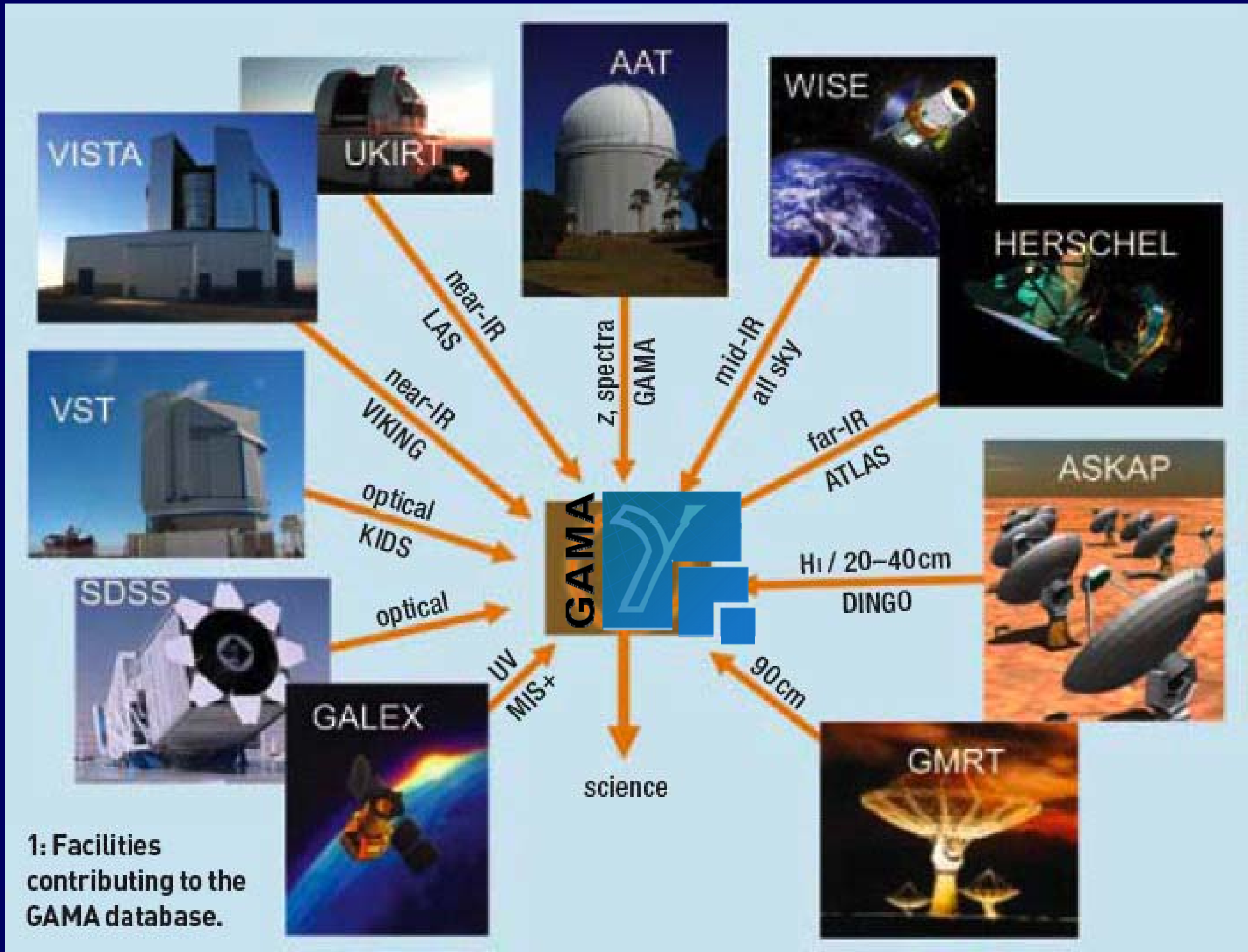
HI and radio continuum observations of GAMA groups and clusters with ASKAP



1: Facilities contributing to the GAMA database.

Richard Tuffs MPI-Kernphysik Heidelberg
(for the ASKAP-Dingo & GAMA teams)

Galaxy And Mass Assembly (GAMA):

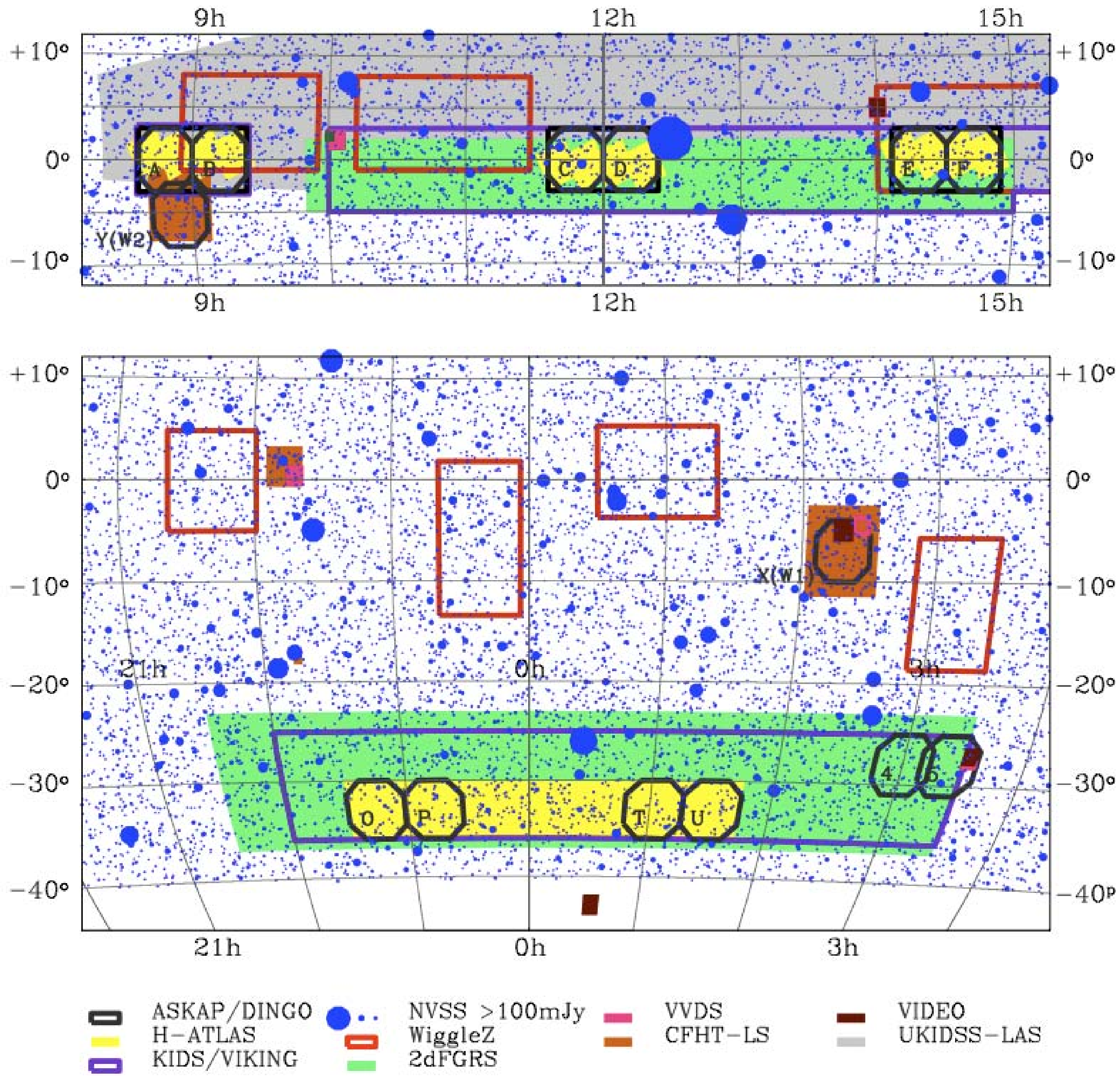
- Large program status spectroscopic survey
  with Anglo Australian Telescope/AAOmega
  PIs S. Driver (ICRAR) & A. Hopkins (AAO)

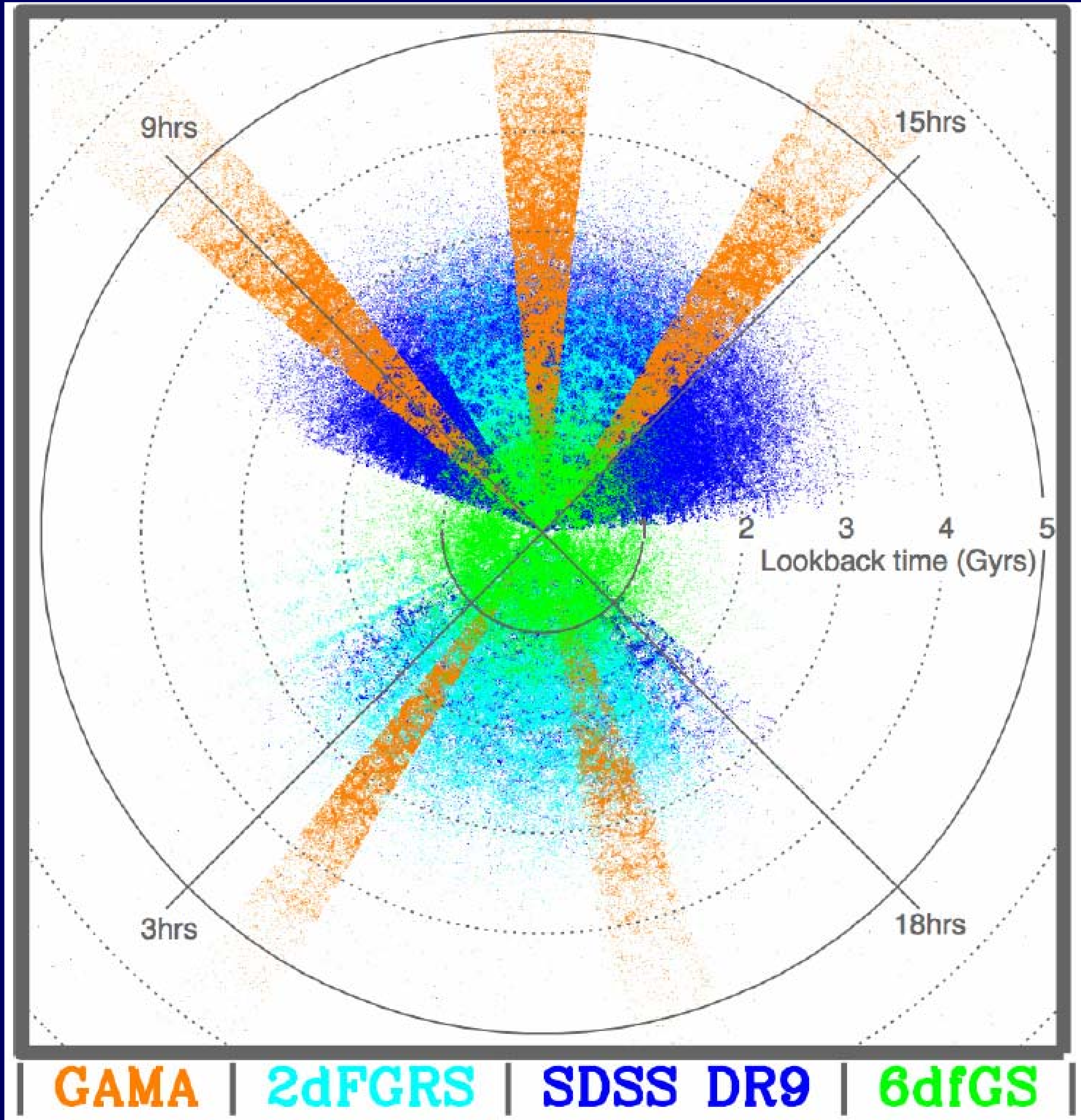
- 300 sq deg with 98% completeness to r 19.8

- 320k redshifts in range 0 < z < 0.4

- survey completion 2014 and public data release 2015
  (currently 250k redshifts)

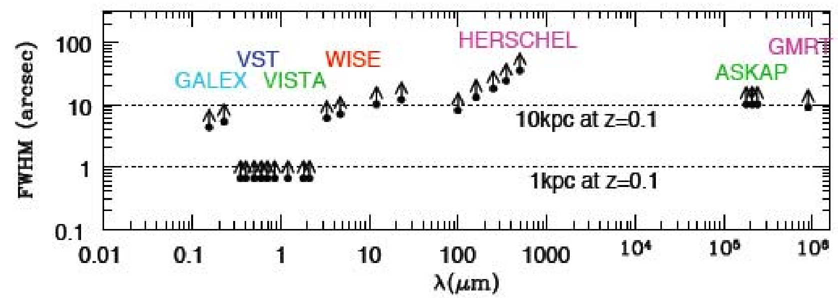
http://www.gama-survey.org


9h
12h
15h
+10°
0°
−10°
A
B
C
D
E
F
Y(W2)
21h
0h
3h
−20°
−30°
−40°
X(W1)
O
P
T
U
4
5
ASKAP/DINGO
H-ATLAS
KIDS/VIKING
NVSS >100mJy
WiggleZ
2dFGRS
VVDS
CFHT-LS
VIDEO
UKIDSS-LAS

