The GAMA Group Catalogue: Construction & Application(s)

Meiert W. Grootes
MPIK , Heidelberg

With
A. S. G. Robotham, R. J. Tuffs
and the GAMA team

MAX-PLANCK-INSTITUT FÜR KERNPHYSIK

OUTLINE

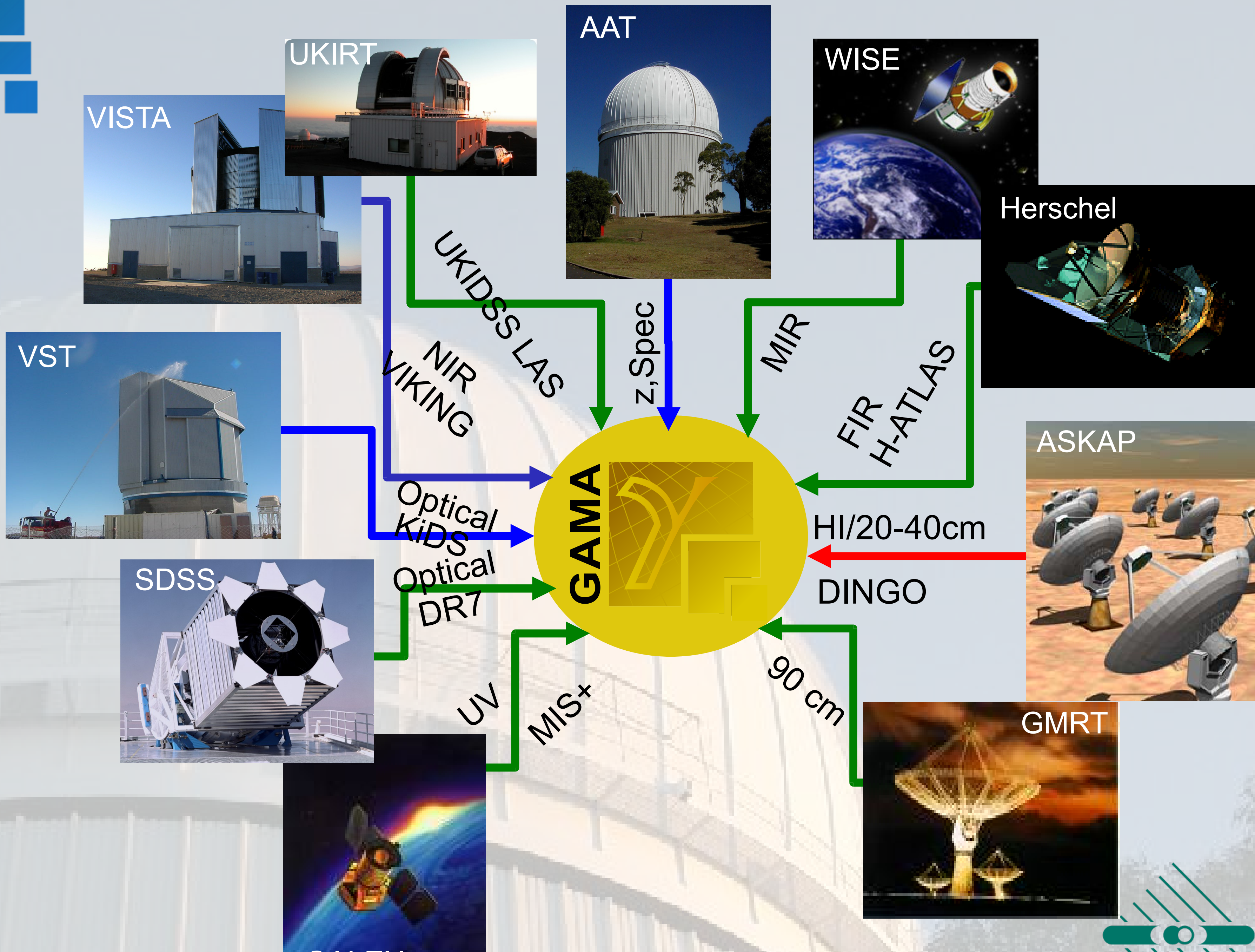
I) The GAMA Group Catalogue (G^{3}C)

On behalf of Aaron S. G. Robotham

(A. S. G. Robotham, et al. 2011, MNRAS, 416, 2640)

II) Science using the G^{3}C

Gas-fuelling as a function of environment (Grootes et al, in prep.)



XMM-XXL consortium meeting
Sesto 25.06.2014

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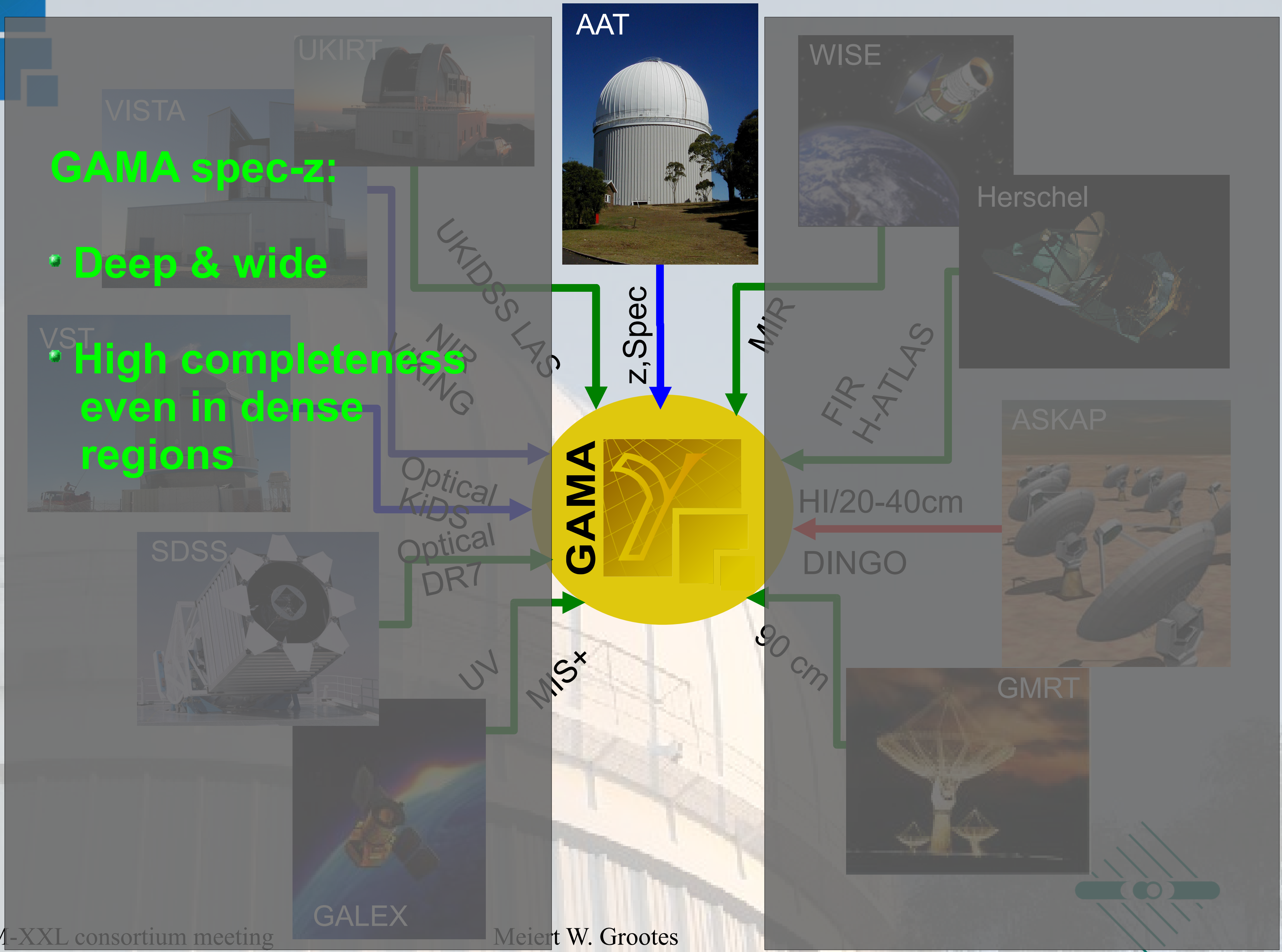
GAMA spec-z:

- Deep & wide
- High completeness even in dense regions



Monthly Notices of the ROYAL ASTRONOMICAL SOCIETY

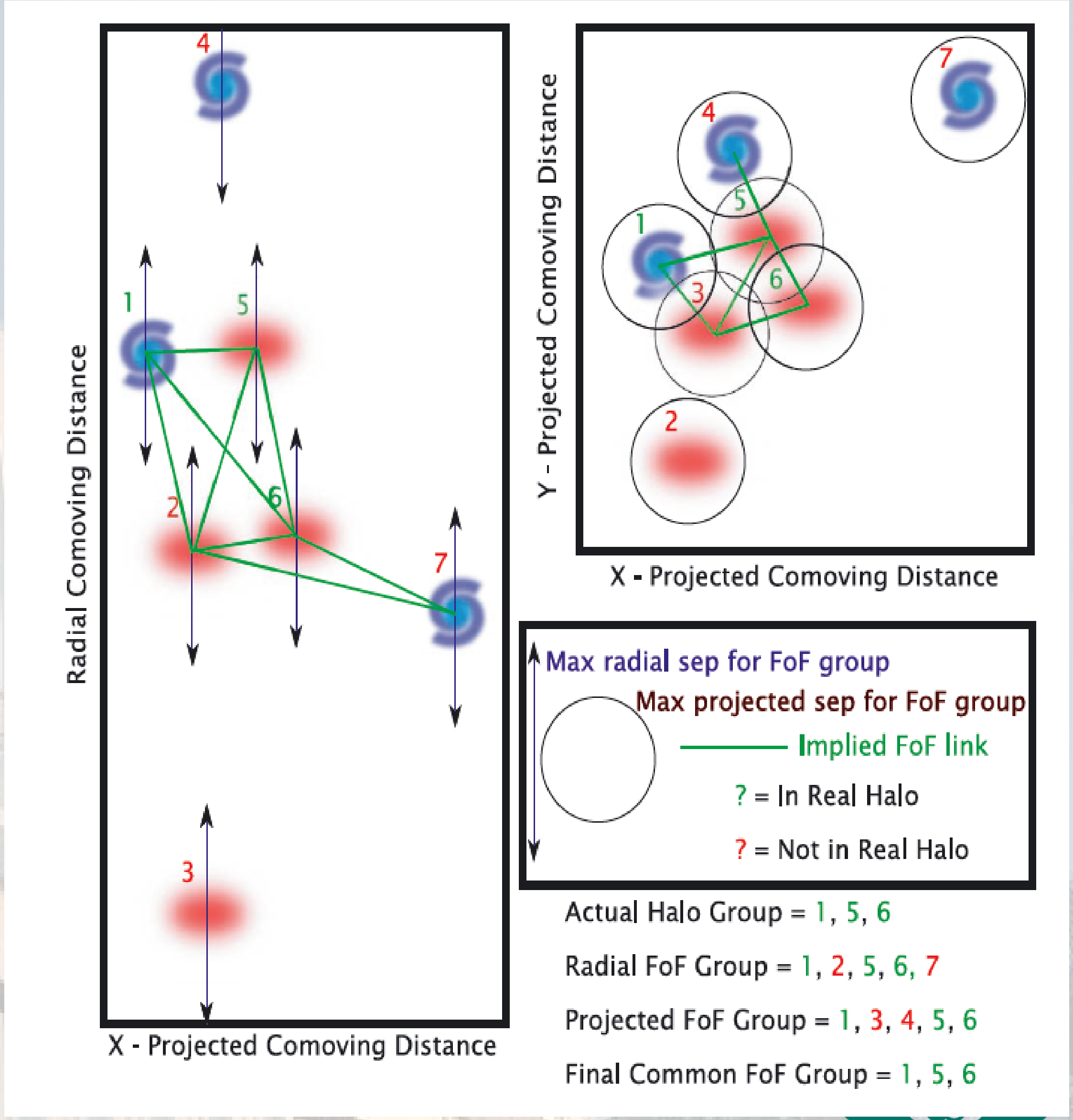
Mon. Not. R. Astron. Soc. **416,** 2640–2668 (2011) doi:10.1111/j.1365-2966.2011.19217.x

Galaxy and Mass Assembly (GAMA): the GAMA galaxy group catalogue (G^3Cv1)

A. S. G. Robotham,[1★] P. Norberg,[2] S. P. Driver,[1,3] I. K. Baldry,[4] S. P. Bamford,[5] A. M. Hopkins,[6] J. Liske,[7] J. Loveday,[8] A. Merson,[9] J. A. Peacock,[2] S. Brough,[6] E. Cameron,[10] C. J. Conselice,[5] S. M. Croom,[11] C. S. Frenk,[9] M. Gunawardhana,[11] D. T. Hill,[1] D. H. Jones,[12] L. S. Kelvin,[1] K. Kuijken,[13] R. C. Nichol,[14] H. R. Parkinson,[2] K. A. Pimbblet,[12] S. Phillipps,[15] C. C. Popescu,[16] M. Prescott,[4] R. G. Sharp,[17] W. J. Sutherland,[18] E. N. Taylor,[11] D. Thomas,[14] R. J. Tuffs,[19] E. van Kampen[7] and D. Wijesinghe[11]

Constructing FoF Groups

- 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.
  - Then construct groups out of common linking.
- Algorithm is calibrated on mock GAMA lightcones (Millenium Simulation + SAM).
  - quantitative optimization

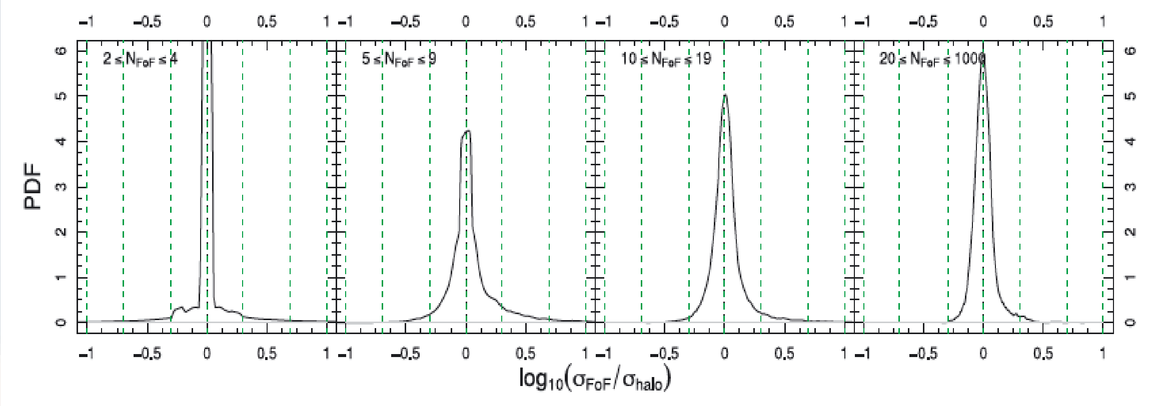


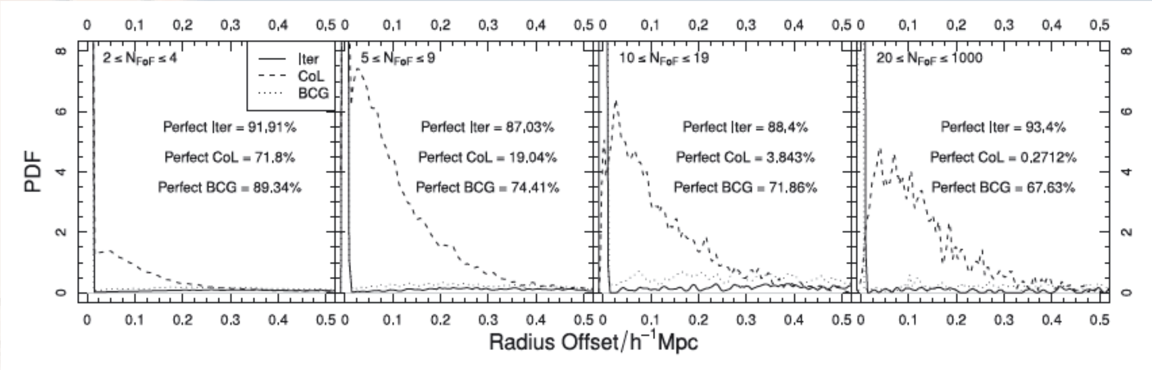
Robotham+2011

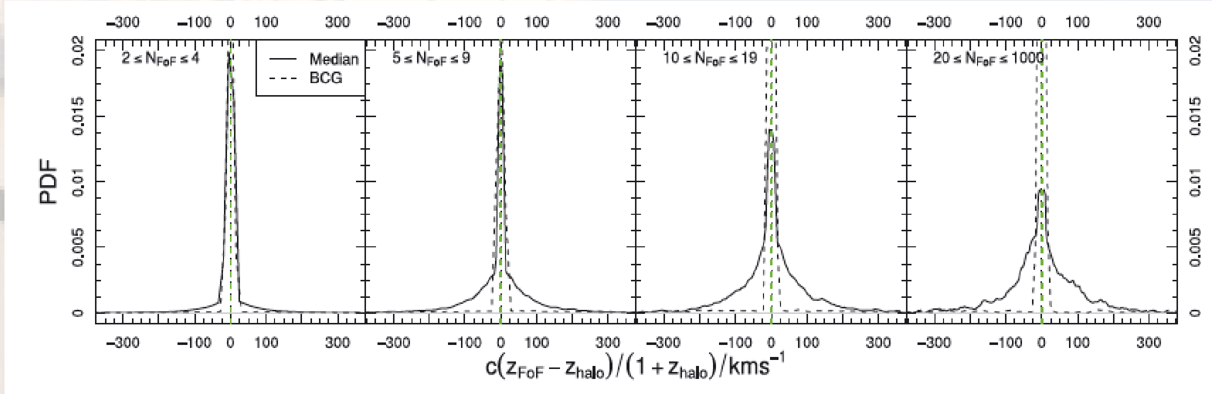
GAMA

Direct Group Properties

- Robustly determine critical parameters σ and group center
- Gapper estimate (Beers+1990, Eke+2004) for σ
- Iterative CoL for group center



