Galaxy And Mass Assembly (GAMA)

The case for a new redshift survey of 250 000 galaxies

Ivan Baldry[1], S. Driver[2], A. Hopkins[3], J. Liske[4], R. Nichol[5], P. Norberg[6], J. Peacock[6], and the GAMA team

[1]Liverpool JMU (ikb@astro.livjm.ac.uk), [2]U. St. Andrews (spd3@st-andrews.ac.uk), [3]U. Sydney, [4]ESO, [5]U. Portsmouth, [6]U. Edinburgh

Abstract

The case is outlined for a new galaxy redshift survey with AAOmega that bridges a crucial gap between the SDSS and VVDS surveys. The science focus is to study structure and the relationship between matter and light on kpc-to-Mpc scales. The range of scales probed will enable direct constraints on the Cold Dark Matter model by: (1) measuring the halo mass function down to $10^{12}\mathcal{M}_\odot$ and its evolution to $z \sim 0.4$; (2) measuring the galaxy stellar mass function to very low mass limits of $10^{7}\mathcal{M}_\odot$ constraining baryonic feedback processes; and (3) quantifying the environment-dependent merger rate since $z \sim 0.4$.

Selection function

High target density is required for dynamical estimates of group **halo masses** with area needed for sufficient cosmic volume. r-band selection provides a high redshift-success rate at a given target density. Joint K and r selection leverages the **stellar mass function**. High completeness is required for **merger rate** measurement via close pairs. GAMA enters **new parameter space** for redshift surveys enabling many new science investigations.

- Sample 1: $r < 19.8$ ($\sim 1000\,\mathrm{deg}^{-2}$)
- Sample 2: $K_{AB} < 18.9$ and $r < 20.5$ ($\sim 300\,\mathrm{deg}^{-2}$)
- Area: $200\,\mathrm{deg}^2$ (e.g., two 4×25 strips or four 5×10 strips)

New parameter space

Field galaxy redshift surveys aim to provide fundamental data on galaxies and the distribution of galaxies. How does GAMA compare with completed and ongoing surveys?

Table 1: Comparison of magnitude-limited redshift surveys with GAMA

survey abbrev.	no. of redshifts	area (deg^2)	selection band(s)	AB mag. limit	completed (2007)
SDSS-main	750 000	8500	r	17.8	nearly
GAMA	250 000	200	r, K	19.8,18.9	proposed
2dFGRS	220 000	1500	b_J	19.3	yes
6dFGS	160 000	17000	K,...	14.6,...	nearly
2MRS	100 000	37000	K	14.1	
VVDS-wide	100 000	16	I	22.5	
VVDS-deep	50 000	1.5	I	24.0	
LCRS	26 000	700	R	17.7	yes
CfA2	18 000	17000	B	15.4	yes
AGES	15 000	9	R, B_W	20.2,20.4	
PSCz	15 000	34000	FIR	9.5	yes
MGC	10 000	37.5	B	19.9	yes

As surveys are selected with different wavelengths, we cannot directly compare depth. A useful metric, related to magnitude limit, is the **number density on the sky of redshifts obtained.** This is particularly important in relation to measurements of environment on sub-Mpc scales. This metric is plotted versus **survey area** in Figure 1 for magnitude-limited surveys as well as for more targeted surveys.