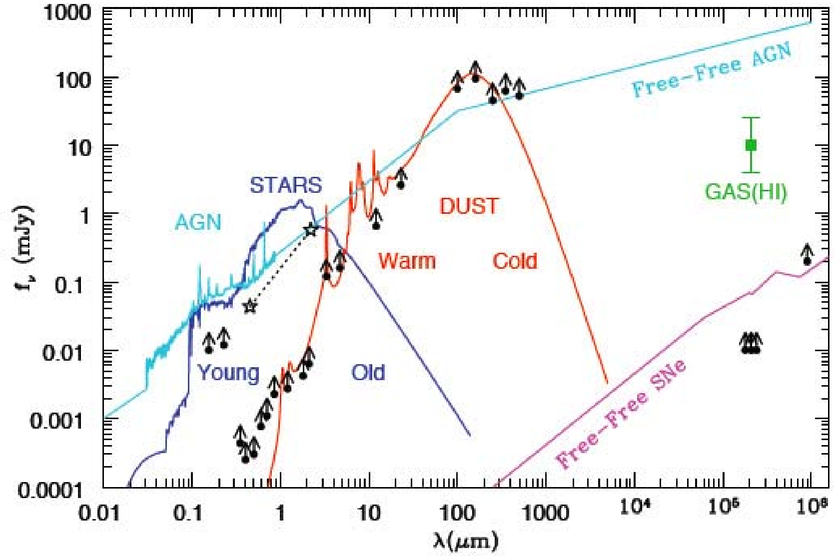

9hrs
15hrs
1
2
3
4
5
Lookback time (Gyrs)
3hrs
18hrs
GAMA
2dFGRS
SDSS DR9
6dfGS

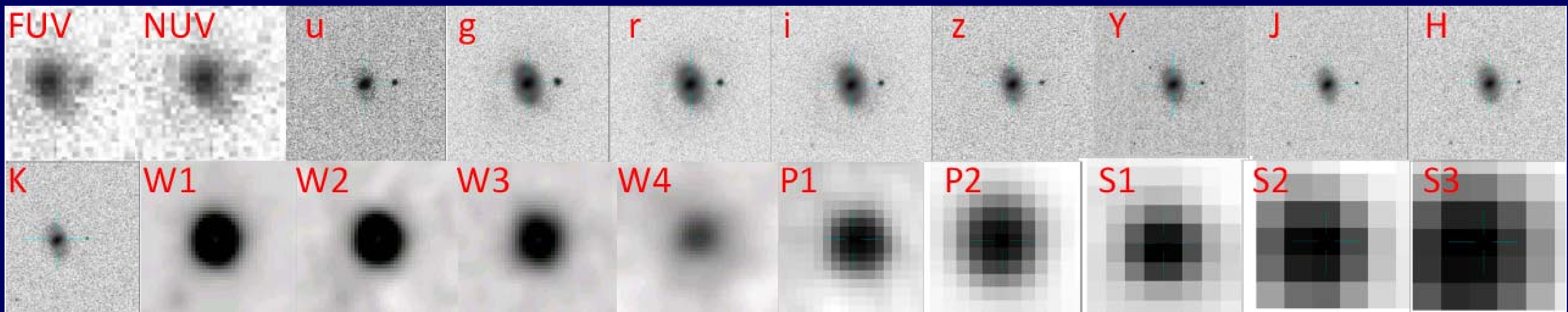
GAMA Multiwavelength Campaign

GAMA Spatial Resolution

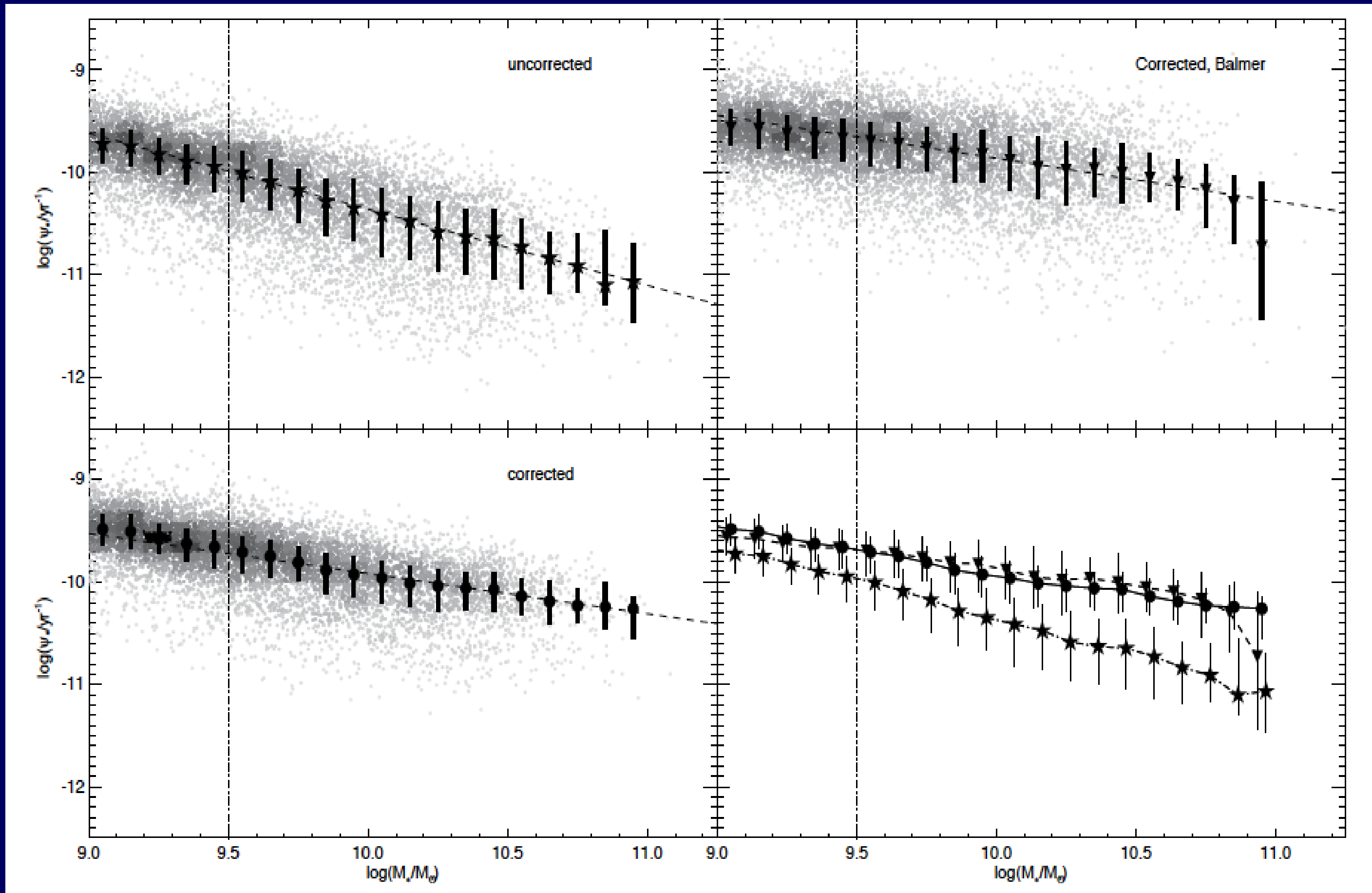


GAMA Sensitivity





Correcting for attenuation by dust



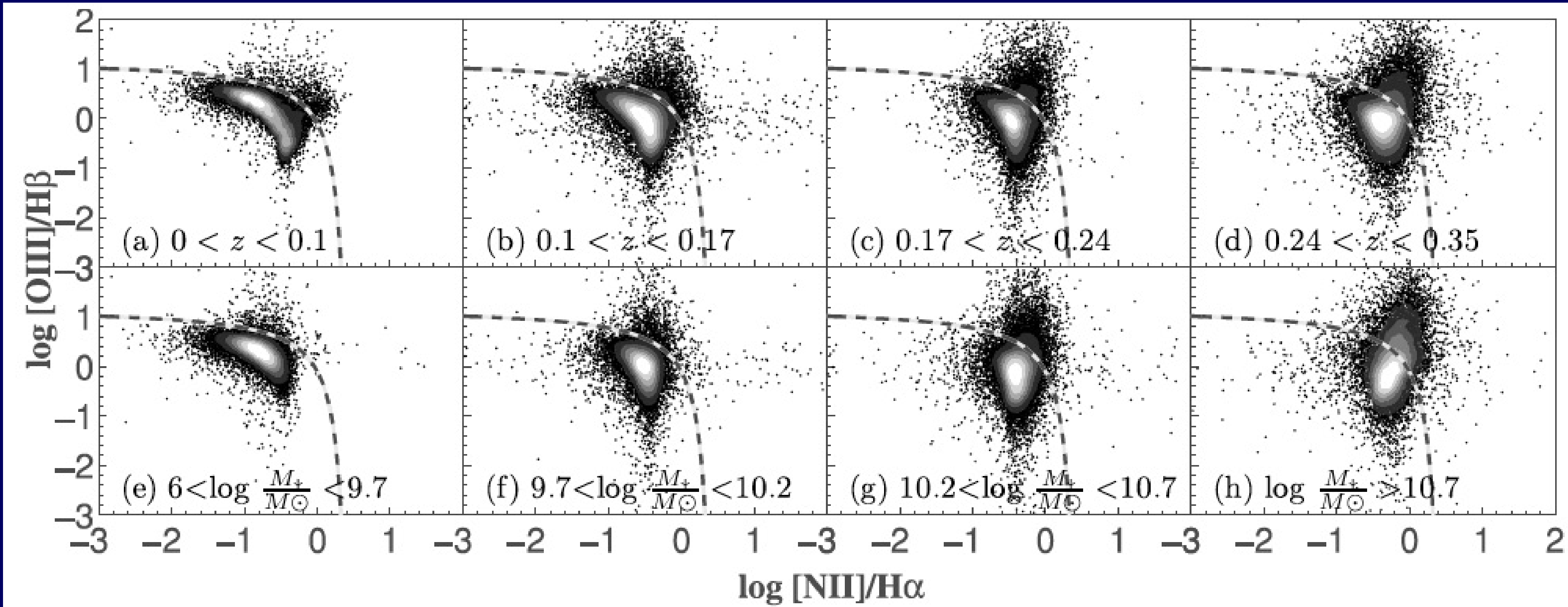
Grootes et al., 2013 ApJ, 766, 59

- attenuation determined object-by-object from UV/optical - MIR/FIR/submm in conjunction with measured morphology using radiation transfer SED modelling

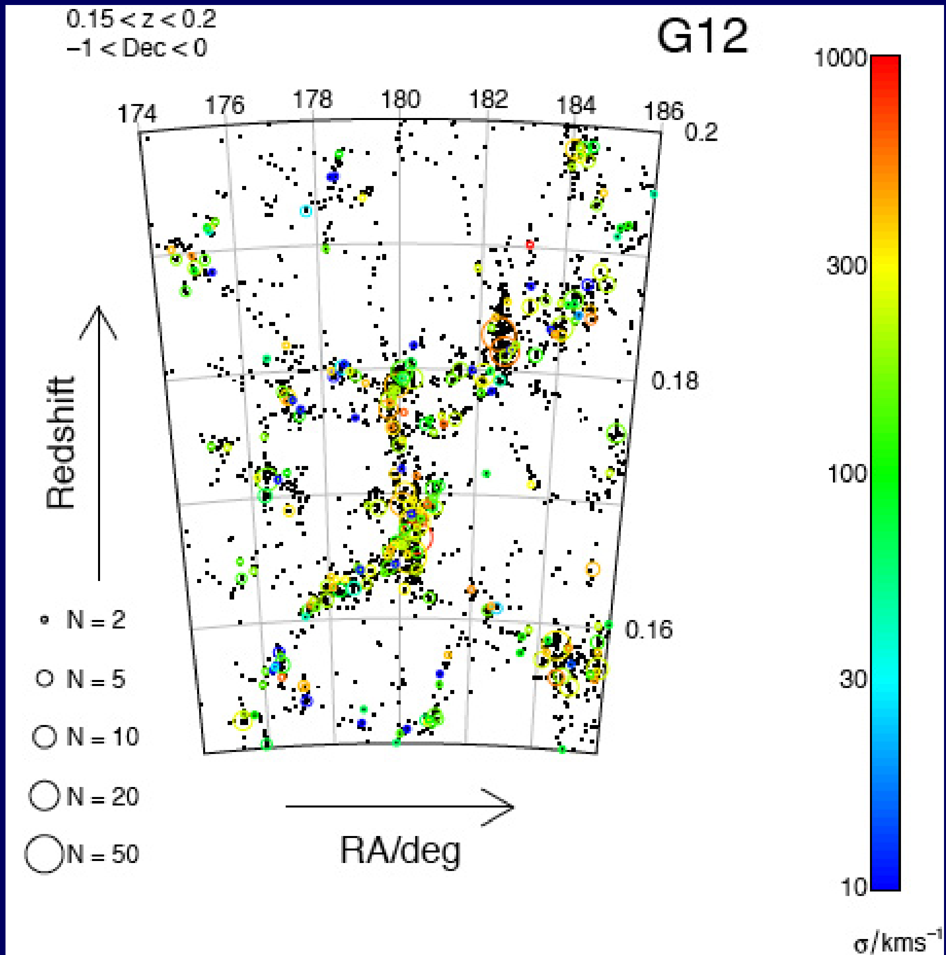
- Corrected relation for morphologically-selected spiral galaxies (volume-limited at 10^9.5 M_solar for z < 0.13) very tight ($\sigma \approx$ 0.27 dex).