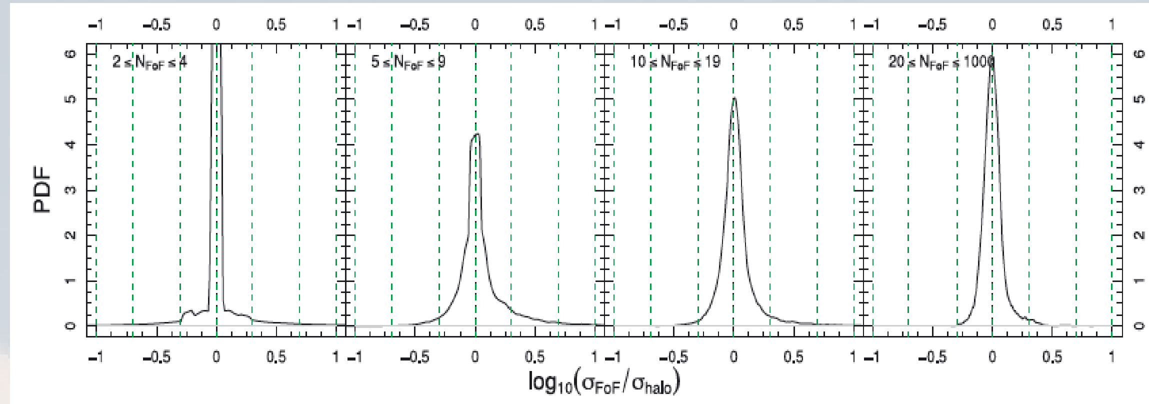


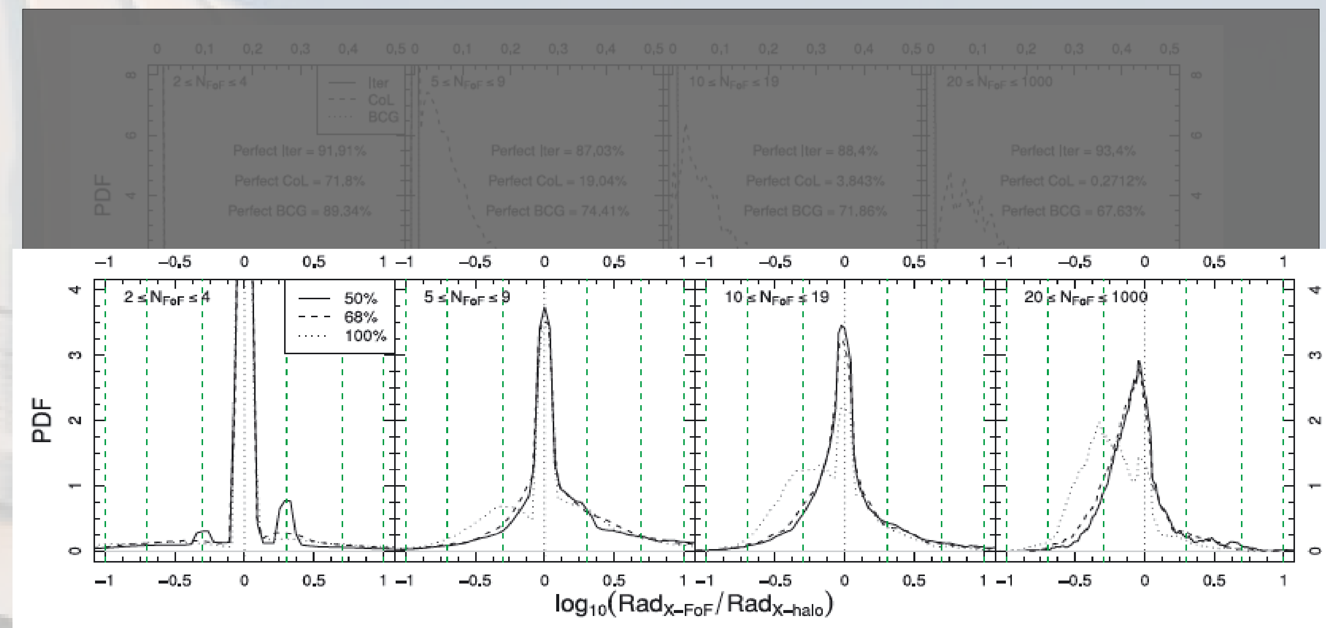


Robotham+2011

Direct Group Properties

- Robustly determine critical parameters σ and group center
- Gapper estimate (Beers+1990, Eke+2004) for σ
- Iterative CoL for group center
- Combine with robust estimate of group radius





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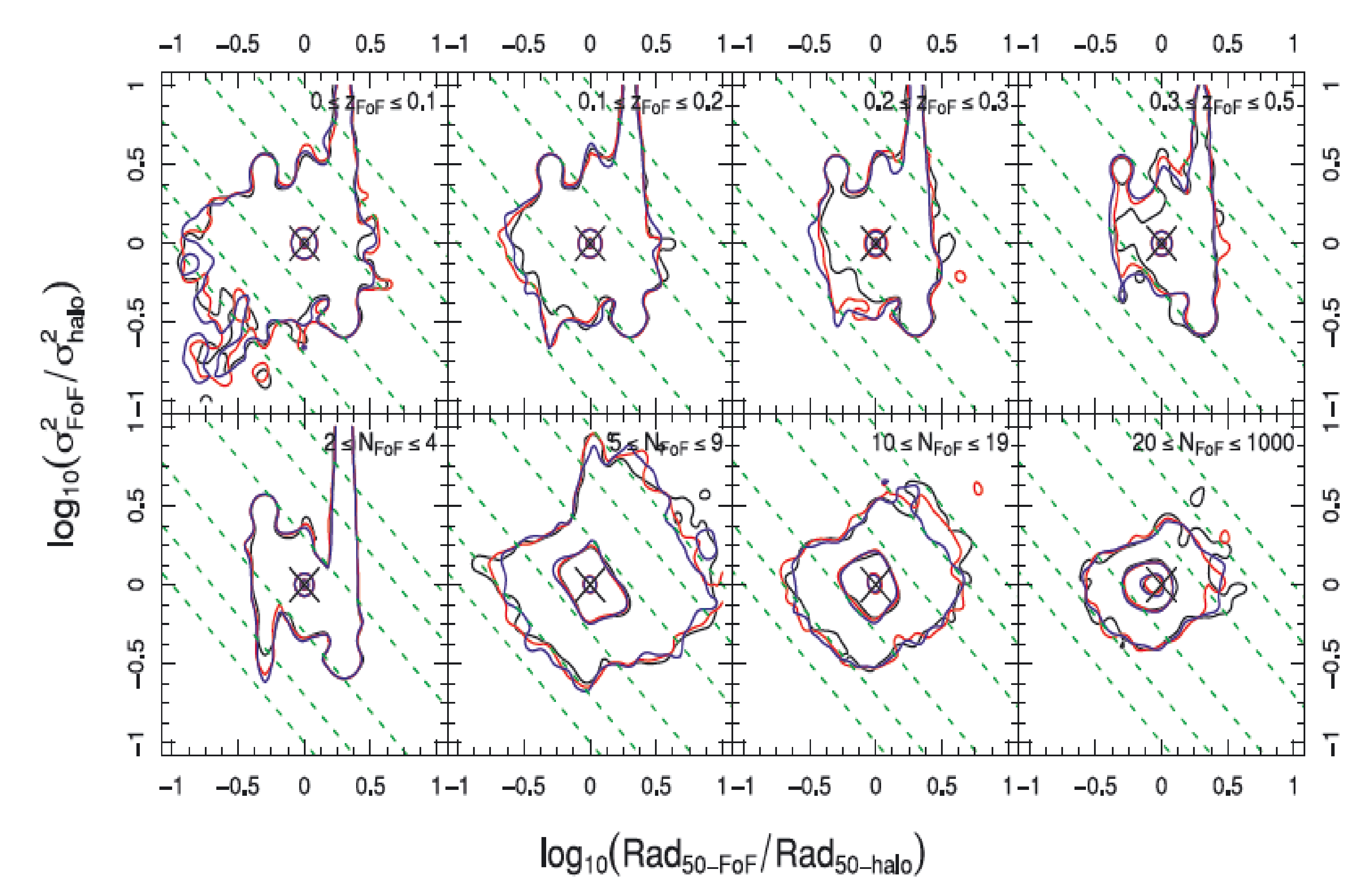
M α σR^2 : Mass estimator

- Worry about correlated bias
- No evidence for strong correlated biases
- Viable mass estimator



Robotham+2011

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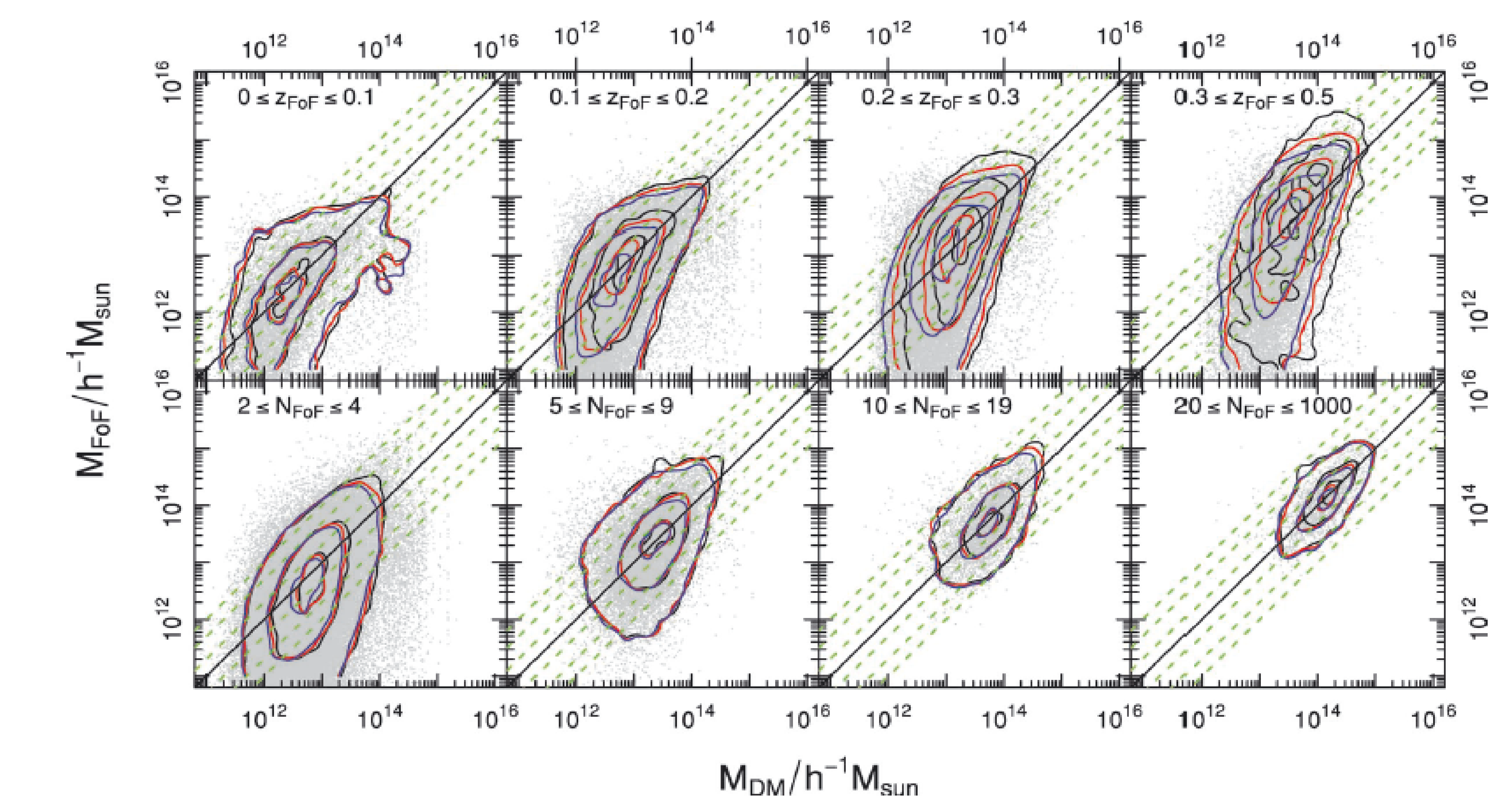
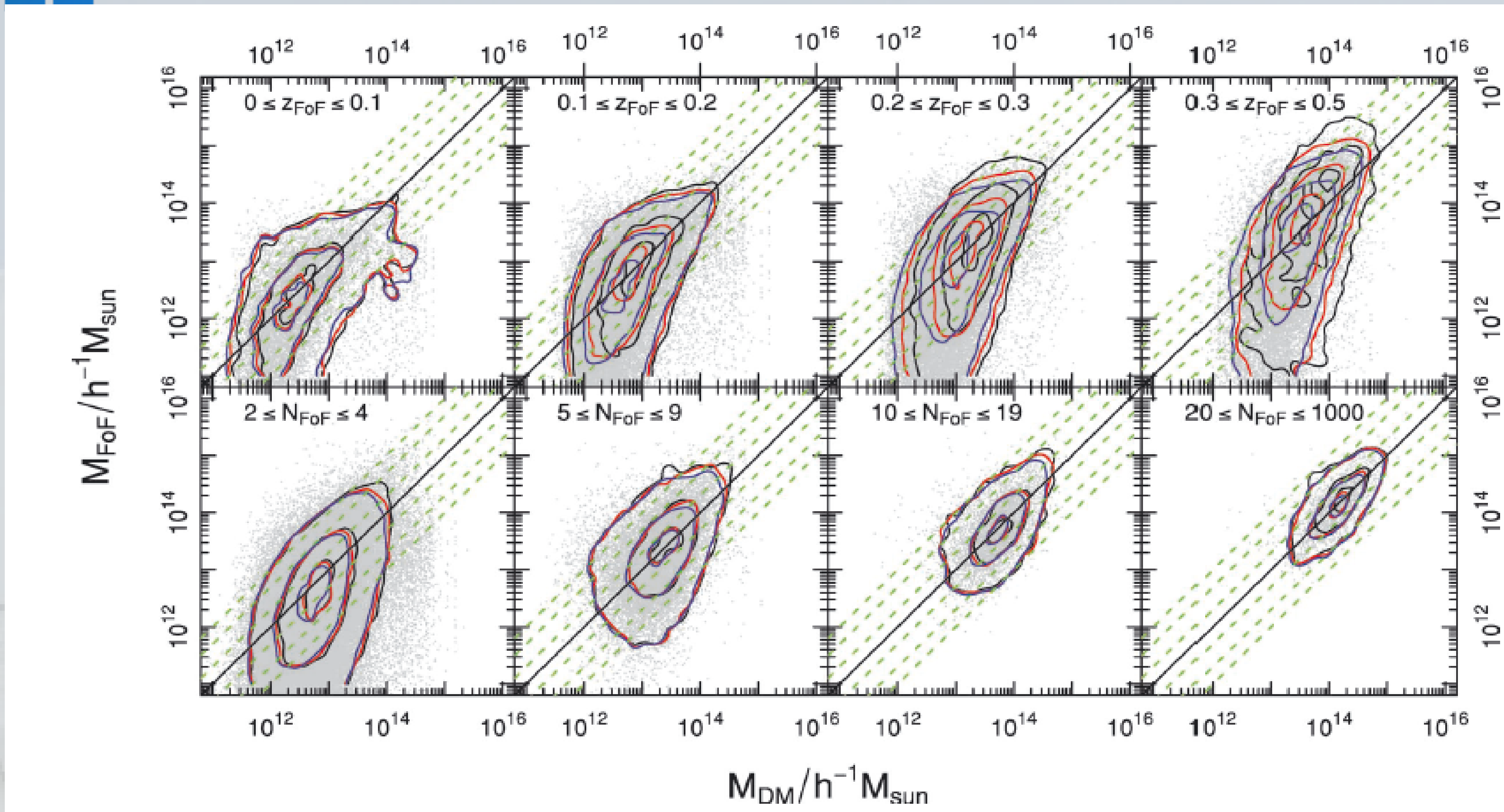


Robotham+2011

$$A(N_{\rm FoF}, z_{\rm FoF}) = A_c + \frac{A_N}{\sqrt{N_{\rm FoF}}} + \frac{A_z}{\sqrt{z_{\rm FoF}}},$$

	A_c	A_N	A_z
$r_{AB} \le 19.0$	-4.3 ± 3.1	22.5 ± 1.7	3.1 ± 1.1
$r_{AB} \le 19.4$	-1.2 ± 1.7	20.7 ± 1.4	2.3 ± 0.6
$r_{AB} \le 19.8$	$+2.0 \pm 1.4$	17.9 ± 1.1	1.5 ± 0.4

