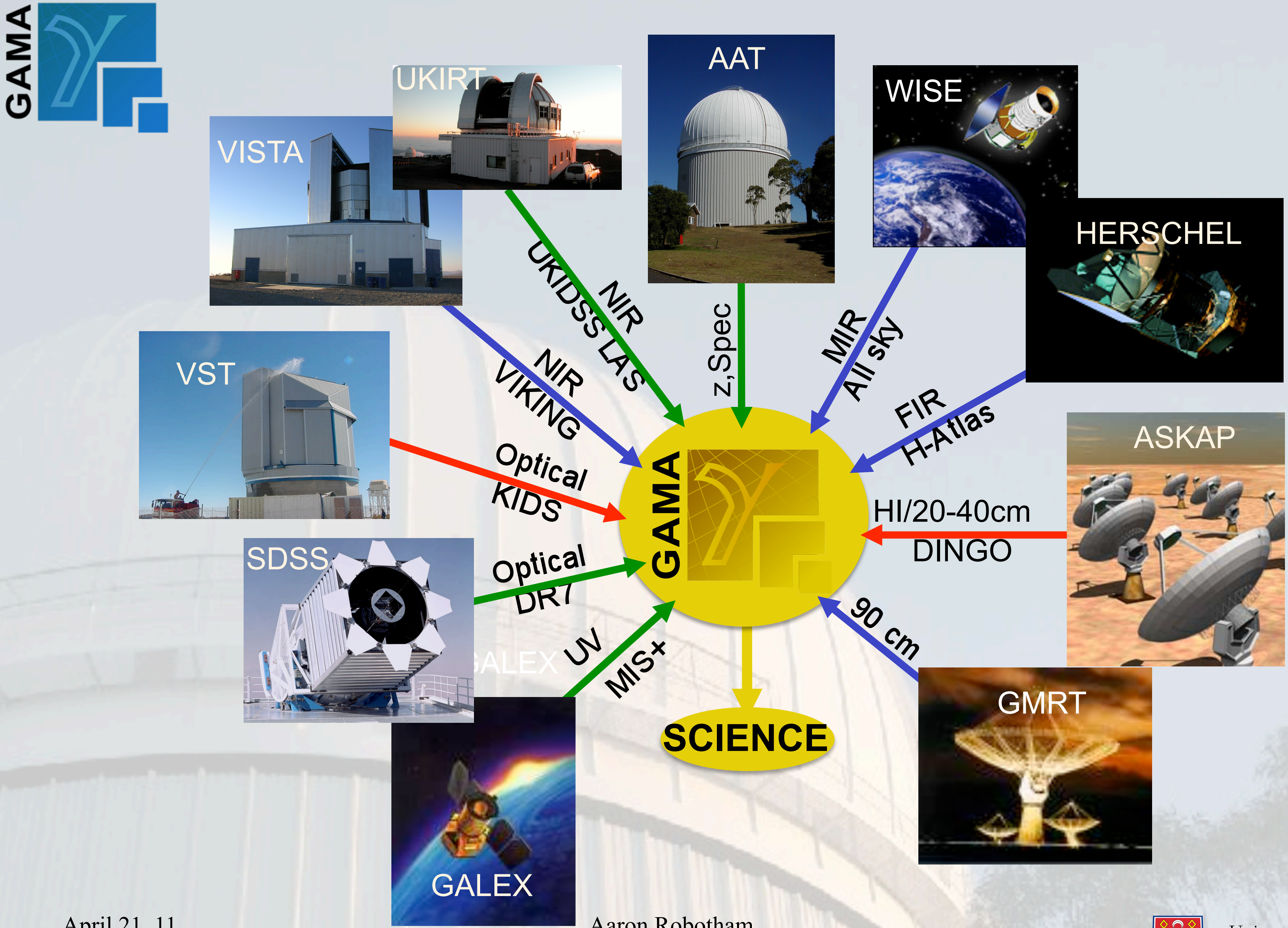
The GAMA Multi-Wavelength Survey: The Stellar-Mass Halo-Mass Paradigm

Aaron Robotham
University of St Andrews
&
The GAMA Team

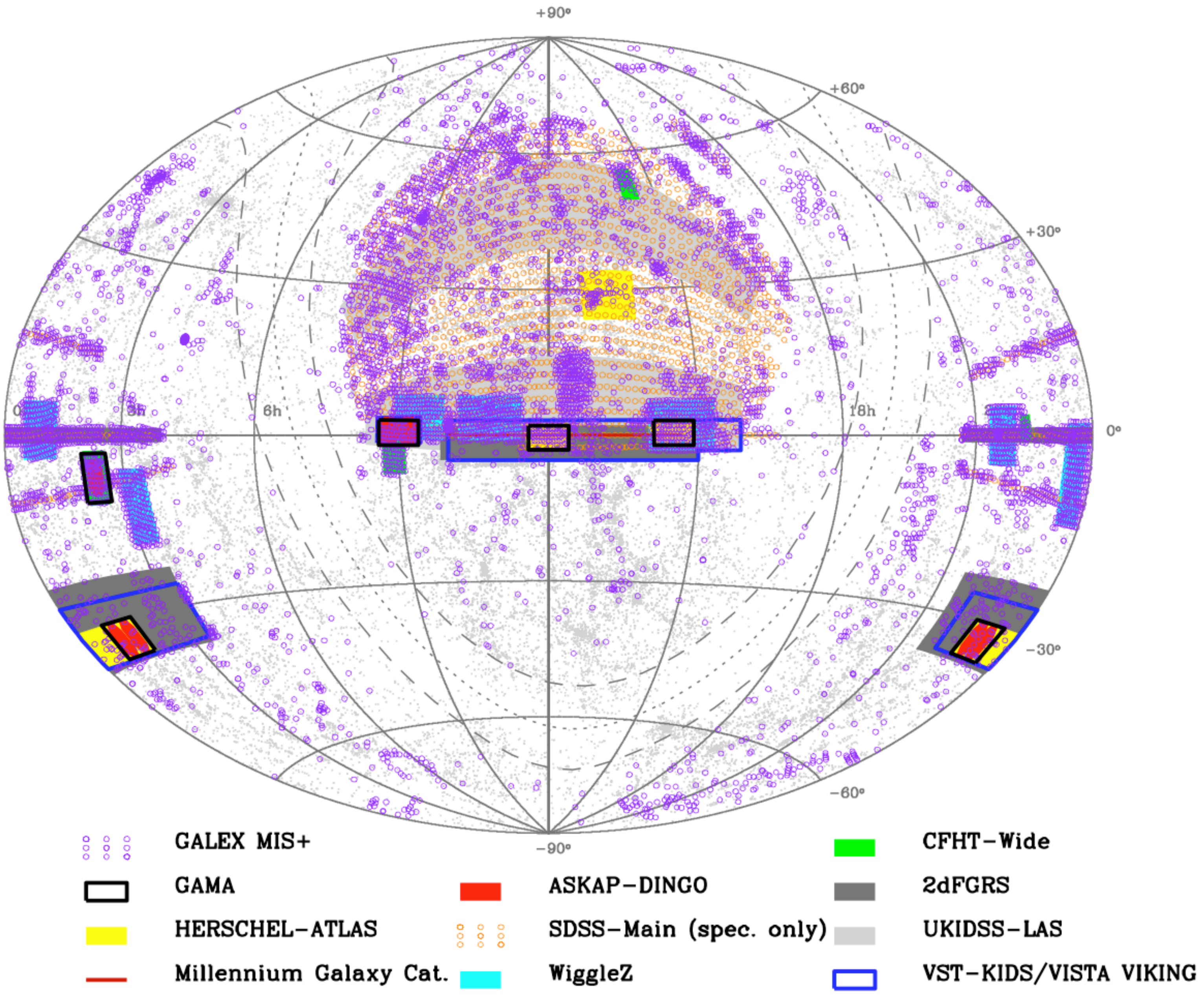
The GAMA Team

GAMA I (II) Outline

- An r-band selected redshift survey:
  - Three (Six) regions each ~ 4x12 deg (5x12 deg)
  - ~1000 targets per sq deg (2dFGRS~120, SDSS~70) ~8 tiles per unit area
  - Testing CDM via HMF, merger rates, and SFE
  - Total allocation 66 (178) nights
- A multi-wavelength study of galaxies:
  - FUV,NUV,ugrizYJHK,mid-IR,far-IR,20cm,21cm,1m (AGN, stars, gas, dust)
  - 1kpc resolution in ugrizYJHK to z<0.1 (structural analysis)
  - Robust halo masses (internal/external environmental markers)
  - Estimated data value A$55 million
- GAMA Team now includes >50 scientist across >30 institutions.

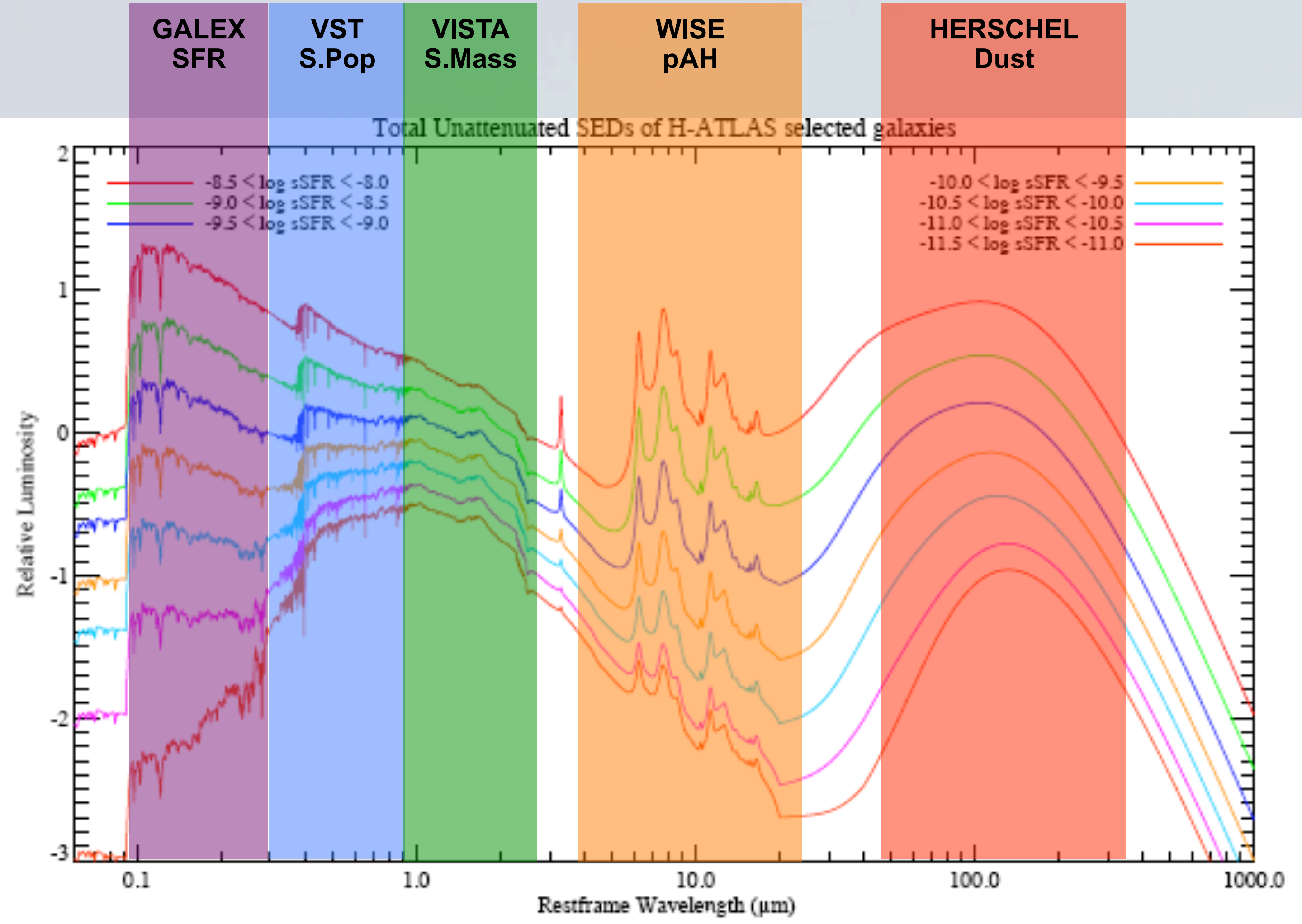


GAMA
UKIRT
VISTA
AAT
WISE
HERSCHEL
VST
ASKAP
SDSS
GMRT
GALEX
NIR
UKIDSS LAS
NIR
VIKING
z,Spec
MIR
All sky
FIR
H-Atlas
Optical
KIDS
HI/20-40cm
DINGO
Optical
DR7
GALEX UV
MIS+
90 cm
GAMA
SCIENCE



+90°
+60°
+30°
0°
-30°
-60°
-90°
6h
18h
GALEX MIS+
GAMA
HERSCHEL-ATLAS
Millennium Galaxy Cat.
ASKAP-DINGO
SDSS-Main (spec. only)
WiggleZ
CFHT-Wide
2dFGRS
UKIDSS-LAS
VST-KIDS/VISTA VIKING

Why do we need all this photometry?



Smith et al (2011)

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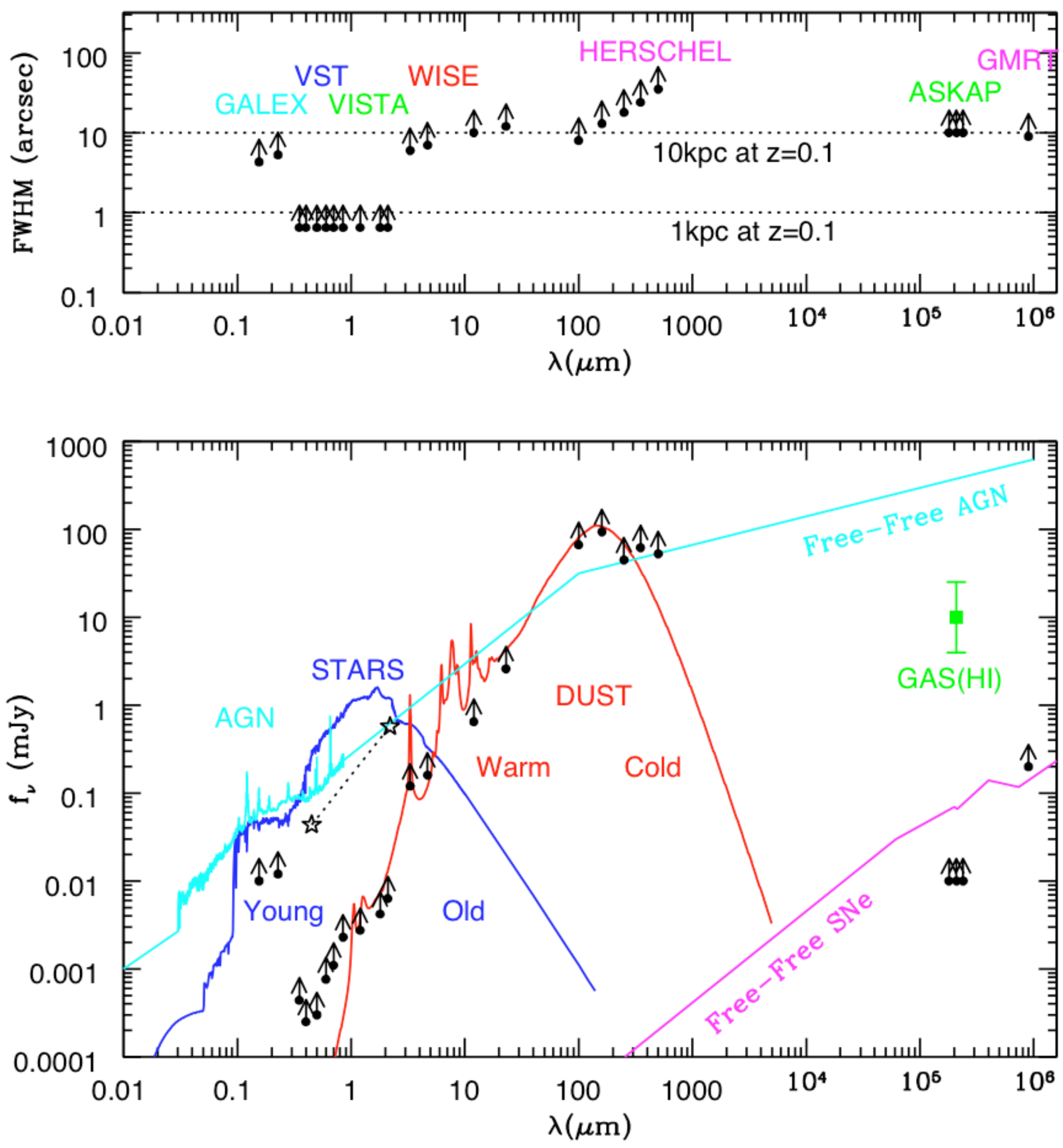
- GAMA surveys will be extremely complimentary in terms of depth.
- Large variation in term of PSF size.
- Optical-NIR have matched aperture Sextractor photometry using seeing convolved mosaics.
- Bigger task is combining GALEX (Ellen Andrae)/ H-ATLAS (Nathan Bourne) and in the future ASKAP…