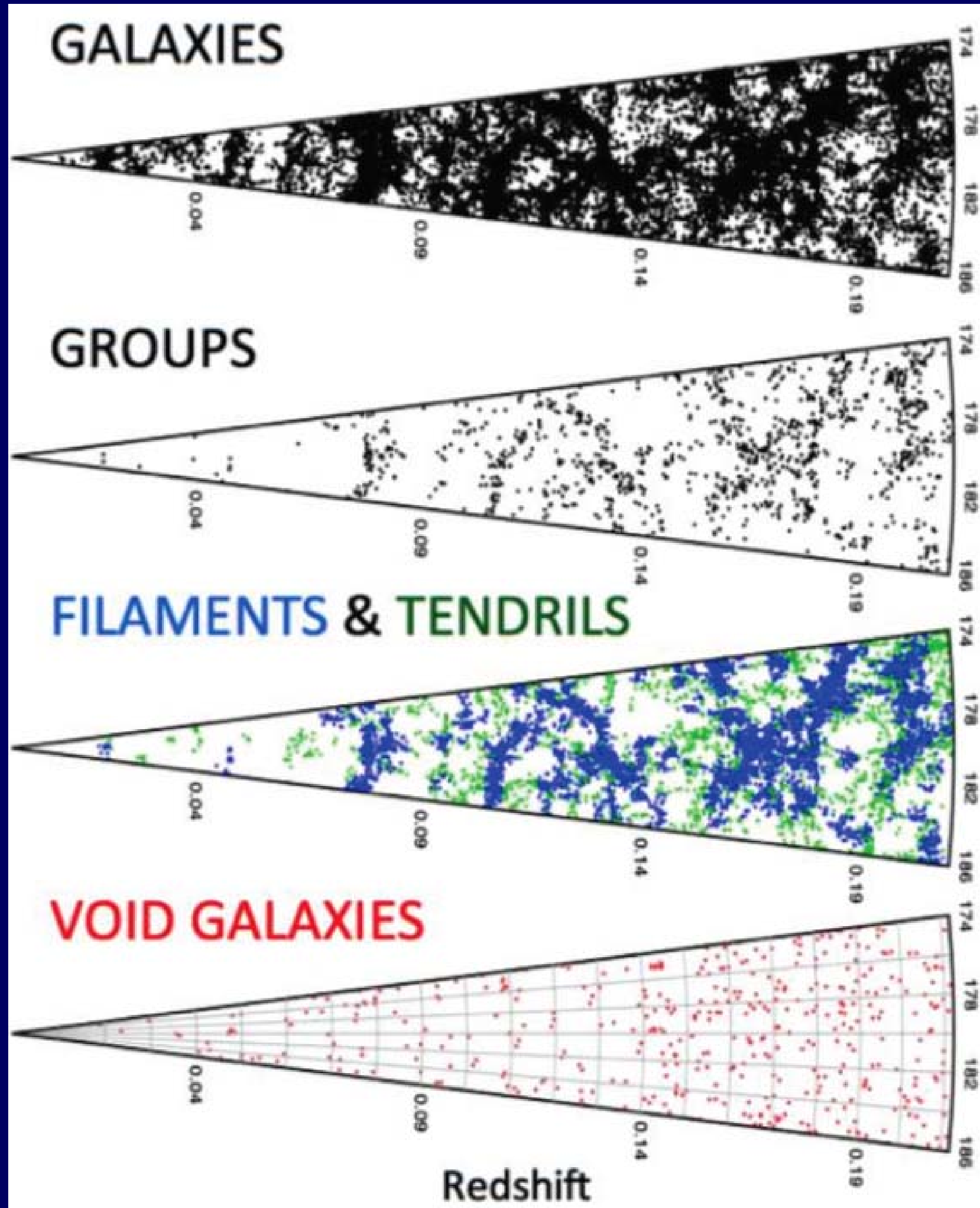
- Marked reduction in scatter with corrected main sequence following a single power law (γ = -0.5)

Quantitative Spectroscopy (Hopkins et al. 2012)



Environment of Galaxies

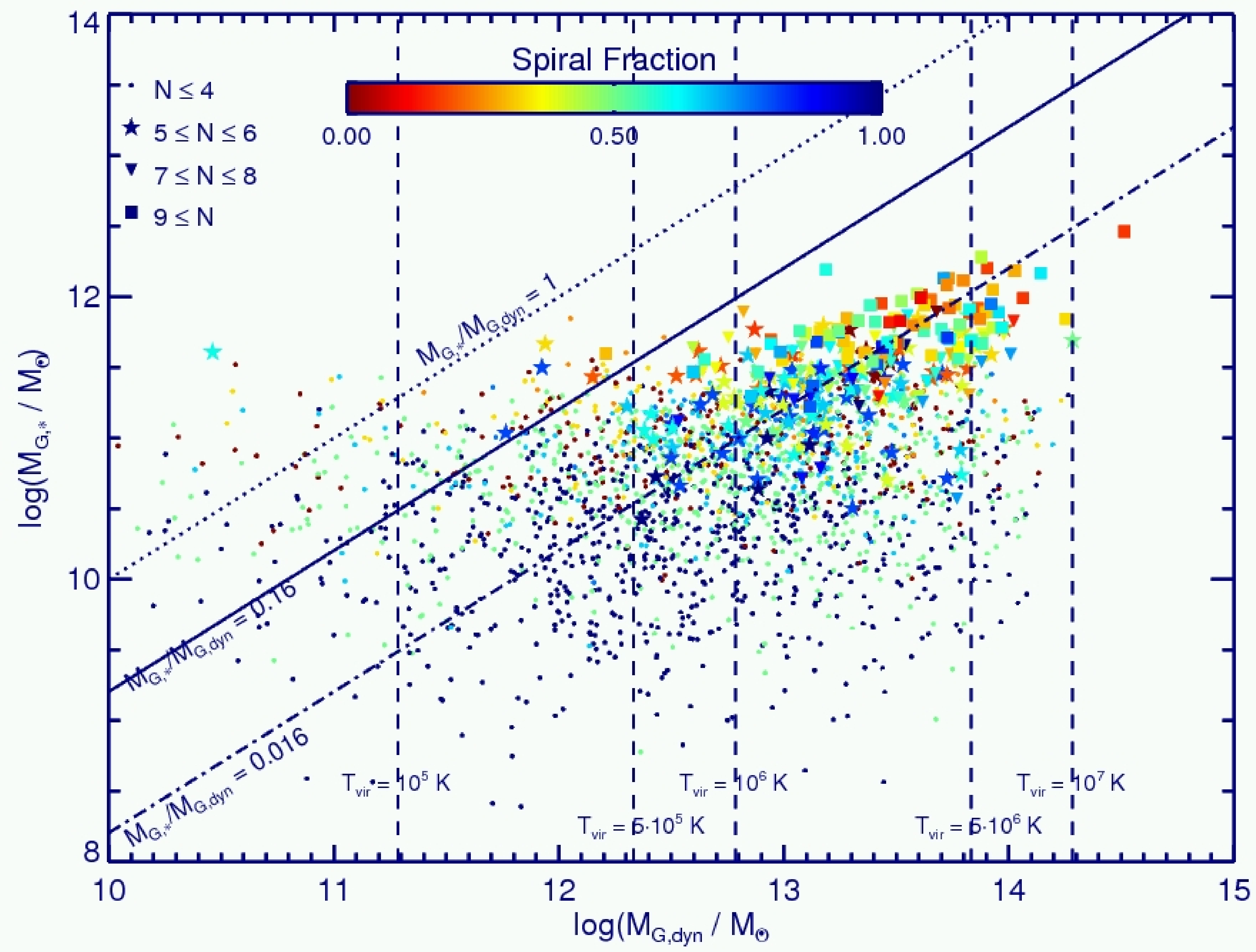




- group kinematics for **90k galaxies in 28k groups** ranging from 10^11 to 3.10^14 M_solar in dynamical mass

Robotham et al. (2011), Alpaslan et al. (2014)

Local Universe GAMA Groups (z < 0.13)



Grootes et al 2013

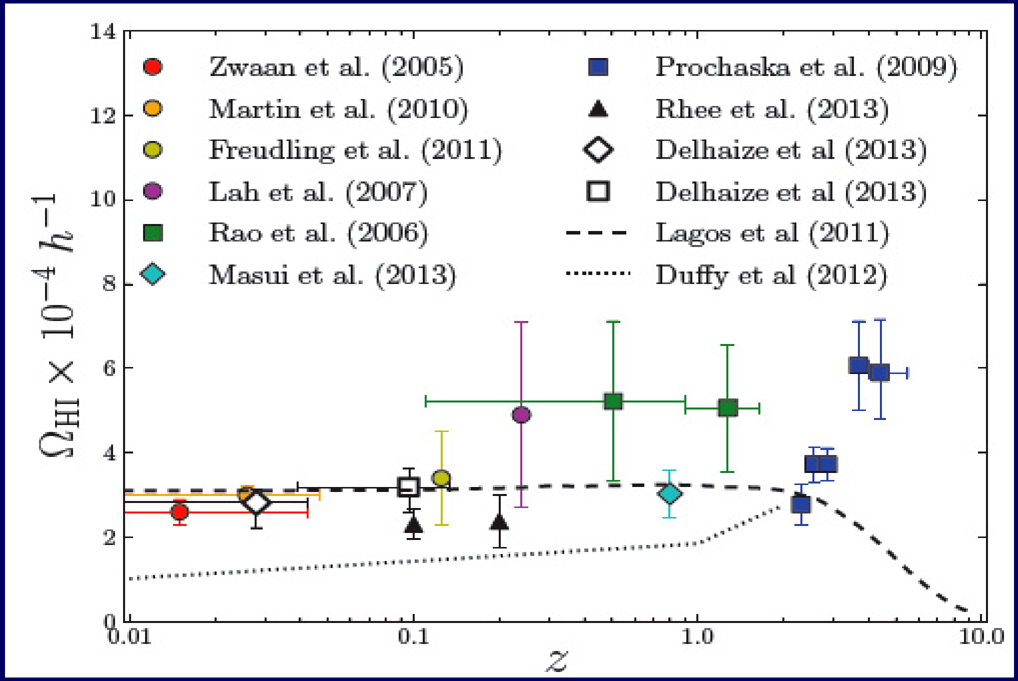
Goals for the ASKAP survey

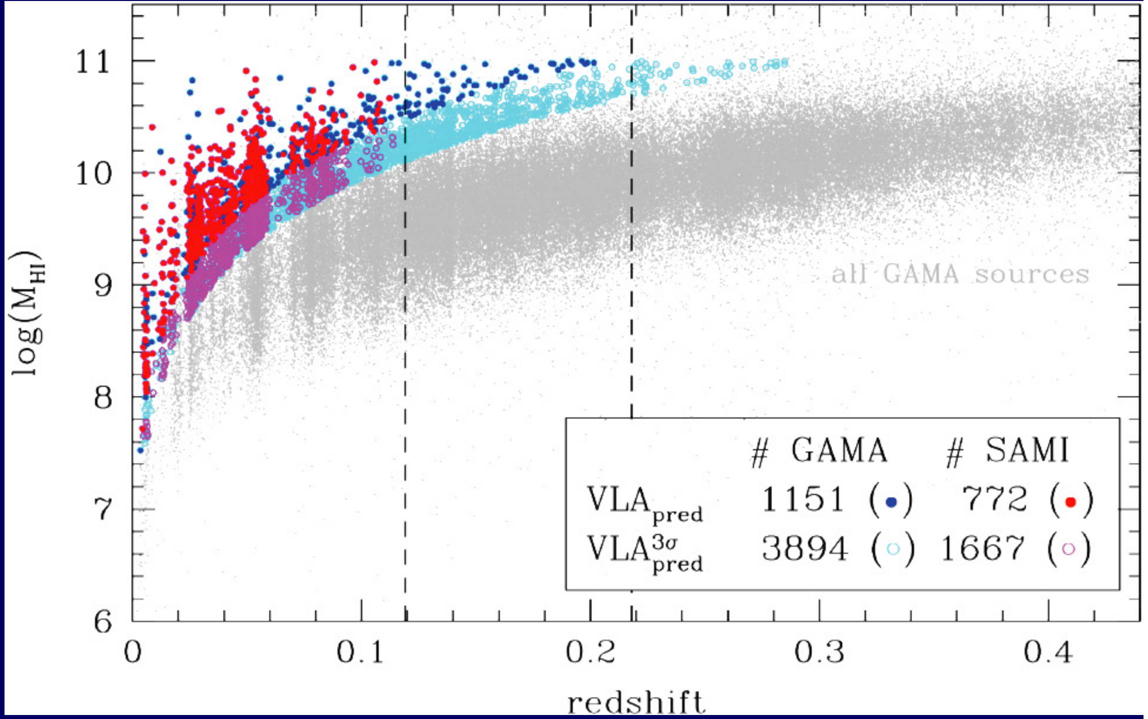
- dependence of HI gas fraction on environment **isolating the IGM-galaxy interaction**

- impact of star formation and AGN feedback on HI gas fraction

- evolution of gas fuelling rate with redshift

analysis will require use of redshift priors





GAMA as an empirical reference for baryonic physics in the ISM and IGM

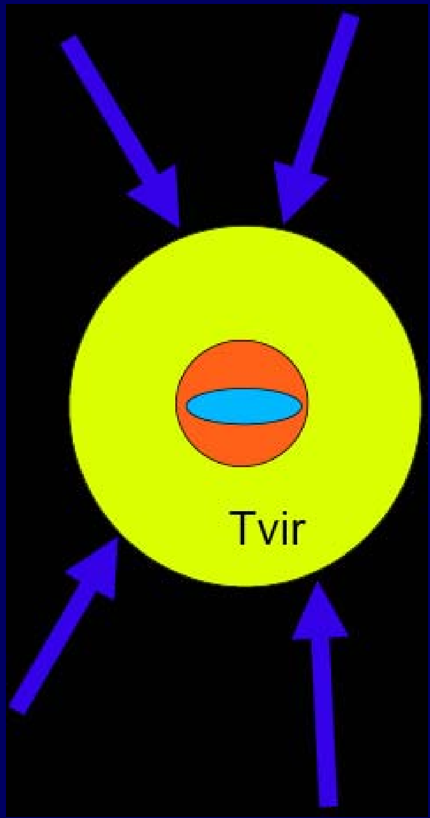
The Formation of Dark Matter structure is well understood in the context of LCDM but what about Baryonic Structure?