$M \propto \sigma R^2$: Mass estimator



Robotham+2011

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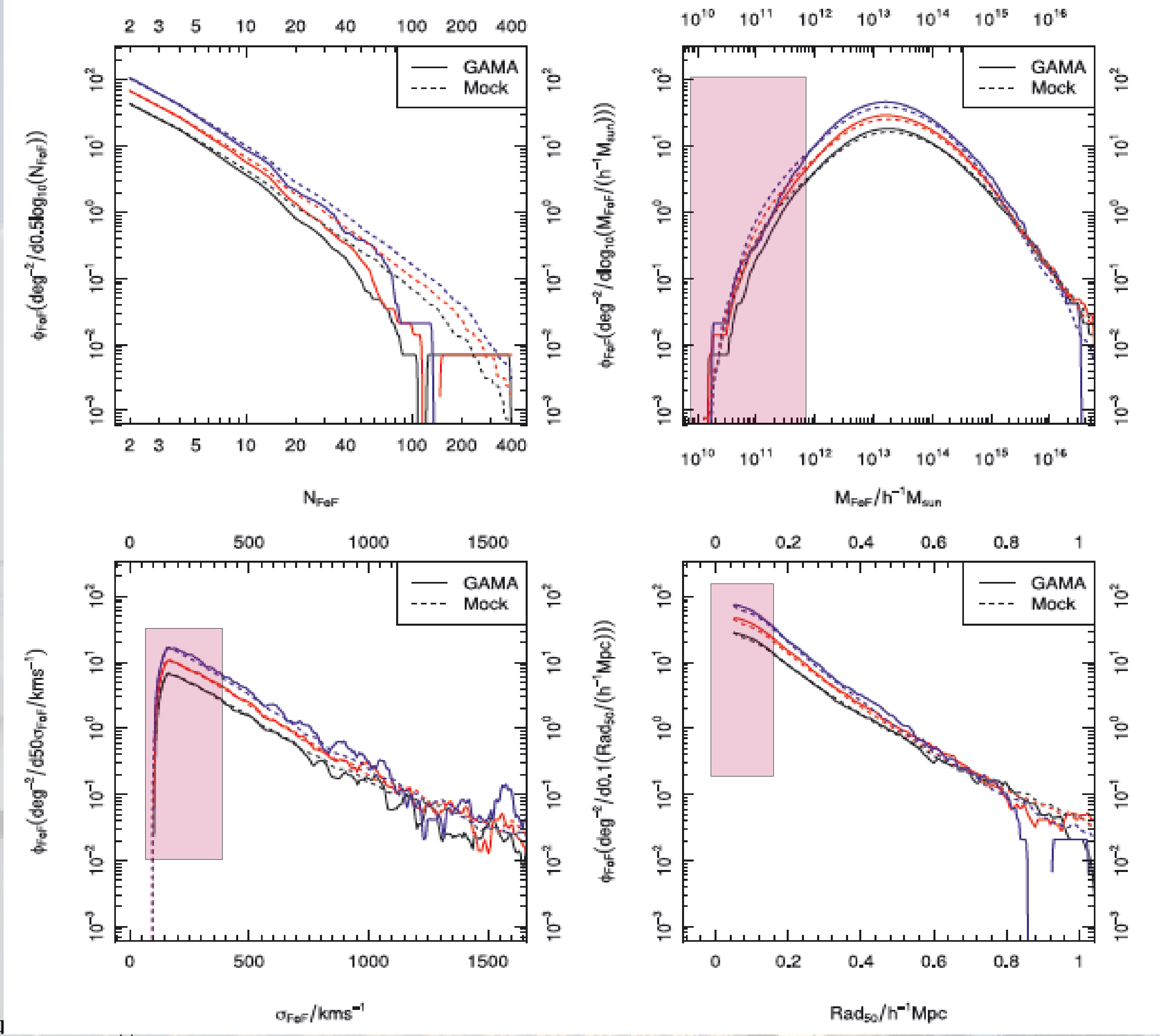
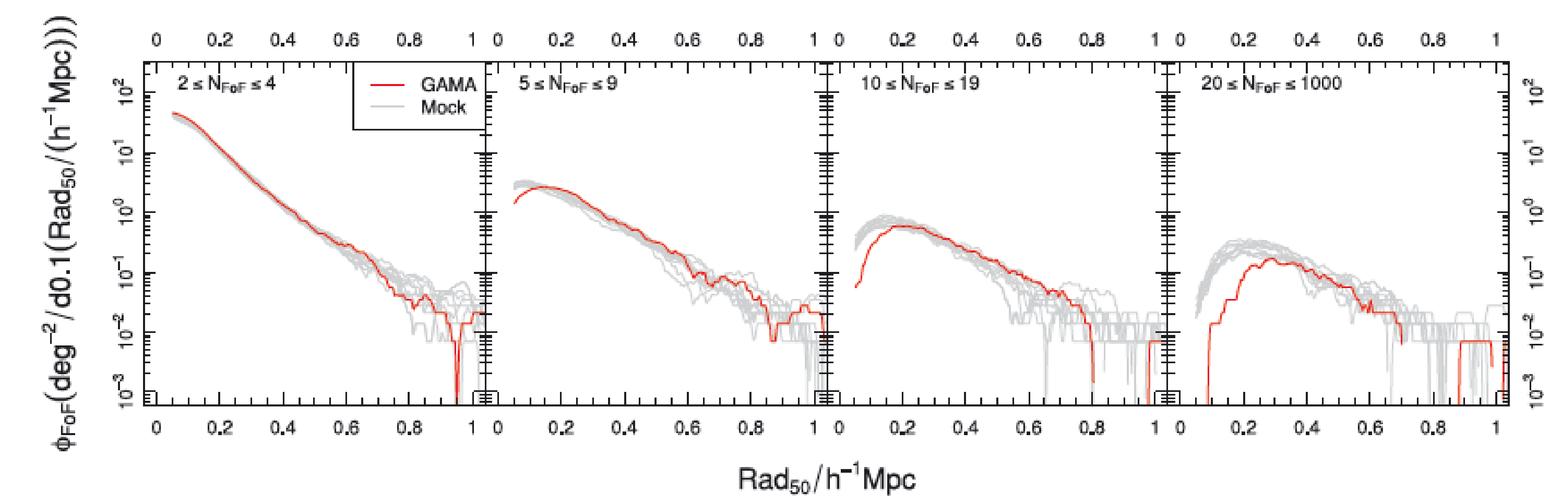
Global Group Properties



Robotham+2011

So what is going on at low mass ?

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



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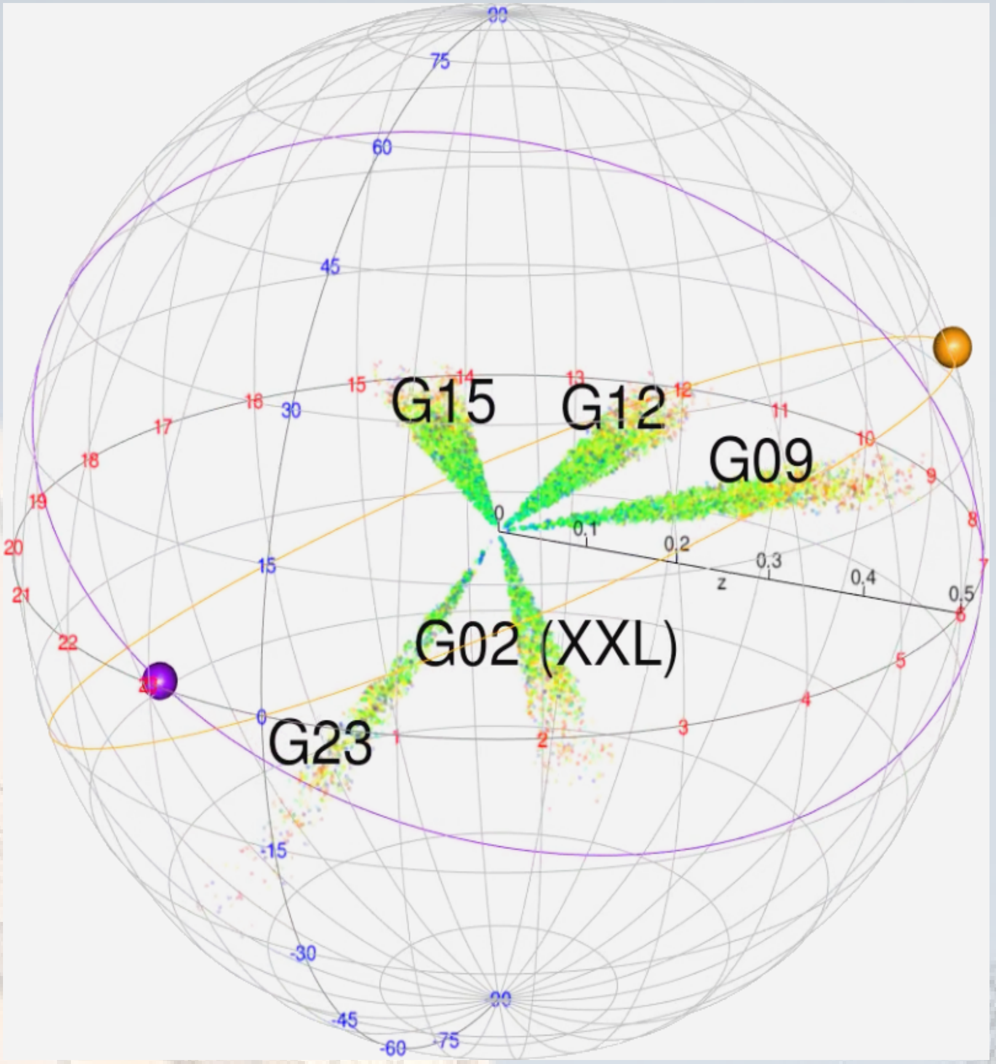
- It would appear that the recipe used for “simulating” dynamical friction is far too crude, and doesn’t merge groups rapidly enough.

The GAMA Galaxy Group Catalog

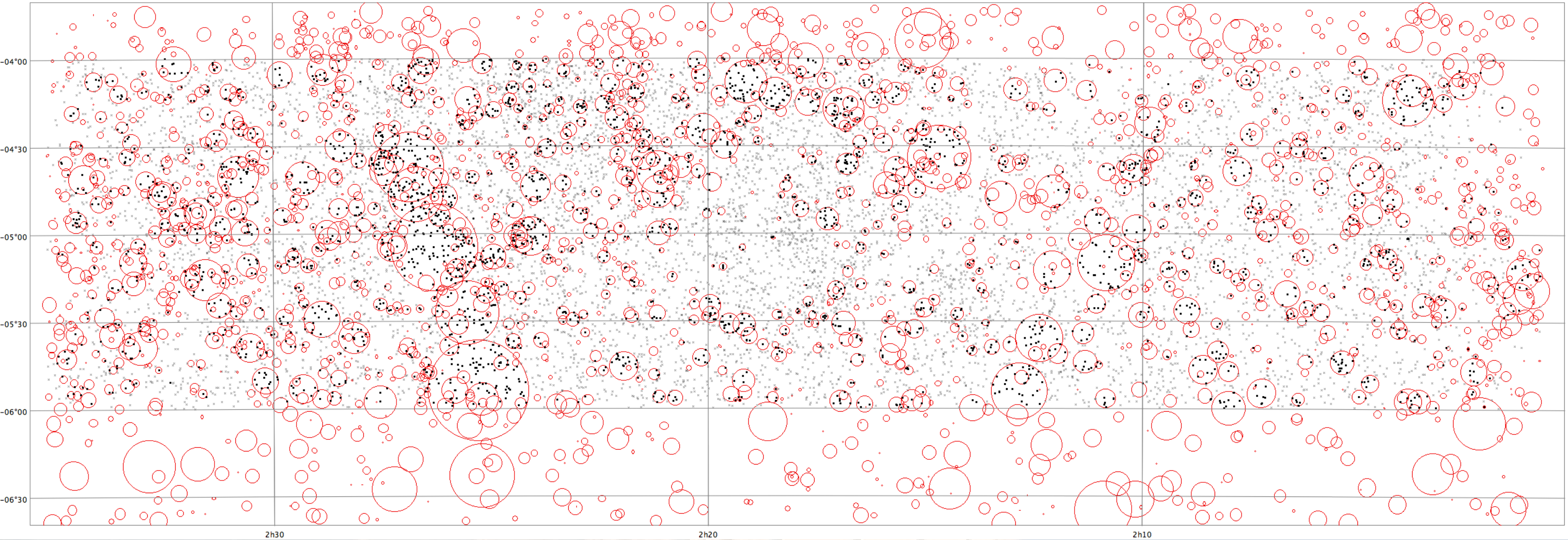
Region	Groups	Gals in Groups
G02	3,476	10,172
G02 (XXL)	1,919	5,836
G09	7,558	22,845
G12	8,235	25,443
G15	8,045	24,980
G23	2,692	7,968

- Generally we place ~40% of GAMA r<19.8 galaxies into groups.



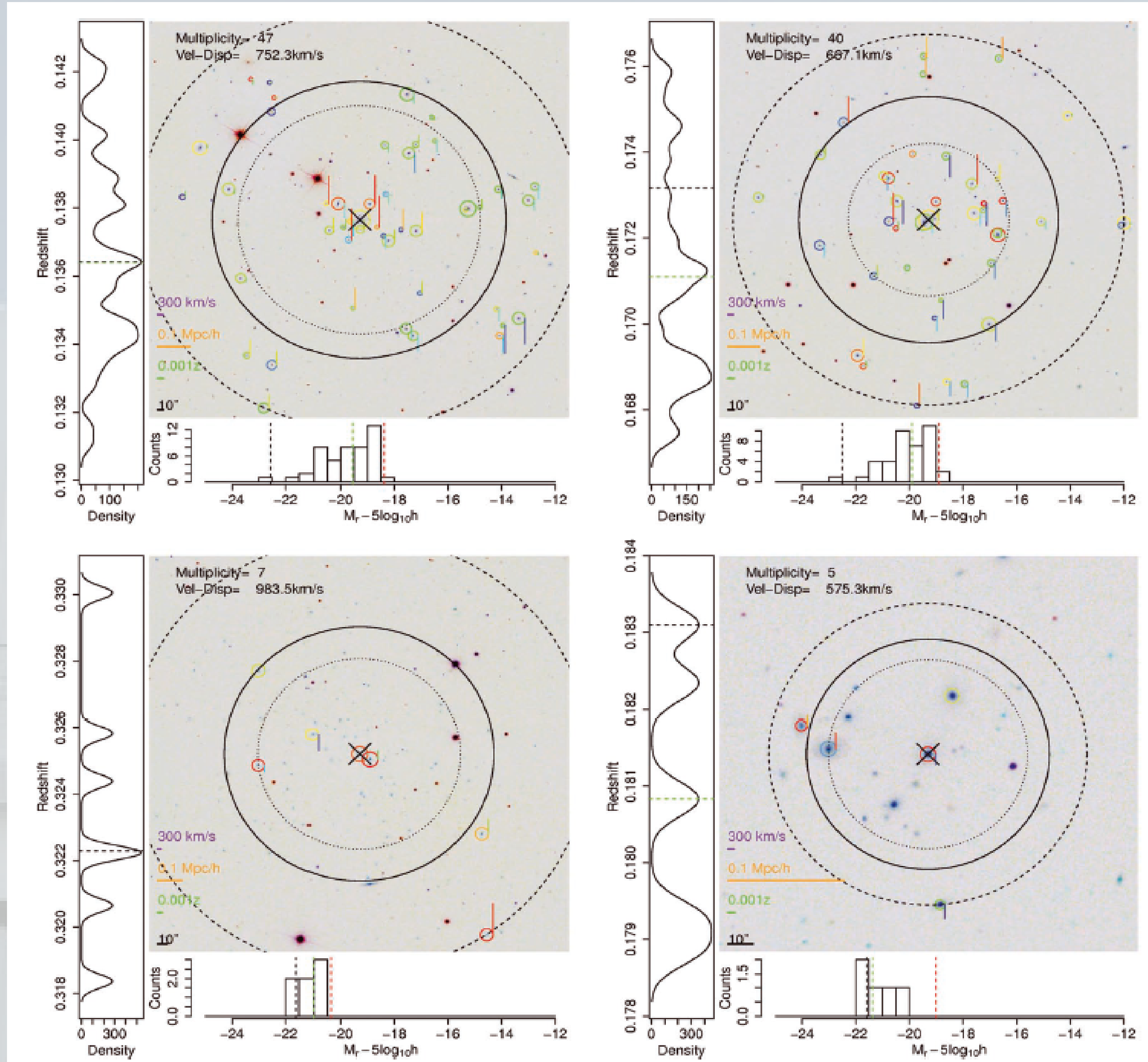
Credit: A. Robotham

G02 XXL Groups



Credit: A. Robotham

- Red circles indicate full extent of GAMA group
- Black crosses indicate XXL sources (all within XXLN cat) within this extent.
- Gray points indicate all other XXL sources.
- 3,222 / 9,474 XXLN objects lie within the projected extent of *known* GAMA groups.



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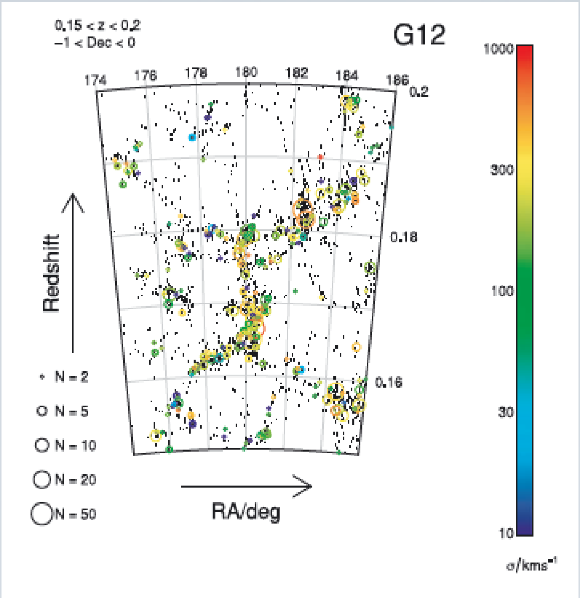
Beyond Groups: Filaments, Tendrils, and Voids

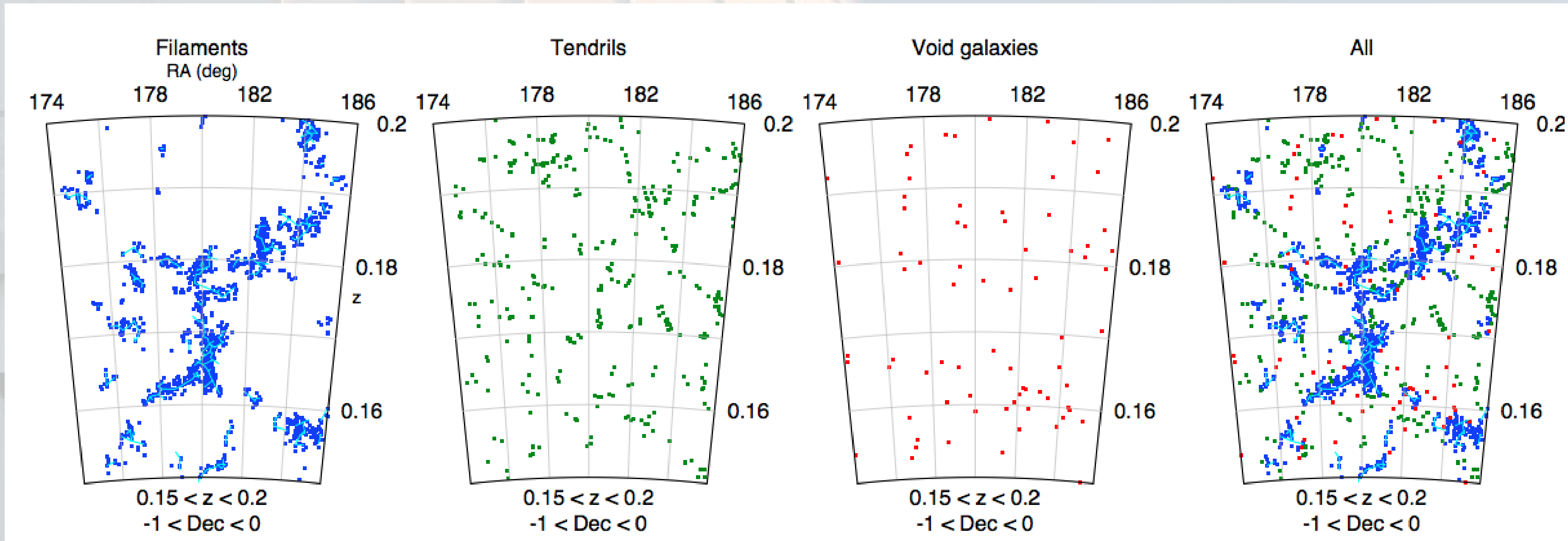
Galaxy and Mass Assembly (GAMA): Fine filaments of galaxies detected within voids

Mehmet Alpaslan[1,2], Aaron S.G. Robotham[2], Danail Obreschkow[2], Samantha Penny[3],

M. Alpaslan et al, 2014, MNRAS, 440,106



Robotham+2011



Alpaslan+2014

Current GAMA Group Papers

2011

2011MNRAS.416.2640R	1.000	10/2011	A E F X R C S U
Robotham, A. S. G.; Norberg, P.; Driver, S. P.; Baldry, I. K.;	Galaxy and Mass Assembly (GAMA): the GAMA galaxy group catalogue (G3Cv1)		

2012

2012IAUS..284..352G	1.000	08/2012	A E T C U
Grootes, Meiert W.; Tuffs, Richard J.; Andrae, Ellen;	Environmental dependence of SFRs in late-type GAMA galaxies		
2012MNRAS.424.1448R	1.000	08/2012	A E F X R C S N U
Robotham, A. S. G.; Baldry, I. K.; Bland-Hawthorn, J.; Driver, S. P.;	Galaxy And Mass Assembly (GAMA): in search of Milky Way Magellanic Cloud analogues		
2012MNRAS.426.2832A	1.000	11/2012	A E F X R C U
Alpaslan, Mehmet; Robotham, Aaron S. G.;	Galaxy And Mass Assembly (GAMA): estimating galaxy group masses via caustic analysis		