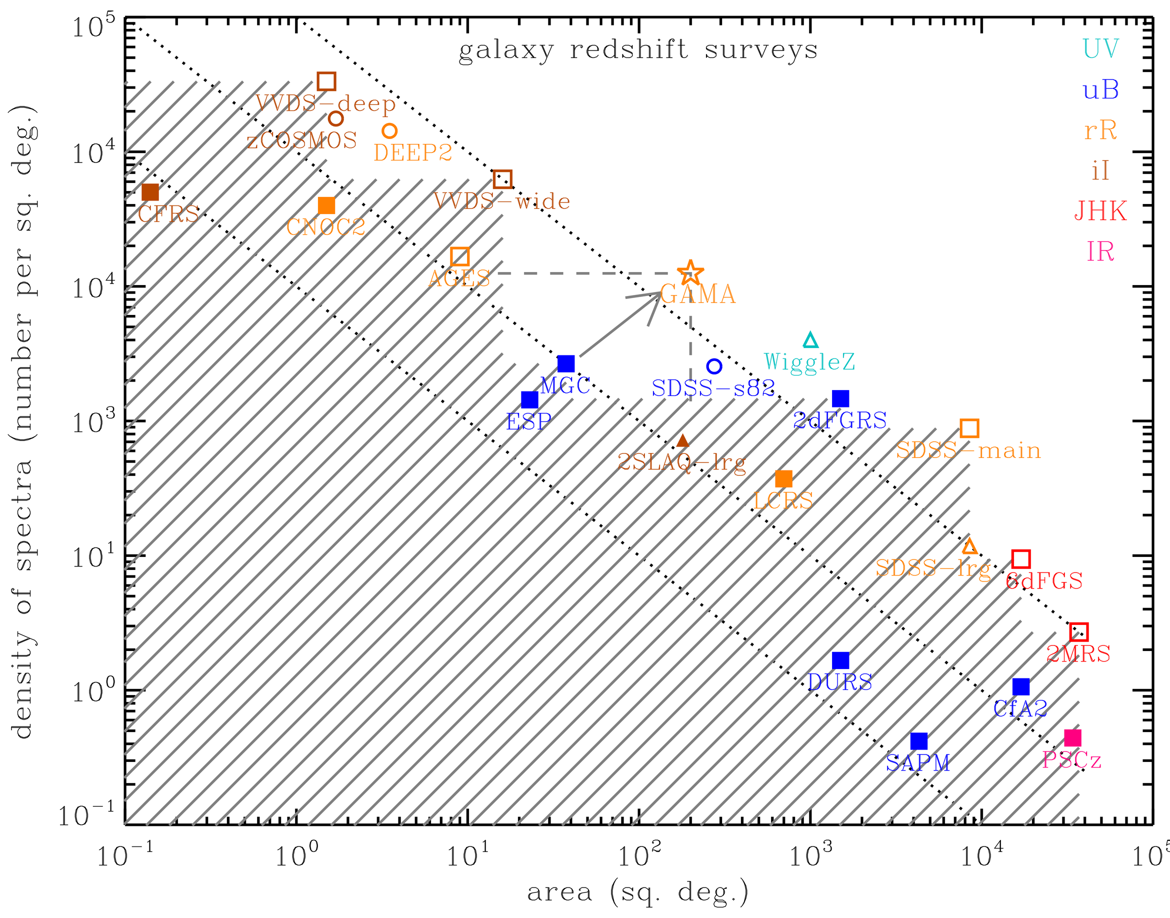


Figure 1: Comparison between galaxy redshift surveys: *squares* represent predominantly magnitude-limited surveys; *circles* represent surveys involving colour cuts for photometric redshift selection; while *triangles* represent highly targeted surveys. Filled symbols show completed surveys and the grey region shows the parameter space covered by magnitude-limited surveys. GAMA shown by a *star* cuts significantly into new parameter space. Surveys are colour coded according to selection wavelength.

- The proposed GAMA survey has 14 times the target density of SDSS (main galaxy sample) while covering 12 times the area of VVDS.

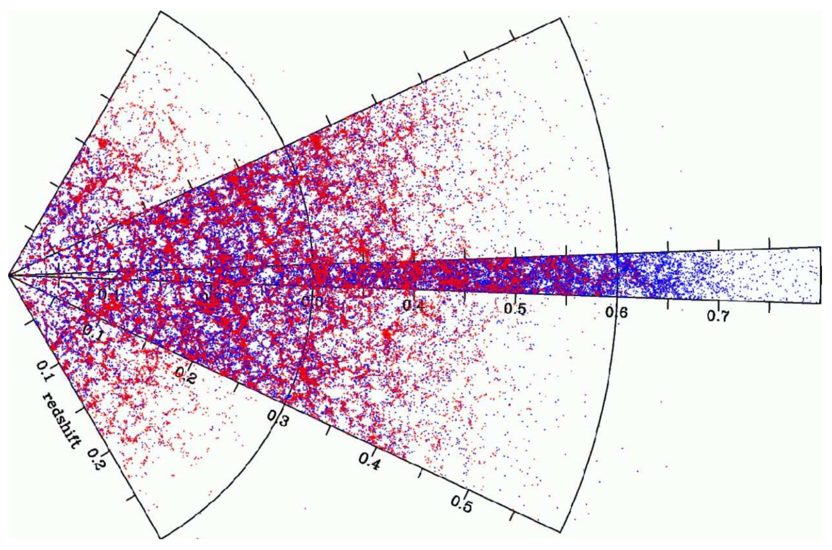


Figure 1B: Simulations of survey sections for SDSS, GAMA and VVDS-wide

Halo mass function and galaxy formation efficiency

At any redshift, the halo mass function is well established via numerical simulations, requiring no knowledge of the baryonic physics, and is precisely predicted over five orders of magnitude in halo mass. This theoretical prediction of cold dark matter (CDM) is one of the most robust predictions available.