Fundamental process is gas accretion:
Baseline two-stage picture of Rees & Ostriker (1977); White & Rees (1978):

(I) IGM gas falling into a DM halo on timescale $t_{freefall}$ shock heats to:

$$T_{\rm vir} \sim \frac{m_p}{k_B}\left(G^2 M_{\rm vir}^2 H(z)^2 \Delta_{\rm vir}(z)\right)^{1/3}$$

(II) virialised IGM gas cools on timescale $t_{cool} > t_{freefall}$ forming a centrifugally supported disk where stars form



Use local spirals in GAMA groups of known dynamical mass Mdyn **as test particles to probe influence of environment on processes driving star formation. Isolate processes as far as possible. Use GAMA Group catalogue of Robotham et al. (2011).**

Requirements:

- Ability to probe wide range of group environments on an object-by-object basis down to Mvir = 10^12Msun
  => use GAMA group catalogue with z < 0.13 cut and multiplicity >= 3

- Measurement of integrated SFRs for spirals with $M_* >= 10^9 M_{solar}$ at z 0.13 with time resolution better than $t_{freefall}$ of ca. 10^9yr
  => use NUV (2200A) medium deep (1500s exposure) photometry
  (the entire GAMA 300sq. deg. footprint was surveyed with GALEX)

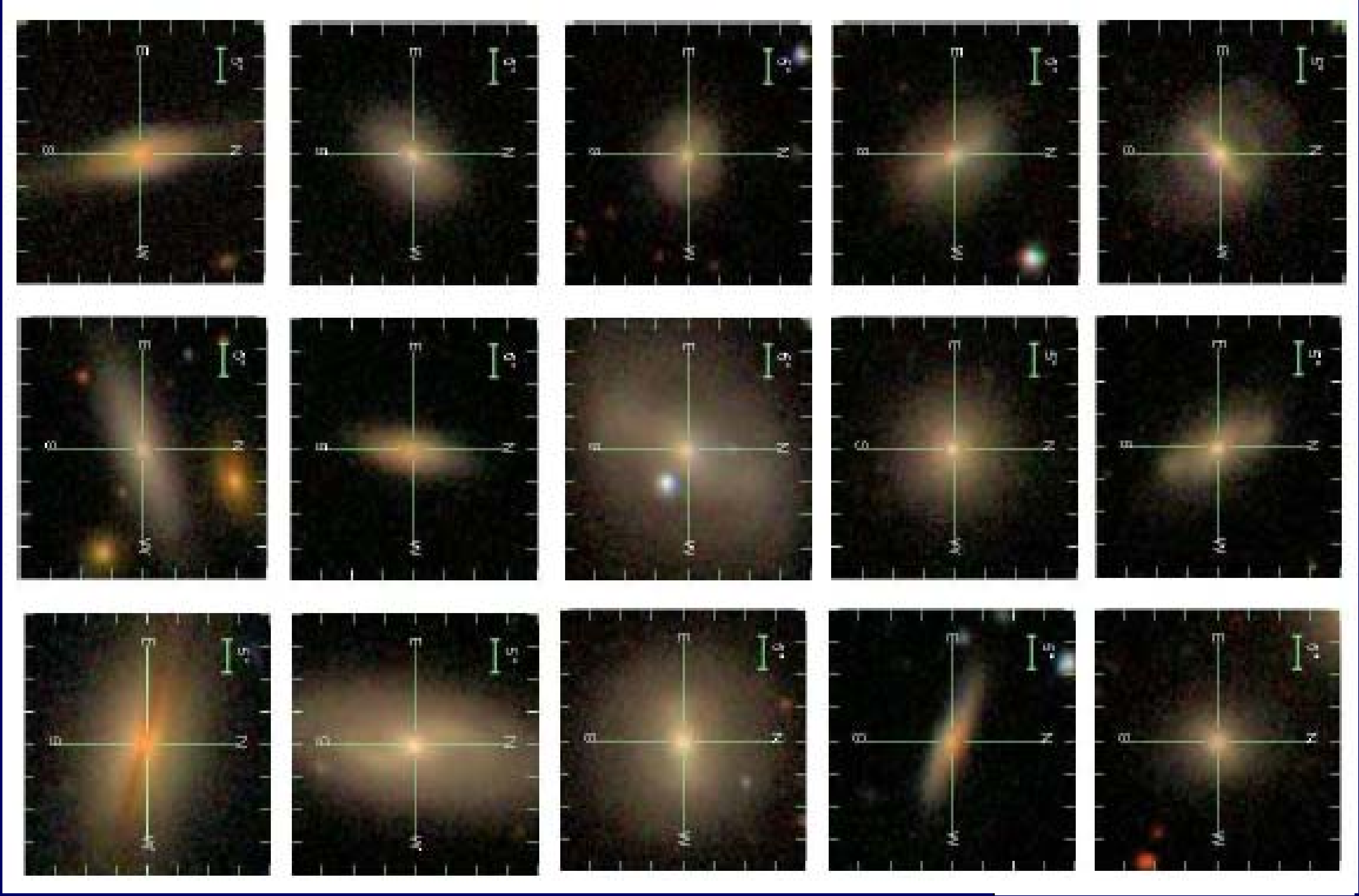
- Ability to separate effect on SFR of galaxy-galaxy interactions
  => remove from spiral galaxy sample all members of close pairs (within projected separation < 50/h kpc)

- Ability to separate effect of galaxy mass on SFR
  => search for shift in sSFR vs M_* relation at fixed M_* (requires a very precise determination of the relation)

- Ability to separate effect of morphology on SFR
  => use a pure sample of spiral galaxies unbiased in SFR

- Precise corrections for dust attenuation
  => use radiation transfer technique of Popescu et. al. (2011)
  constrained by measured angular sizes and inclinations of disks

Selecting Spiral Galaxies

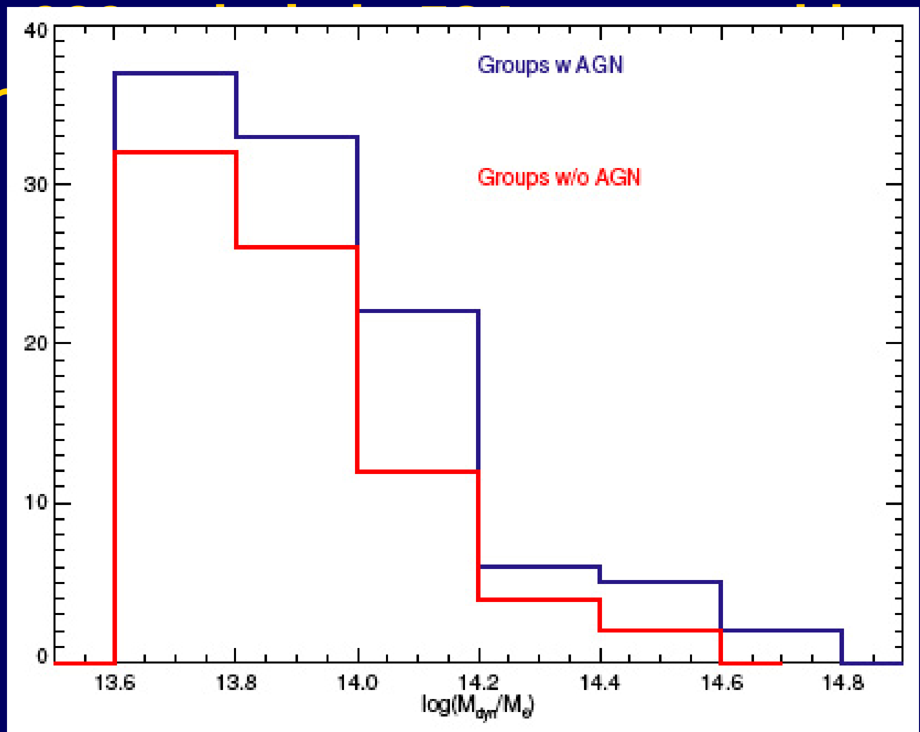


Random selection of red morphologically-selected spiral galaxies

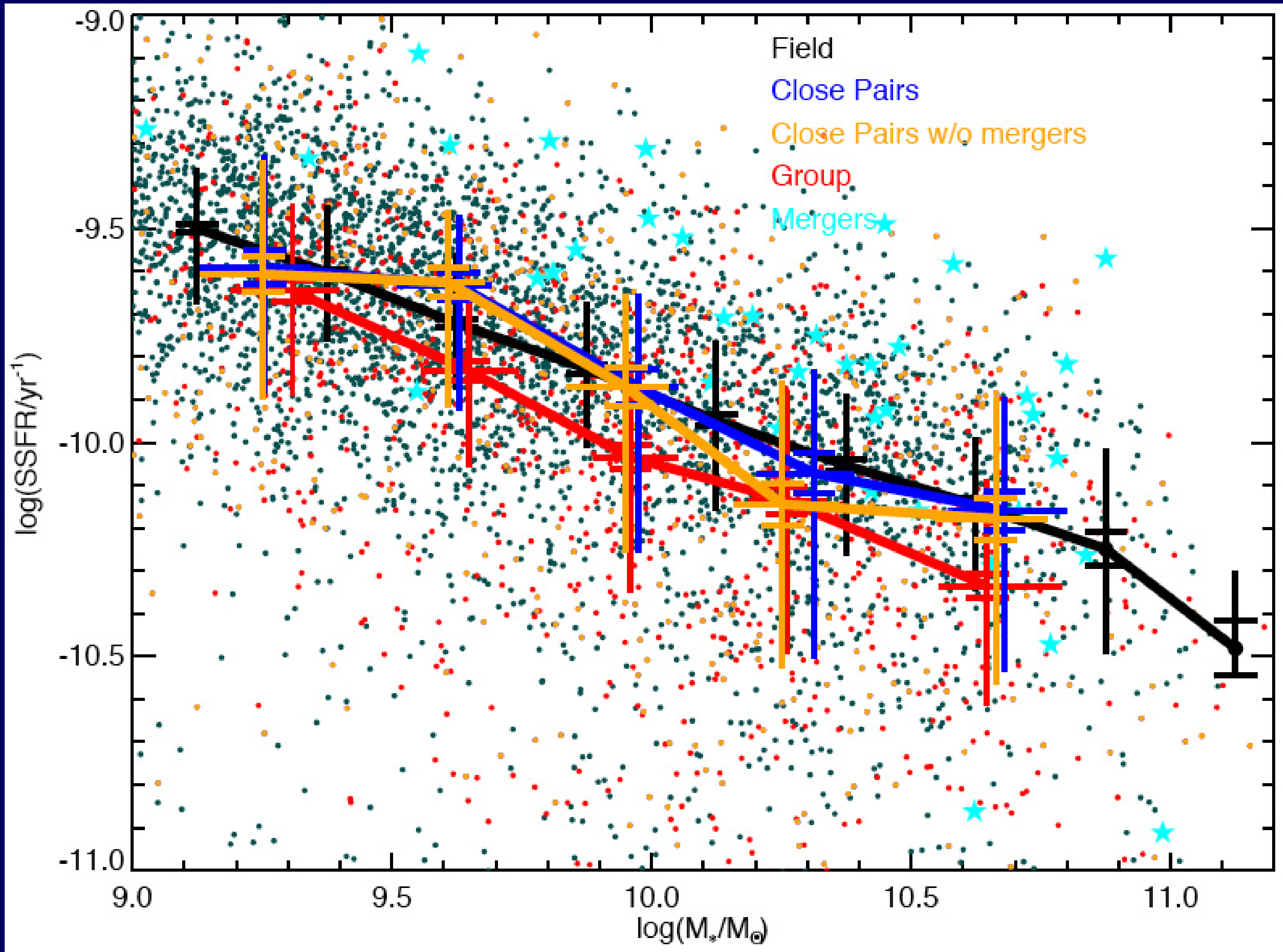
Summary of Galaxy Sample

- z < 0.13
- m_r > 19.4 => volume limited at M_* 10^9.5 M_sun
- projected separation from nearest neighbour >= 50/h kpc
- 98% pure spiral sample selected using log(n),log(r_e),M_i
- GALEX coverage at 2200A to 1500s depth => 300Myr time resolution
- galaxies hosting AGN not included