2013

2013AN....334..466L	1.000	04/2013	A E F X R U
Lara-López, M. A.; Hopkins, A. M.; Robotham, A.;	Galaxy And Mass Assembly (GAMA): The M-Z relation for galaxy groups		
2013MNRAS.431..167R	1.000	05/2013	A E F X R C S U
Robotham, A. S. G.; Liske, J.; Driver, S. P.; Sansom, A. E.;	Galaxy And Mass Assembly (GAMA): the life and times of L★ galaxies		
2013ApJ...772..104O	1.000	08/2013	A E F X D R C S U
Owers, M. S.; Baldry, I. K.; Bauer, A. E.; Bland-Hawthorn, J.;	Galaxy and Mass Assembly (GAMA): Witnessing the Assembly of the Cluster ABELL 1882		
2013MNRAS.433.2727S	1.000	08/2013	A E F X R C S U
Schneider, Michael D.; Cole, Shaun; Frenk, Carlos S.;	Galaxy And Mass Assembly (GAMA): galaxy radial alignments in GAMA groups		
2013MNRAS.435.2903B	1.000	11/2013	A E F X R C S U
Brough, S.; Croom, S.; Sharp, R.; Hopkins, A. M.; Taylor, E. N.;	Galaxy And Mass Assembly: resolving the role of environment in galaxy evolution		

Galaxy evolution

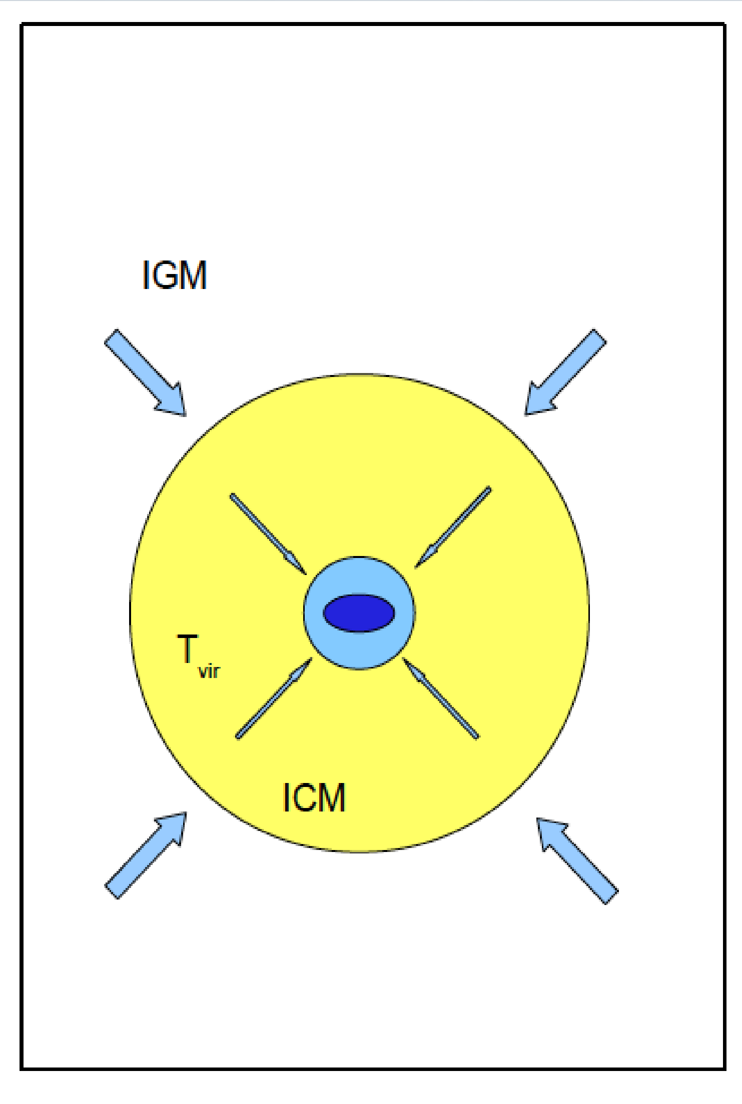
2014...

2014arXiv1401.0986G	1.000	01/2014	A X C U
Guo, Qi; Lacey, Cedric; Norberg, Peder; Cole, Shaun;	Herschel-ATLAS/GAMA:How does the far-IR luminosity function depend on galaxy group properties?		
2014MNRAS.438..177A	1.000	02/2014	A E F X R C U
Alpaslan, Mehmet; Robotham, Aaron S. G.;	Galaxy And Mass Assembly (GAMA): the large-scale structure of galaxies and comparison to mock universes		
2014MNRAS.440..762O	1.000	05/2014	A E F X R C U
Oliva-Altamirano, P.; Brough, S.; Lidman, C.; Couch, W. J.;	Galaxy And Mass Assembly (GAMA): testing galaxy formation models through the most massive galaxies in the Universe		
2014MNRAS.440L.106A	1.000	05/2014	A E F X R C U
Alpaslan, Mehmet; Robotham, Aaron S. G.;	Galaxy and Mass Assembly (GAMA): fine filaments of galaxies detected within voids		

II) Gas-fuelling as a Function of Environment

Why Bother with Gas-fuelling ?

- DM Structure formation well understood in context of LCDM but processes by which baryonic mass component of galaxies is assembled are much more unclear.



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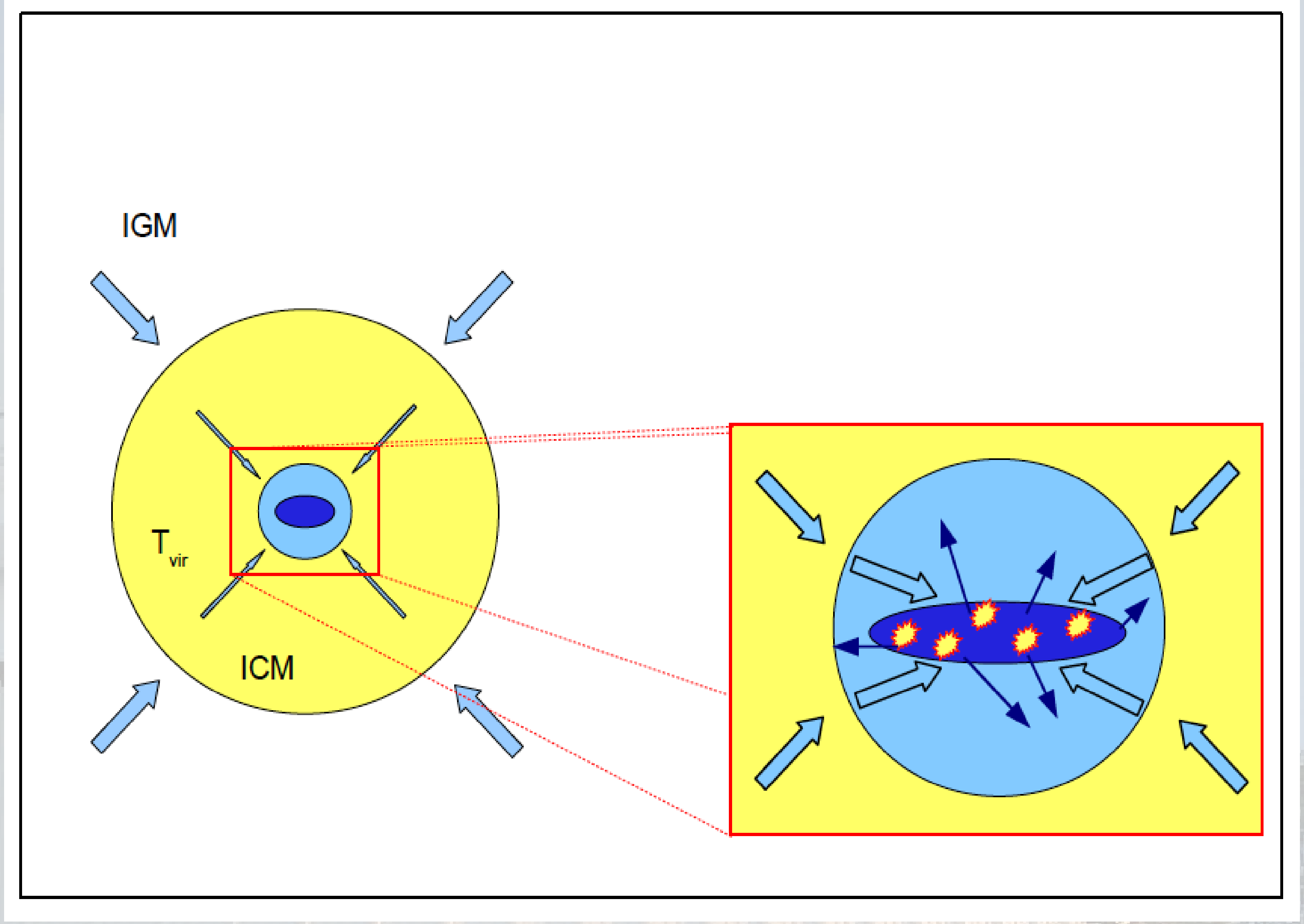

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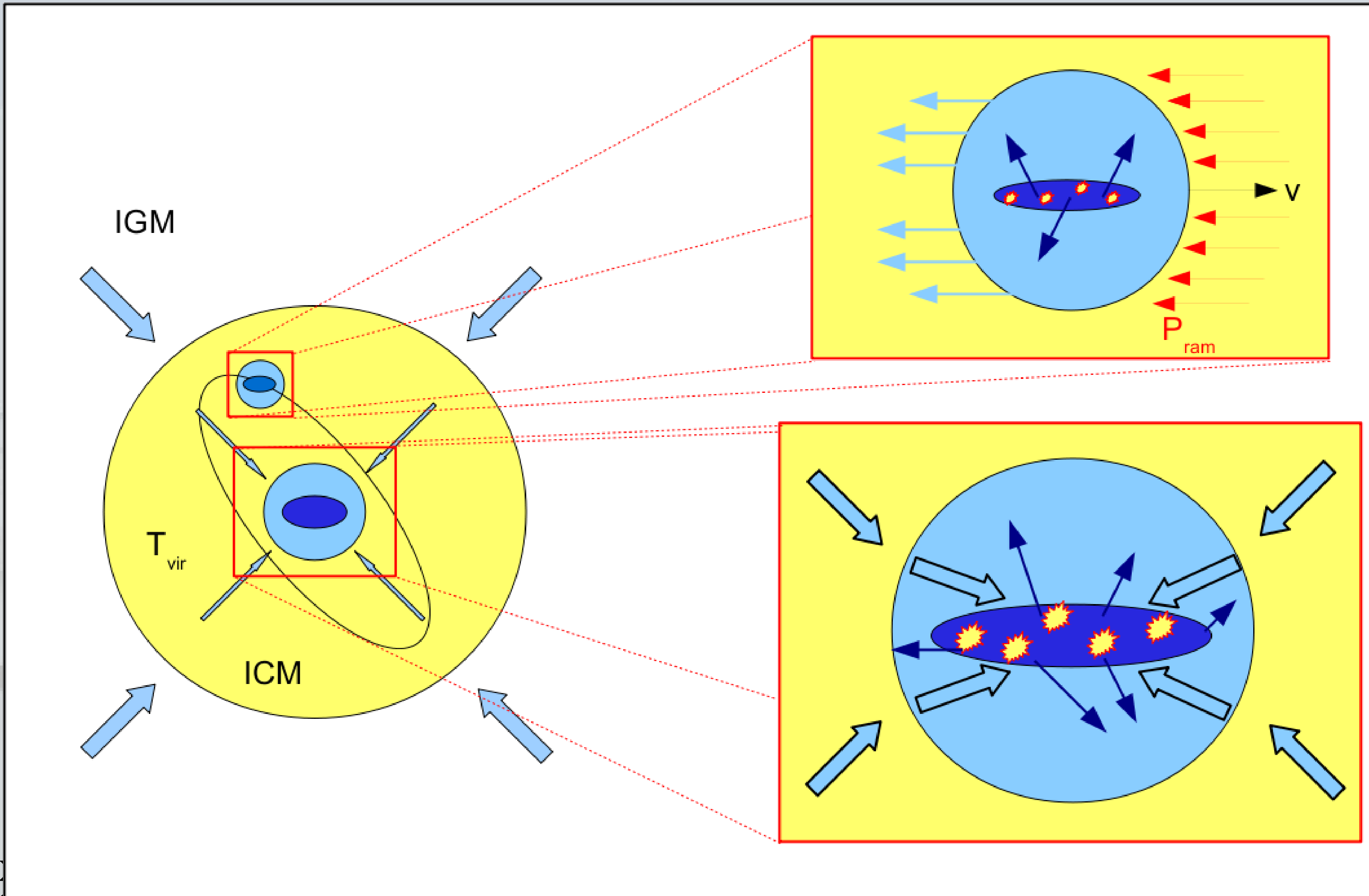

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Why Bother ?

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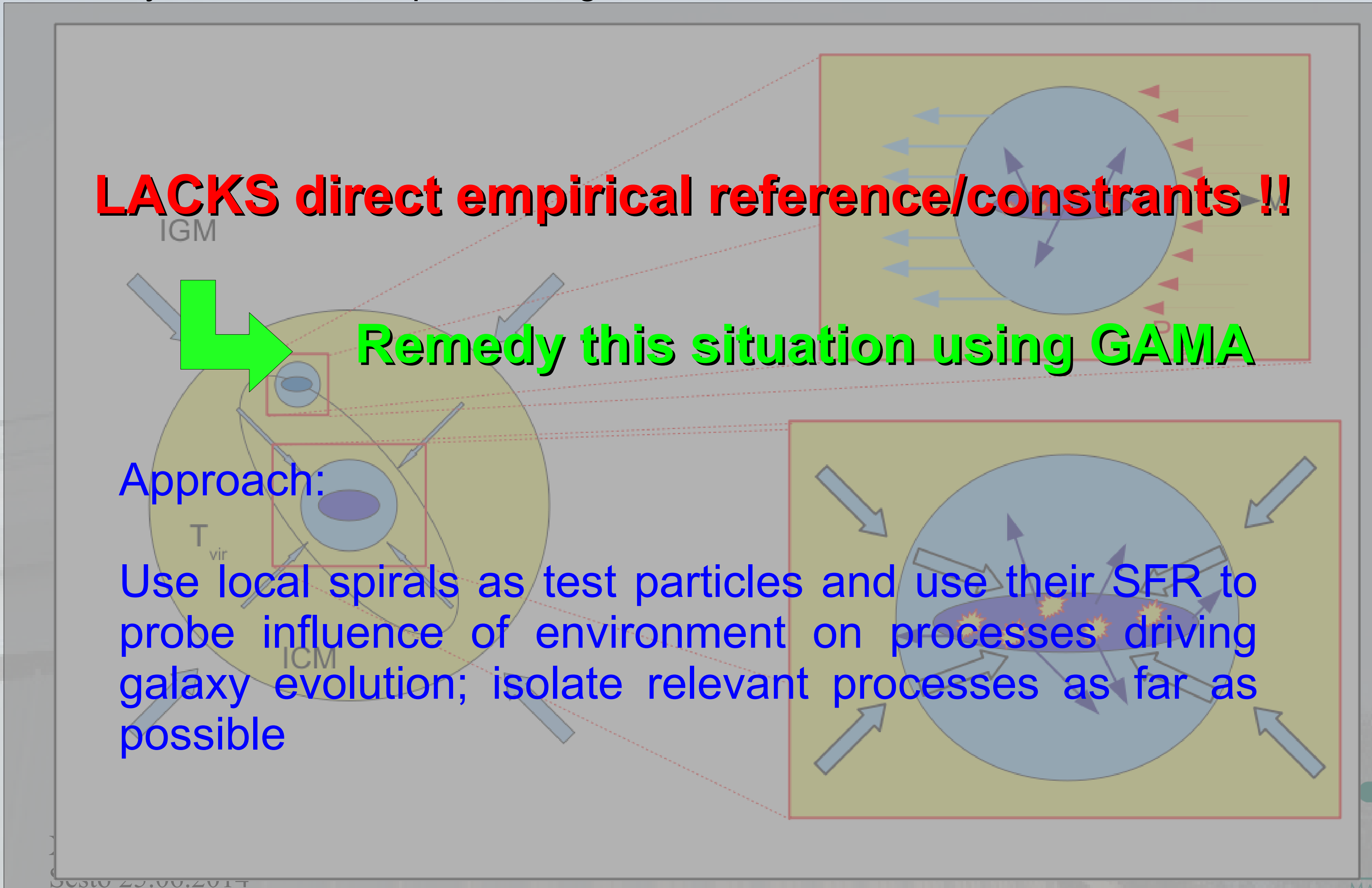

LACKS direct empirical reference/constrants !!