Observationally the halo masses can be obtained through **dynamical mass estimates of galaxy groups**, for example, the 2dFGRS Percolation-Inferred Galaxy Group (2PIGG) catalogue (Eke et al. 2004). This catalogue is incomplete below about $10^{14}\mathcal{M}_\odot$. It was not deep enough to probe low-mass halos over a sufficiently representative volume. The extra depth of GAMA (see Figure 1) increases the number of galaxy group members by a factor of two to three, and together with increased spectral resolution, enables the detection of significantly lower mass groups. This is shown for simulations of GAMA in Figure 2.

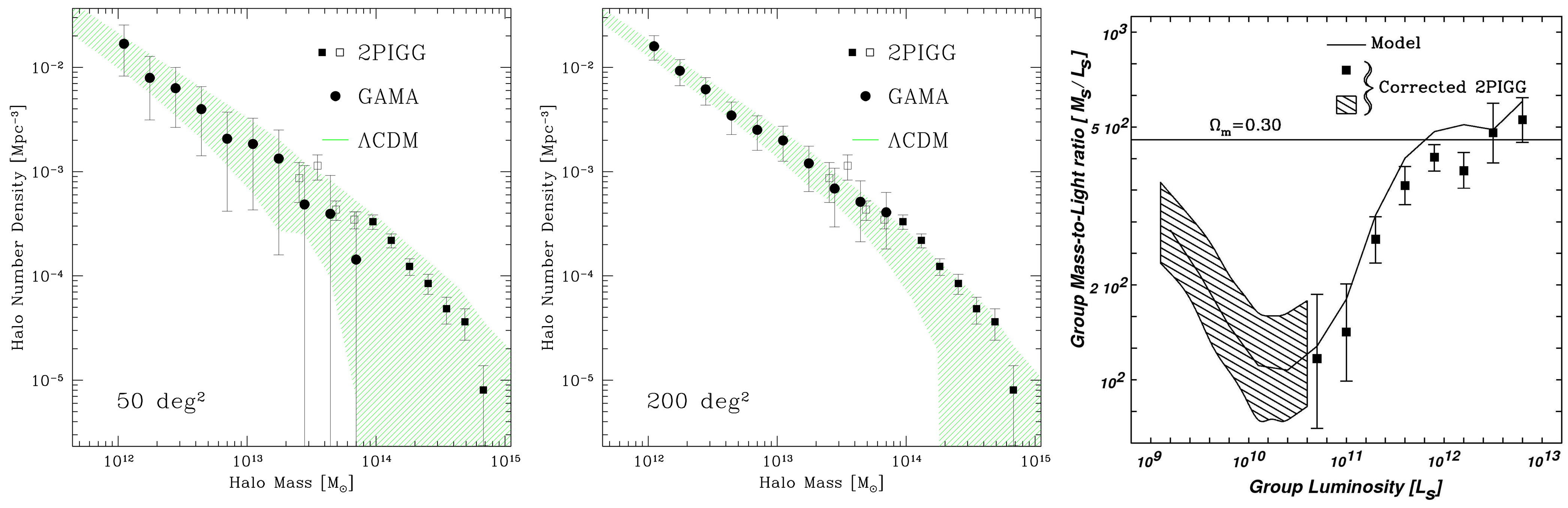


Figure 2 left and middle panels: Comparison of a simulated GAMA group mass function (*circles*) to the 2PIGG mass function (*squares*) and a ΛCDM model (shaded area) for $50\,\mathrm{deg}^2$ and $200\,\mathrm{deg}^2$, respectively. Right panel: The 2PIGG group mass-to-light ratio (M/L) as a function of group luminosity (*squares*). The M/L is predicted to be a minimum around $10^{13}\mathcal{M}_\odot$ and the shaded region is expected to be probed by GAMA (figure adapted from Eke et al. 2006).

- GAMA will constrain the halo mass function over three orders of magnitude; in combination with SDSS/2dFGRS, will provide accurate halo occupancy numbers from rich clusters down to local group scale masses; and will probe the evolution in the number density of $\sim 10^{14}\mathcal{M}_\odot$ halos out to $z \sim 0.4$.

