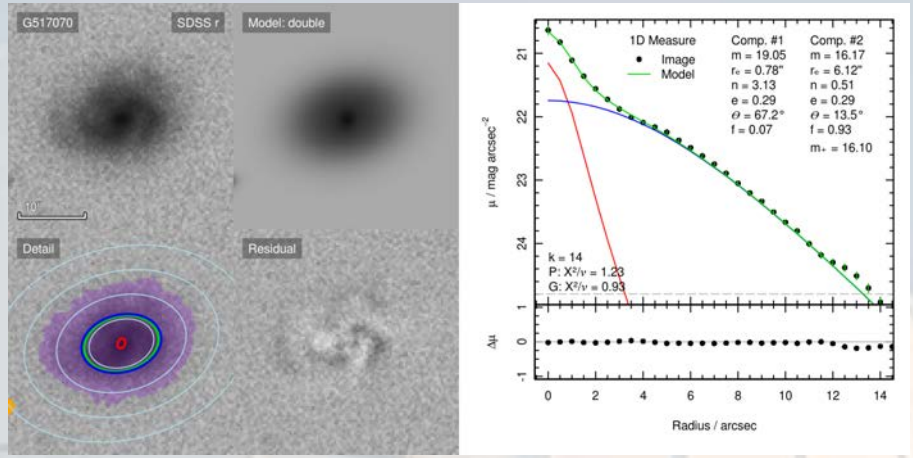
GAMA: The Galaxy And Mass Assembly Survey

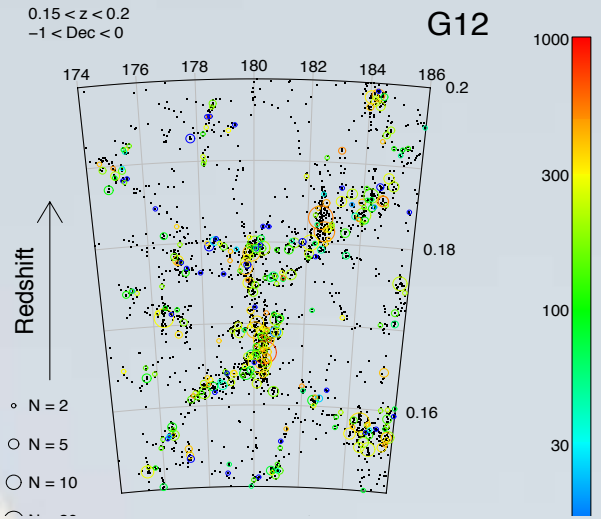
Aaron Robotham
&
The GAMA Team

Structure on 1kpc to 100Mpc scales

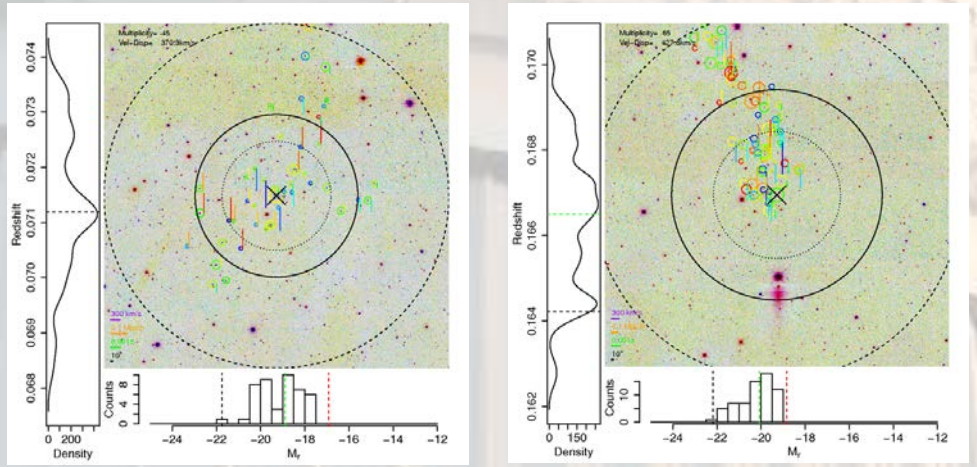
Galaxy Decomposition (1-20kpc)