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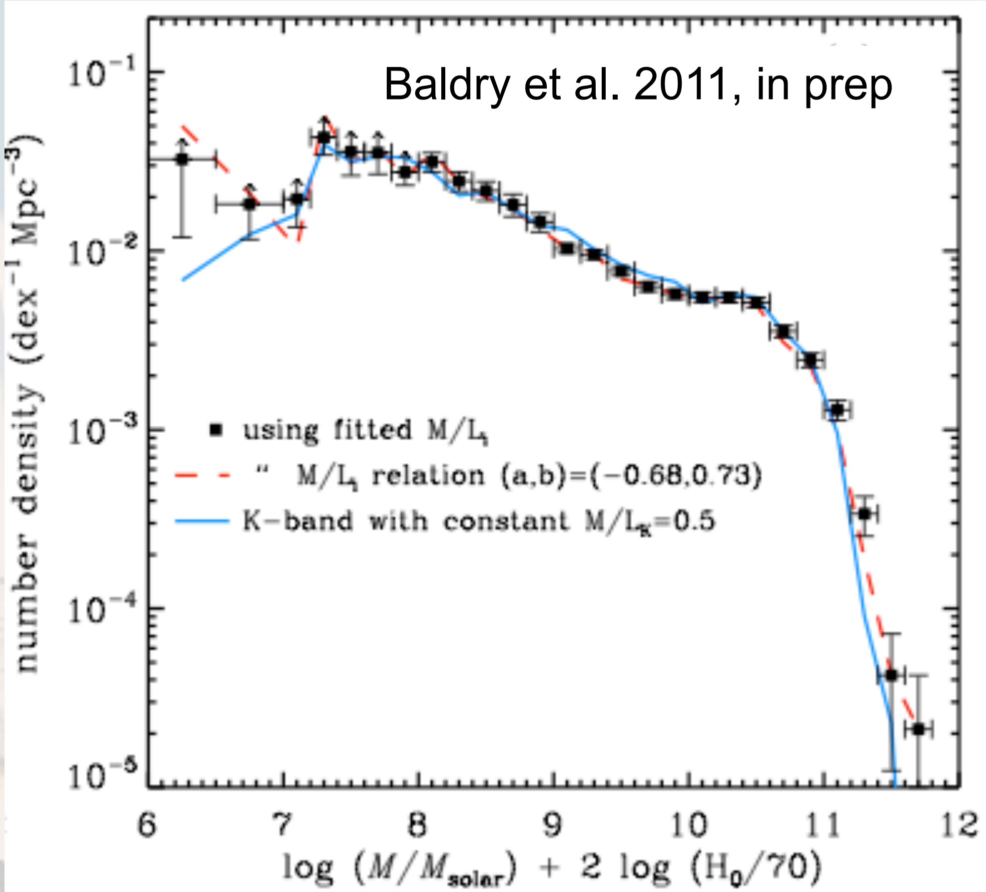
This range of photometry gives GAMA high fidelity stellar mass

- Ned Taylor has produced stellar masses for GAMA using a vast library of SEDs combining UV – optical – IR data (2011, MNRAS in prep).

- Currently have issues with optical to IR match, but work is ongoing to resolve this.

- Stellar masses have been used to create the GAMA GSMF (Baldry 2011, in prep).

- For the first time we see the GSMF upturn with K-band data!



Why do we need all this spectroscopy?

Photo-z versus spectro-z

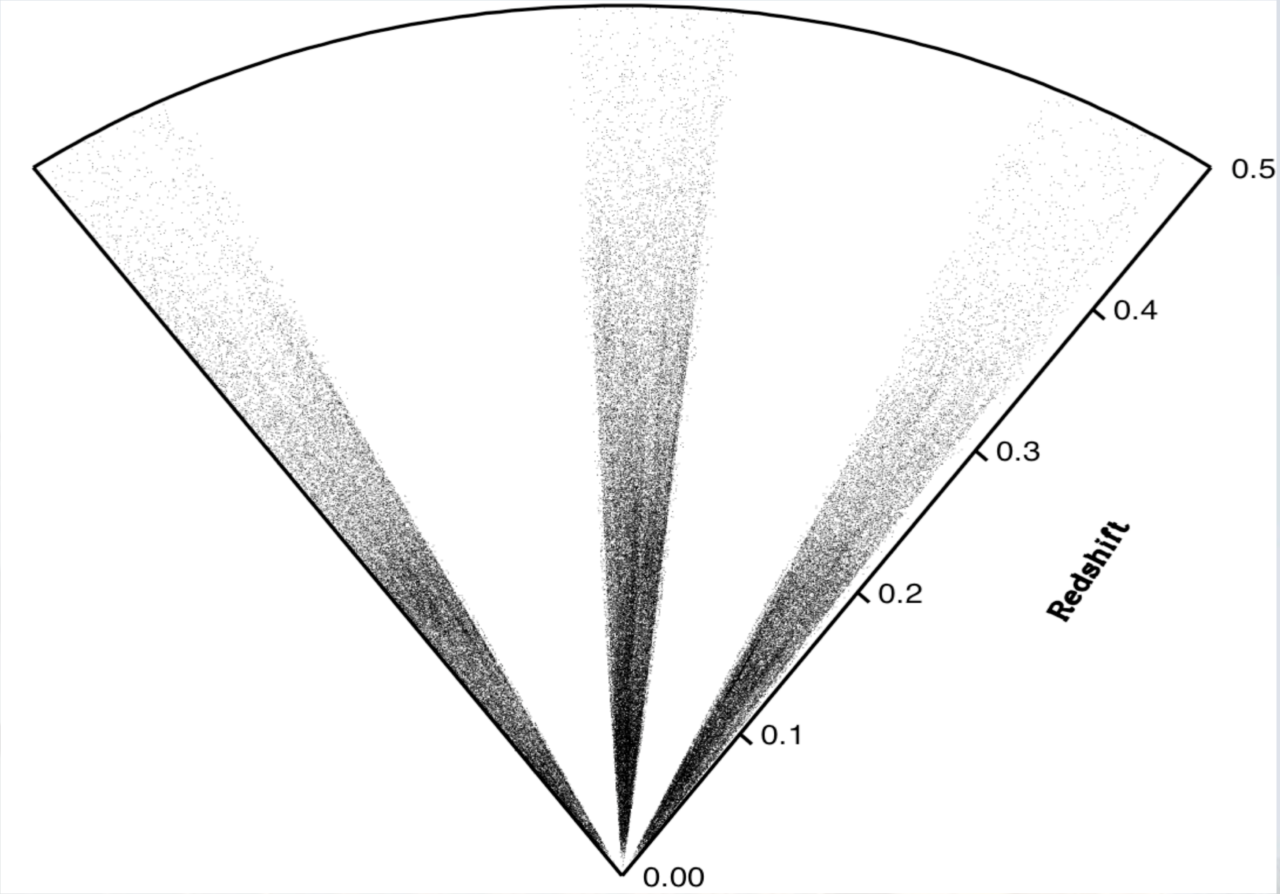


Photo-z credit:
Hannah Parkinson

Why do we need all this spectroscopy?

Photo-z versus spectro-z

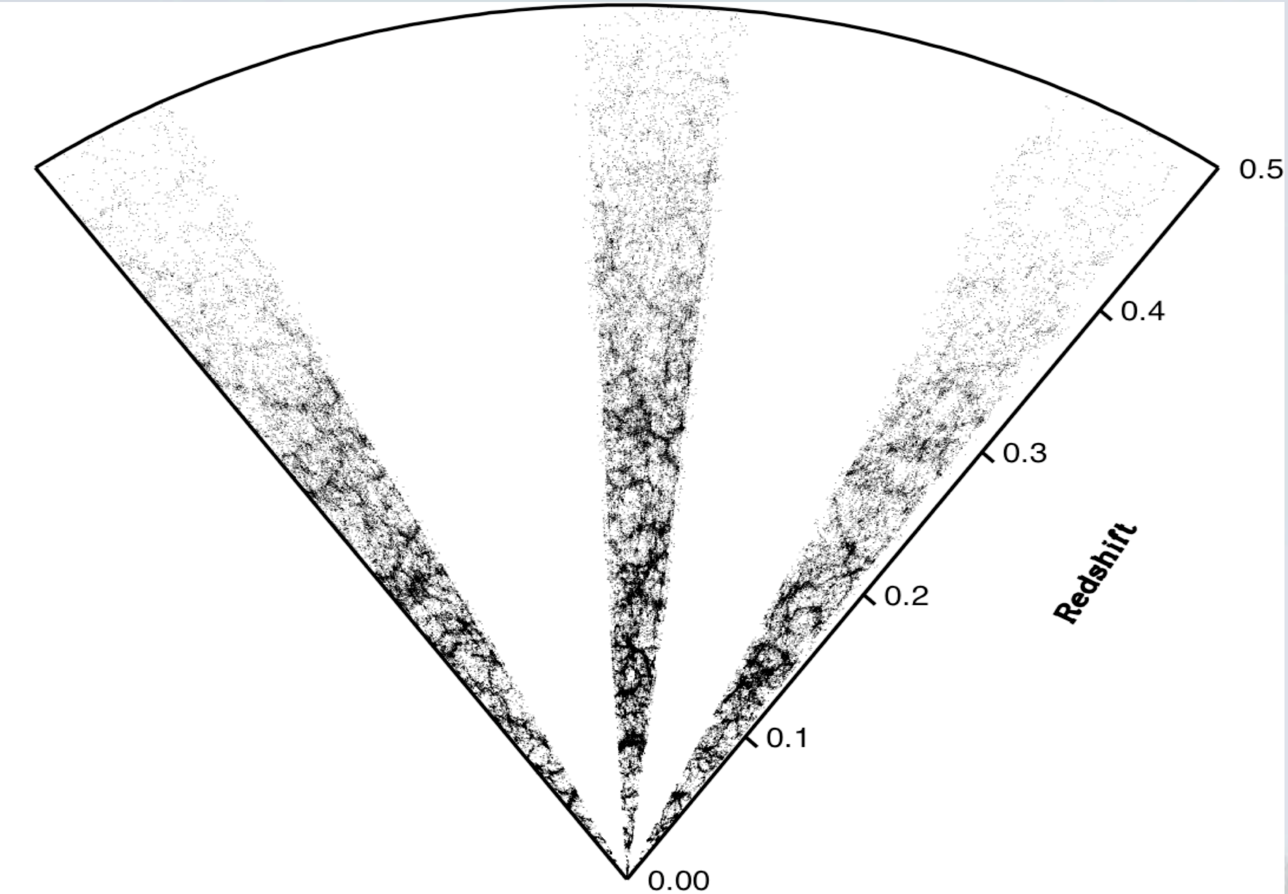
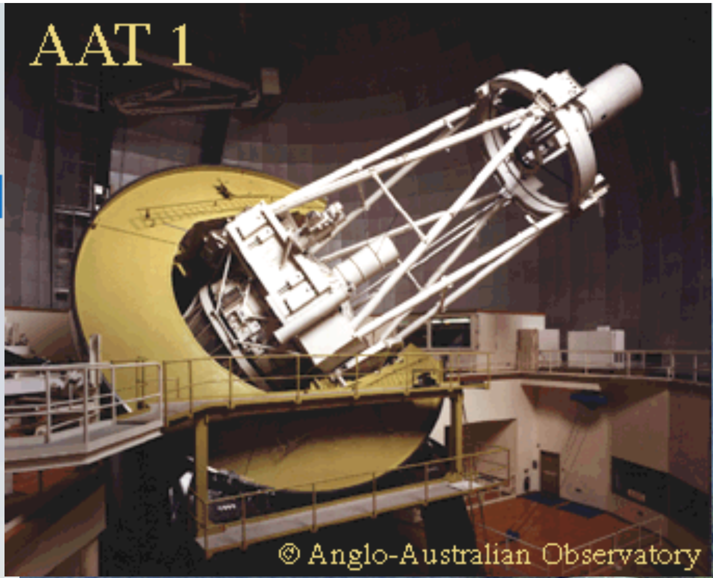
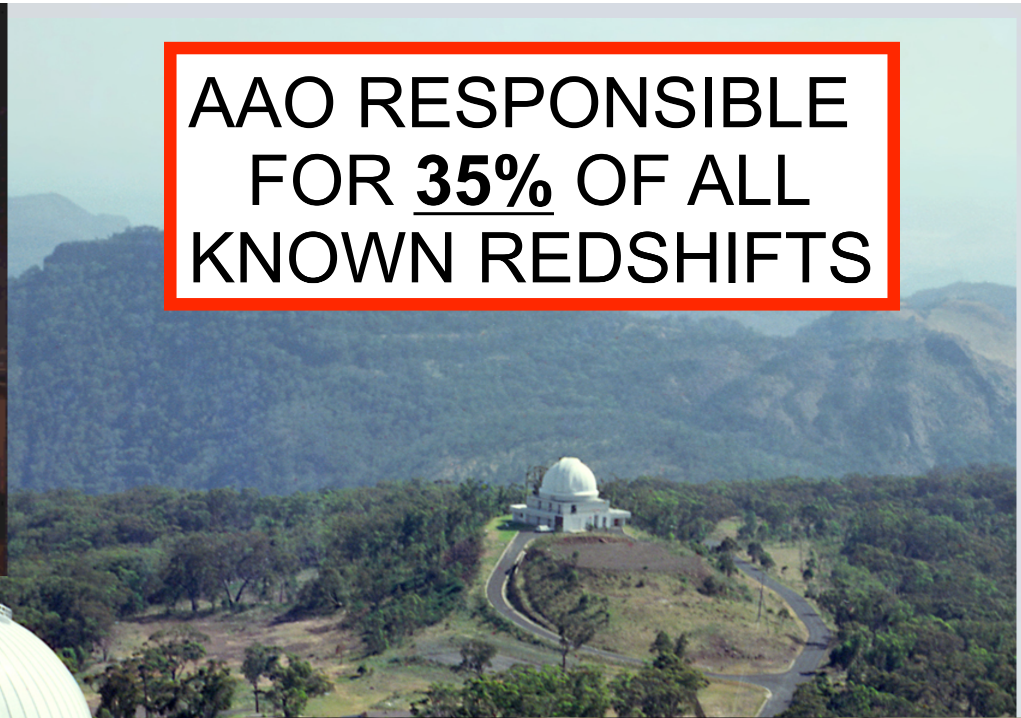