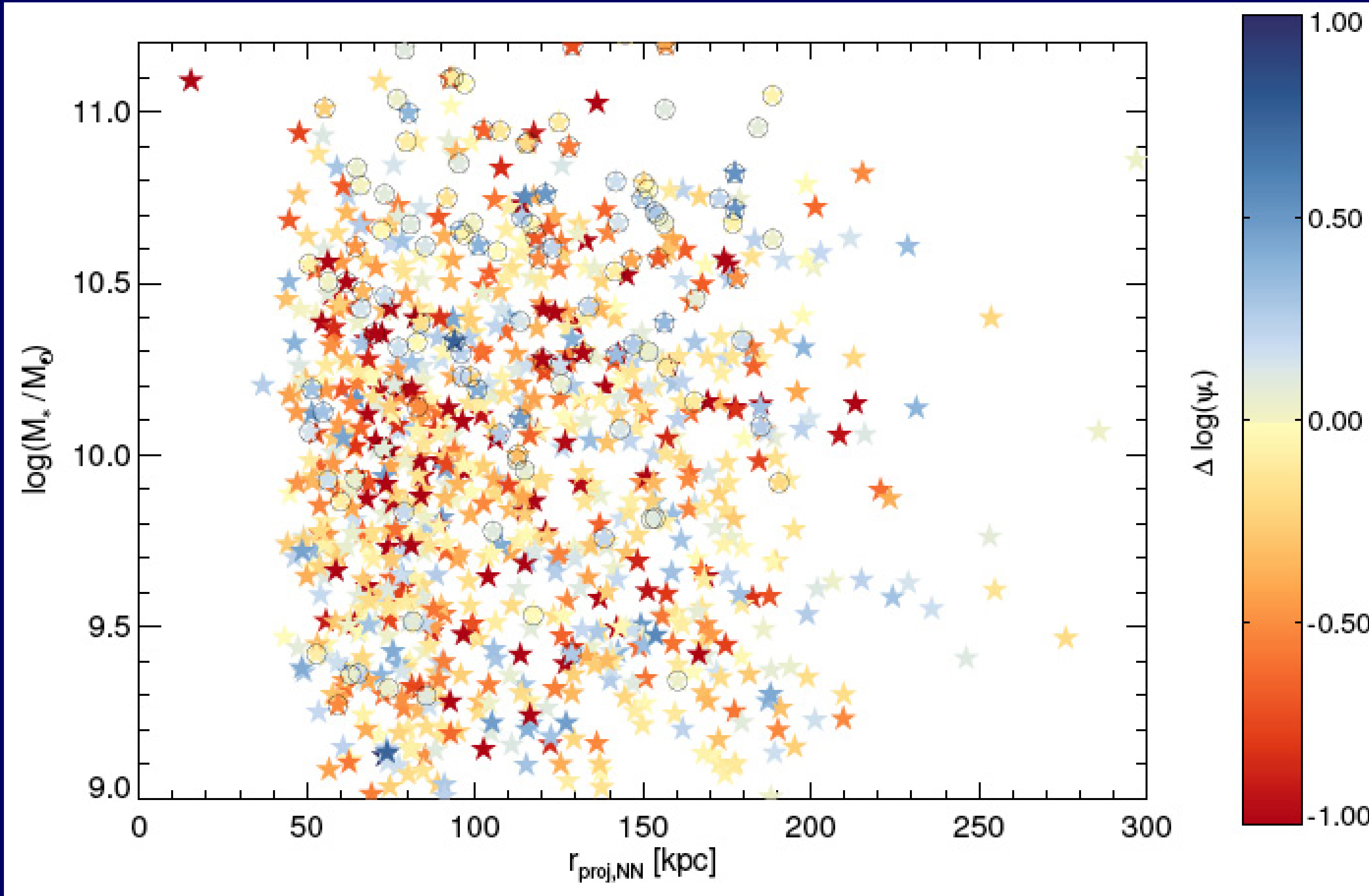
=> We isolate the galaxy - IGM interaction



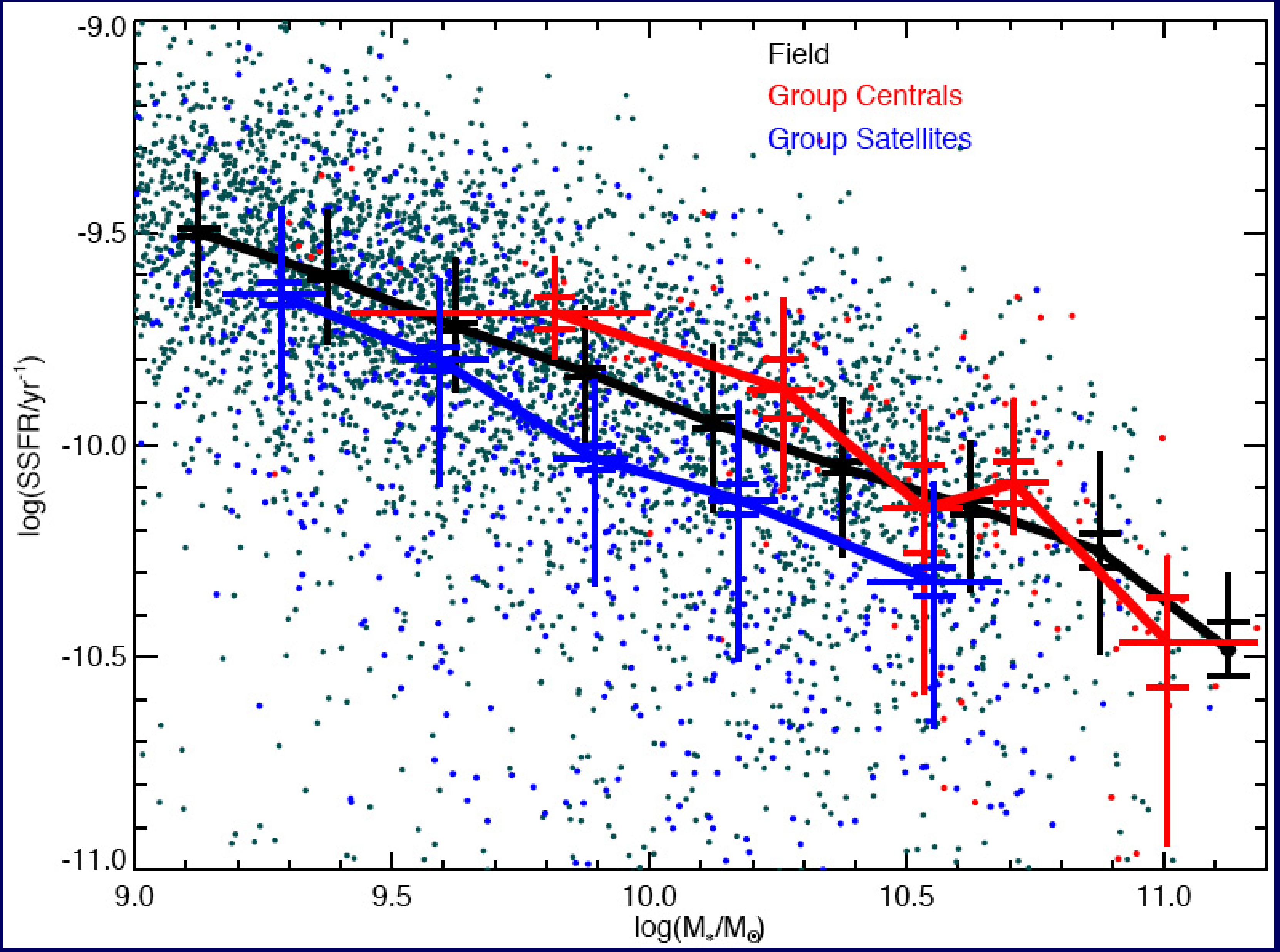
Influence of interactions and mergers on SFR in spirals



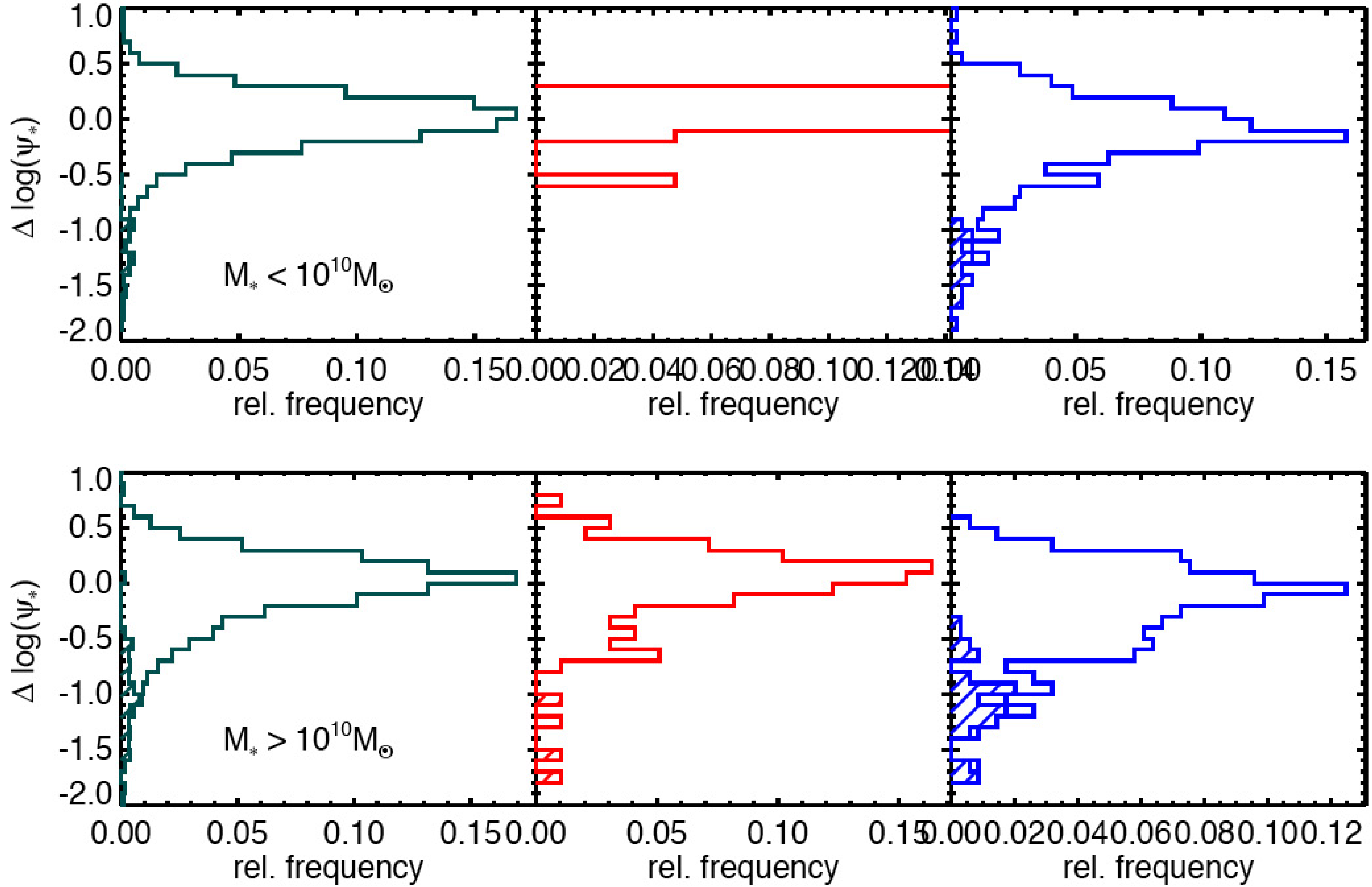
Dependence of sSFR on projected distance to nearest neighbour