Remedy this situation using GAMA

Approach:

Use local spirals as test particles and use their SFR to probe influence of environment on processes driving galaxy evolution; isolate relevant processes as far as possible

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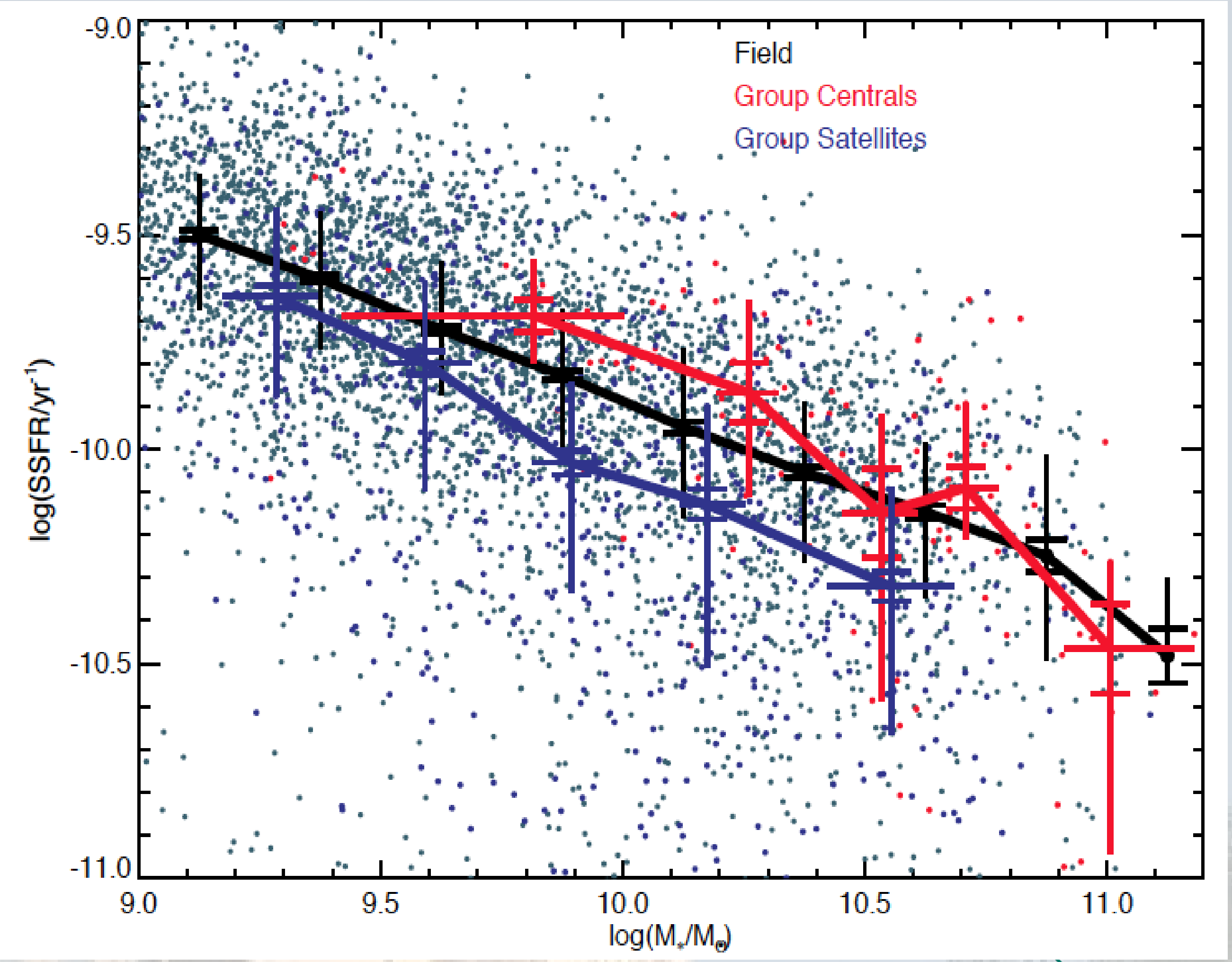
Requirements

Basic Requirements:

- Ability to probe wide range of environments down to low halo masses
  The G^3C provides the perfect database
- Ability to isolate galaxy-galaxy interactions from galaxy-IGM interactions
  do not consider close pairs/interacting galaxies
- Ability to isolate galaxy specific effects, in particular morphology
  Select a complete morphologically defined sample unbiased in SFR and employ SSFR-M* relation
- Sensitivity to timescales << $t_{dyn} \approx 1$ Gyr
  Use NUV as starformation rate trace
- Very high precision in intrinsic SFR measures to be sensitive to small effects due to environment
  Use radiation-transfer based attenuation corrections
- Consider satellite & central galaxies separately

GAMA Satellites and Centrals

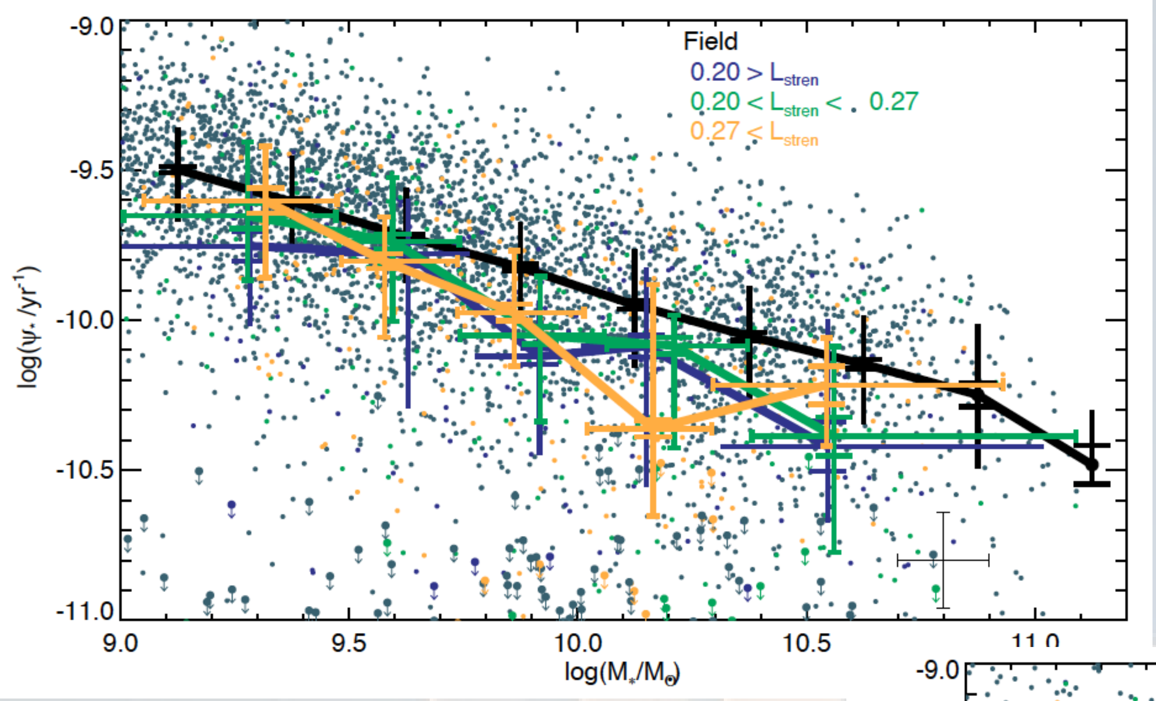
- Group Central spirals show enhanced SFR
- Median SFR of satellite spirals suppressed w.r.t Field



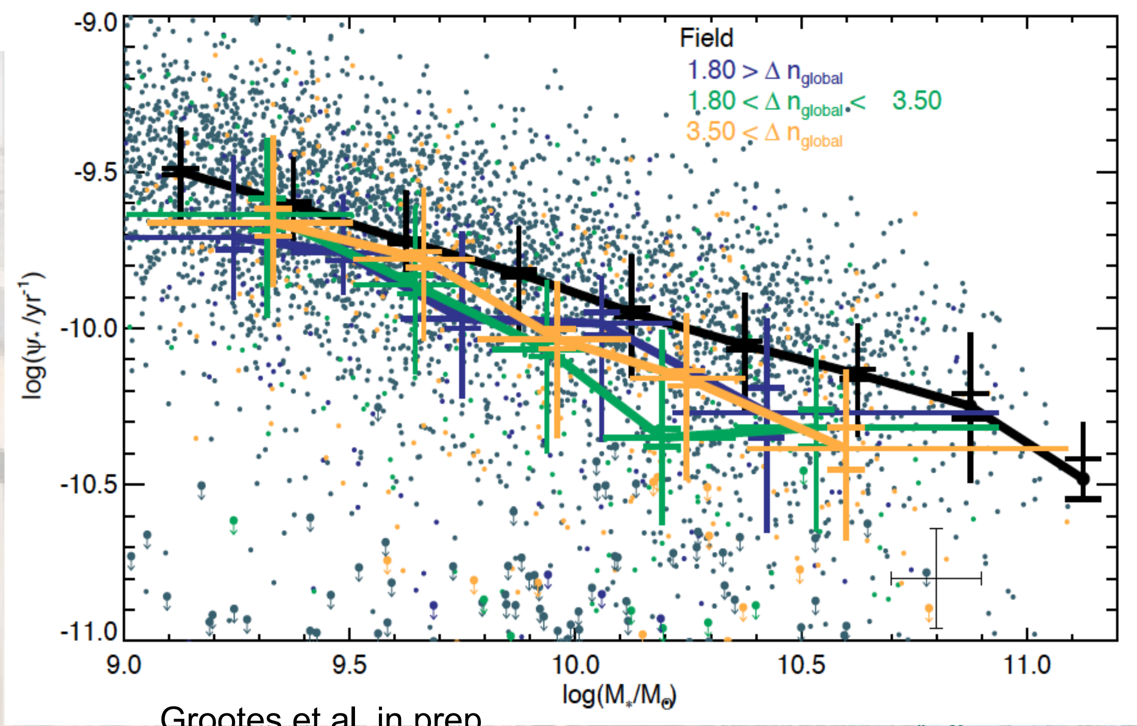
Grootes et al, in prep.

GAMA Satellite Spirals by Environment

Group Compactness



Global Overdensity



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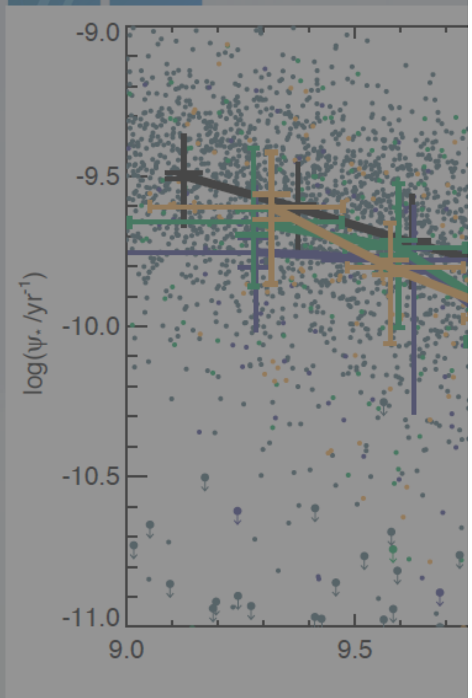
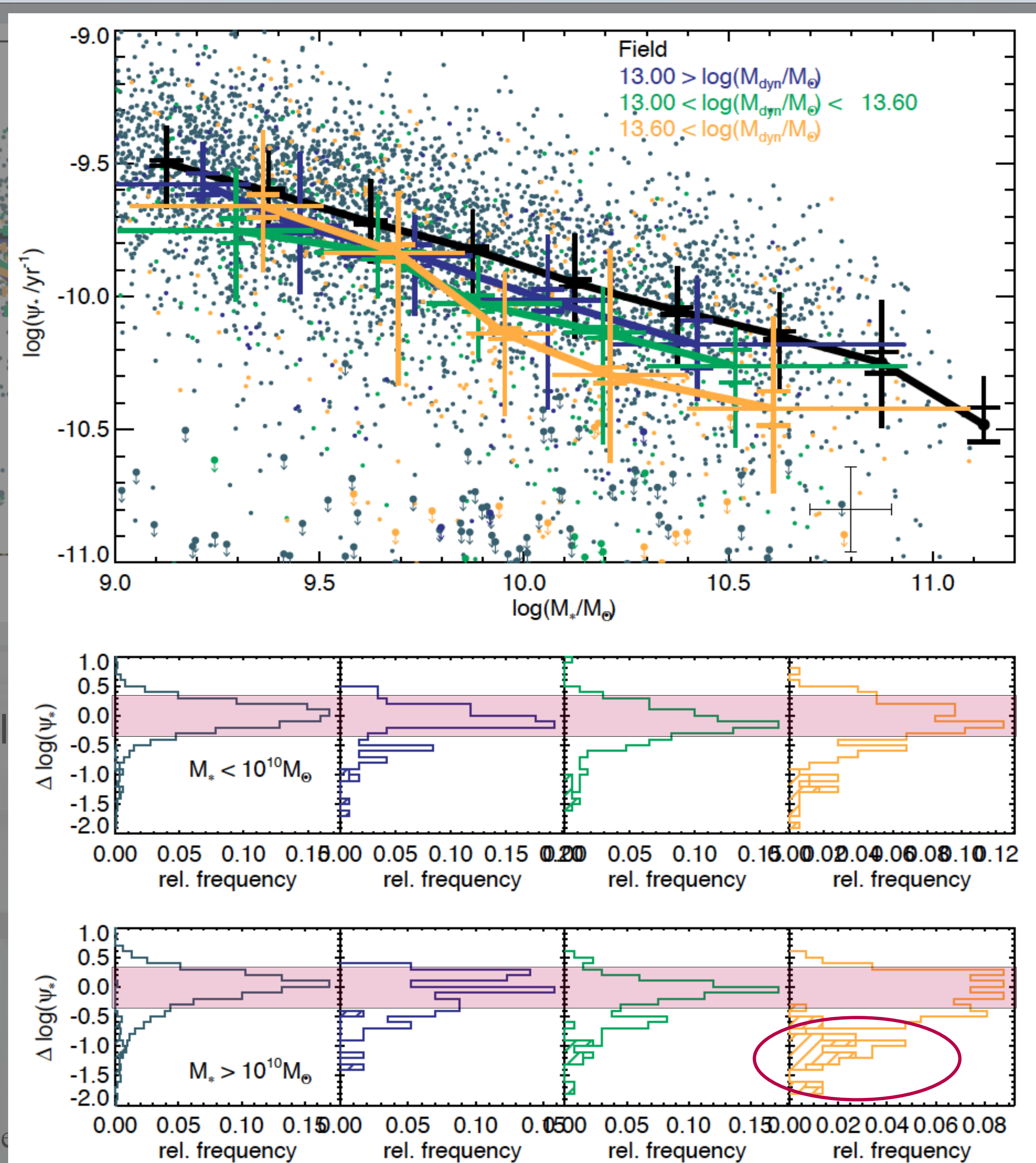
GAMA Satellite Spirals by Environment



Global

DMH Mass



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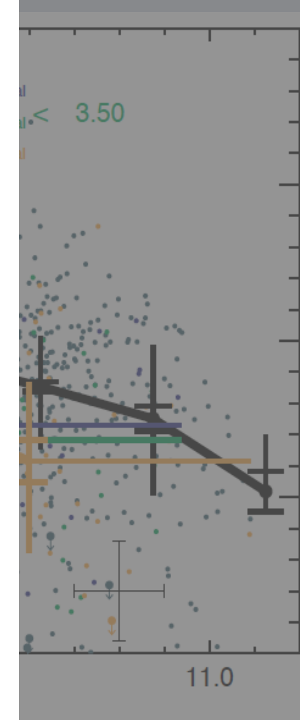
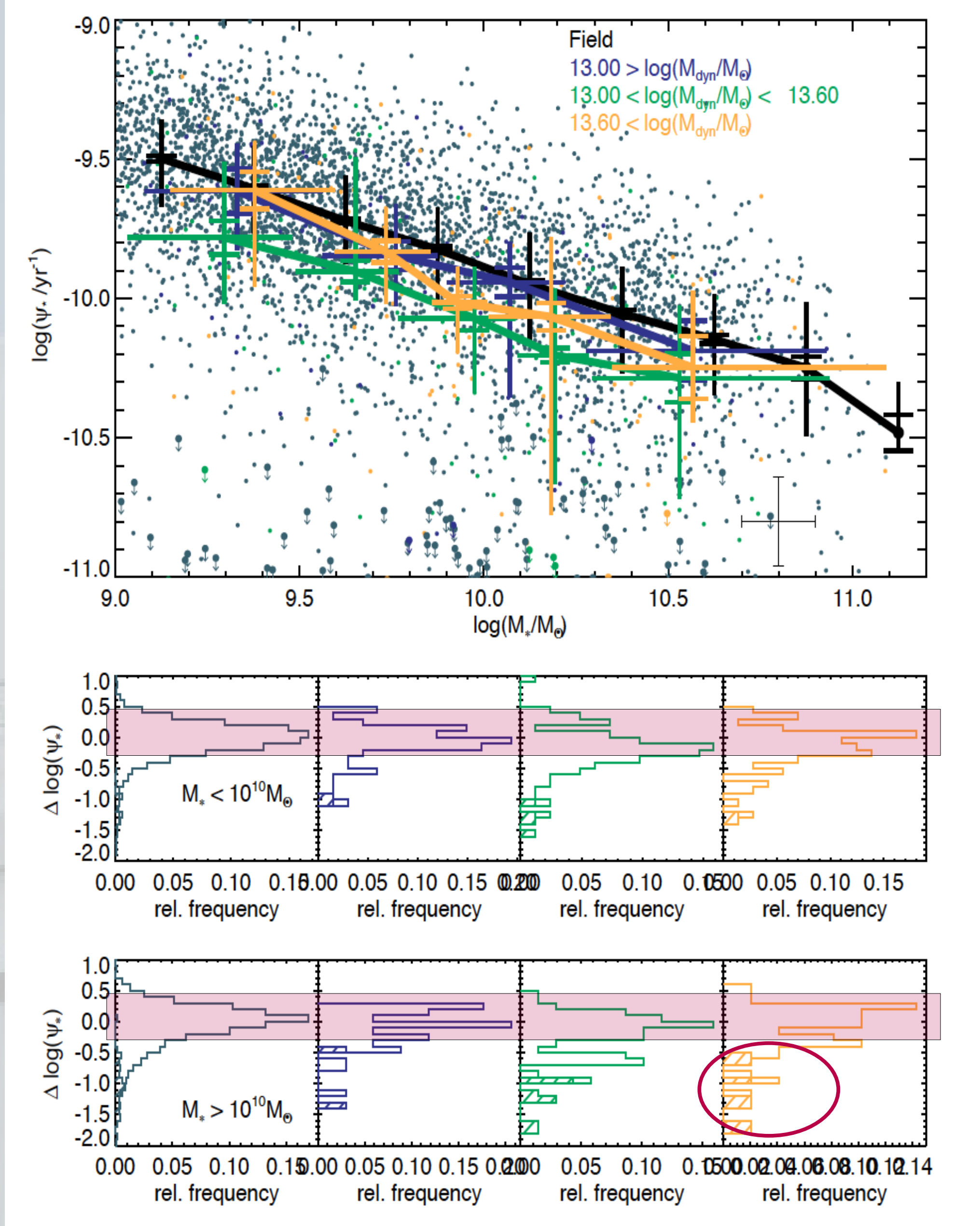
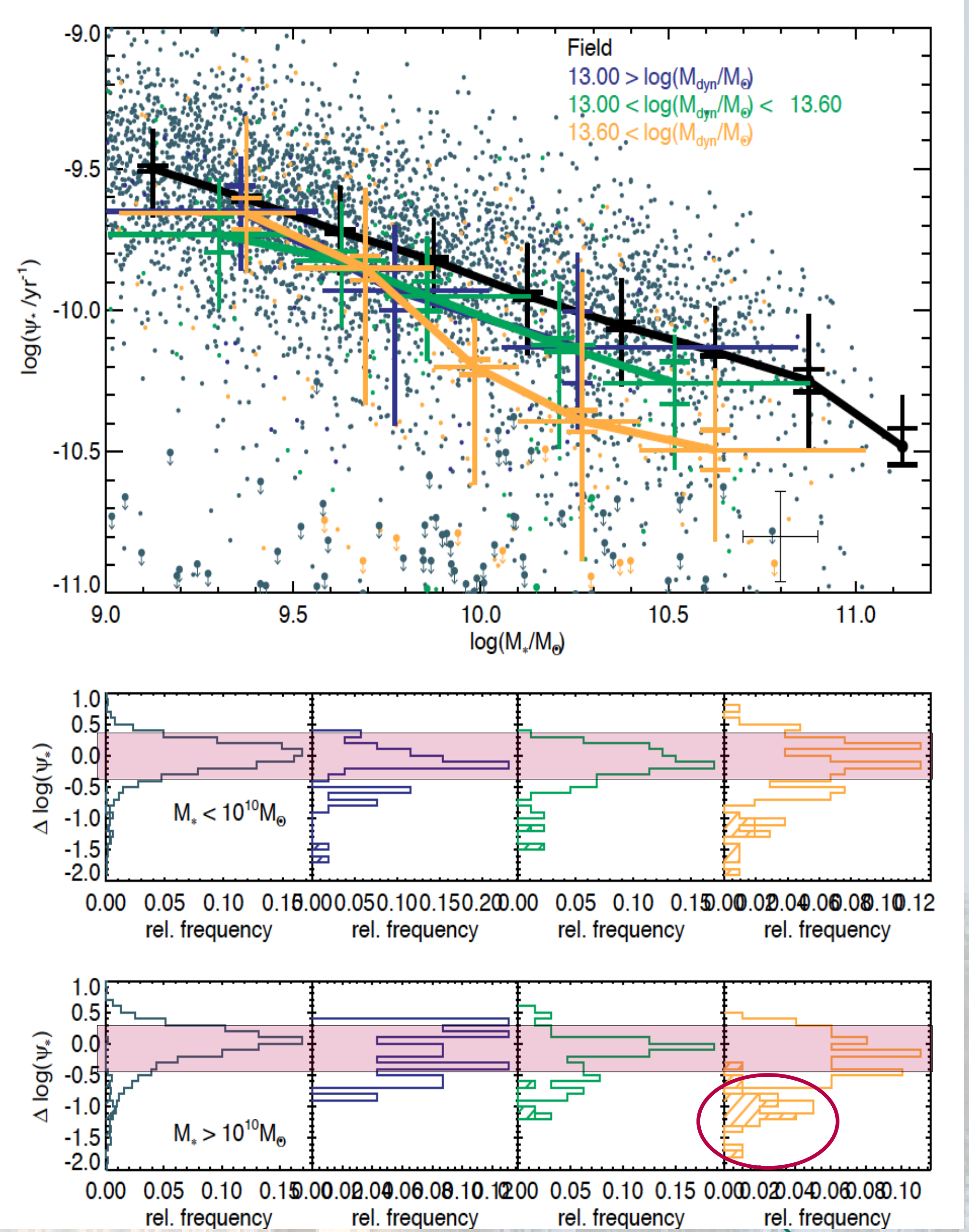