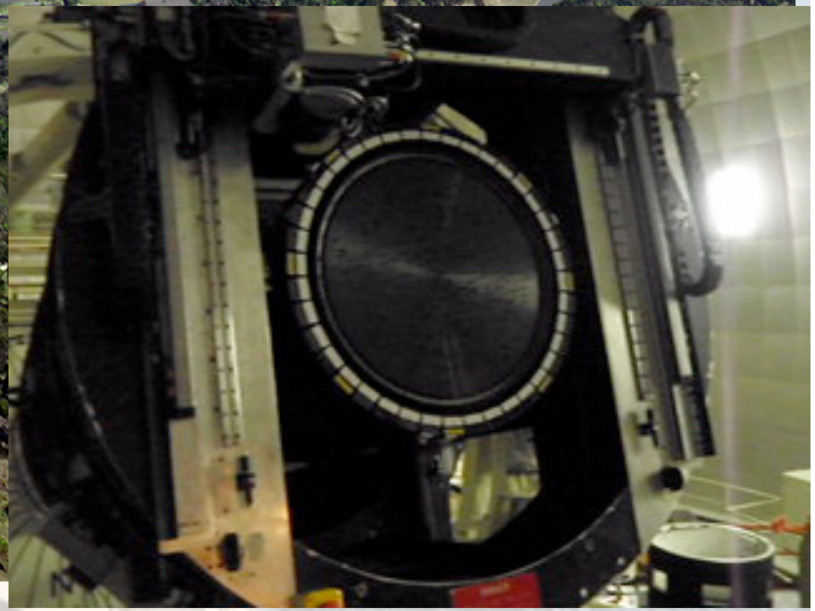
Photo-z credit:
Hannah Parkinson

GAMA

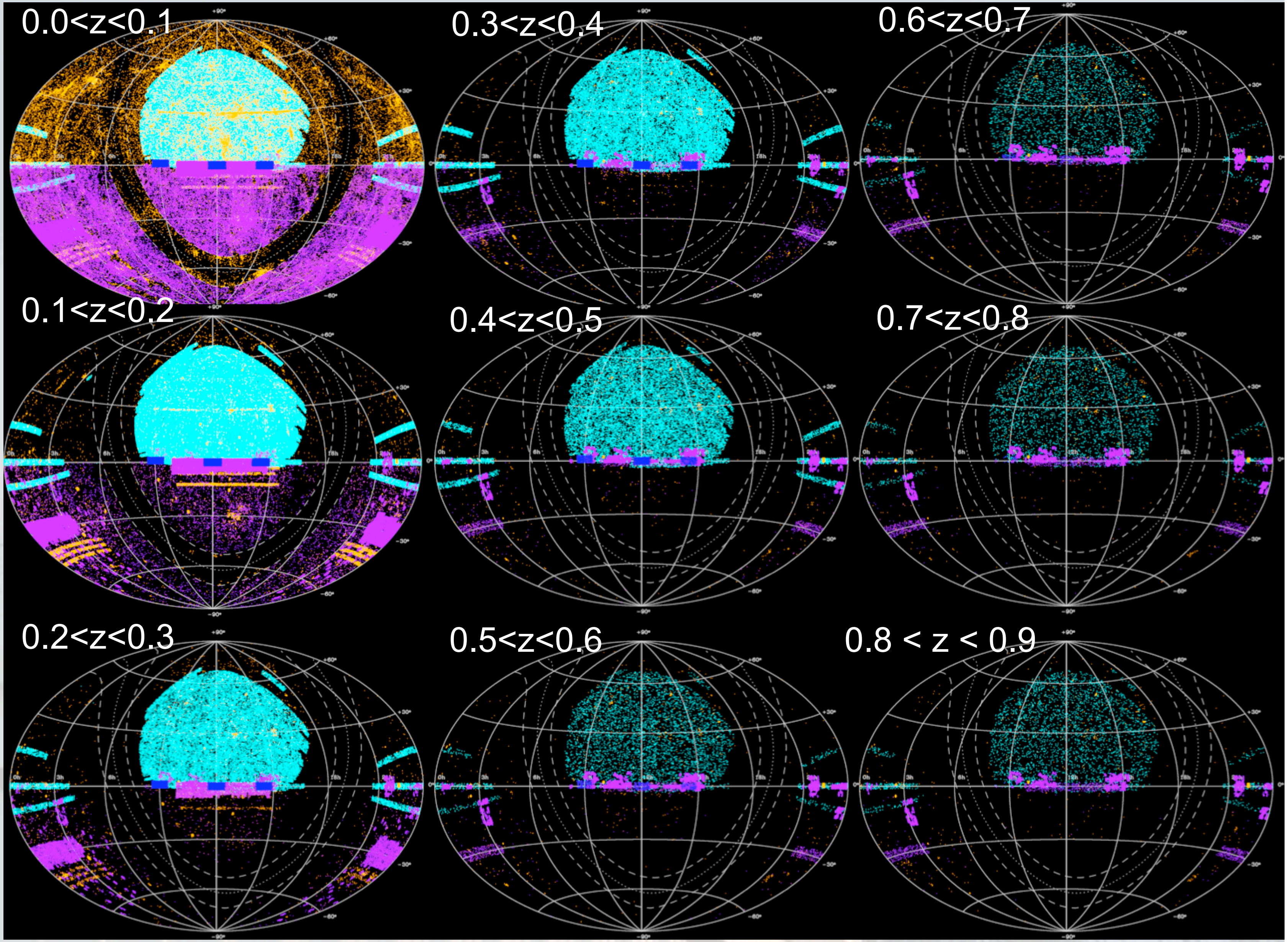




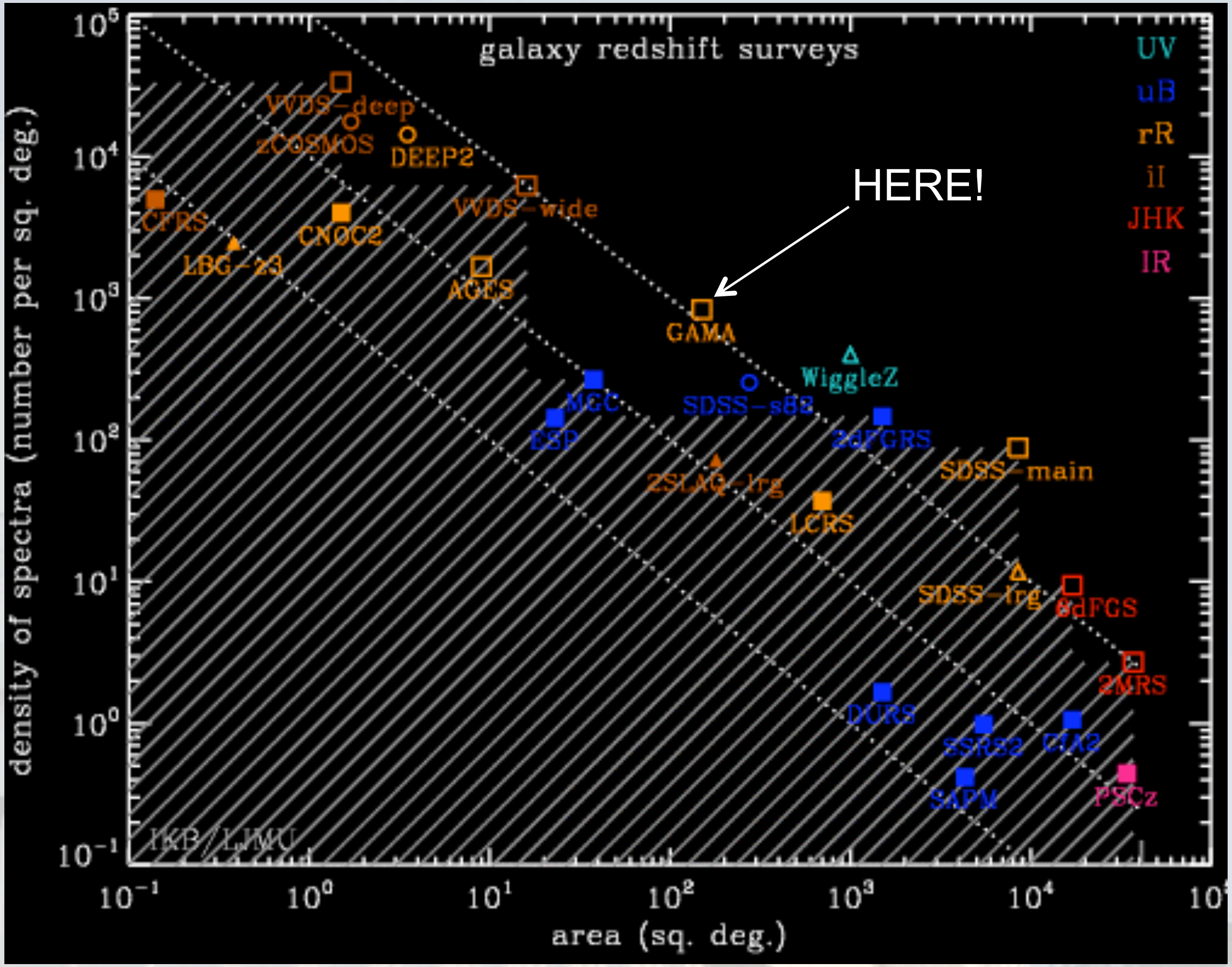
AAO RESPONSIBLE FOR 35% OF ALL KNOWN REDSHIFTS



All 2.5million known redshifts as of 01/08/2010



Where does GAMA fit in?



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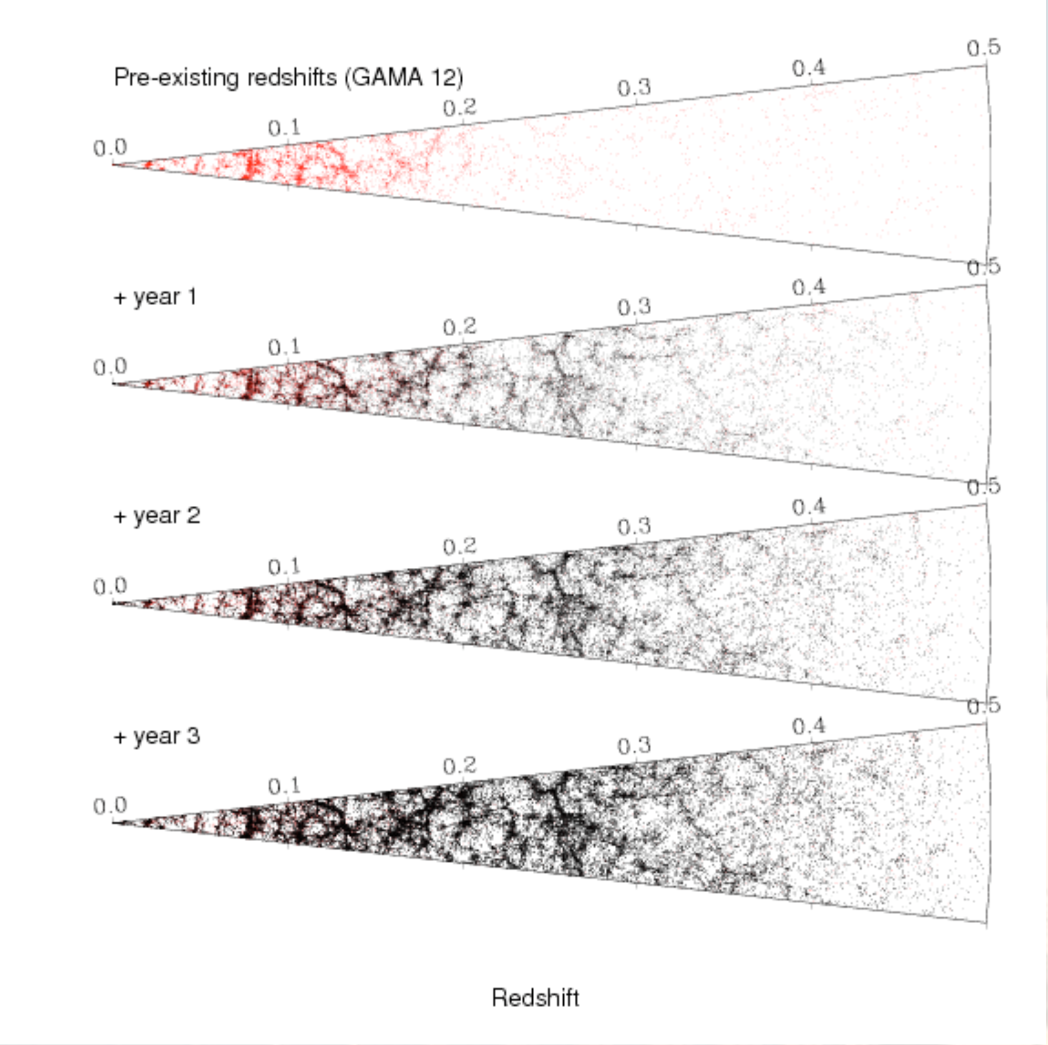


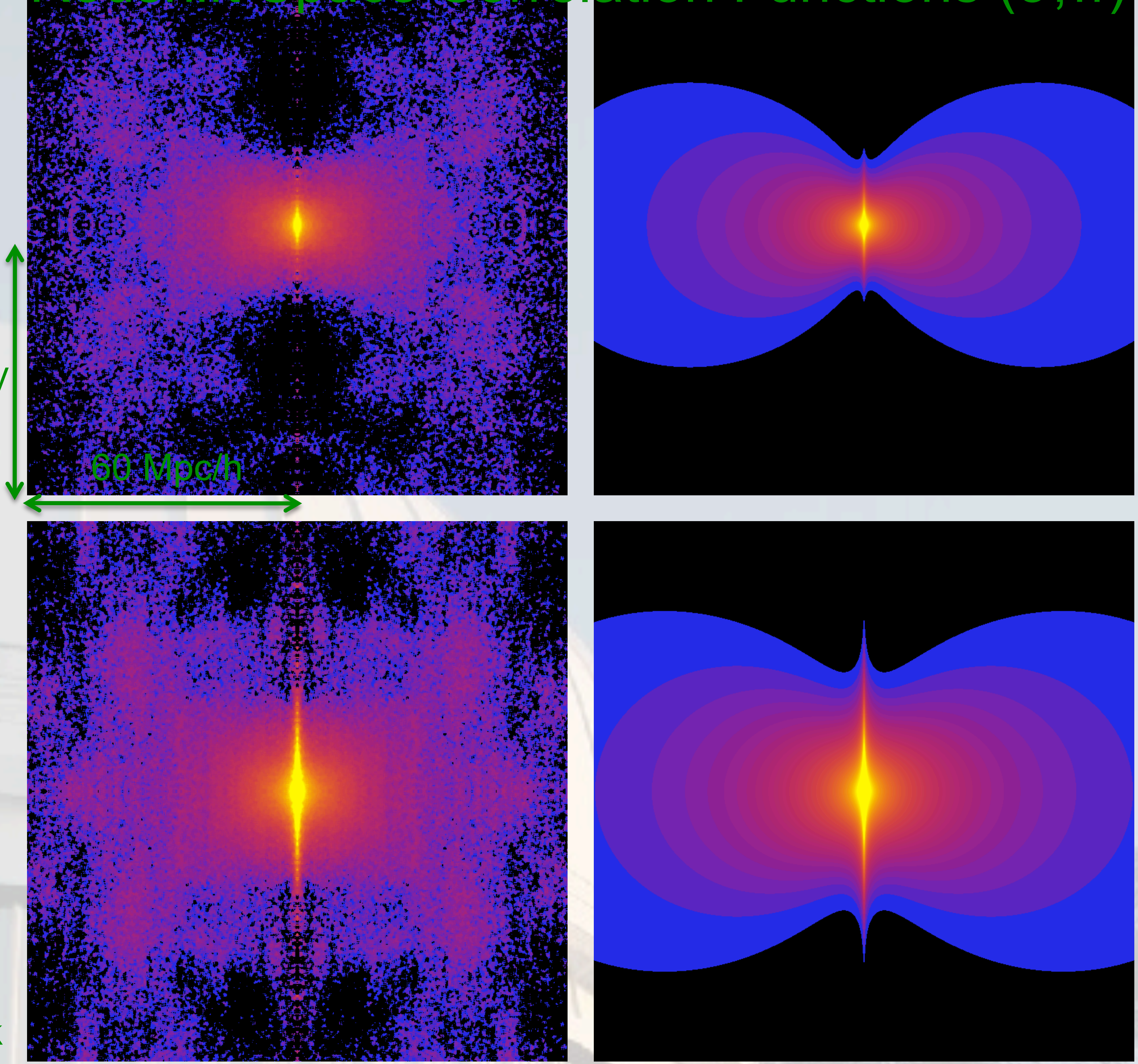
Pre-existing SDSS/2dFGRS (r<17.77)

Year 1 (r<19.0)

Year 2 (r<19.4)

Year 3 (r<19.8)

Redshift Space Correlation Functions (σ,π)



GAMA Galaxy Group Catalogue
Alias: G^3C

- Tried various implementations of FoF and halo based grouping

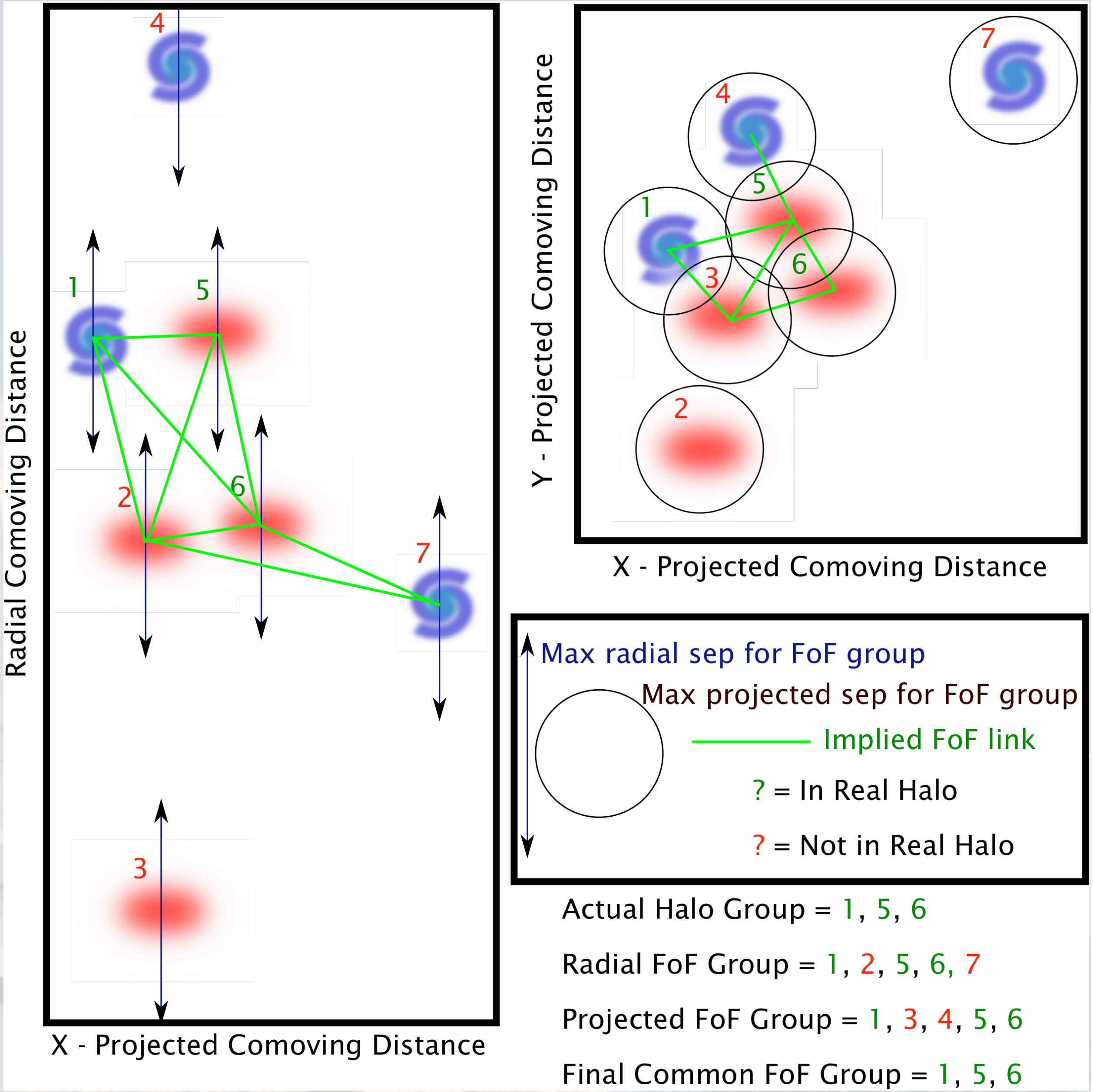
- FoF: - Links built between individual galaxies
  - Groups built from finding common links

- Halo: - Cores of groups found by constructing the voronoi tessellation
  - Scale core membership to define group extent

- FoF grouping much more flexible and successful when tested against mocks, used as the basis of the final group catalogue algorithm.