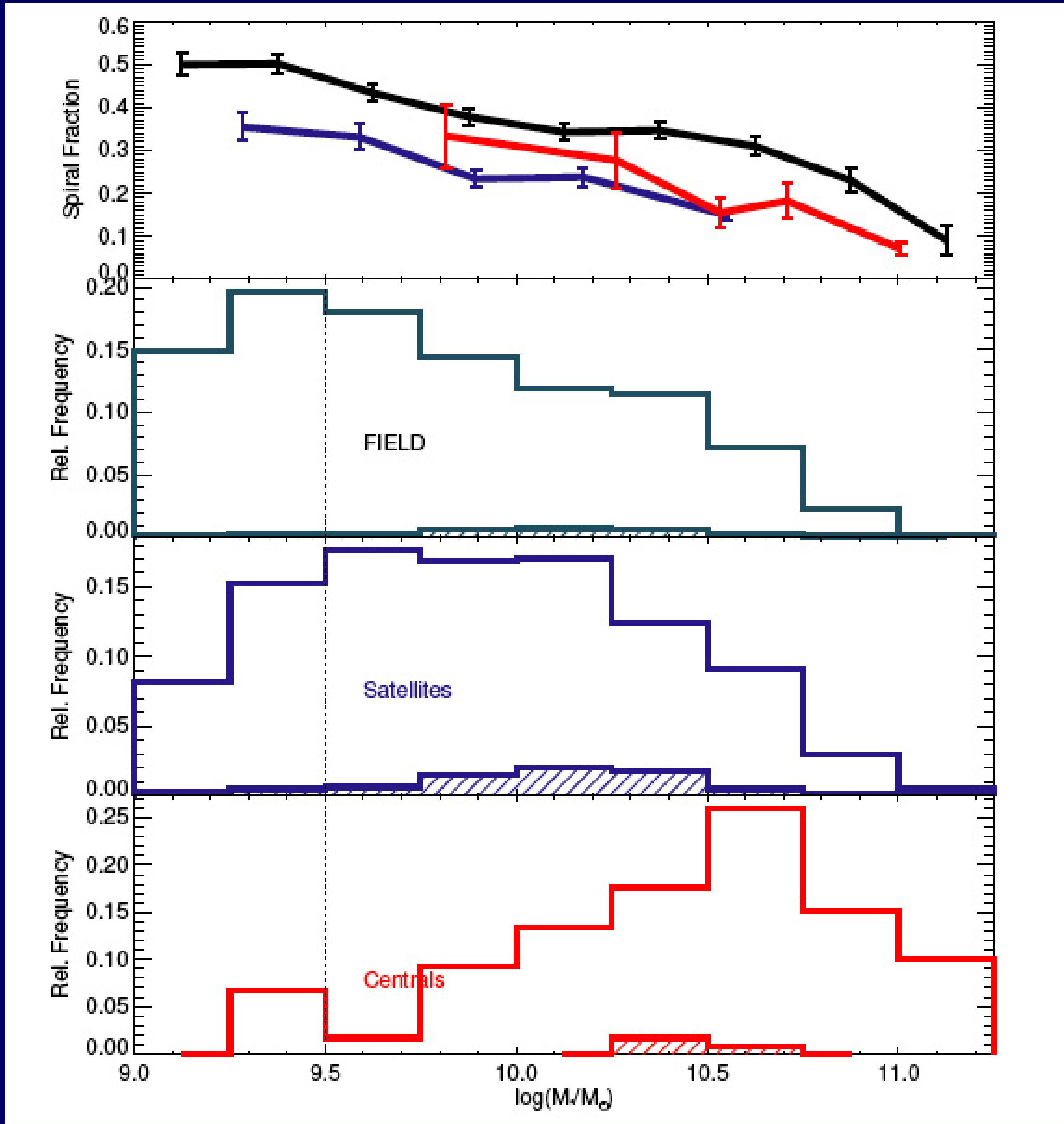
Group Centrals and Group Satellites



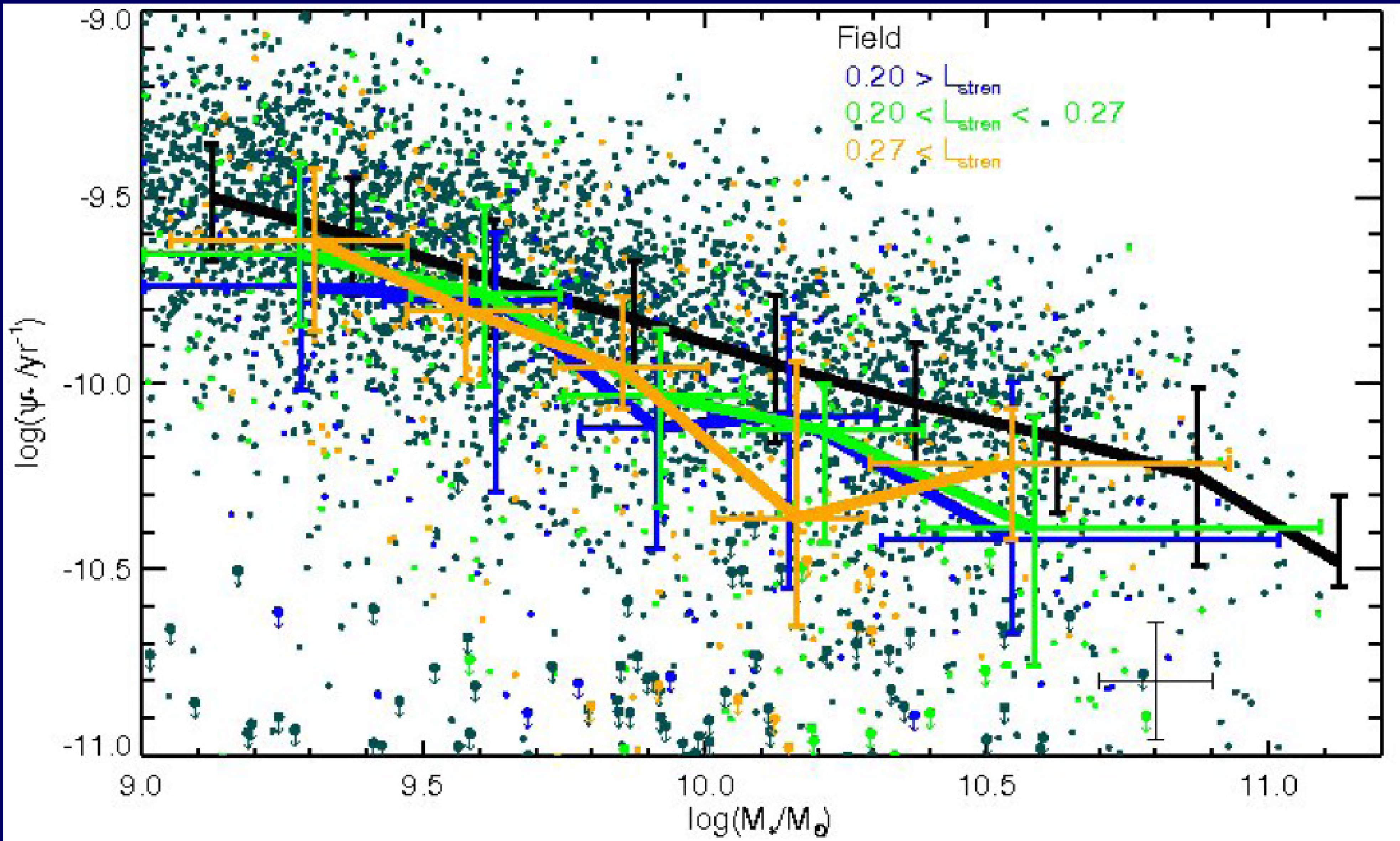
Group Centrals and Group Satellites



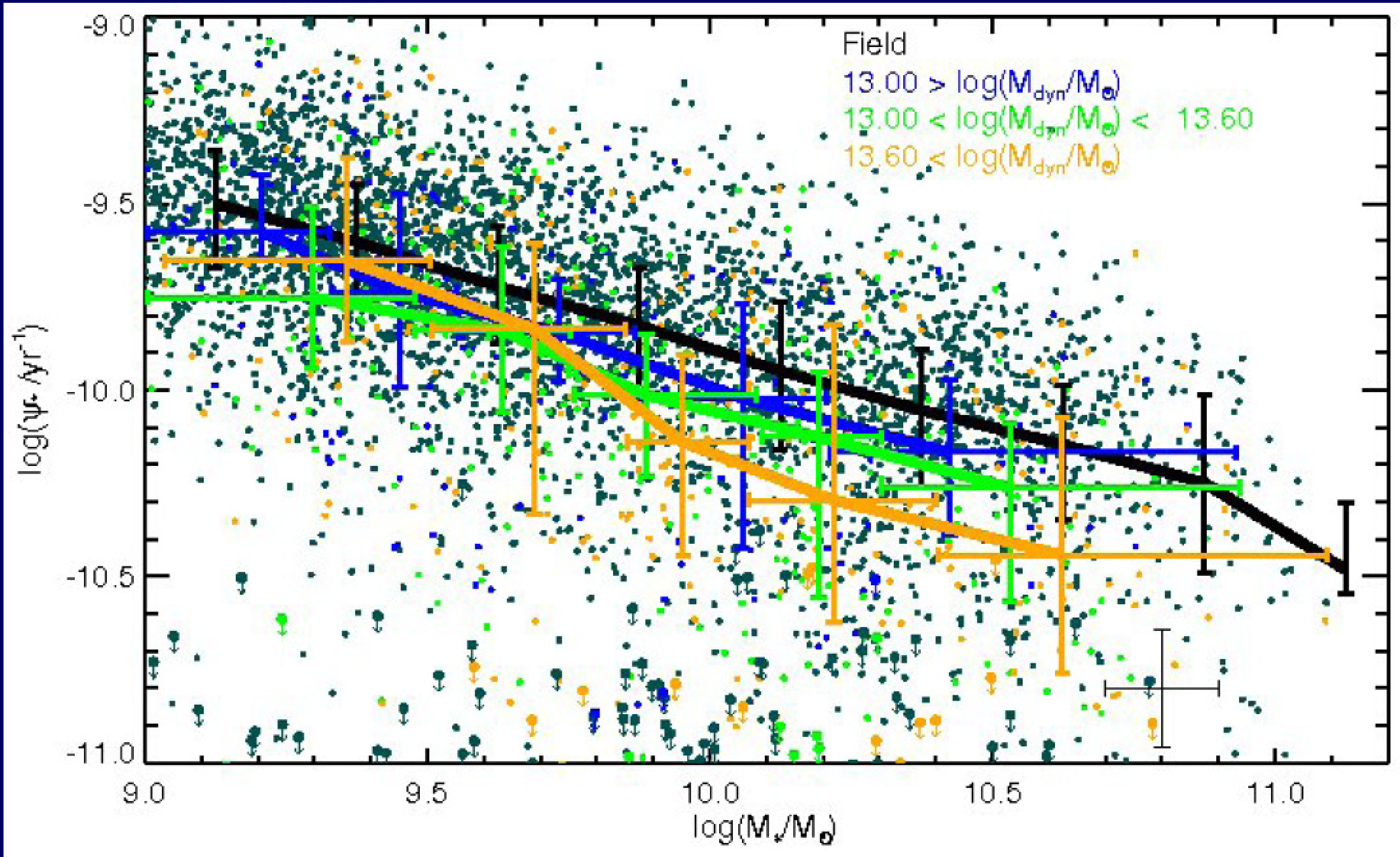
Group Centrals and Group Satellites



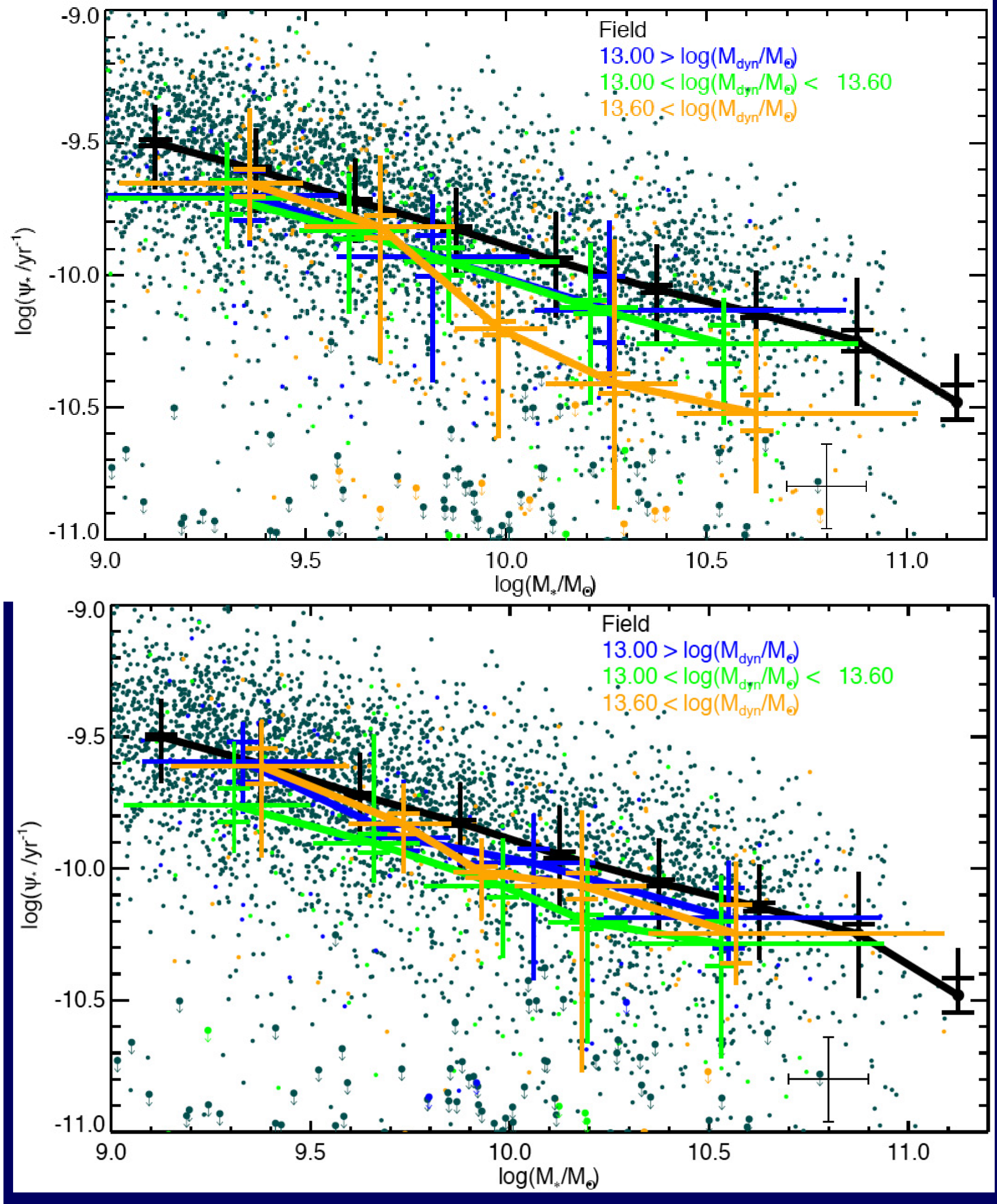
Satellite Spirals: dependence of sSFR on galaxy density



