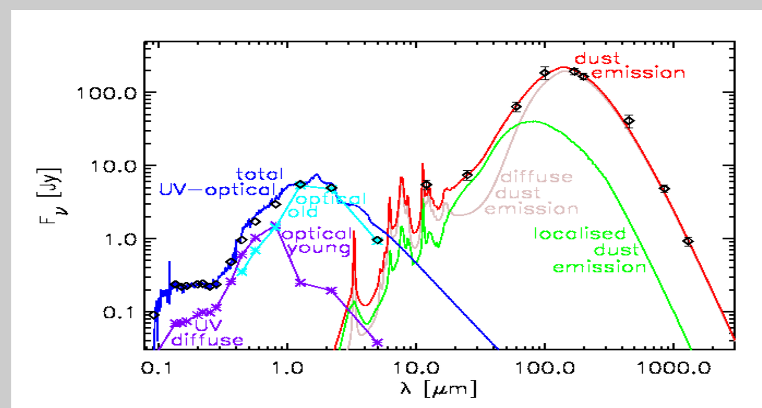

Fig. I1: The best fit radiation transfer model SED of a normal spiral galaxy, showing dust emission components and the intrinsic SED of stellar emission components.

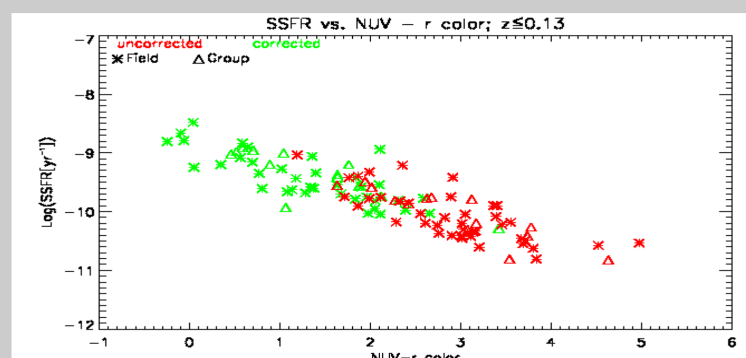

Fig. I2: corrected(green) and uncorrected(red) specific SFR (SSFR) and NUV-r color for detected GAMA galaxies in the H-ATLAS SDP field. The scatter in color and SSFR is improved.

ALMA will be able to precisely measure the molecular gas content of these objects. In combination with the neutral gas content (ASKAP) and the SFRs from HERSCHEL/GAMA this will allow a direct measurement of the gas consumption timescales in galaxies in the local universe and their dependence on the DMH mass of their hosts.

In addition ALMA and HERSCHEL will provide a direct imaging diagnostic for warm accretion through the imaging of the distribution of dust emission and molecular gas in the IGM of selected GAMA groups. In particular, the unprecedented angular resolution of ALMA will readily distinguish between molecular material which has condensed from primordial virialized gas and that associated with ISM tidally stripped from interacting galaxies in the groups over the useable redshift range of GAMA groups (out to z = 0.4).

Some evidence for ongoing SF in the hot virialized IGM of the prototypical compact group Stephan's Quintet has already been provided through the discovery ([14]) of a large-scale correspondence between the FIR and X-ray emissions of the IGM (*Fig. 7*). The FIR emission is not related to tidal features, and appears to trace a component of obscured (and therefore young) SF regions in the IGM

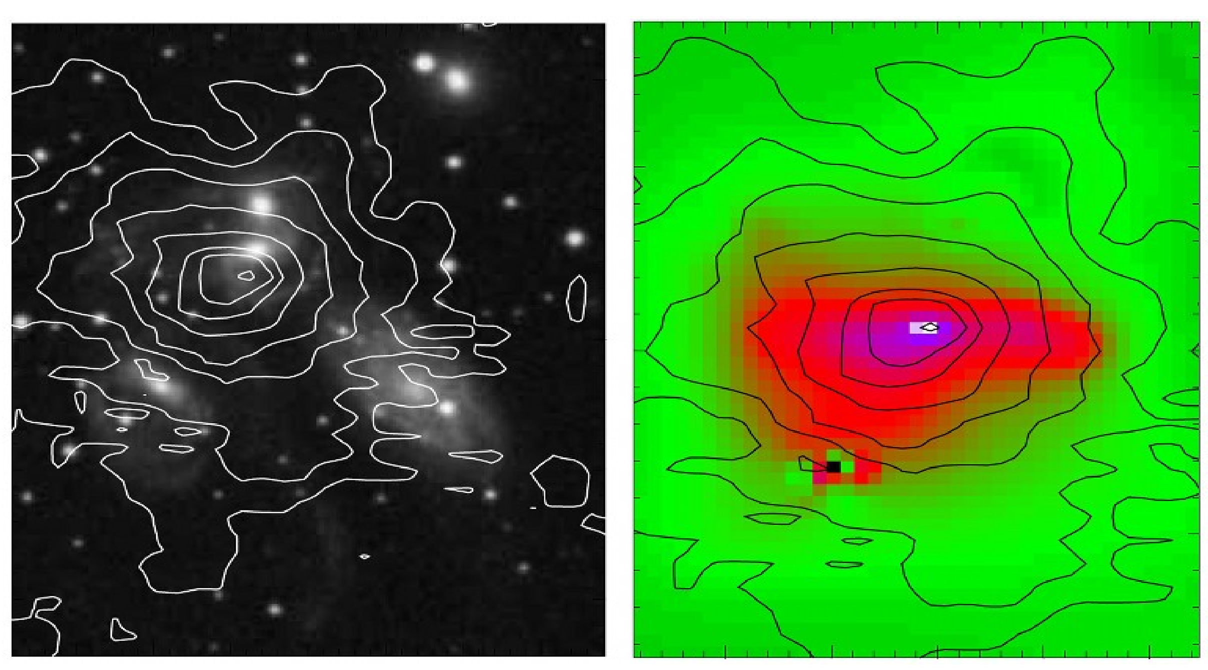

Fig. 7: Overlay of contours of the FIR emission from the IGM (after subtraction of galaxy-contribution) on a B-band image (left) and a X-ray emission map (right). The visible correspondence between the FIR and X-ray emission is most plausibly interpreted as distributed SF in the hot IGM (taken from [14]).

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DR1 available

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