• At the simplest level we:

- Calculate the GAMA luminosity function (LF).
- Require that galaxies are significantly linked when they are locally overdense.
- Do this separately radially and in projection.
- We then construct groups out of common linking.



Some technical points…

• To create meaningful group catalogues we need to understand the biases expected by choosing different approaches to grouping

• Solution is to test on mock catalogues- created by Alex Merson (Durham) and Peder Norberg. This is a combination of the Millennium Simulation (MS) plus the GALFORM Semi-Analytic (SA) galaxy formation recipe on top.

• 27 GAMA like volumes (z= 0 -> 0.5, 48 sqdeg) exist with known associations between dark matter halos and semi-analytic galaxies (Richard Bower 2006).

• In some sense, we need an approaching to grouping that does "the best job" at recovering correct groupings

Some technical points…

• Chosen approach is to optimise for both finding halos and accurately determining purity of halos

• To find halos we say match is successful when bijective: more than ½ of mock group is in same group as more than ½ of FoF group

- Find fraction of bijective FoF and mock groups where N>5 (because this is hard)

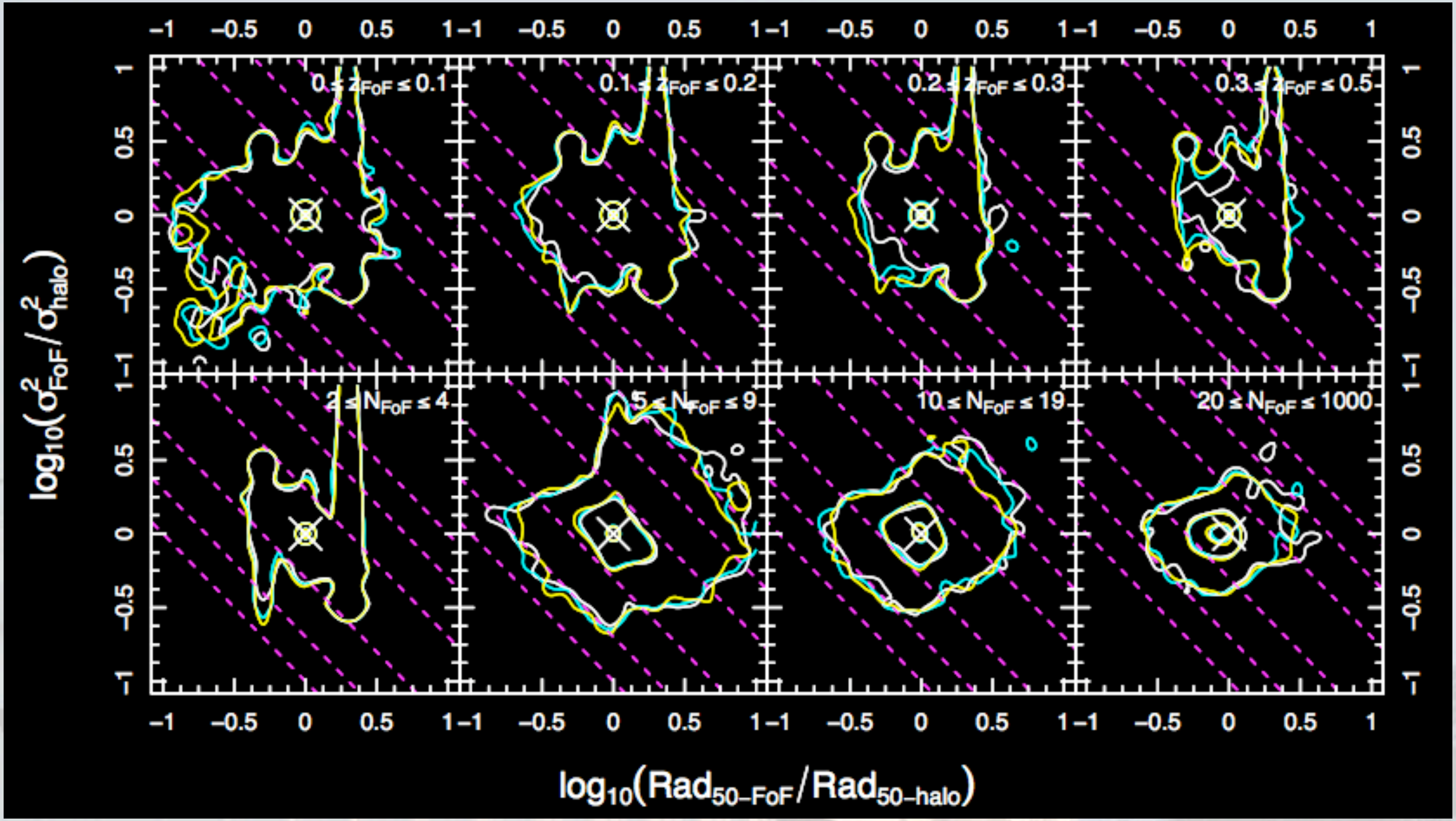
• To find halo purity find fraction of galaxies that are common as a fraction of best matching FoF/ mock group

- Scale by multiplicity and calculate overall purity for FoF and mock groups

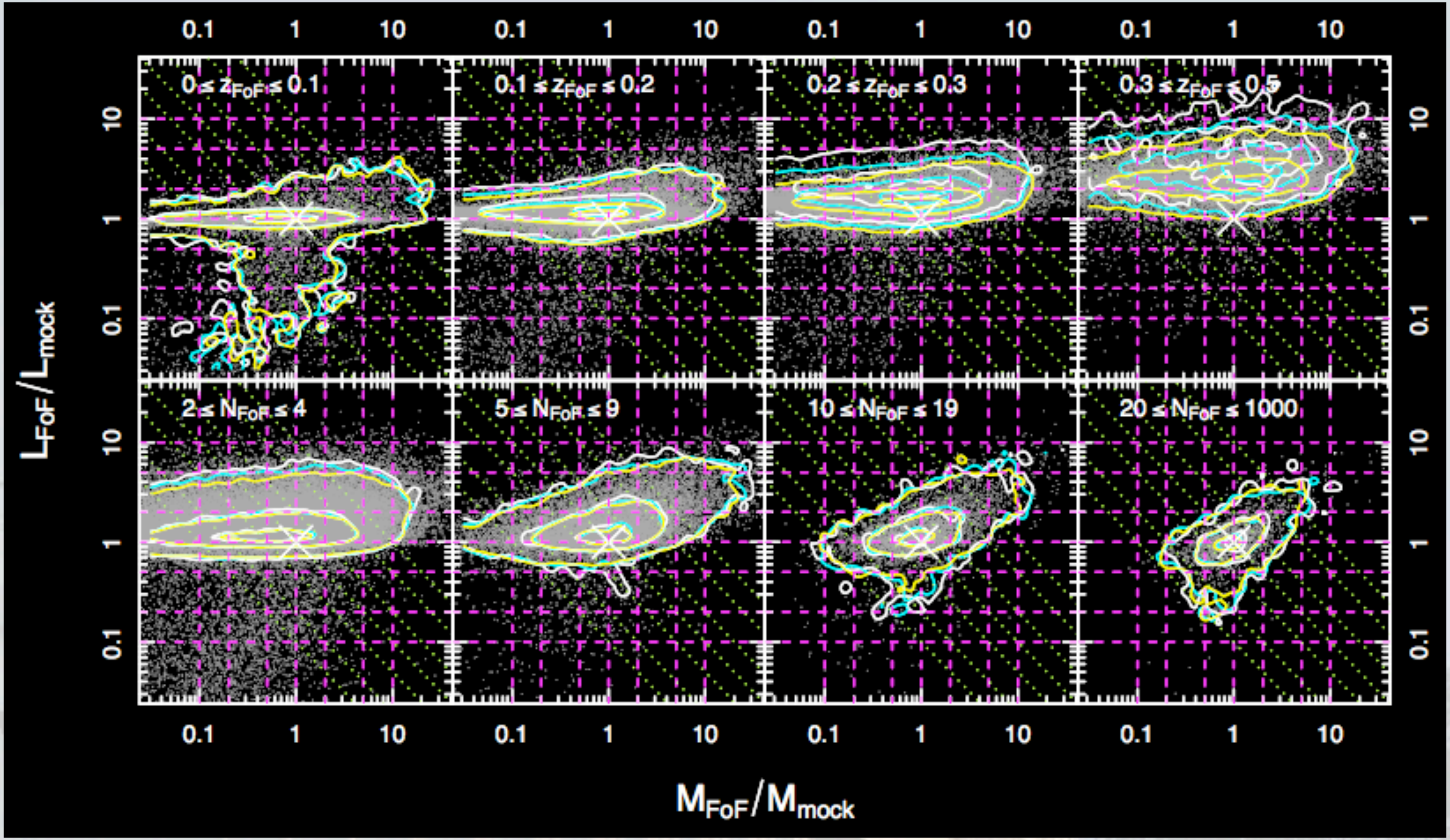
• This approach penalises over <u>AND</u> under grouping!

How good do we expect our groups to be?

$$M \propto \sigma^2 r$$



Group Dynamical Mass and Luminosity using global correction



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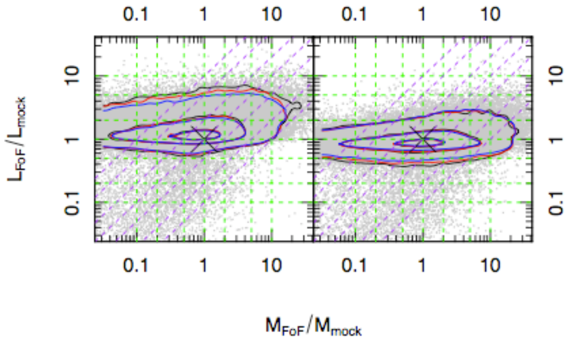
Even if we perfectly recover the groups, scaling is not constant!

$$M = A\sigma^2 r$$

$$L_{\rm FoF} = L_A L_{\rm ob} \frac{\int_{-30}^{-14} \phi_{\rm GAMA}(M_r)dM_r}{\int_{-30}^{M_{r-\rm lim}} \phi_{\rm GAMA}(M_r)dM_r} 10^{0.4 M_{r-\odot}}$$

	$2 \leqslant N_{\rm FoF} \leqslant 4$			$5 \leqslant N_{\rm FoF} \leqslant 9$			$10 \leqslant N_{\rm FoF} \leqslant 19$			$20 \leqslant N_{\rm FoF} \leqslant 1000$		
	19.0	19.4	19.8	19.0	19.4	19.8	19.0	19.4	19.8	19.0	19.4	19.8
$0 \leqslant z_{\rm FoF} \leqslant 0.1$	20.00	18.98	18.00	11.78	10.84	10.85	11.37	12.00	11.51	12.05	12.58	12.68
$0.1 \leqslant z_{\rm FoF} \leqslant 0.2$	20.18	19.45	19.17	10.34	10.52	10.71	10.96	11.07	10.91	9.19	10.36	10.90
$0.2 \leqslant z_{\rm FoF} \leqslant 0.3$	21.21	21.53	19.82	8.99	10.28	11.17	8.00	8.56	9.89	6.73	8.33	9.64
$0.3 \leqslant z_{\rm FoF} \leqslant 0.5$	13.56	17.37	17.76	4.37	6.11	7.85	3.45	5.43	6.72	4.84	5.59	6.87

	$2 \leqslant N_{\rm FoF} \leqslant 4$			$5 \leqslant N_{\rm FoF} \leqslant 9$			$10 \leqslant N_{\rm FoF} \leqslant 19$			$20 \leqslant N_{\rm FoF} \leqslant 1000$		
	19.0	19.4	19.8	19.0	19.4	19.8	19.0	19.4	19.8	19.0	19.4	19.8
$0 \leqslant z_{\rm FoF} \leqslant 0.1$	1.01	1.03	1.05	1.01	1.02	1.02	1.23	1.18	1.11	1.62	1.60	1.54
$0.1 \leqslant z_{\rm FoF} \leqslant 0.2$	0.79	0.85	0.90	0.76	0.83	0.87	0.88	0.92	0.96	0.95	1.03	1.07
$0.2 \leqslant z_{\rm FoF} \leqslant 0.3$	0.46	0.58	0.68	0.47	0.57	0.66	0.55	0.63	0.74	0.58	0.71	0.79
$0.3 \leqslant z_{\rm FoF} \leqslant 0.5$	0.21	0.31	0.40	0.23	0.34	0.42	0.31	0.40	0.49	0.27	0.47	0.53