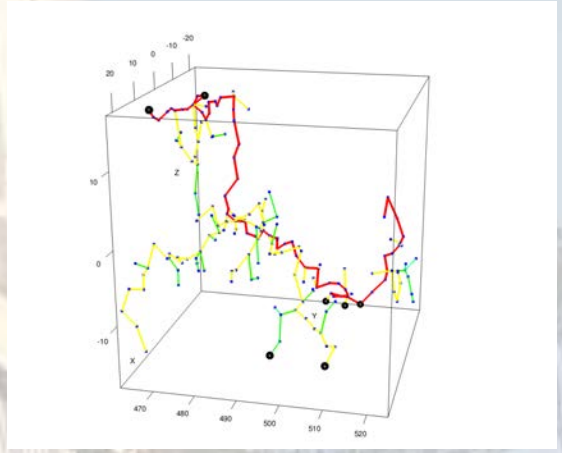
Superclusters (1-10Mpc)

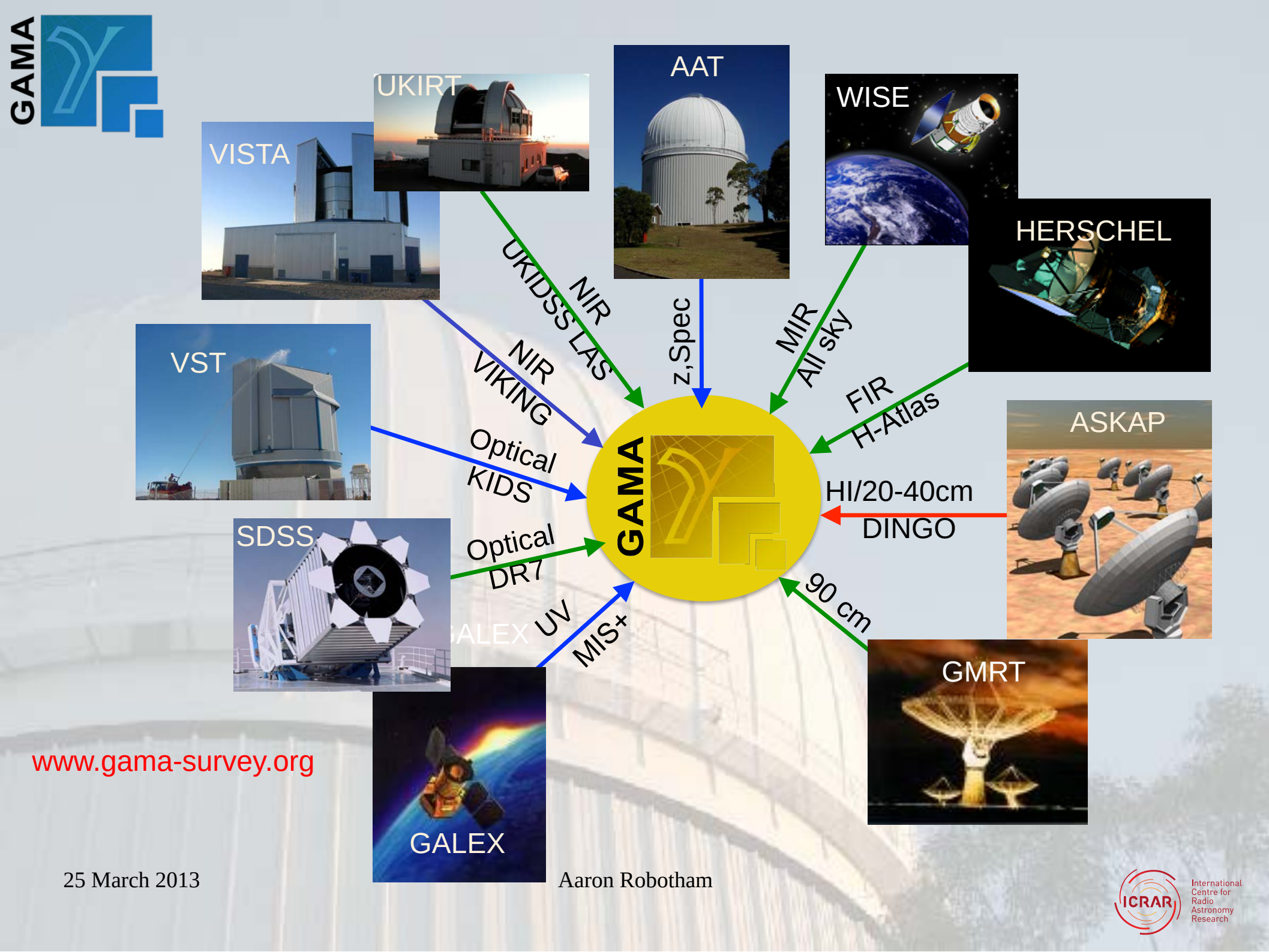