The Role of AGN

Without AGN



With AGN



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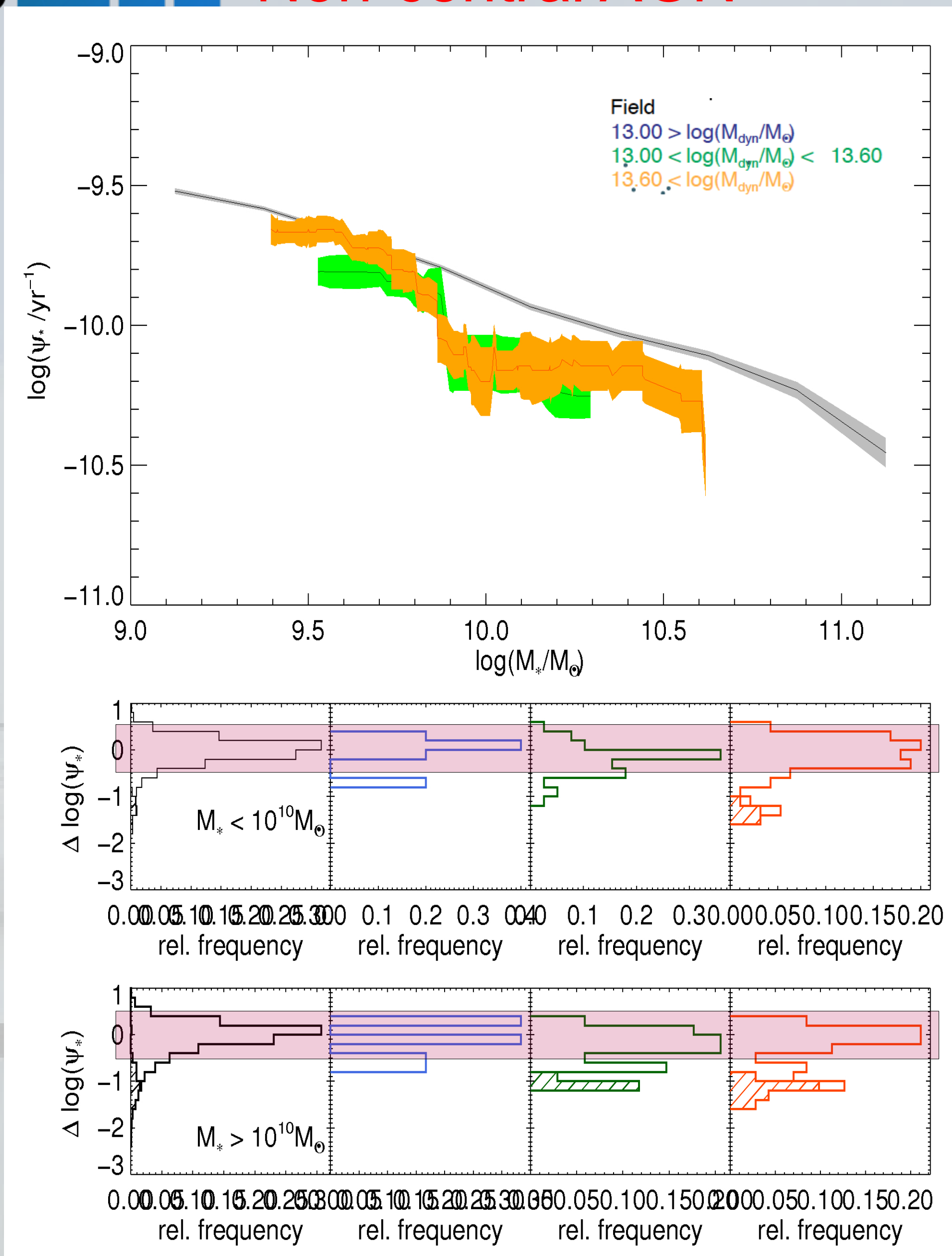
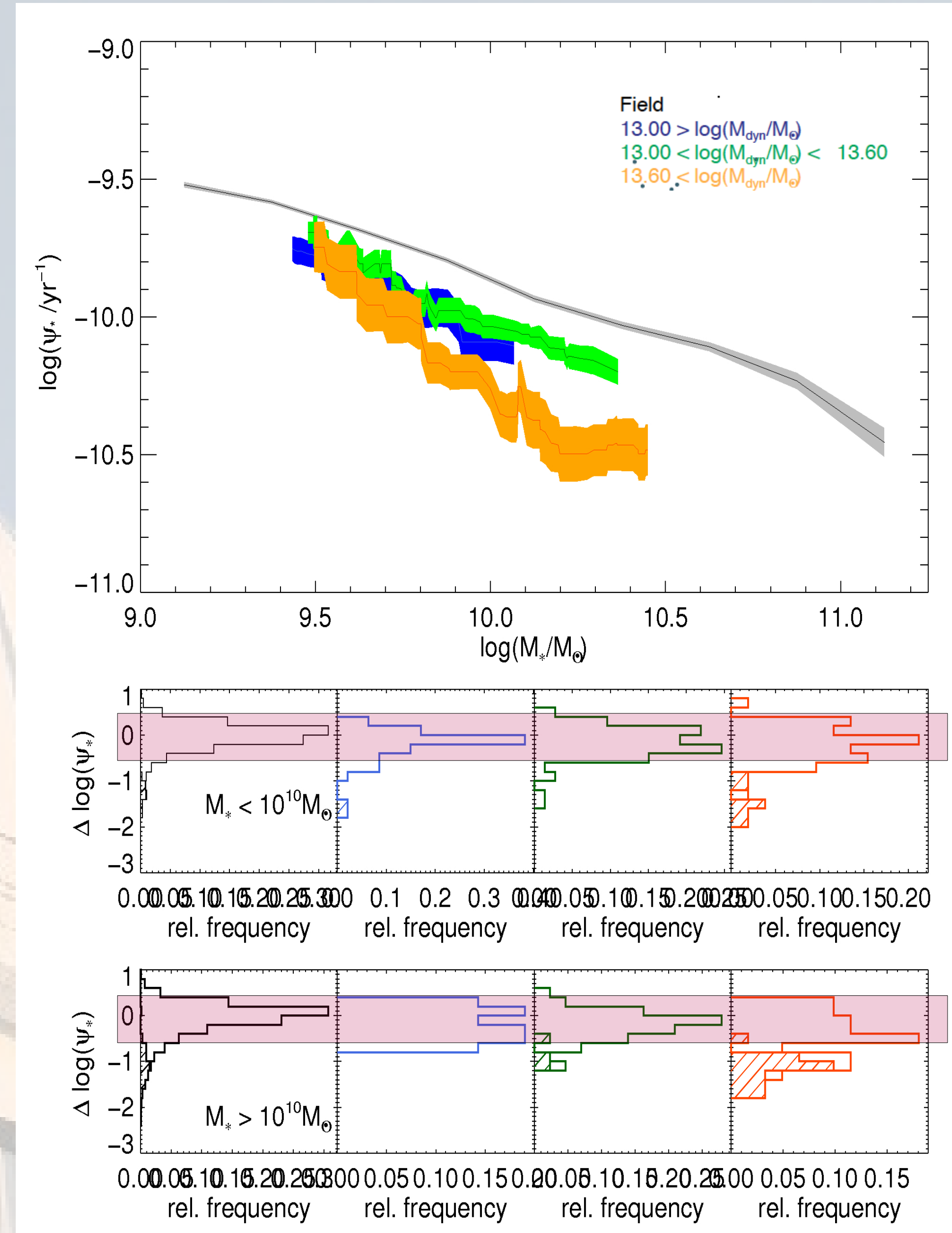
AGN: Central or not

Non-central AGN



Central AGN



Grootes et al, in prep.

Adding AGN

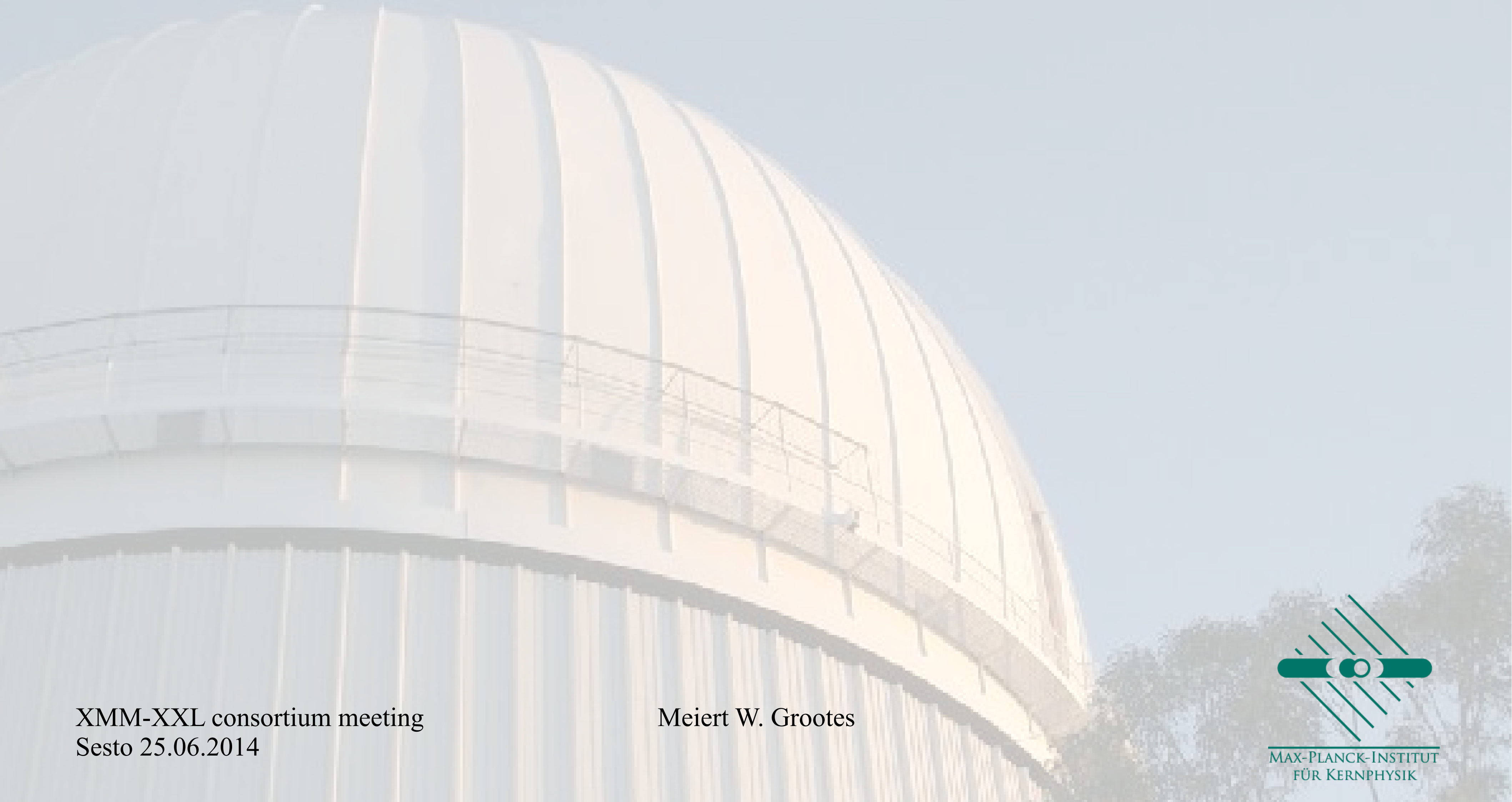
Without AGN | With AGN

Conclusions

- Majority of satellite spirals form stars at the rate of field counter-parts! Gas-fuelling appears to be on-going for these objects!
- Presence of a (central) AGN influences the size of the population of spiral satellites with suppressed SFR. Implies AGN feedback mechanism acting through IGM

- **X-ray data would be great to try to:**
- **Look at IGM of (stacked) selected groups w and w/o AGN**
- **Characterize the properties of the (central) AGN in selected groups**

GAMA



XMM-XXL consortium meeting
Sesto 25.06.2014

Meiert W. Grootes

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Groups: 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 (see Merson 2013). This is a combination of the Millennium Simulation (MS) plus the GALFORM Semi-Analytic (SAM) 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

Groups: 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 AND under grouping!

Groups: Technical Points

$$E_{\mathrm{FoF}} = \frac{Ng_{\mathrm{bij}}}{Ng_{\mathrm{FoF}}}$$

N bijective groups
N FoF groups

$$E_{\mathrm{mock}} = \frac{Ng_{\mathrm{bij}}}{Ng_{\mathrm{mock}}}$$

N bijective groups
N mock groups

$$E_{\mathrm{tot}} = E_{\mathrm{FoF}} E_{\mathrm{mock}}$$

Group detection FoM
1 if perfect

$$S_{\mathrm{tot}} = E_{\mathrm{tot}} Q_{\mathrm{tot}}$$

Final cost function to optimise. 1 if perfect.

$$Q_{\mathrm{FoF}} = \frac{\sum_{i=1}^{Ng_{\mathrm{FoF}}} P_{\mathrm{FoF}}[i] * Nm_{\mathrm{FoF}}[i]}{\sum Nm_{\mathrm{FoF}}}$$

N bijective galaxies in FoF groups
N galaxies in FoF groups

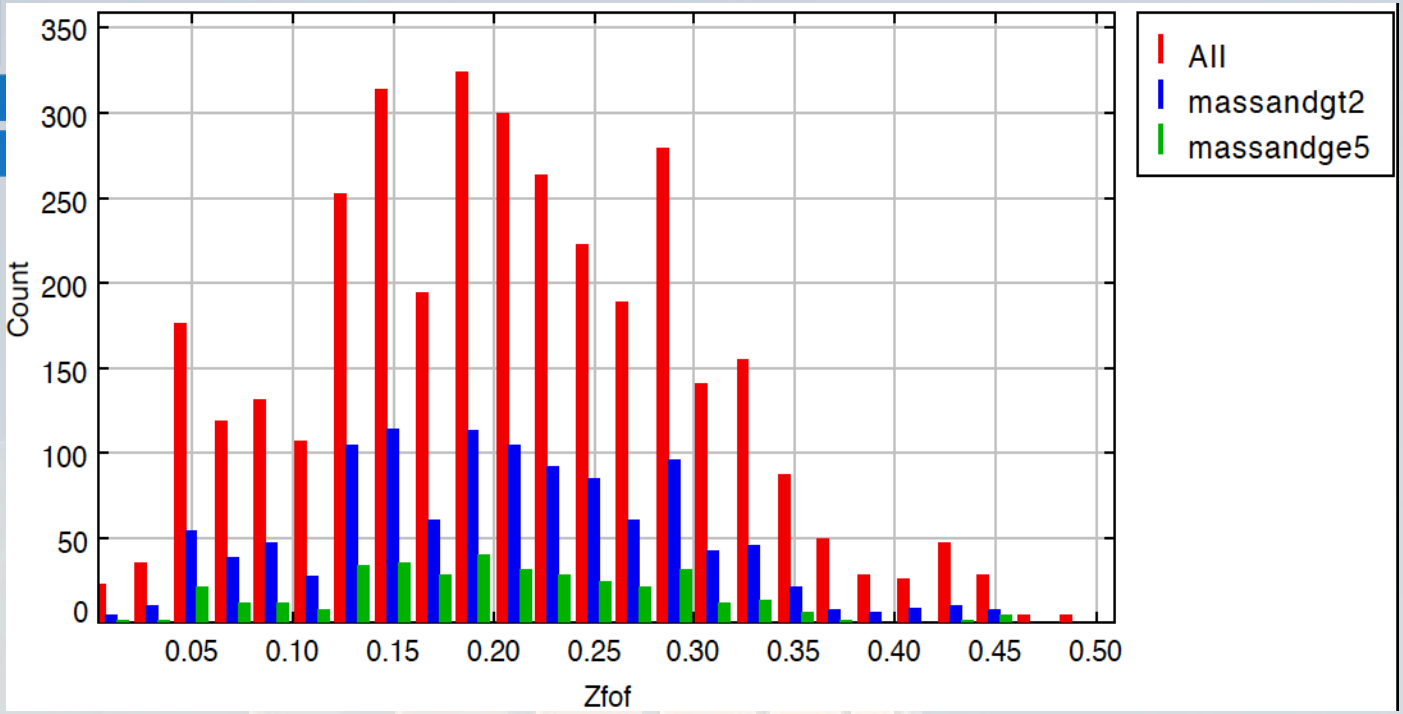
$$Q_{\mathrm{mock}} = \frac{\sum_{i=1}^{Ng_{\mathrm{mock}}} P_{\mathrm{mock}}[i] * Nm_{\mathrm{mock}}[i]}{\sum Nm_{\mathrm{mock}}}$$