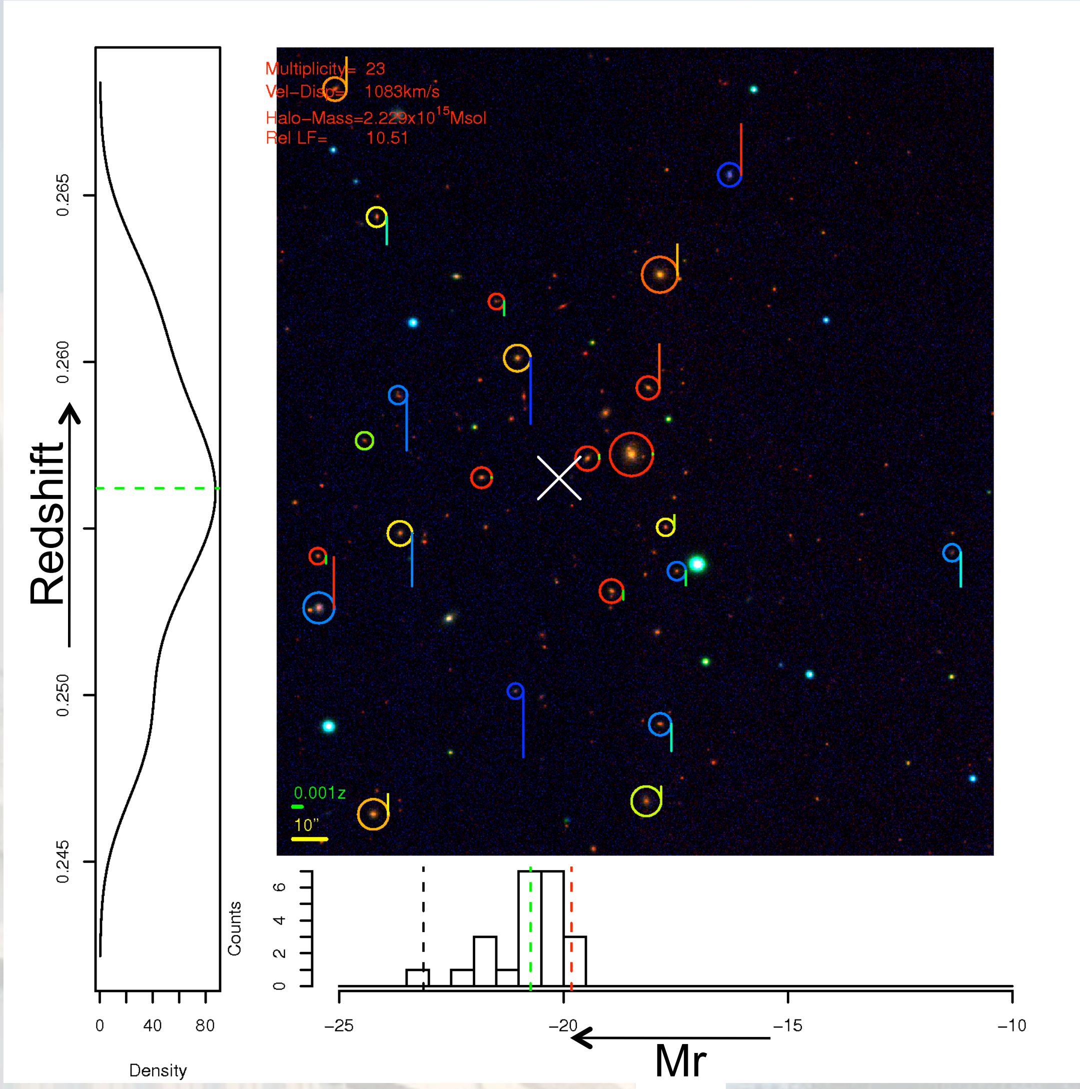


Cluster

Z ~ 0.26

23 w. GAMA

4 pre GAMA



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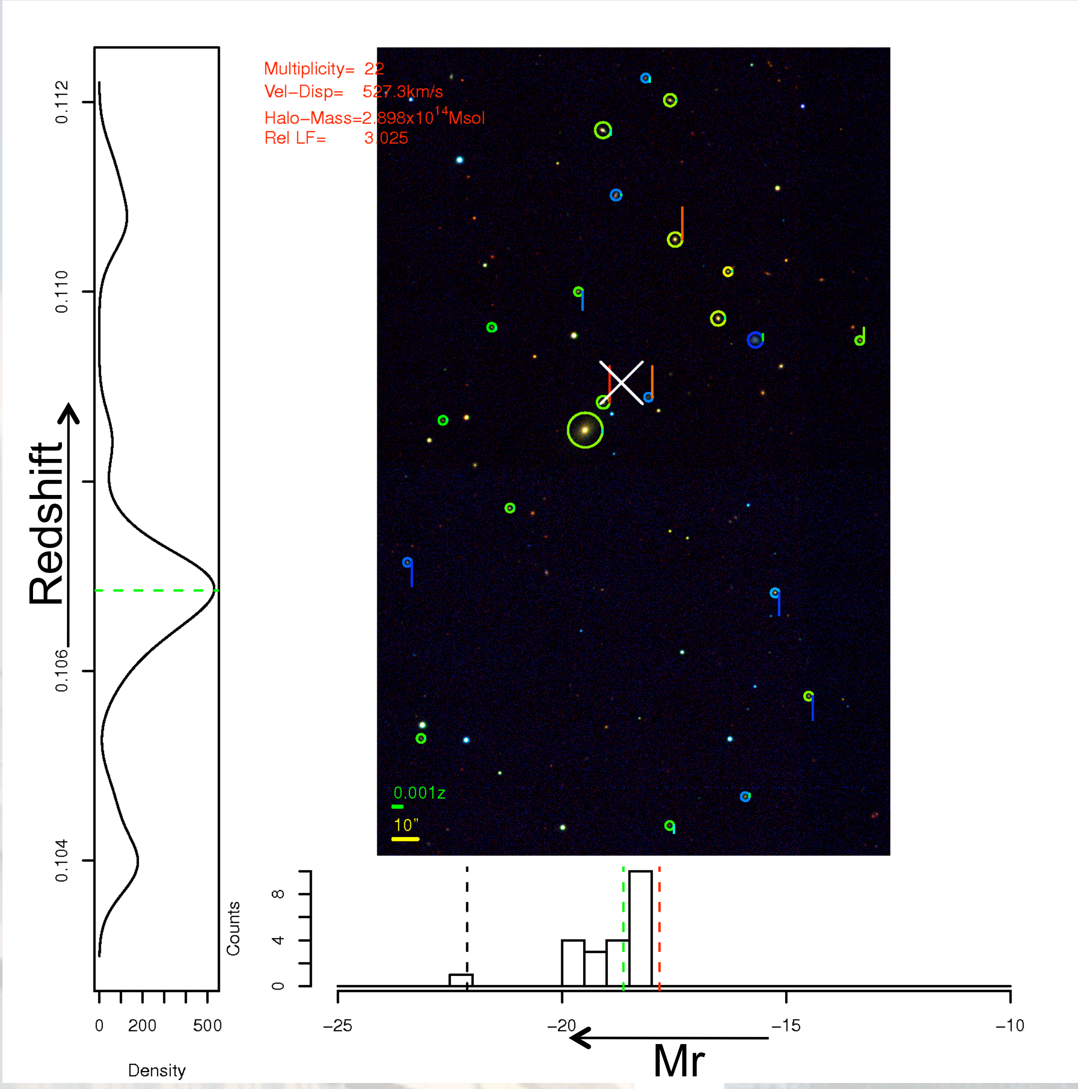
Fossil Group

Z ~ 0.11

22 w. GAMA

1 pre GAMA

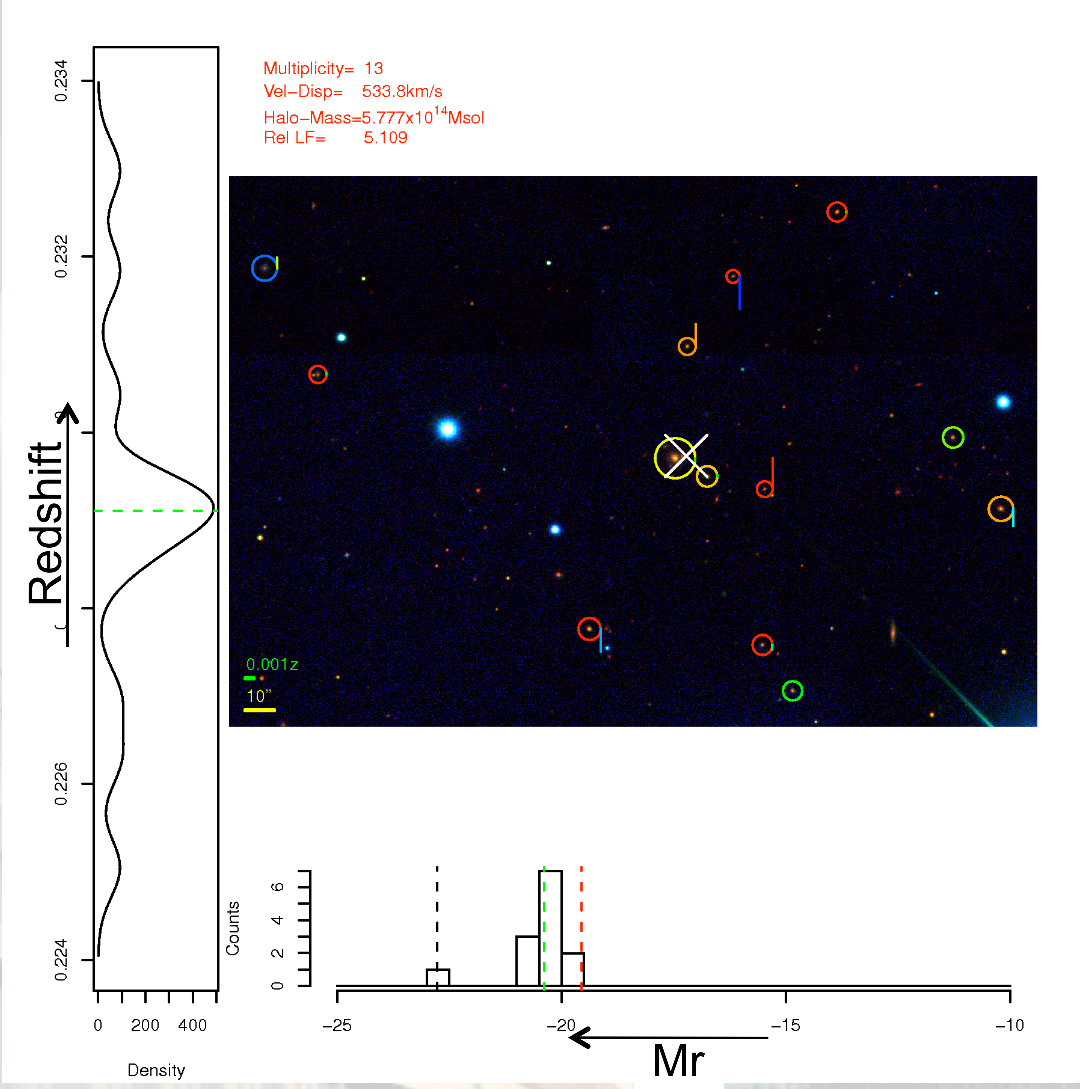


Fossil Group

Z ~ 0.23

13 w. GAMA

1 pre GAMA



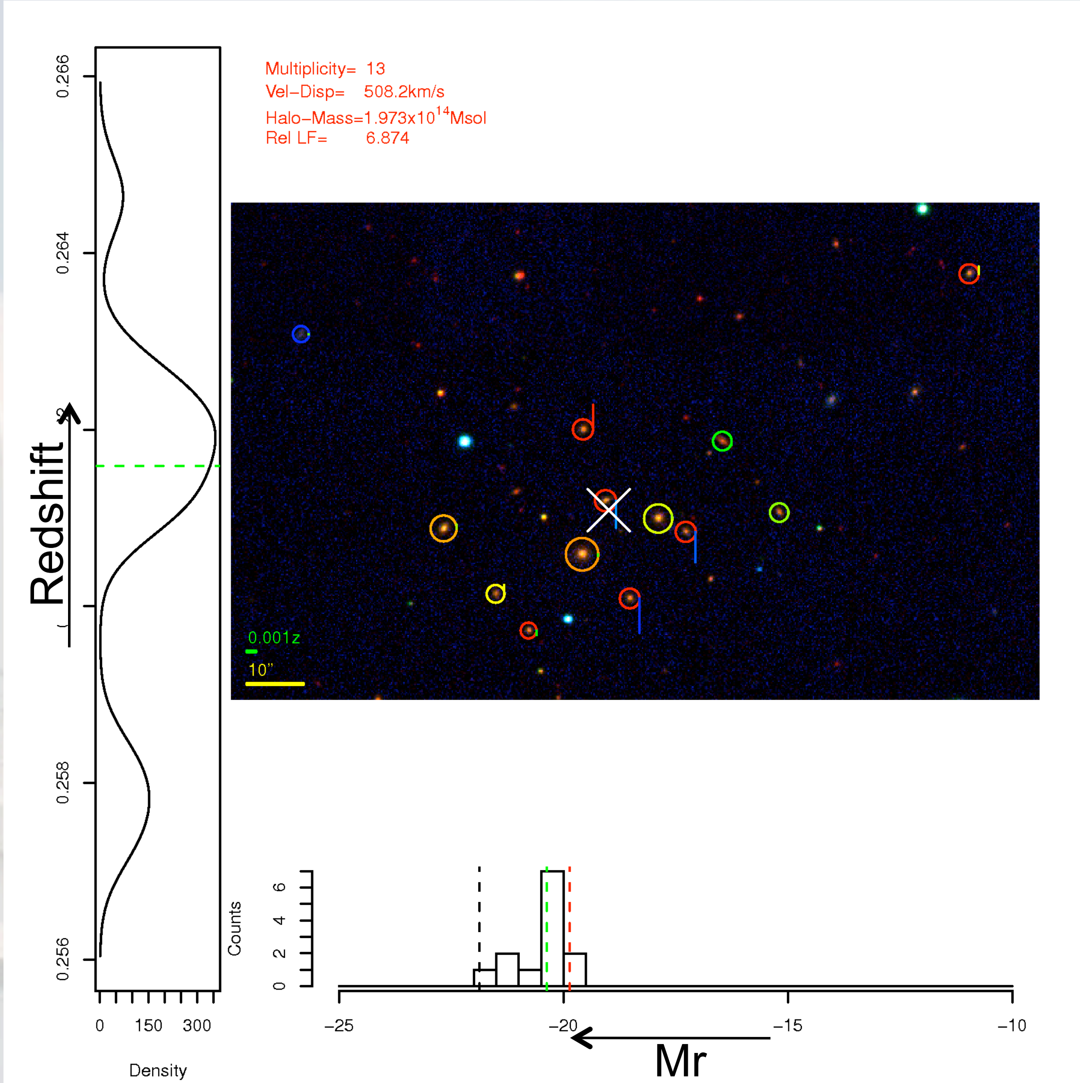
Large group

Z ~ 0.26

13 w. GAMA

0 pre GAMA

Perfect group!



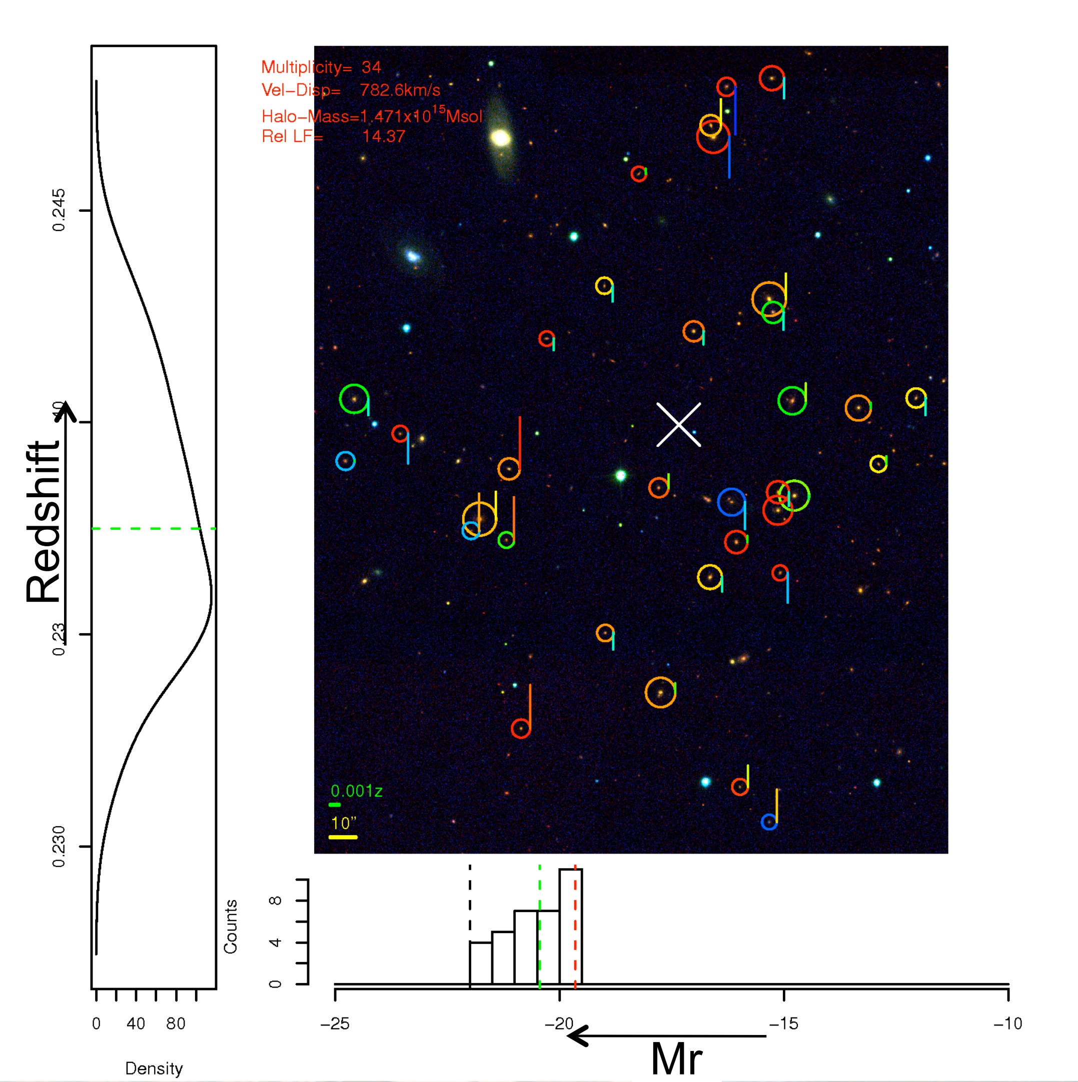
Cluster

Z ~ 0.24

34 w. GAMA

5 pre GAMA

Perfect cluster!