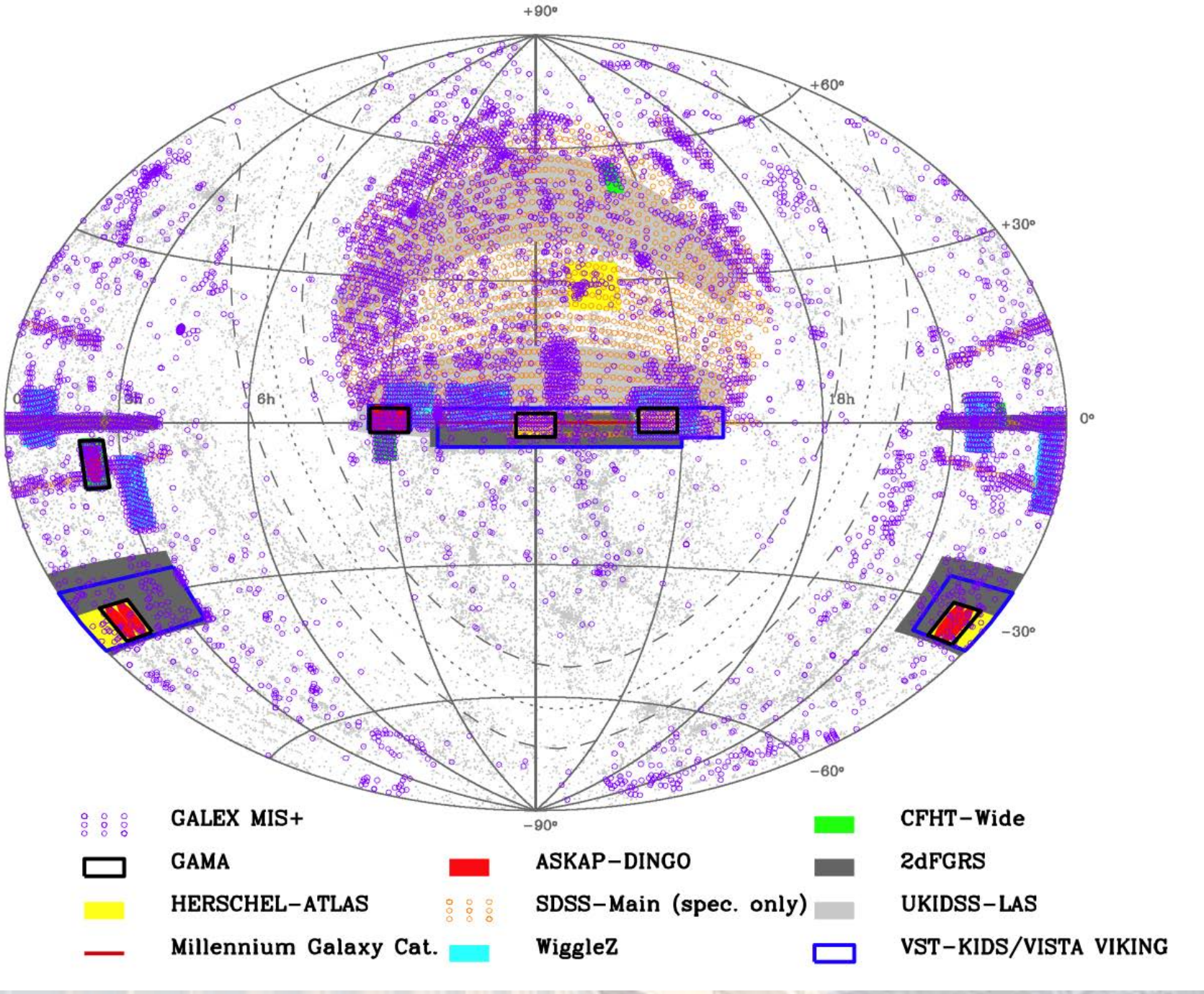
Groups (100kpc-1Mpc)