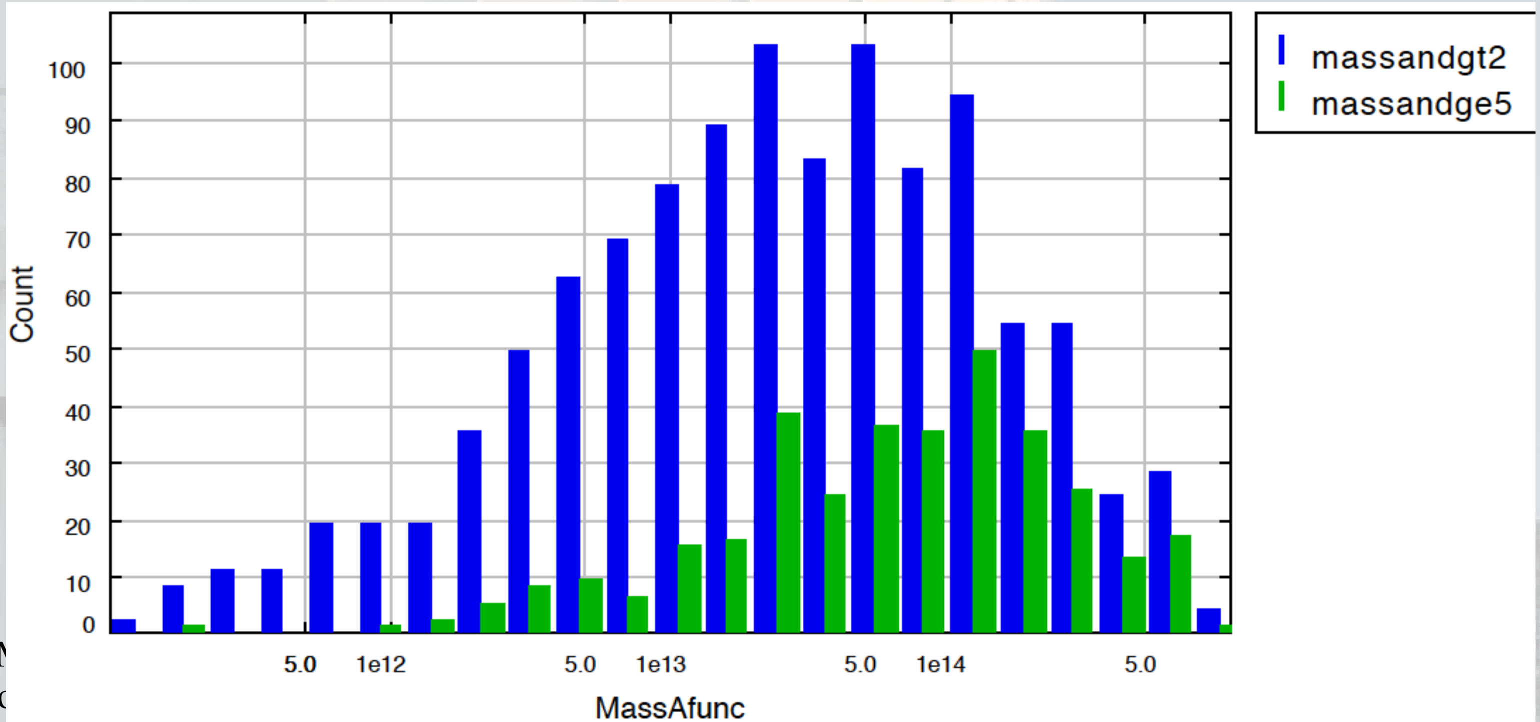
N bijective galaxies in mock groups
N galaxies in mock groups

$$Q_{\mathrm{tot}} = Q_{\mathrm{FoF}} Q_{\mathrm{mock}}$$

Group purity FoM
1 if perfect

GAMA





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The GAMA Survey: redshifts ...

Area: 280 deg^2

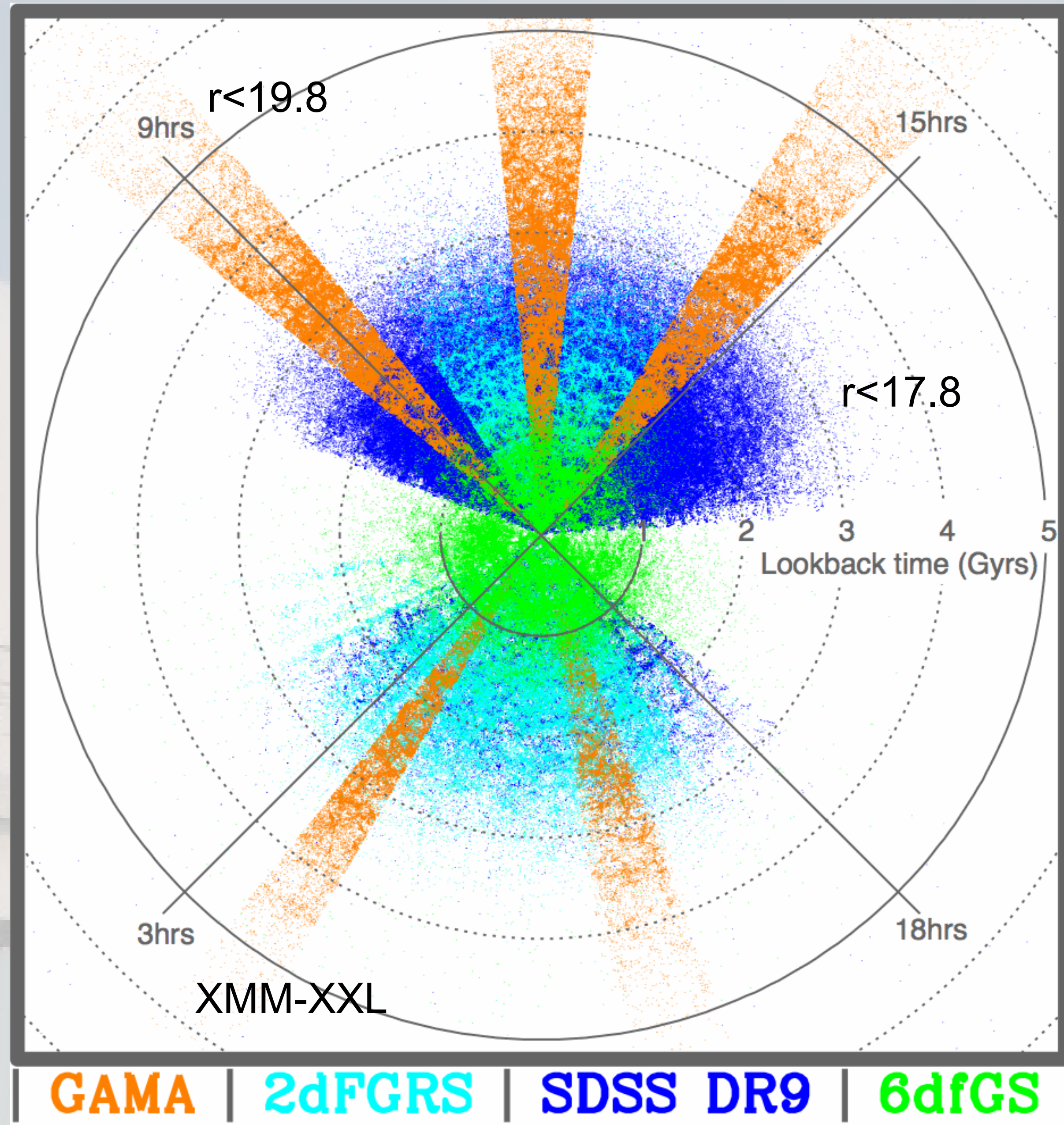
~250,000 spec z

Placed between shallow and deep surveys

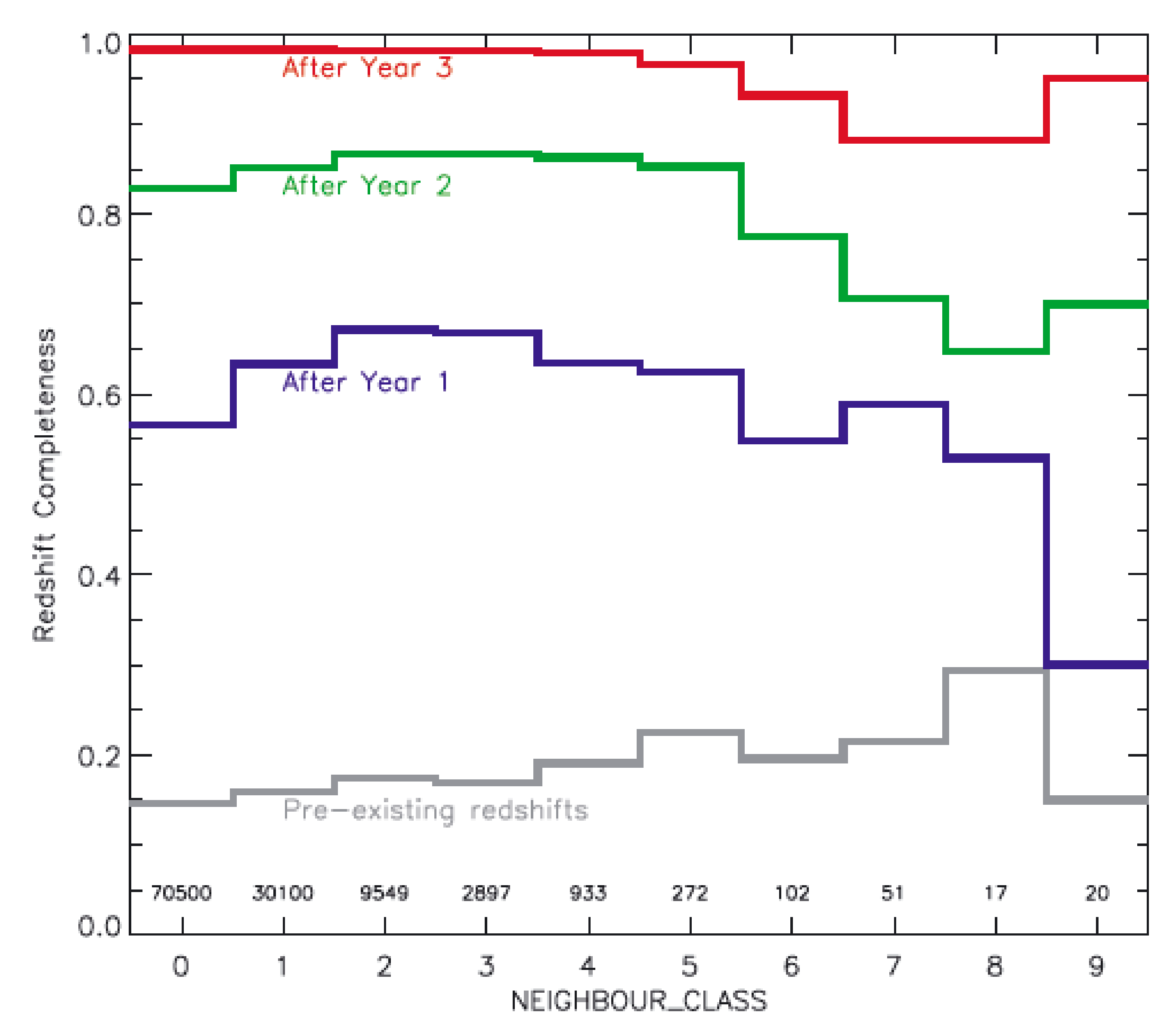
Robust against cosmic variance

Probes LSS over cosmological volume

www.gama-survey.org



... but not any old redshifts



- Much effort has been put into ensuring GAMA is highly complete on compact (sub 30'') scales.
- Implemented "greedy" tiling (details in Robotham et al 2010)
- In dense regions SDSS drops to ~50% completeness. High completeness inside the group/cluster scale requires multi-pointing strategy.
- GAMA >98% complete overall and >95% complete for 5 neighbours within 40''

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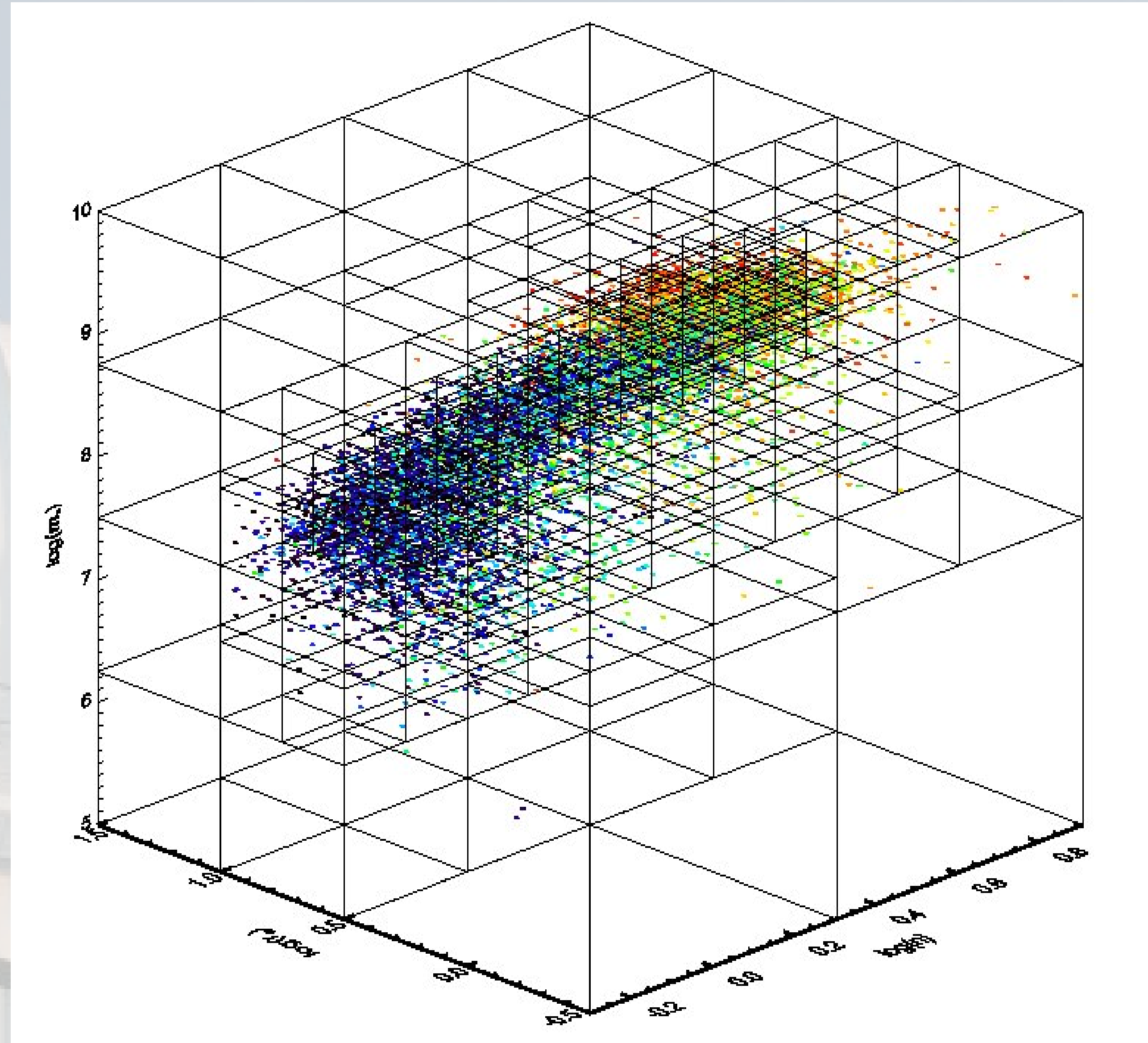
Selecting Spiral Galaxies

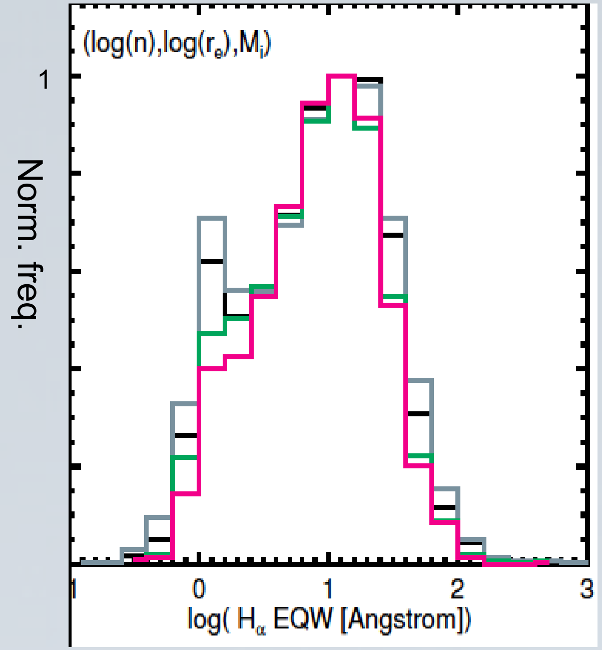
- Use Galaxy Zoo classifications as benchmark
- Consider multiple parameters NOT linked to SF but may separate E's and Sp's
- Adaptively discretize parameter space and define subvolume linked to Sp's
- Test using independently classified samples and Independent observables



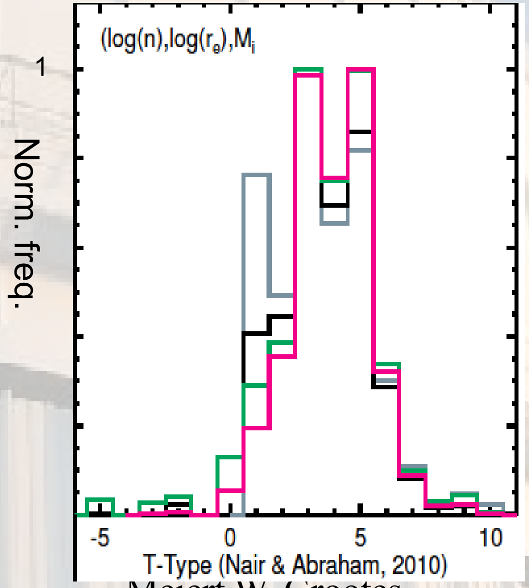
Grootes et al., 2013, submitted

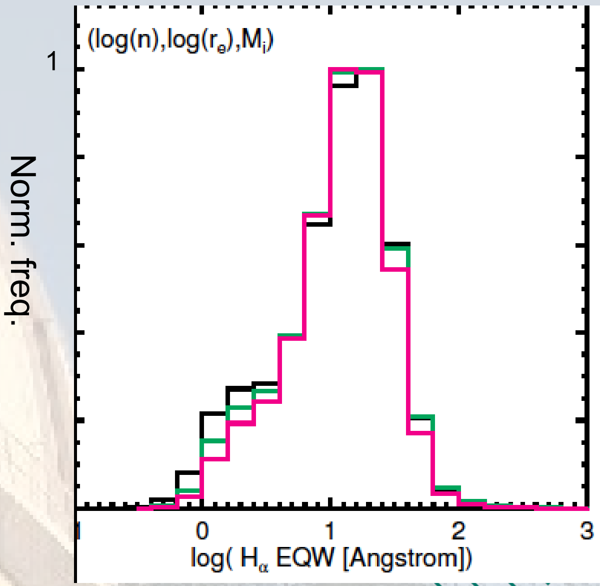
Selecting Spiral Galaxies

- Best parameter combination is $(\log(n), \log(r_e), M_i)$
- Very pure samples of spirals (< 2% contamination by visually classified ellipticals)
- Completeness of GZ spirals @ ≥ 77 %
- Very good recovery of Hα EQW distribution
- Good recovery of T-type distribution, slight bias against S0/Sa



Pure sample with robust morphologies including quiescent sources.