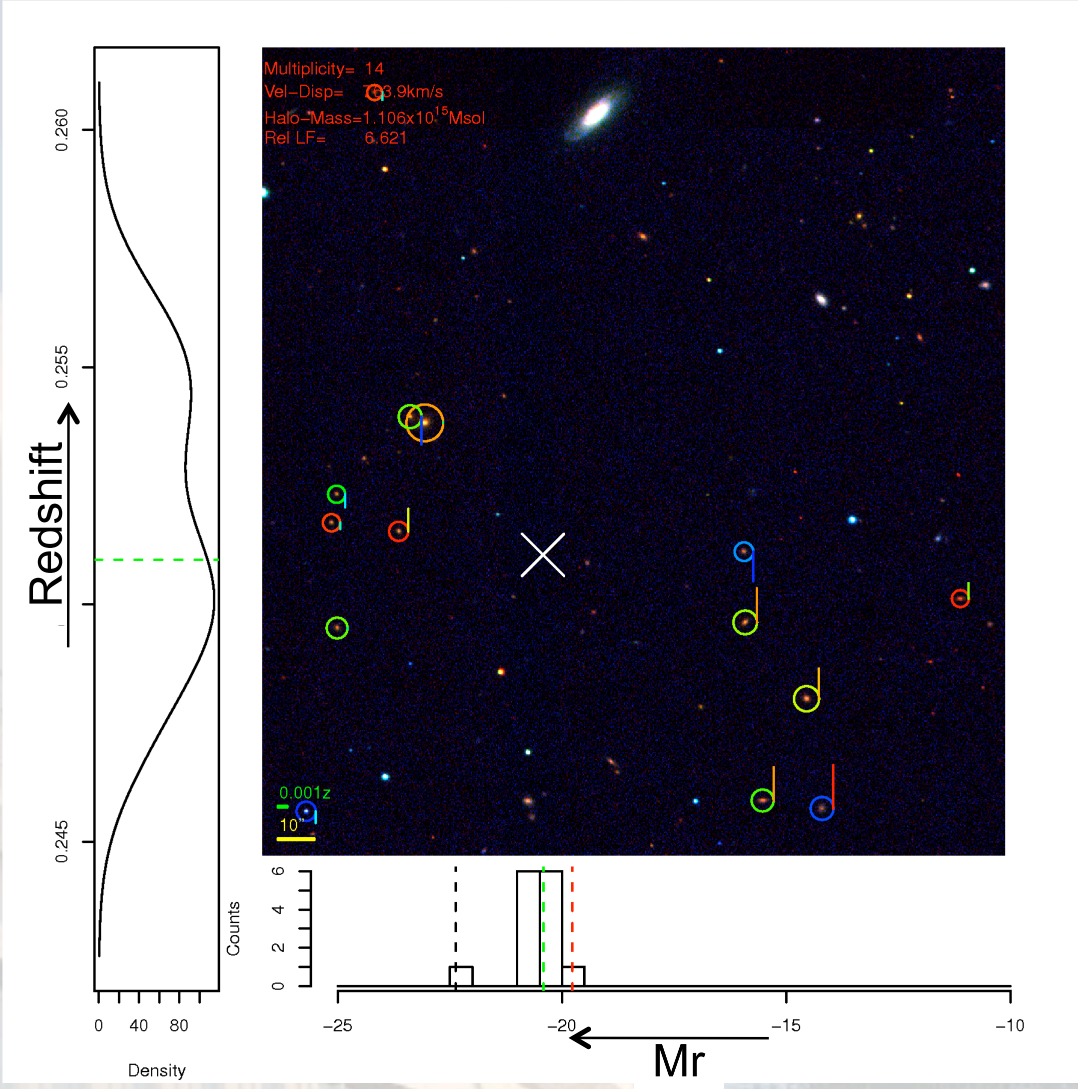
Large Group

Z ~ 0.25

14 w. GAMA

1 pre GAMA

2 groups?



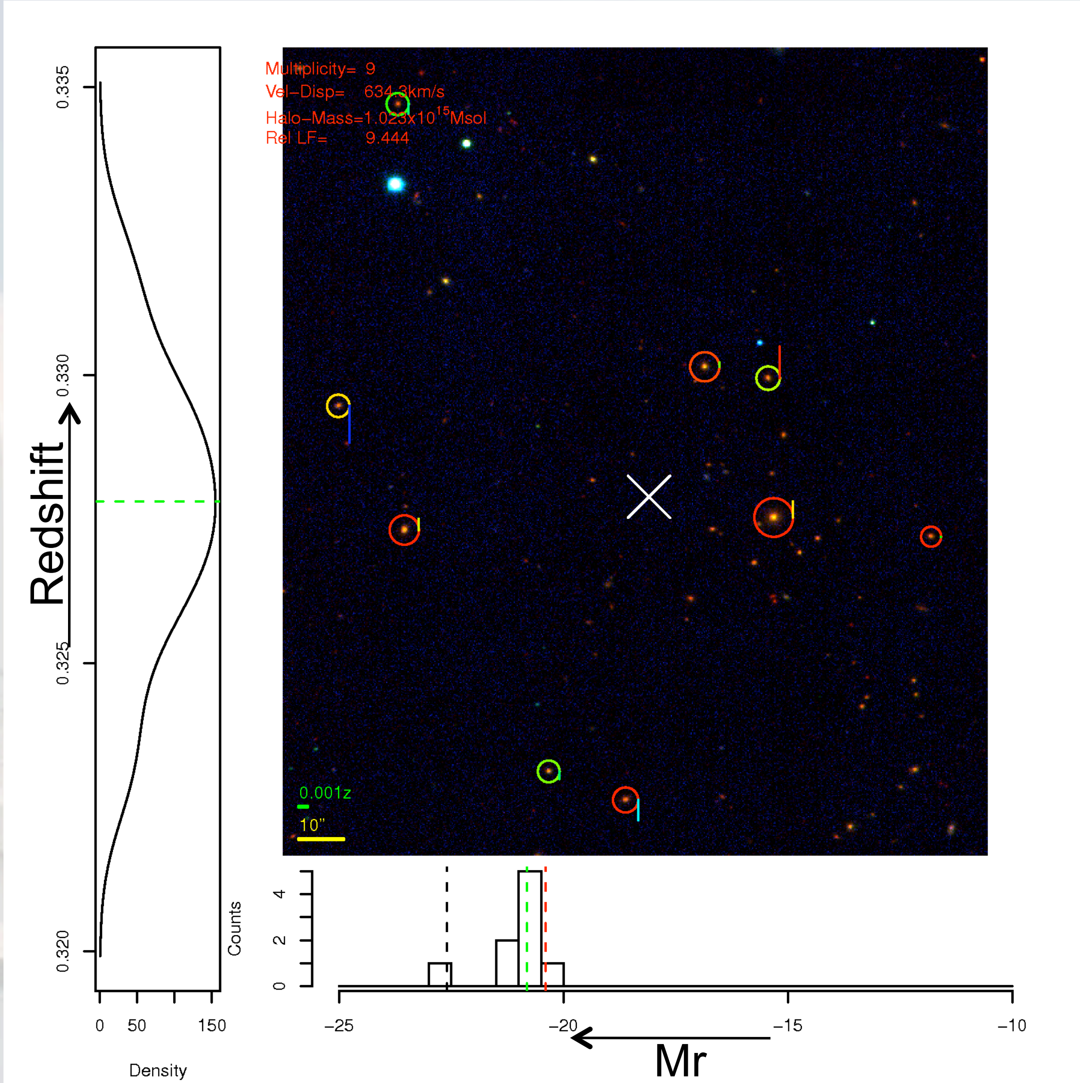
Fossil Group

Z ~ 0.33

9 w. GAMA

1 pre GAMA

Tip of the iceberg.



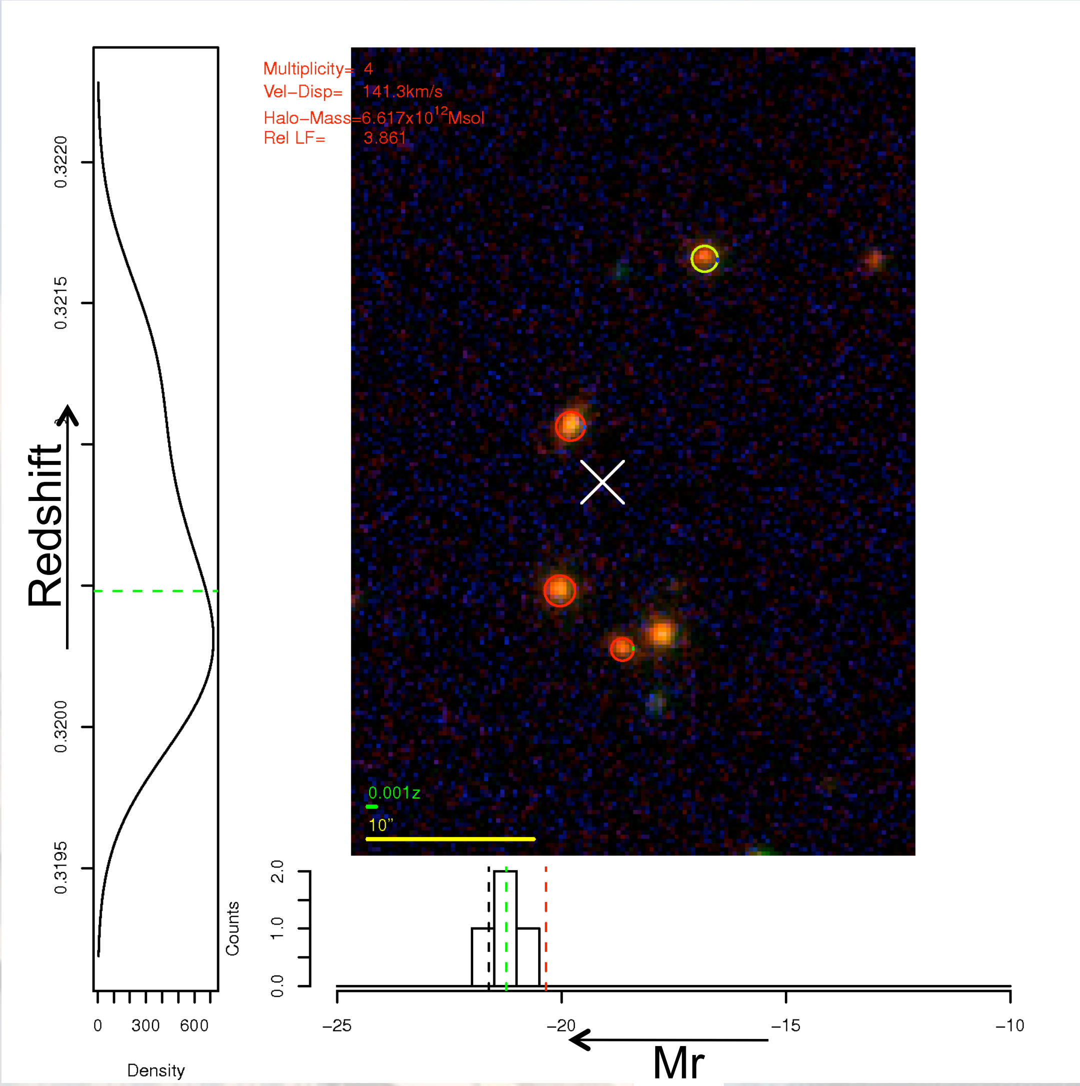
Small Group

Z ~ 0.32

4 w. GAMA

0 pre GAMA

All within 2dF fibre collision radius.



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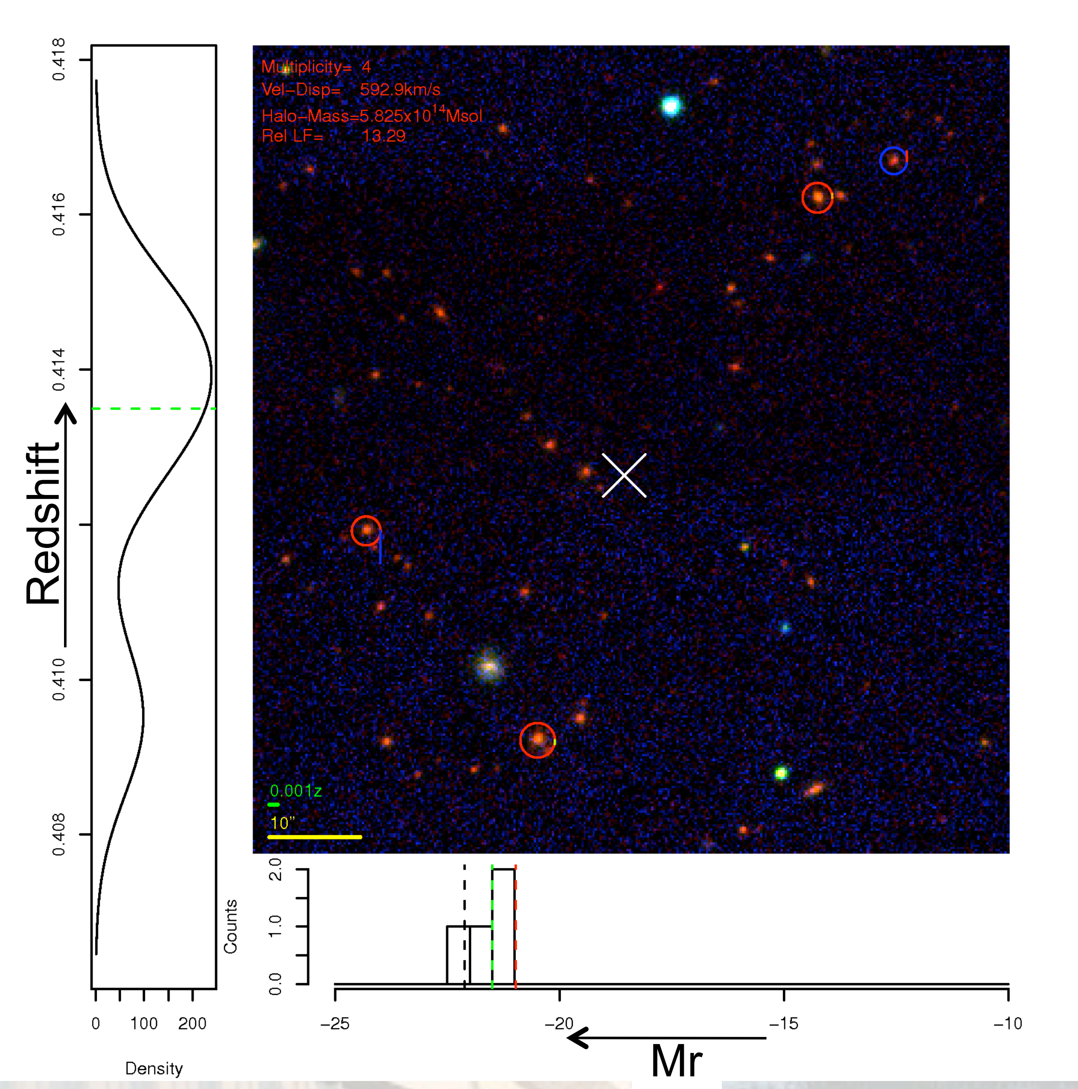
Group

Z ~ 0.41

4 w. GAMA

0 pre GAMA

Huge number of background members.