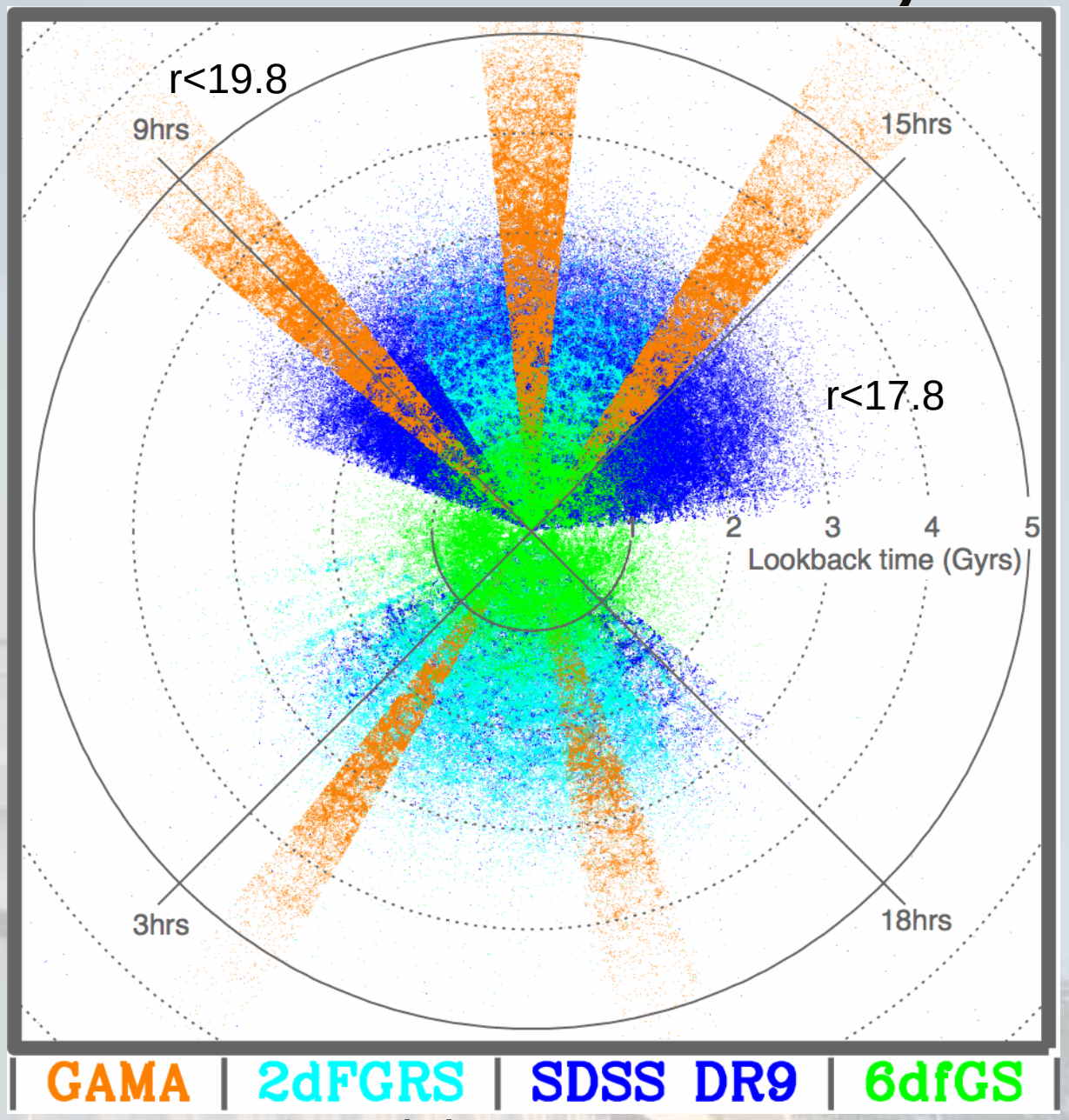
Filaments (10-100Mpc)