Stellar mass function and baryonic feedback

The total mass for groups is an important measure but cannot probe to individual galaxy masses. On these scales the CDM model predicts that the mass function of sub-halos that host galaxies should be a steeply rising power law. This is at odds with observations of the galaxy luminosity function which is relatively flat. The favoured explanation requires star-formation efficiency to vary as a function of halo mass, such that low-mass halos are extremely inefficient. The change in efficiency with halo mass determines the slope, and any change in slope, of the galaxy stellar mass function (GSMF).

Observationally the GSMF is determined from **optical or near-IR luminosity with an estimate of mass-to-light ratios from colours or spectra**. The present compendium of data probes to $\sim 10^{8.5}\mathcal{M}_\odot$ with a slight indication of a change in slope (Figure 3 left). GAMA will extend this by an order of magnitude down to below $10^{7.5}\mathcal{M}_\odot$ using both r-band selection, which is optimum for the low-metallicity dust-free galaxies, and K-band selection, which picks up more moderate-metallicity dusty galaxies at a given stellar mass (Figure 3 right).

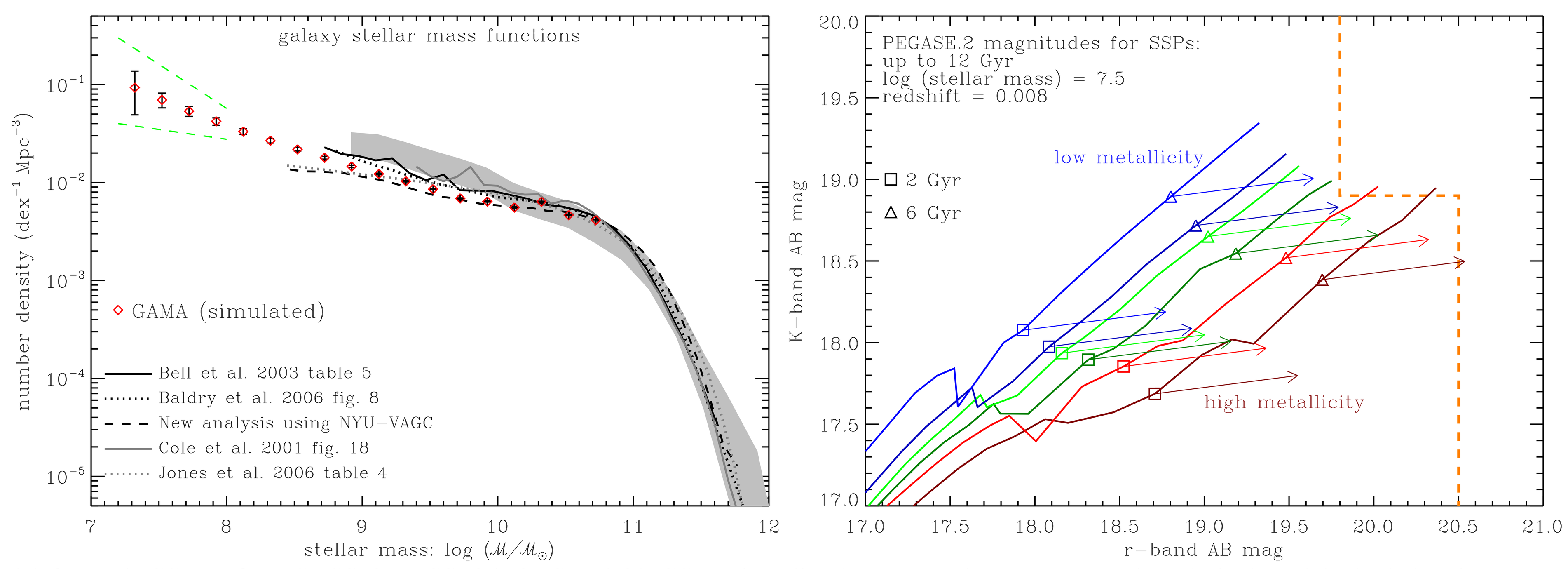


Figure 3 left panel: GSMFs from SDSS, 2MASS+2dFGRS and 6dFGS (various lines), compared to a recent semi-analytical model (shaded region; De Lucia et al. 2006) and a simulation of the numbers expected from GAMA (*diamonds* with error bars). The prediction shown is based on galaxies with $0.008 < z < 0.1$ and errors are purely Poisson. Right panel: Magnitudes for simple stellar populations (SSPs) with the same stellar mass. The *arrows* represent the dust attenuation vector for an SMC extinction law with $A_V = 1\,\mathrm{mag}$. The *orange line* represents the GAMA selection function.