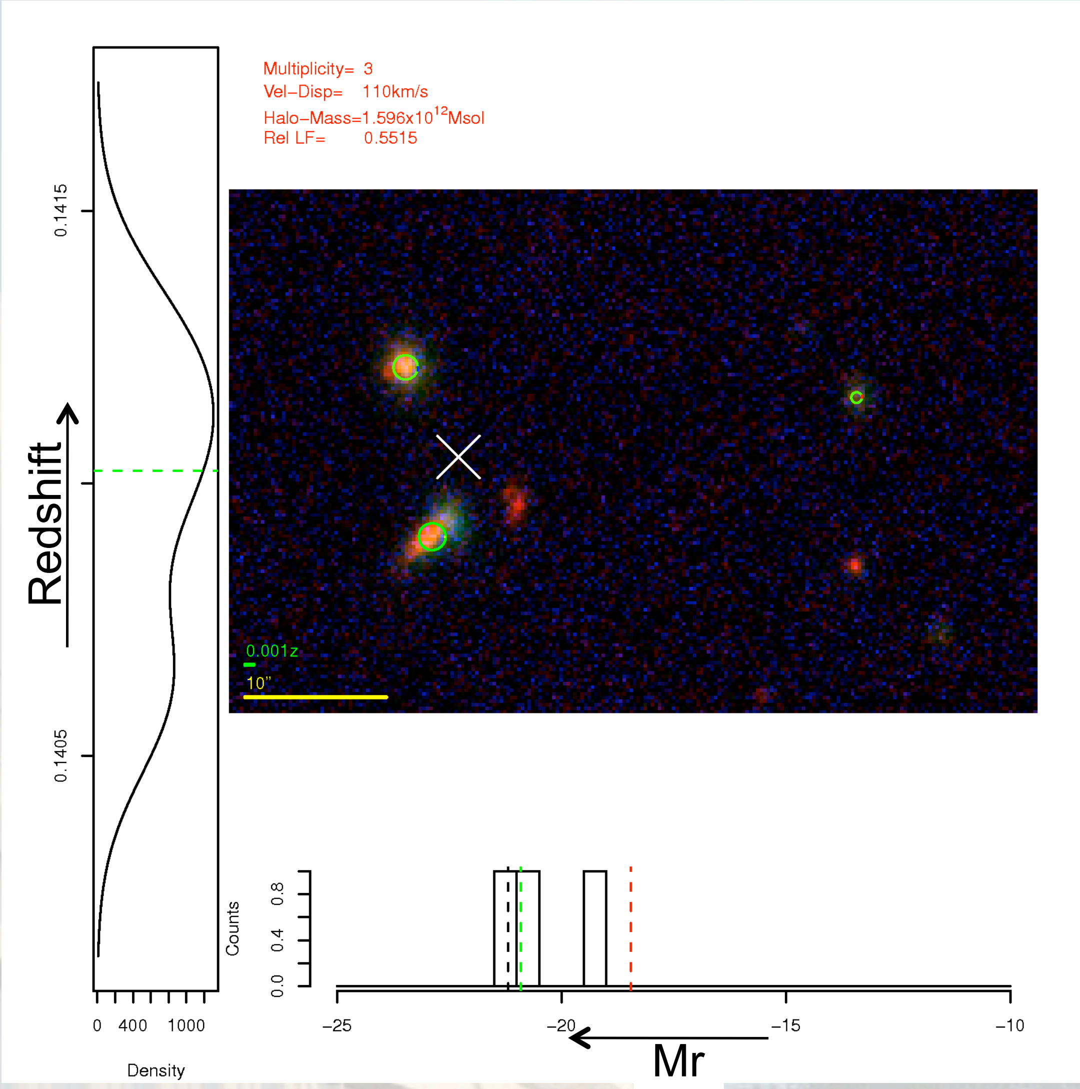
Small Group

Z ~ 0.14

3 w. GAMA

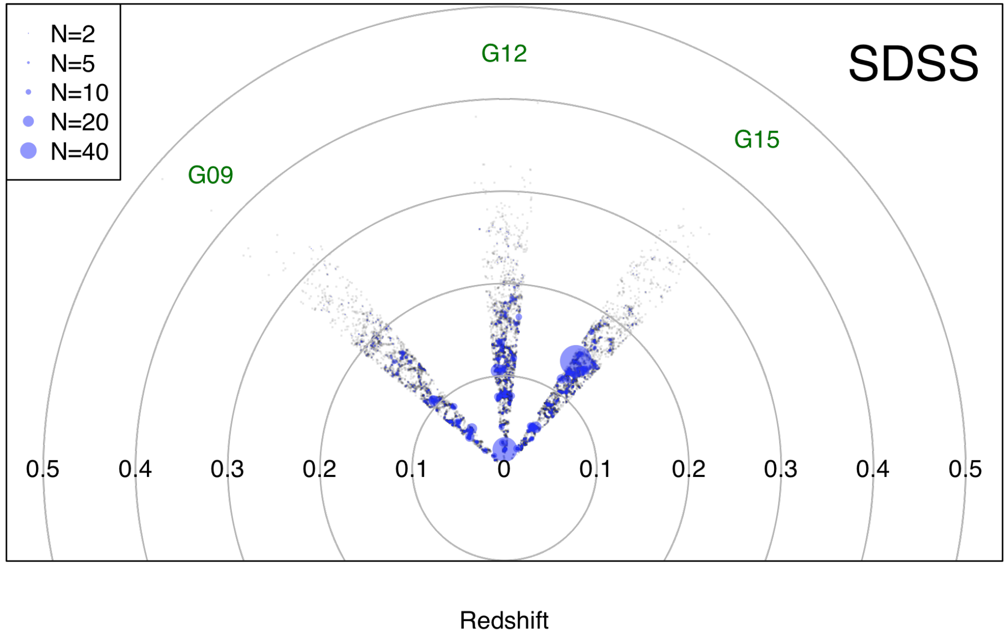
1 pre GAMA

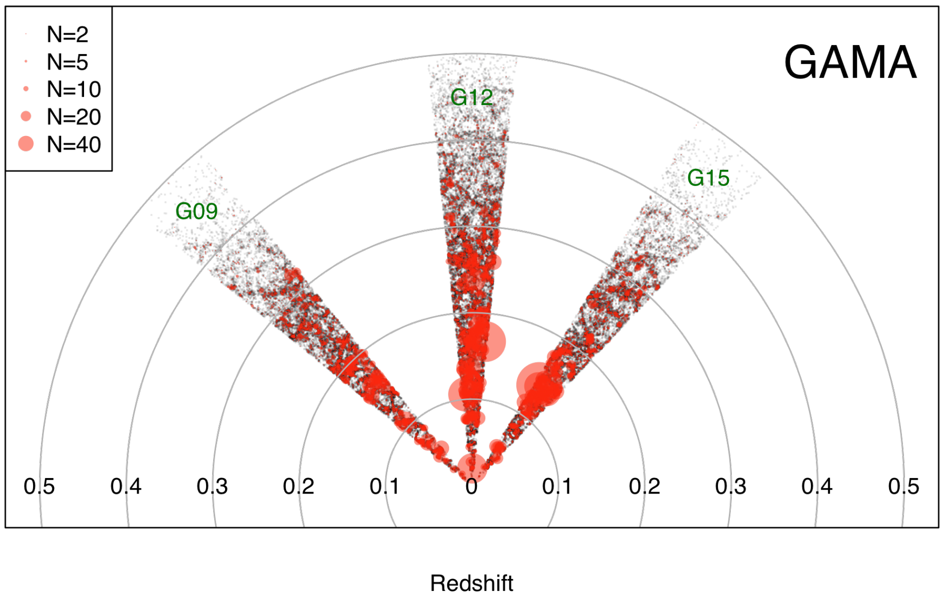
Mergers?



How do we do overall?

SDSS: r<17.77





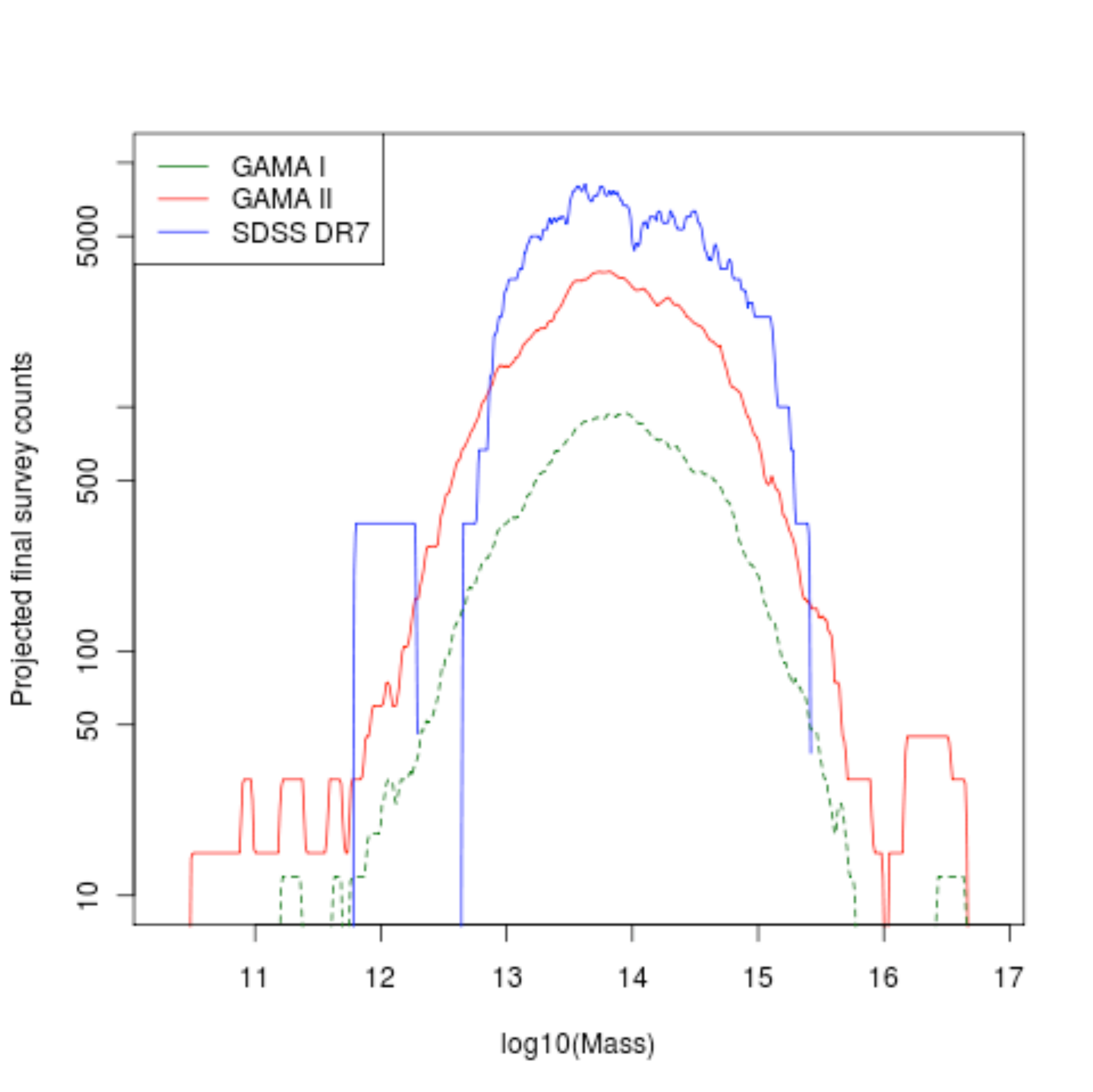
GAMA I:
G09/G15 r<19.4
G12 r<19.8

SDSS versus GAMA: N>=5 (high fidelity groups)

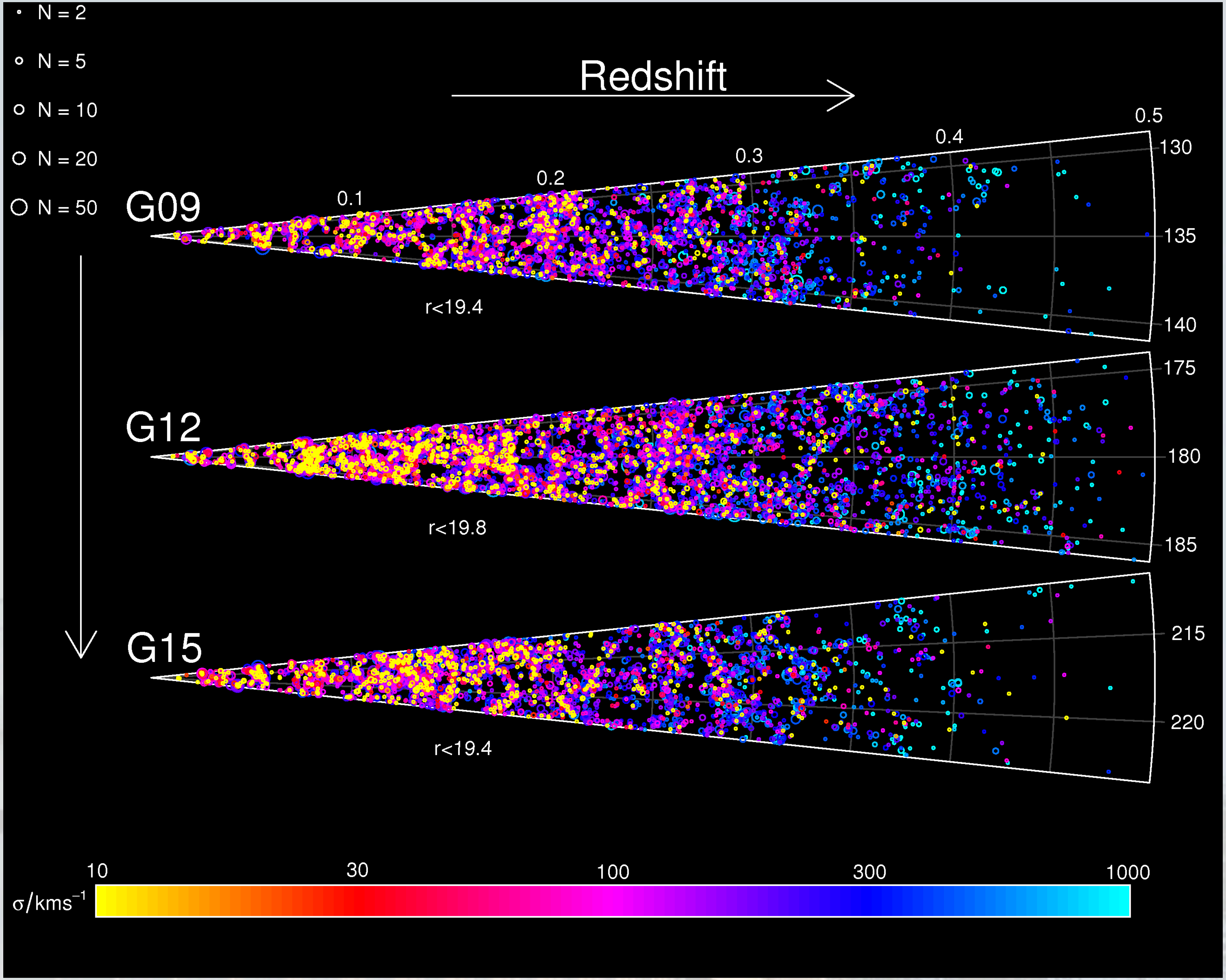
- SDSS DR7 (done):
  8000 sqdeg r<17.77
  ~ 60 -> 70% comp. in dense regions

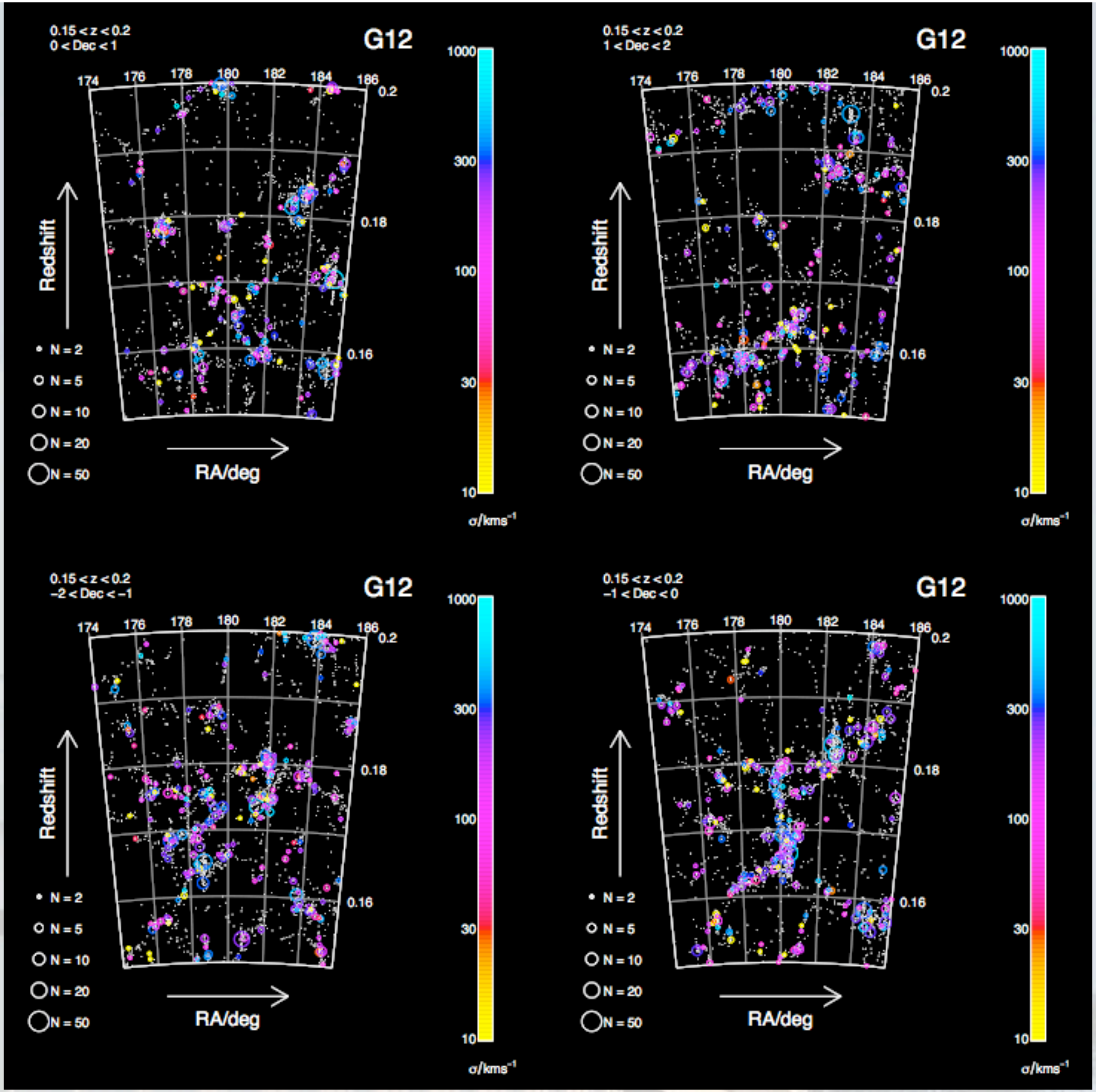
- GAMA I (done):
  144 sqdeg r<19.4 (for this plot)
  ~ 99% comp.