GAMA
UKIRT
AAT
WISE
VISTA
HERSCHEL
UKIDSS LAS
NIR
z,Spec
MIR
All sky
NIR
VIKING
FIR
H-Atlas
VST
Optical
KIDS
ASKAP
GAMA
HI/20-40cm
DINGO
SDSS
Optical
DR7
90 cm
UV
MIS+
GMRT
GALEX
www.gama-survey.org
25 March 2013
Aaron Robotham
ICRAR
International Centre for Radio Astronomy Research


+90°
+60°
+30°
0°
-30°
-60°
-90°
0h
3h
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

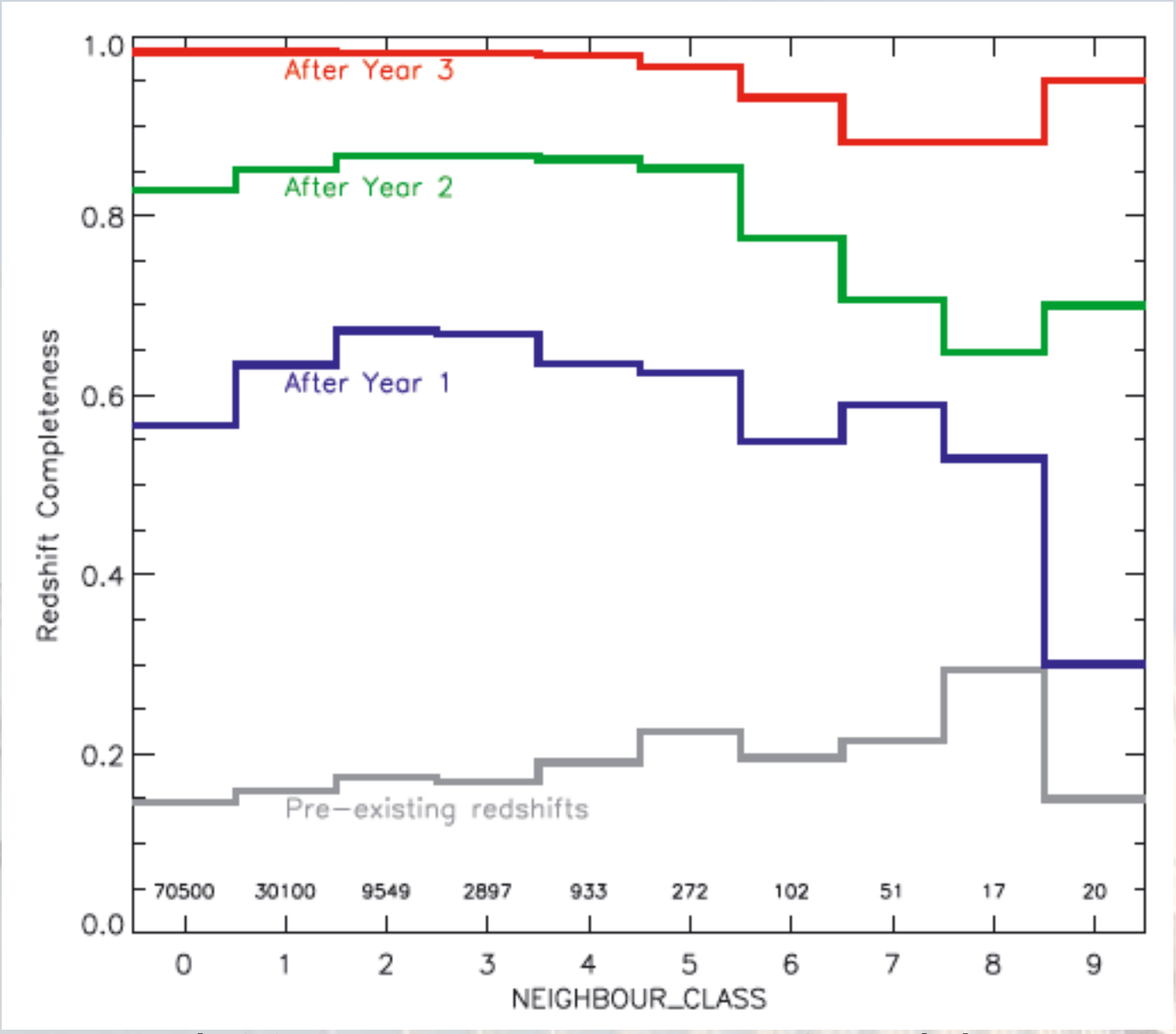
The GAMA Survey



www.gama-survey.org

International Centre for Radio Astronomy Research