- GAMA will measure the field GSMF down to nearly $10^{7}\mathcal{M}_\odot$ at $z \gtrsim 0.008$ (in the Hubble flow); and will accurately probe the variation of the GSMF over about five environment and five redshift bins.

Galaxy merger rates

The buildup of both dark matter halos and the baryonic mass of galaxies is one of the principal modes of growth in CDM models.

Observationally the galaxy merger rate is measured either by **finding galaxies in pairs that are close enough** (on the sky and in redshift space) or by identifying recent merger remnants through their **asymmetric light distribution**. These methods require spectroscopy that is highly complete for close pairs (difficult because of fibre-placement restrictions) and high-resolution imaging, respectively. GAMA will require ~ 10 configurations per AAOmega pointing overcoming close-pair bias and will obtain high-resolution imaging from VST-KIDS and VISTA-VIKING surveys.

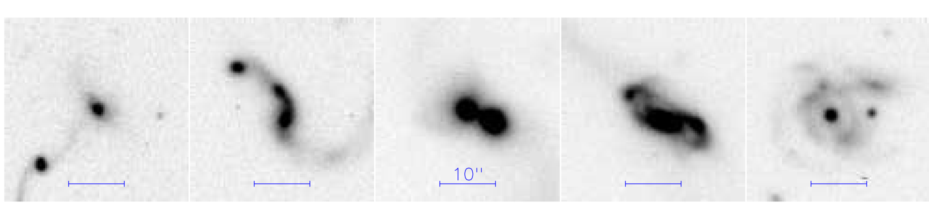
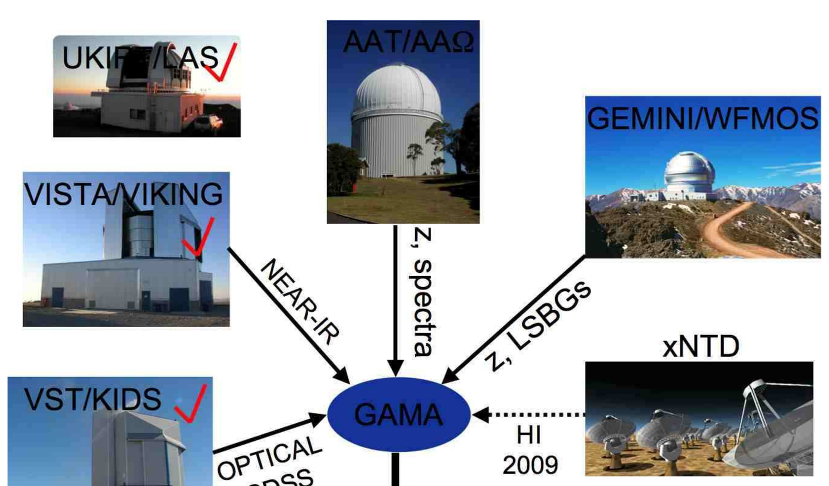


Figure 4: Examples of dynamically close pairs representing the pre- to post-merger phases.

- GAMA will measure major- and minor-merger rates over a range of environments at low redshift, and any variation in the major-merger rate to $z \sim 0.4$.

Imaging data

The galaxies for GAMA spectroscopy will initially be selected from SDSS and UKIDSS data and the final GAMA database will combine data from the latest world-class facilities. This will include **sub-arcsecond imaging** from VST and VISTA; and potentially **deep radio imaging** from xNTD, an SKA pathfinder facility.



Optimum spectroscopic instrument for GAMA

AAOmega is the upgraded multi-object spectrograph fed from the 2dF robotic fibre positioner on the Anglo-Australian Telescope. The field of view is 2-degrees diameter with **392 fibres**. The fibres feed a dual-beam spectrograph with VPH gratings which can be used to obtain complete spectral coverage from **370 to 880 nm** with a resolving power of ~ 1300.

A completely optimistic estimate of observing time would be 800 hours or 100 clear nights (assuming 370 science fibres per configuration, and 1 and 2 hour integrations for 85% and 15% of targets, respectively). Allowing for weather, seeing, broken fibres, etc., a more realistic estimate is 150 nights.