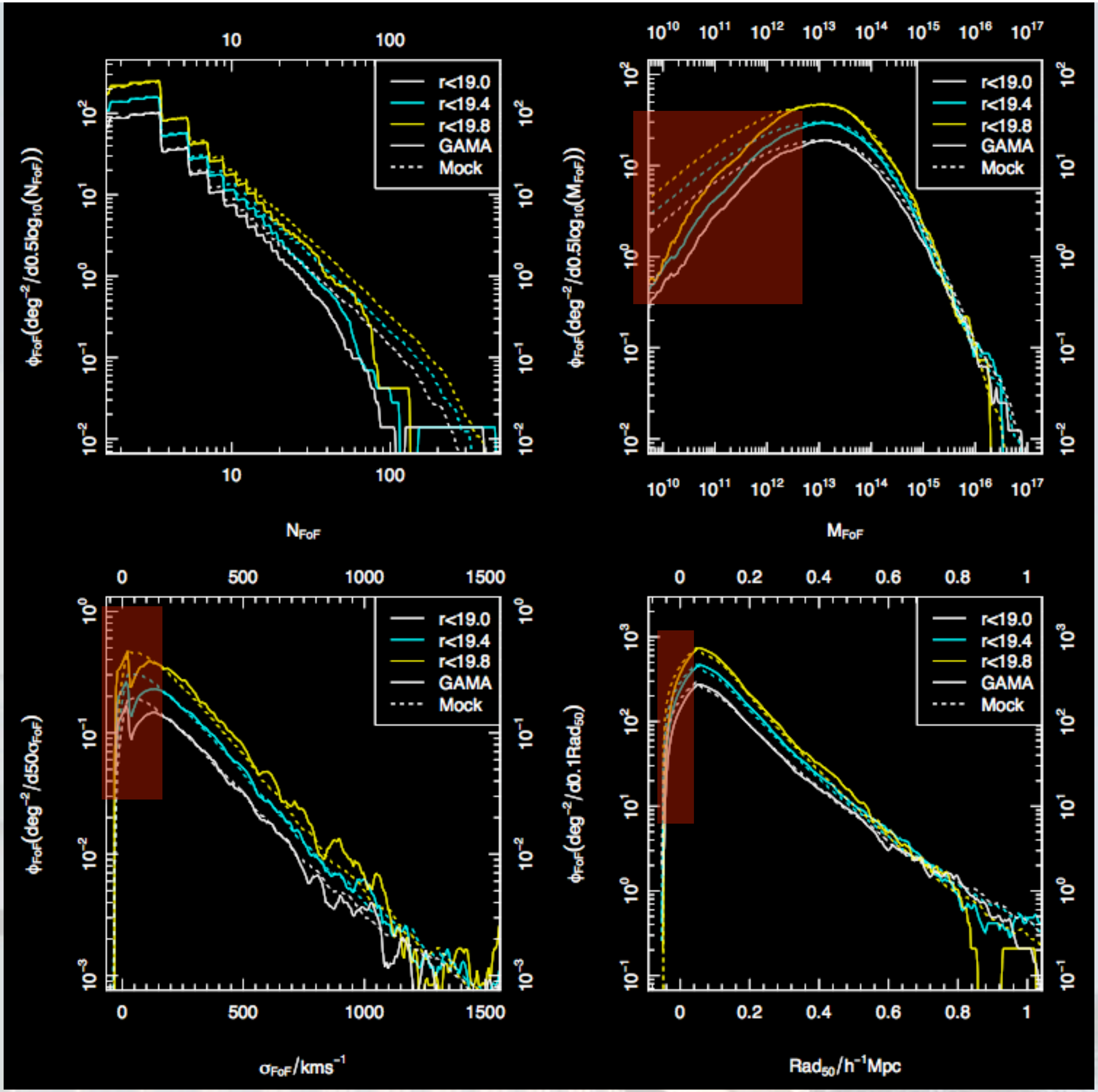
- GAMA II (doing):
  360 sqdeg r<19.8
  ~ 95 -> 99% comp.



GAMA


N = 2
N = 5
N = 10
N = 20
N = 50
Redshift
G09
G12
G15
0.1
0.2
0.3
0.4
0.5
130
135
140
175
180
185
215
220
r<19.4
r<19.8
r<19.4
10
30
100
300
1000
σ/kms^{-1}

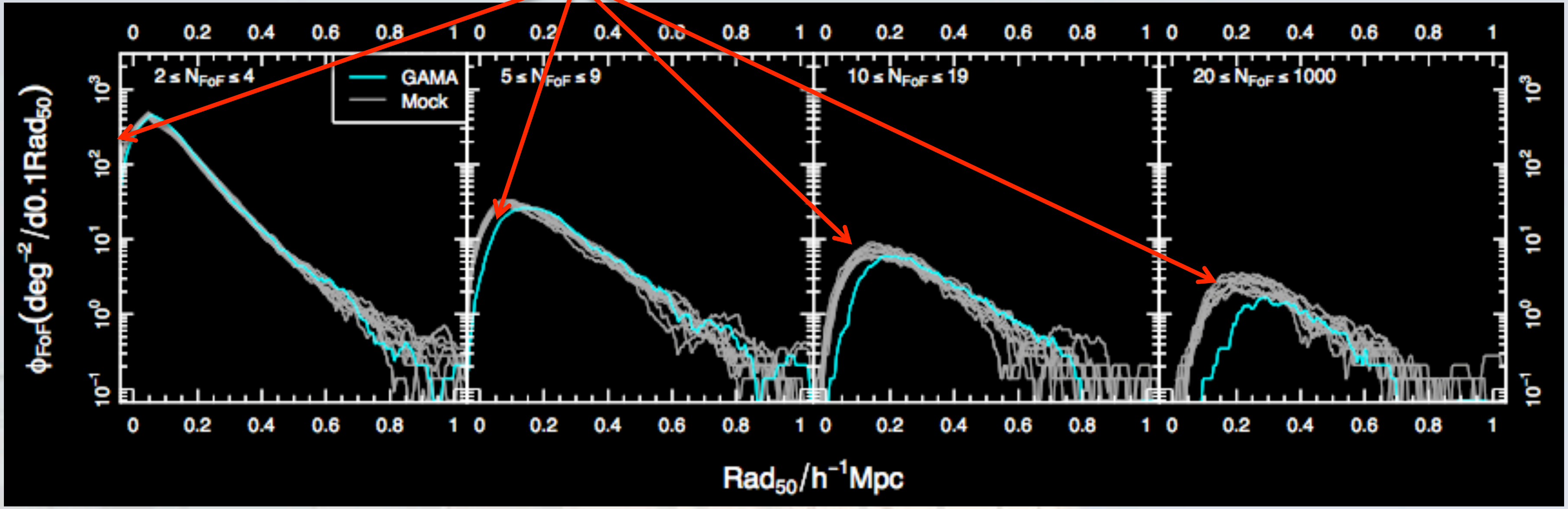

0.15 < z < 0.2
0 < Dec < 1
G12
0.15 < z < 0.2
1 < Dec < 2
G12
0.15 < z < 0.2
−2 < Dec < −1
G12
0.15 < z < 0.2
−1 < Dec < 0
G12
174
176
178
180
182
184
186
0.2
0.18
0.16
Redshift
RA/deg
N = 2
N = 5
N = 10
N = 20
N = 50
1000
300
100
30
10
σ/kms⁻¹



r<19.0
r<19.4
r<19.8
GAMA
Mock
N_{FoF}
M_{FoF}
σ_{FoF}/kms^{-1}
$Rad_{50}/h^{-1}Mpc$
$\phi_{FoF}(deg^{-2}/d0.5log_{10}(N_{FoF}))$
$\phi_{FoF}(deg^{-2}/d0.5log_{10}(M_{FoF}))$
$\phi_{FoF}(deg^{-2}/d50\sigma_{FoF})$
$\phi_{FoF}(deg^{-2}/d0.1Rad_{50})$

So what is going on at low mass?

- Problem appears to be that the mocks (MS + SA) produce far too many compact groups.



- It would appear that the recipe used for "simulating" dynamical friction is far too crude, and doesn't merge groups rapidly enough.

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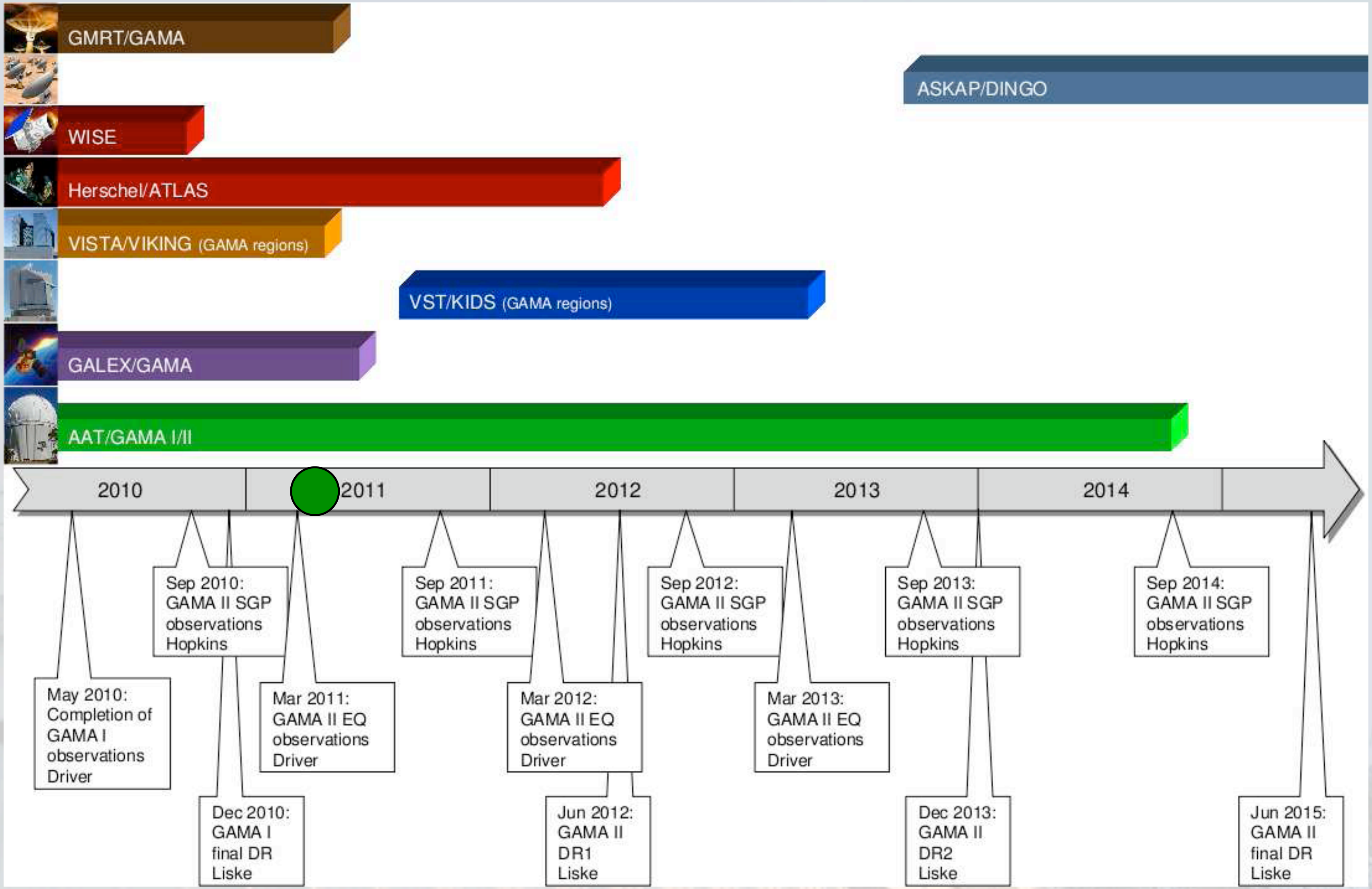
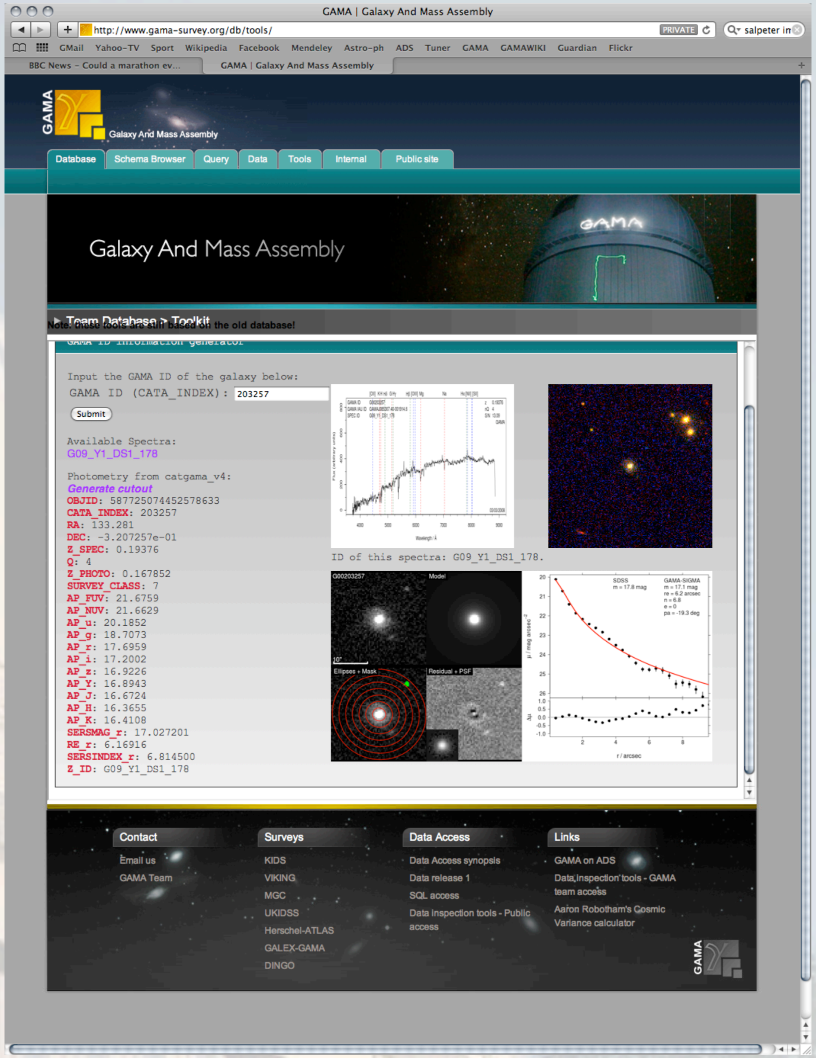
What next…



GMRT/GAMA
ASKAP/DINGO
WISE
Herschel/ATLAS
VISTA/VIKING (GAMA regions)
VST/KIDS (GAMA regions)
GALEX/GAMA
AAT/GAMA I/II
2010
2011
2012
2013
2014
May 2010: Completion of GAMA I observations Driver
Sep 2010: GAMA II SGP observations Hopkins
Dec 2010: GAMA I final DR Liske
Mar 2011: GAMA II EQ observations Driver
Sep 2011: GAMA II SGP observations Hopkins
Mar 2012: GAMA II EQ observations Driver
Jun 2012: GAMA II DR1 Liske
Sep 2012: GAMA II SGP observations Hopkins
Mar 2013: GAMA II EQ observations Driver
Sep 2013: GAMA II SGP observations Hopkins
Dec 2013: GAMA II DR2 Liske
Sep 2014: GAMA II SGP observations Hopkins
Jun 2015: GAMA II final DR Liske

GAMA Database/Website
http://www.gama-survey.org/

- GAMA website is up and running.
- It includes the first public release of data.
- We have SQL server to search catalogues.
- Other data products:
    - Spectra
    - Swarp mosaics
    - 2D profiles
    - SFR
    - Stellar Mass



Conclusions

- GAMA is offering the astronomical community the definitive low-z galaxy database.

- Phase I is complete, and many papers based on this data are about to be released.

- My work has included producing the GAMA Galaxy Group Catalogue (G^{3}C).
    - We find discrepancies between the data and the MS-SA mocks. Work ongoing to discover origin.

- Now moved on to observing GAMA-II (N+S).

- Email: asgr@st-and.ac.uk / spd3@st-and.ac.uk