Not just any old redshifts…



- Much effort has been put into ensuring GAMA is highly complete on compact (sub 30'') scales.
- We implemented "greedy" tiling (Robotham et al 2010)
- In dense regions SDSS drops to ~50% completeness. High completeness inside the group/ cluster scale requires multi-pointing strategy.

Robotham et al, MRNAS, 2011

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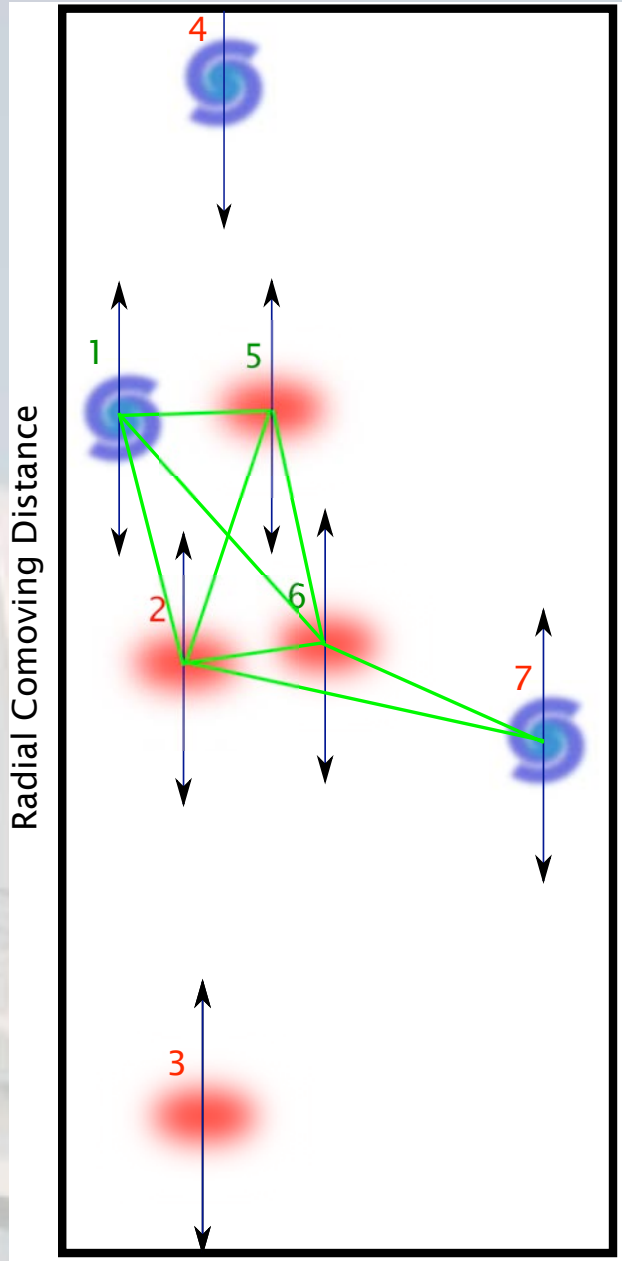
of the
ROYAL ASTRONOMICAL SOCIETY