Satellite Spirals: dependence of sSFR on Group Mass



GAMA Satellite Spirals: dependence of SFR on presence of AGN



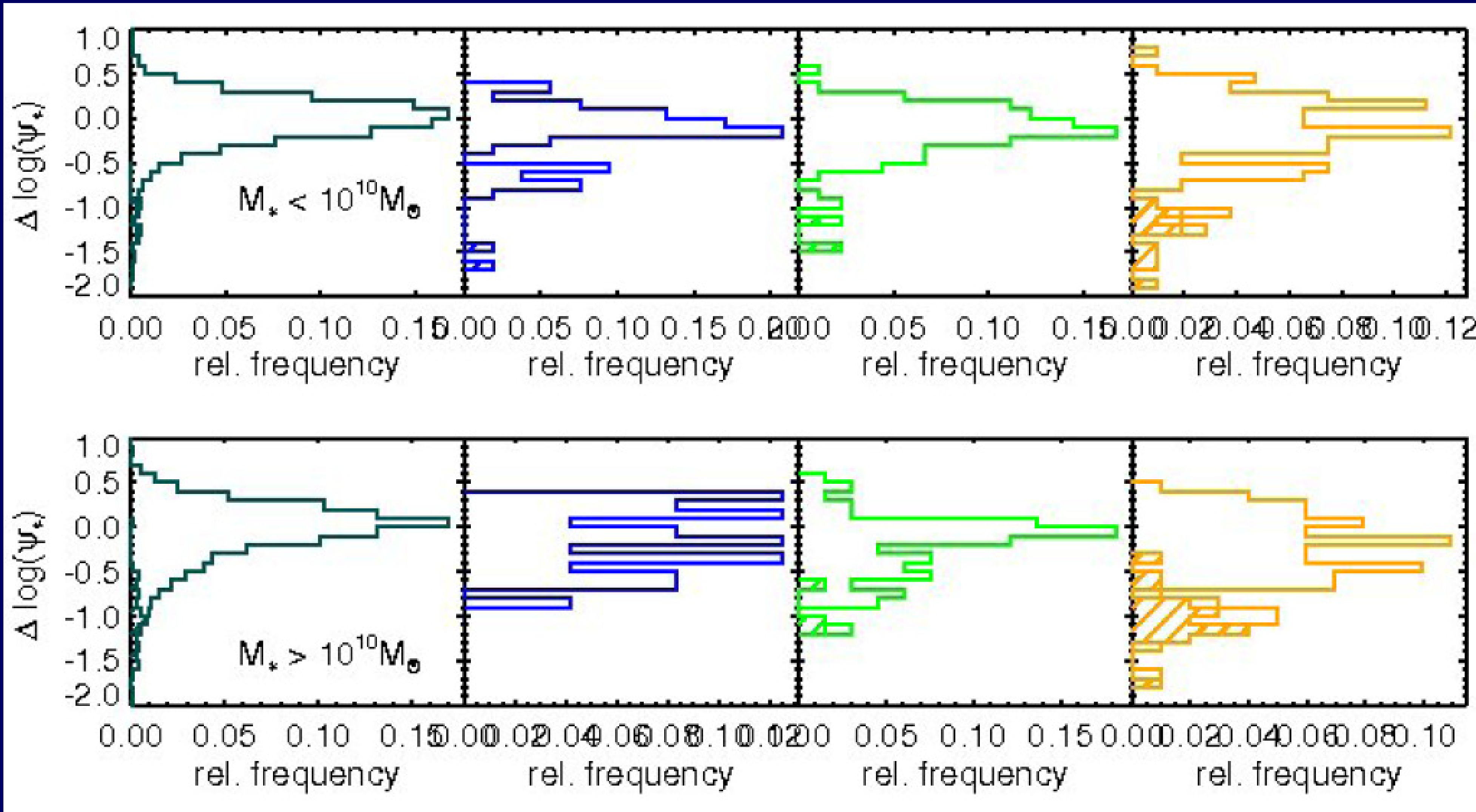
Upper panel:
spirals in groups containing an (optically identified) AGN in another galaxy

Lower panel:
non-AGN host spirals in groups without an AGN

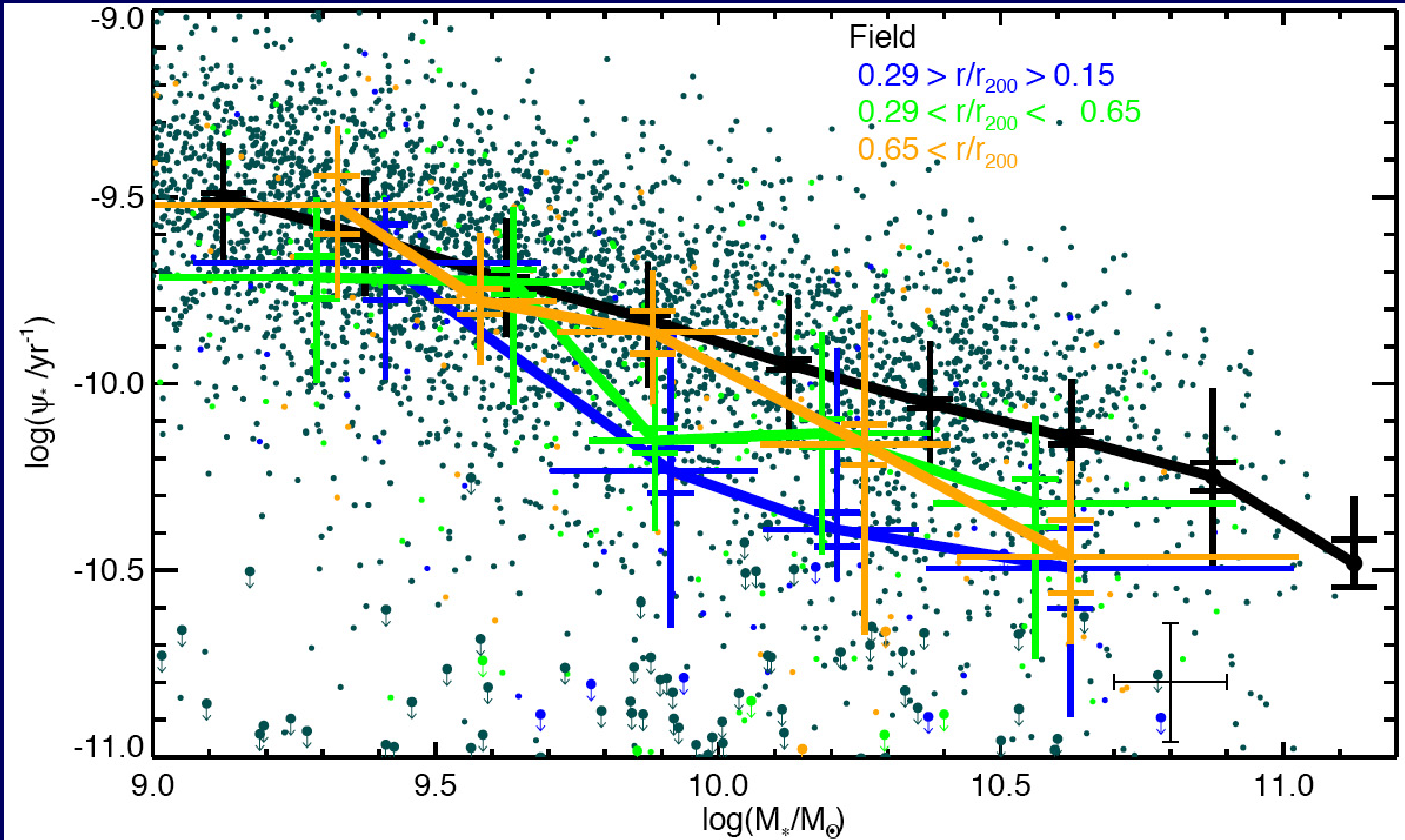
(each panel shows sSFR vs M* for morphologically pure sub-samples of spiral galaxies, inhabiting groups in three ranges of dynamical mass. The spirals are not themselves AGN hosts, and are volume-limited at z<0.13 for log(M*/M_solar) > 9.5)

Grootes et al. (2013)

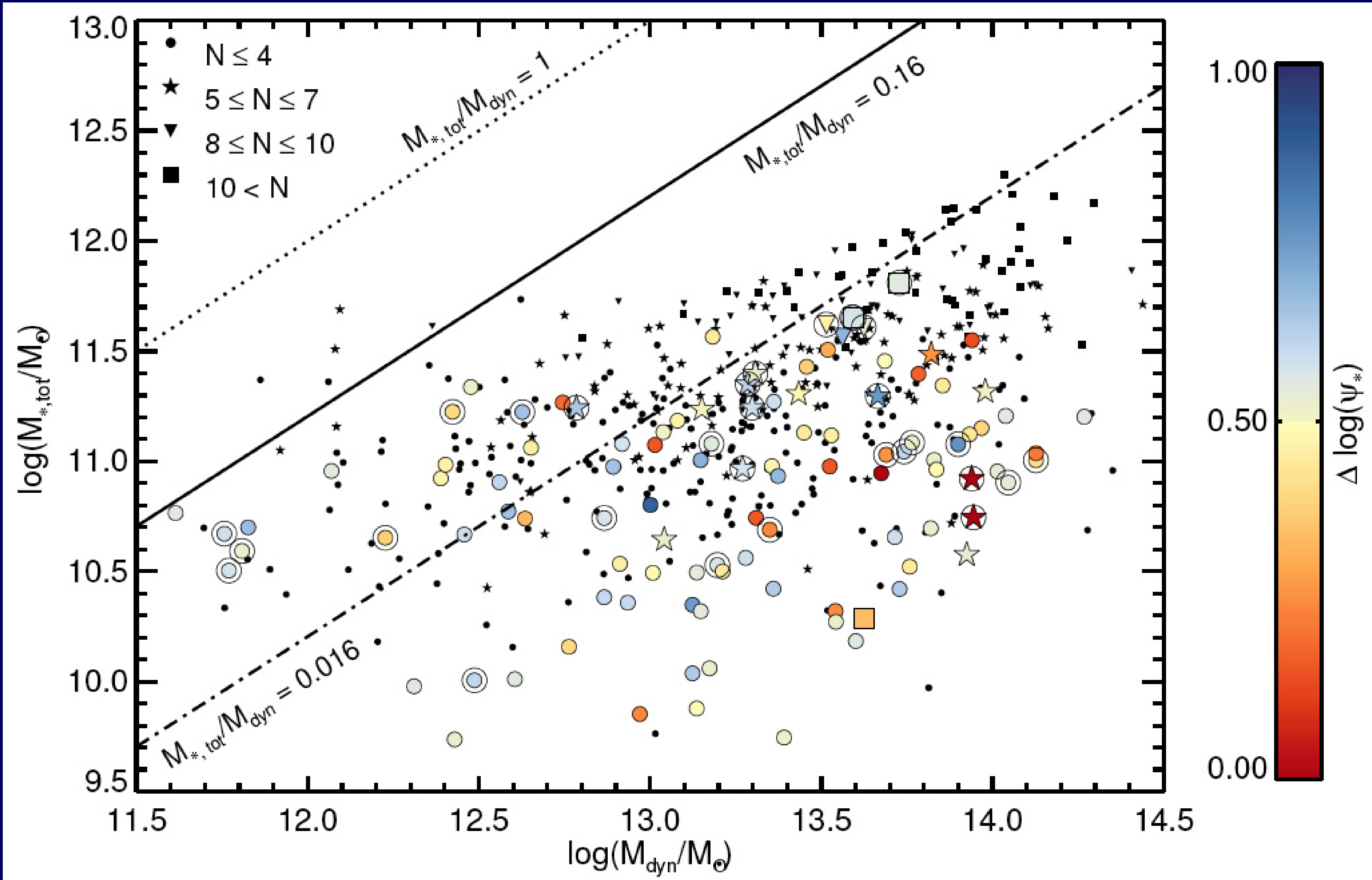
Satellite spirals in groups with an AGN



Satellite spirals in groups with an AGN



GAMA Groups with z < 0.13



Summary and Implications

(I) The large majority of satellite spiral galaxies in groups form stars at the same rate as their counterparts (by mass) in the field. This applies to all galaxy masses and all group masses.

This will require ongoing accretion from the IGM in the group, implying the presence of cold gas in the group IGM and/or a cooling mechanism:.

- if available flow of cold gas depends on halo mass, SFR will be self regulated.

- the specific angular momentum of the stars in satellite spirals should fall as the stellar mass builds up in the cluster, providing a mechanism for morphology transformation

(2) There is evidence for a mild enhancement of SSFR of central spirals in groups compared to field spirals of comparable stellar mass

(3) The lack of environmental dependence of SFR of satellite spirals is only broken when an AGN is present in *another* galaxy (either spiral or spheroidal type) in the group. The distribution in sSFR then becomes bimodal. However this bimodality is only seen for satellites in massive (log(Mdyn / Msun) > 13.6) groups, and is only seen for more massive spirals (log(M* / Msun) > 10.0).