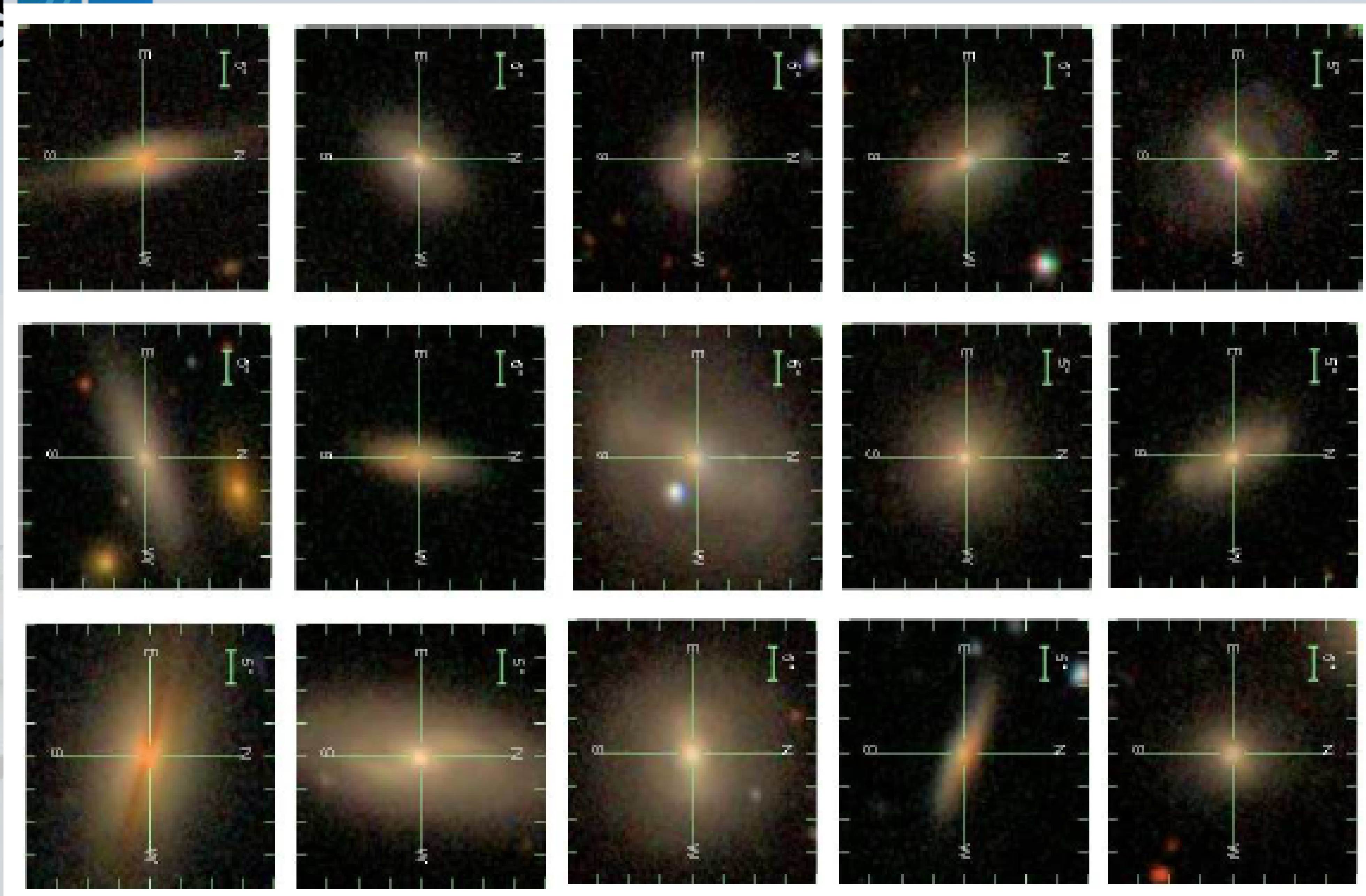




Figs from Grootes et al., 2013 submitted

GAMA

Selecting Spiral Galaxies

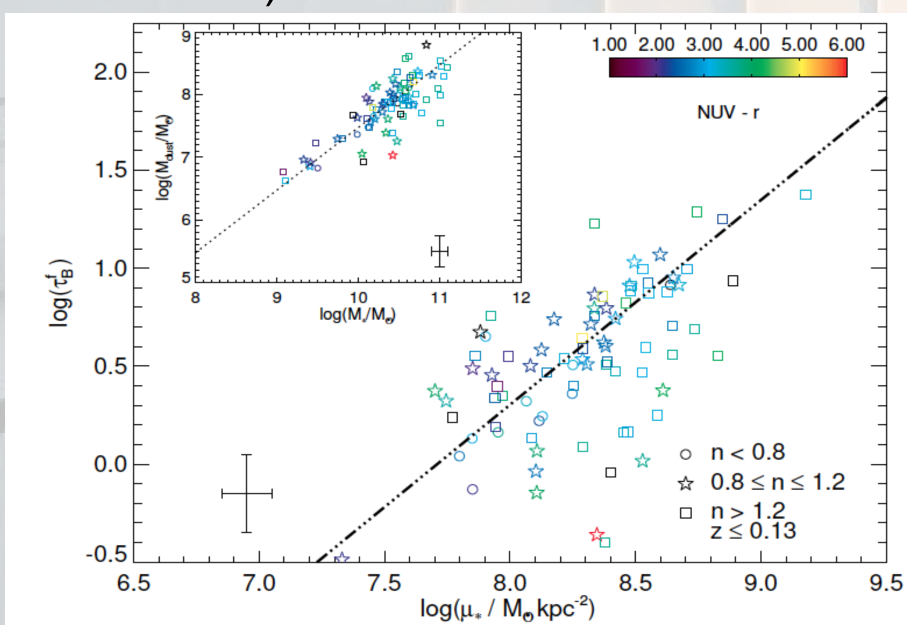


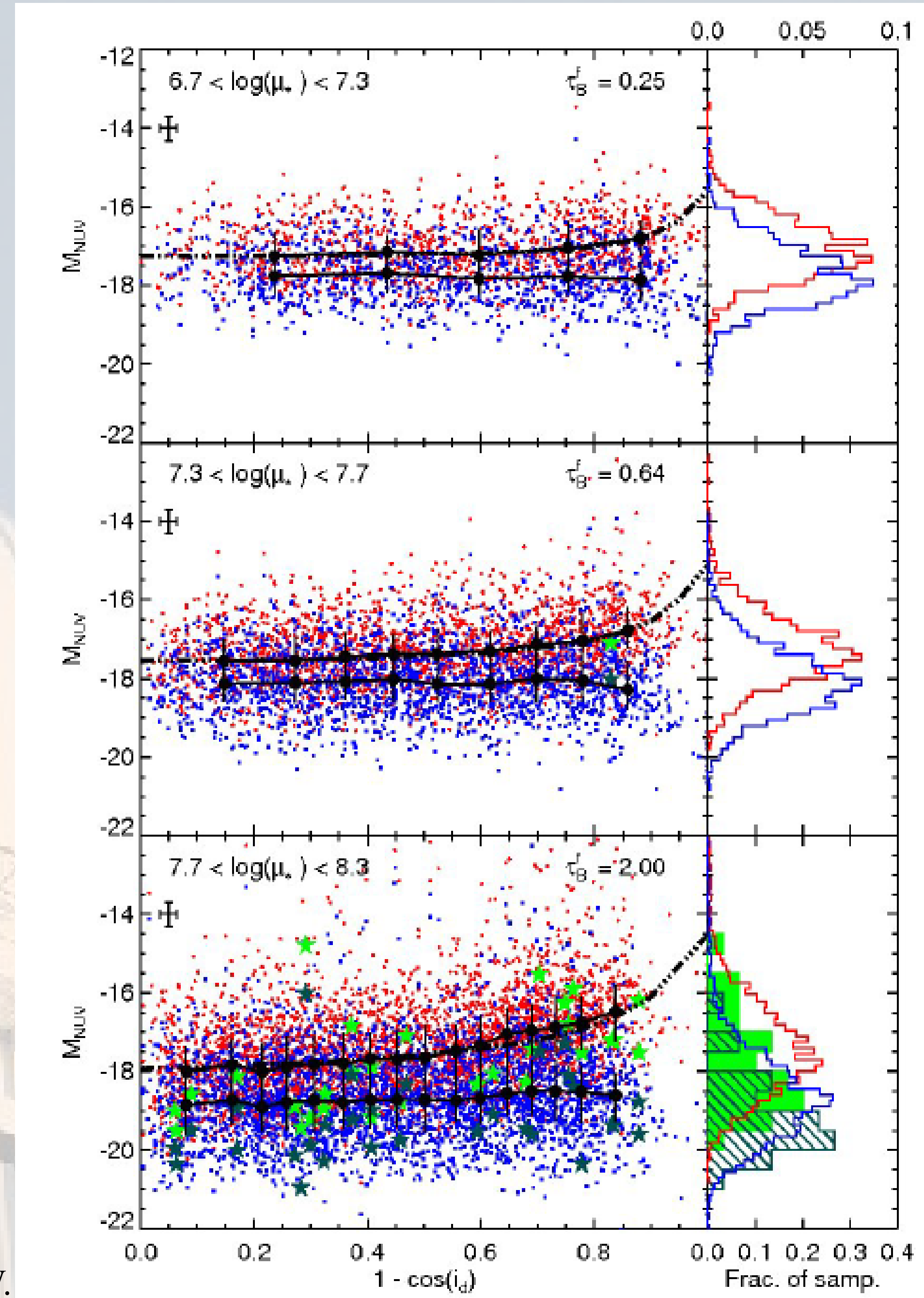
T-Type (Nair & Abraham, 2010)

Figs from Grootes et al., 2013 submitted

Intrinsic SFRs

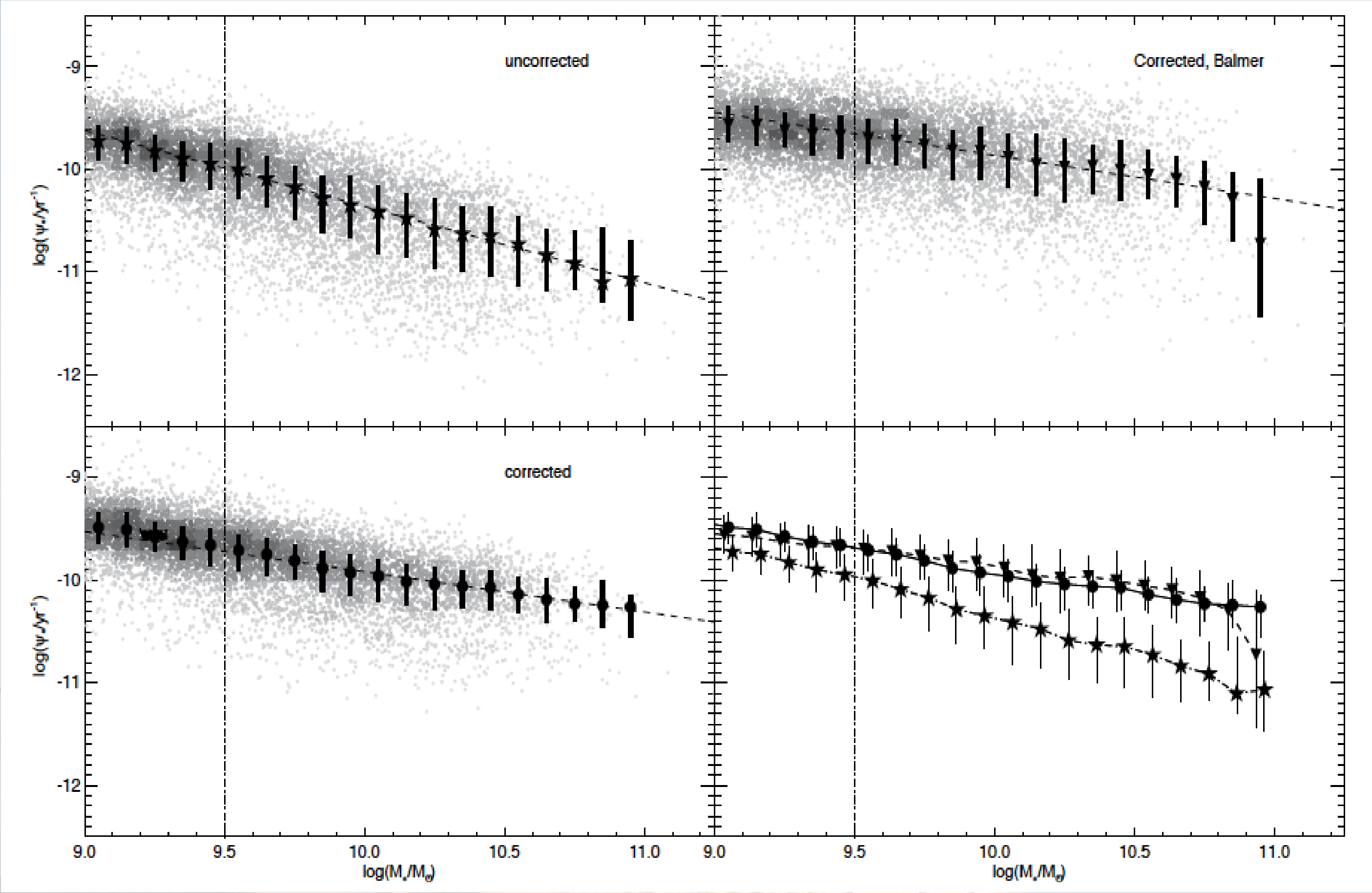
- UV SFR ⟶ total SFR, short timescale (~100 Myr)
- Heavily affected by attenuation (~2 mag, ~1mag due to orientation)
- Use Rad. Trans. Modeling (Popescu+2011)
- Estimate input using only optical info (calibrated on sources with FIR data; H-ATLAS)





Figs, Grootes et al., 2013, ApJ, 766, 59

Intrinsic SFRs

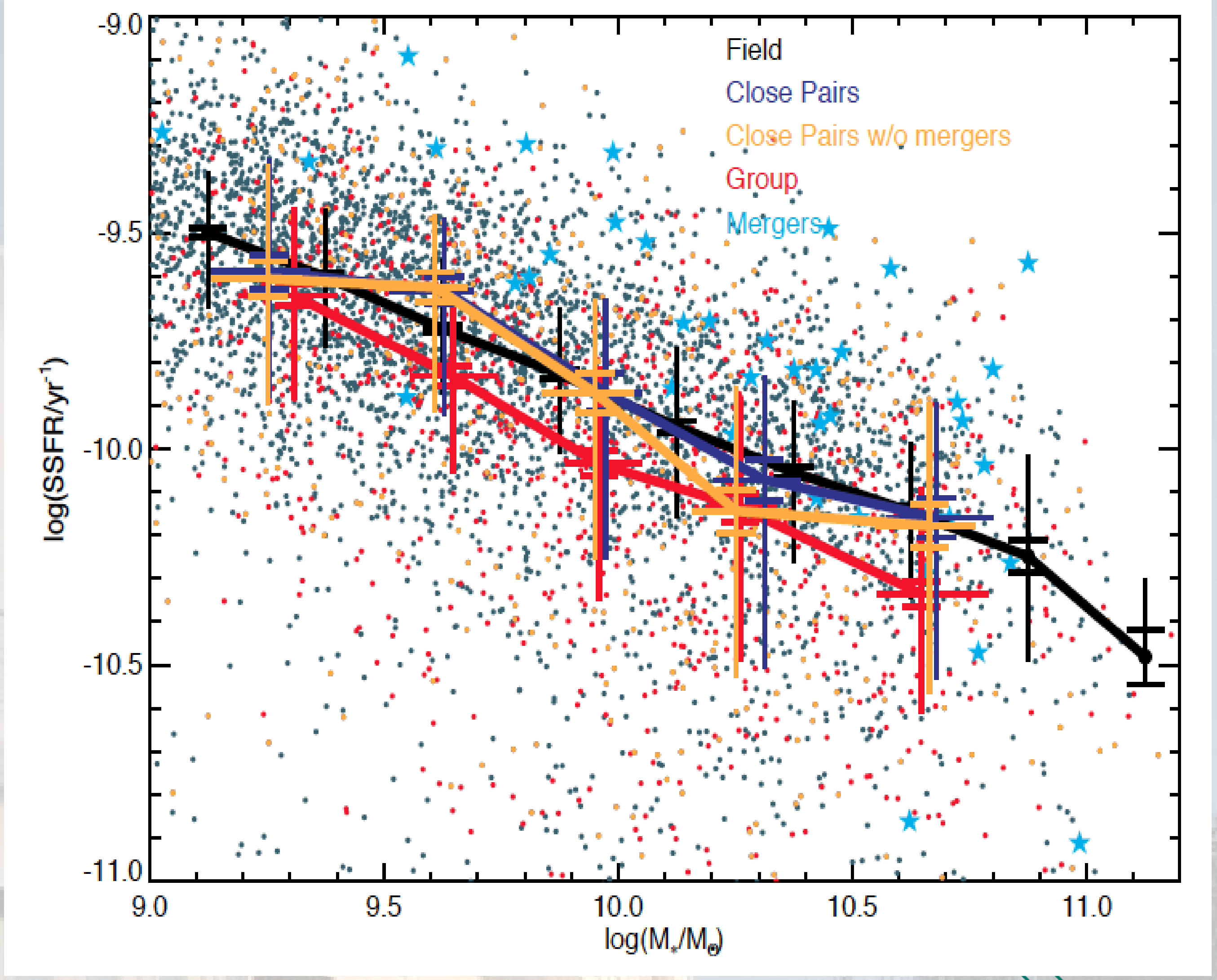


Grootes et al., 2013 ApJ, 766, 59 & submitted

- Spirals following (log(n),log(r_e),M_i) after correction very tight ($\sigma \approx 0.27$ dex) single PL ($\gamma = -0.5$)
- Significant reduction in scatter w.r.t standard attenuation correction methods ⟶ precision and sensitivity

Application to GAMA

- 939 spirals in 584 groups with z<0.13 ; ~4000 Field spirals
- GAMA Field spirals as whole spiral sample (similar scatter)
- Merging systems (including spiral) show enhanced SFR
- Close Pairs (50/h kpc 1000km/s) similar to Field
- 'isolated' group spirals show suppressed median SFR
- Dist. of GAMA group parameters highly similar between group w/ & w/o spiral (being investigated further)



Grootes et al, in prep.