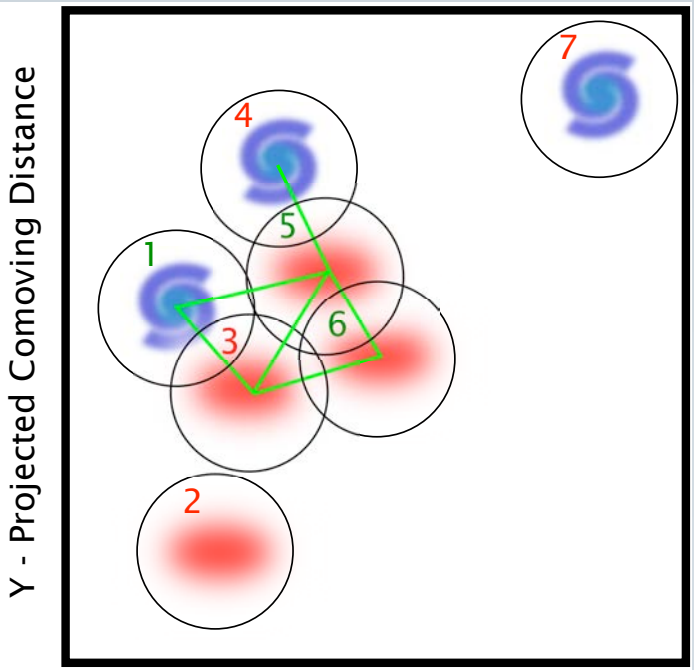
Mon. Not. R. Astron. Soc. **416,** 2640–2668 (2011) doi:10.1111/j.1365-2966.2011.19217.x

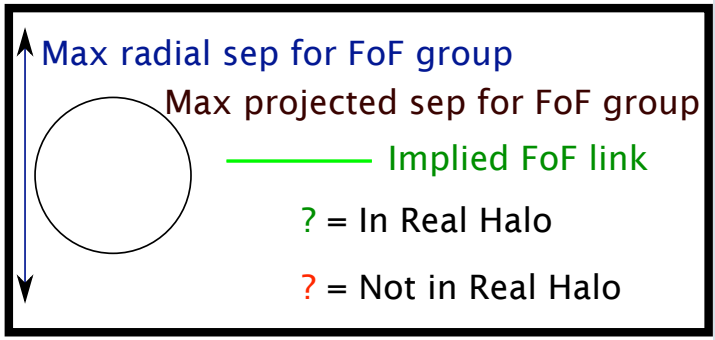
Galaxy and Mass Assembly (GAMA): the GAMA galaxy group catalogue (G^3Cv1)

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]

- 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.