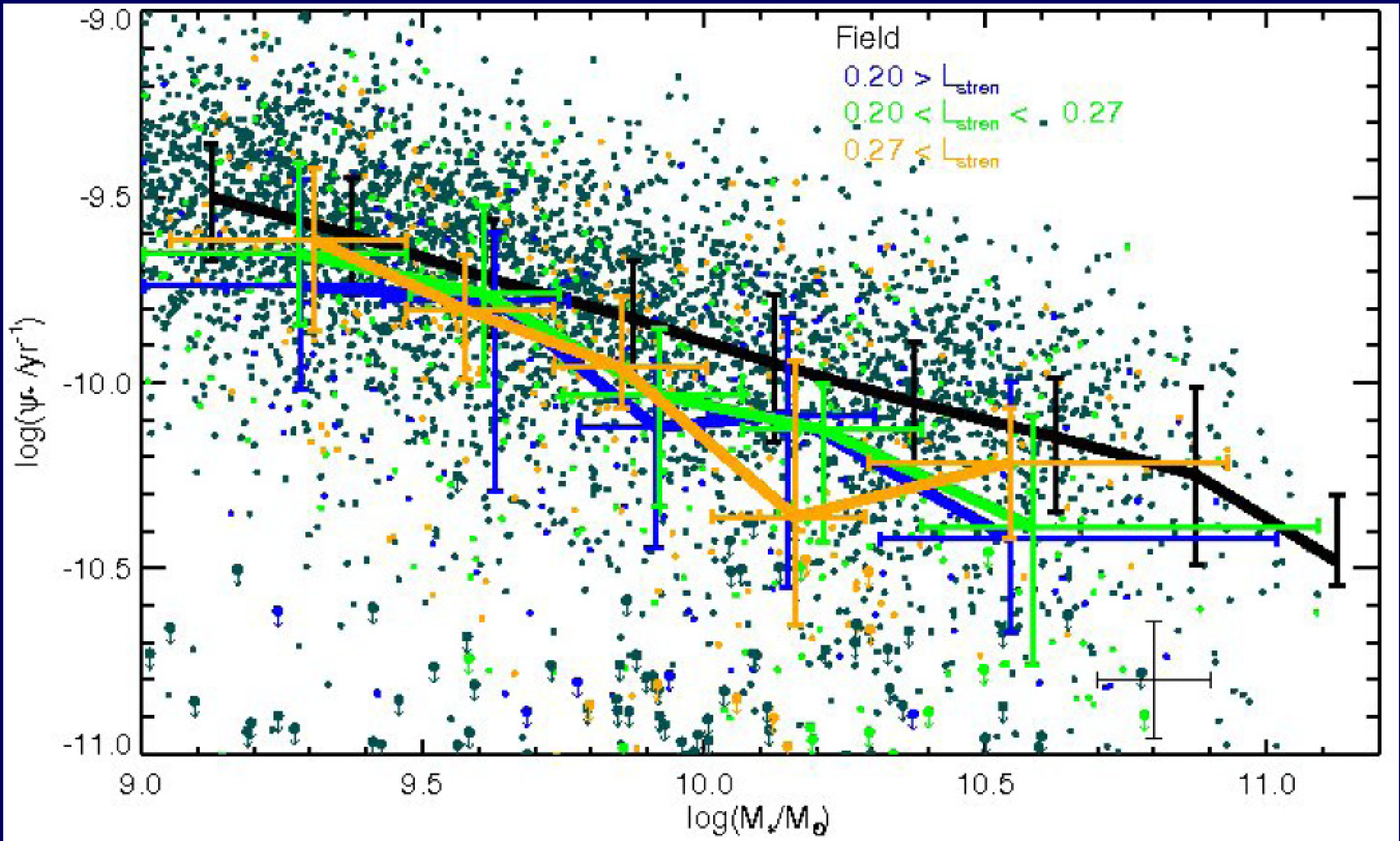
This appears to constitute a new path for AGN feedback and mass quenching of spirals in groups.

- A possible mechanism is the periodic pressurising and puffing up of the IGM through AGN activity on one galaxy, triggered by a galaxy-galaxy interaction in the central regions of a group, followed by a rapid stripping of gas from satellite satellites as they traverse pass the puffed up gas

Open Questions

- What mechanism brings cold gas into satellites in massive groups?

- If self regulation of SFR applies, why is SFR independent of with environment, yet (apparently) changes with epoch?



Field
0.20 > Lstren
0.20 < Lstren < 0.27
0.27 < Lstren
-9.0
-9.5
-10.0
-10.5
-11.0
log(ψ* /yr-1)
9.0
9.5
10.0
10.5
11.0
log(M*/M⊙)

GAMA as an empirical reference

Assume steady state gas flow in which SFR depends only on galaxian property M_*

$$\frac{1}{\tau_{\rm accrete}} = \frac{1}{\tau_{\rm exhaust}} + \frac{1}{\tau_{\rm remove}}$$

$$\tau_{\rm accrete} = M_{\rm ISM}/\dot{M}_{accrete}$$

$$\tau_{\rm remove} = M_{\rm ISM}/\dot{M}_{remove}$$

$$\tau_{\rm exhaust} = M_{\rm ISM}/SFR$$

Selecting Spiral Galaxies

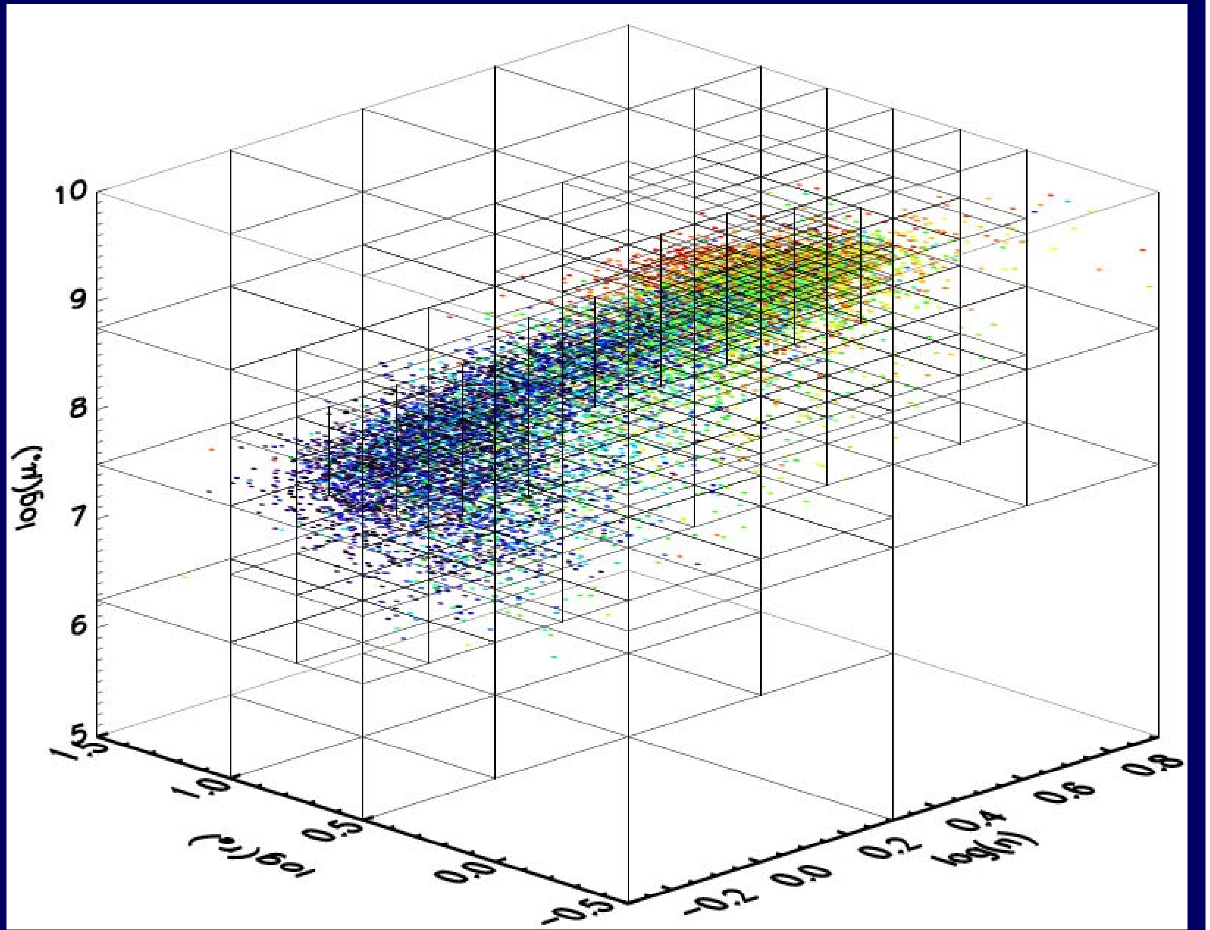
- non-parametric cell-based photometry proxy for morphology, trained on Galaxy Zoo classifications

- Adaptively discretizes parameter space and defines subvolume linked to spirals

- Considers selection based on any set of parameters, including parameters NOT linked to SFR

- excellent performance for parameter space defined by $(\log(n), \log(r_e), M_i)$ (2% impurity from E/S0, 77% completeness of GZ spirals)

- Tested using independently classified samples and Independent observables



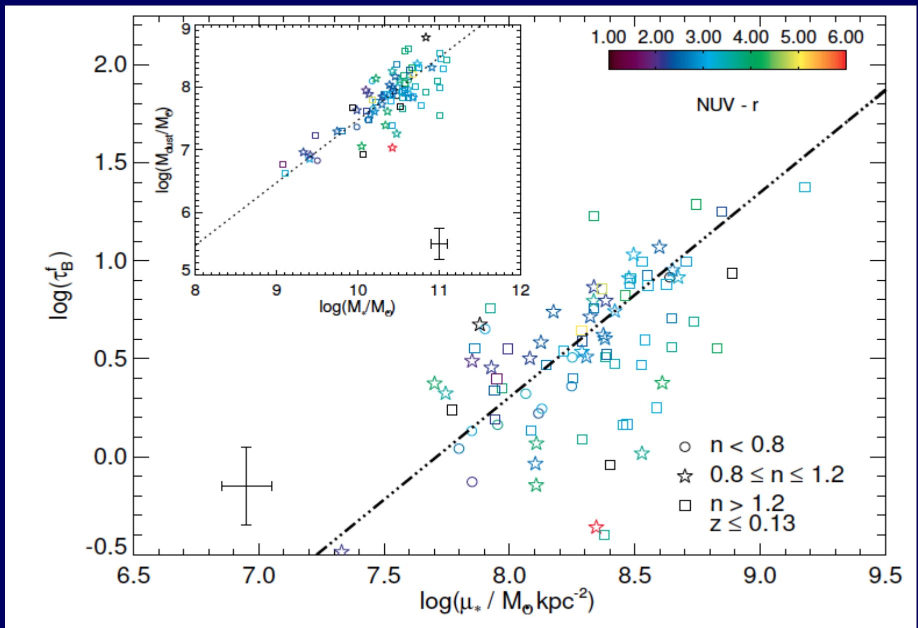
Grootes et al. 2013b

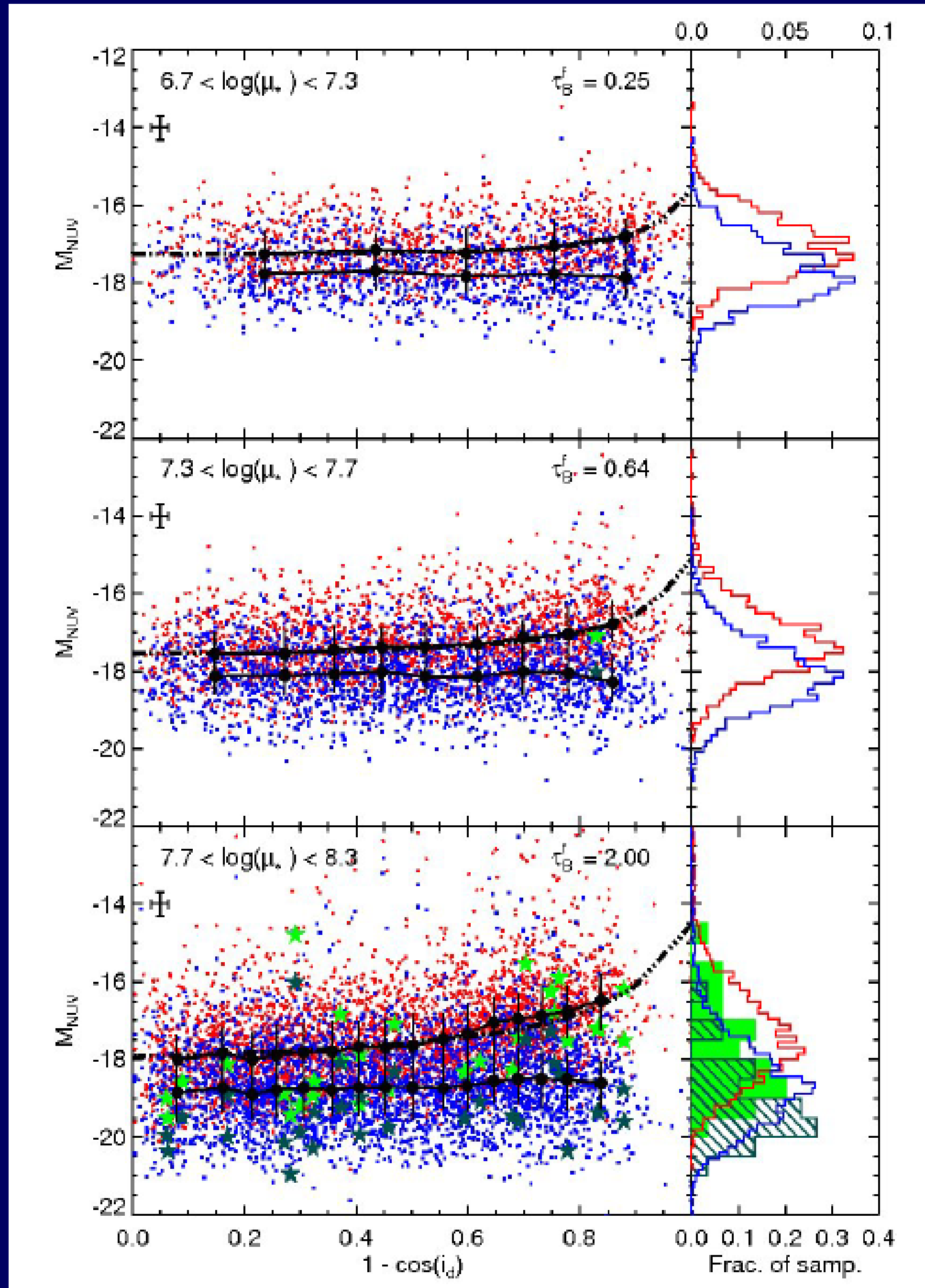
Correcting for attenuation by dust

- NUV heavily affected by attenuation (~2 mag, of which ~1mag due to orientation)

- Use Radiation Transfer Modeling technique of Popescu et al. (2011) constrained by measured angular sizes and b/a ratios in optical bands.

- disk opacity measured from optical parameters using opacity - stellar mass surface density relation of Grootes et al. 2013a ApJ 766, 59





Grootes et al. 2013a