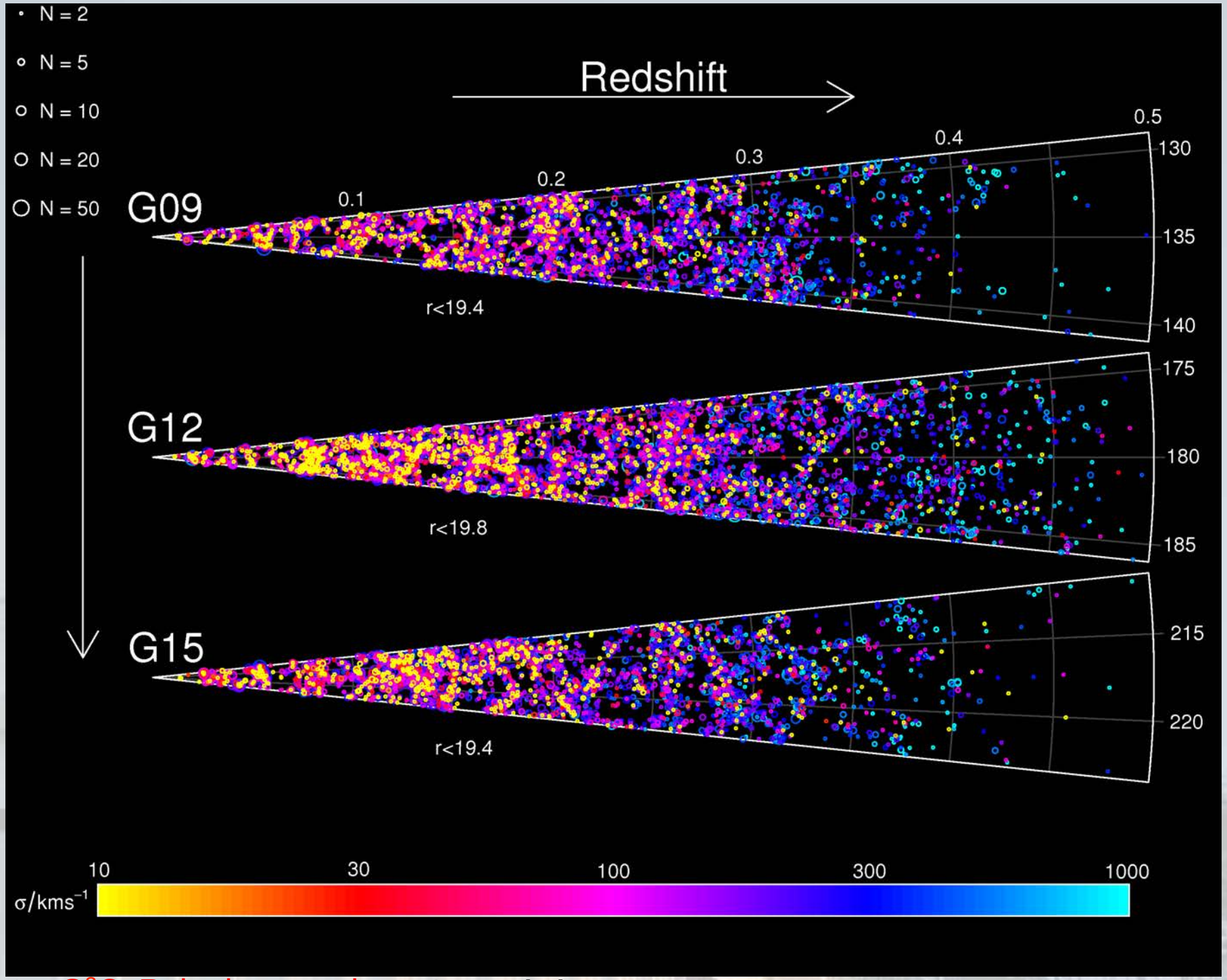


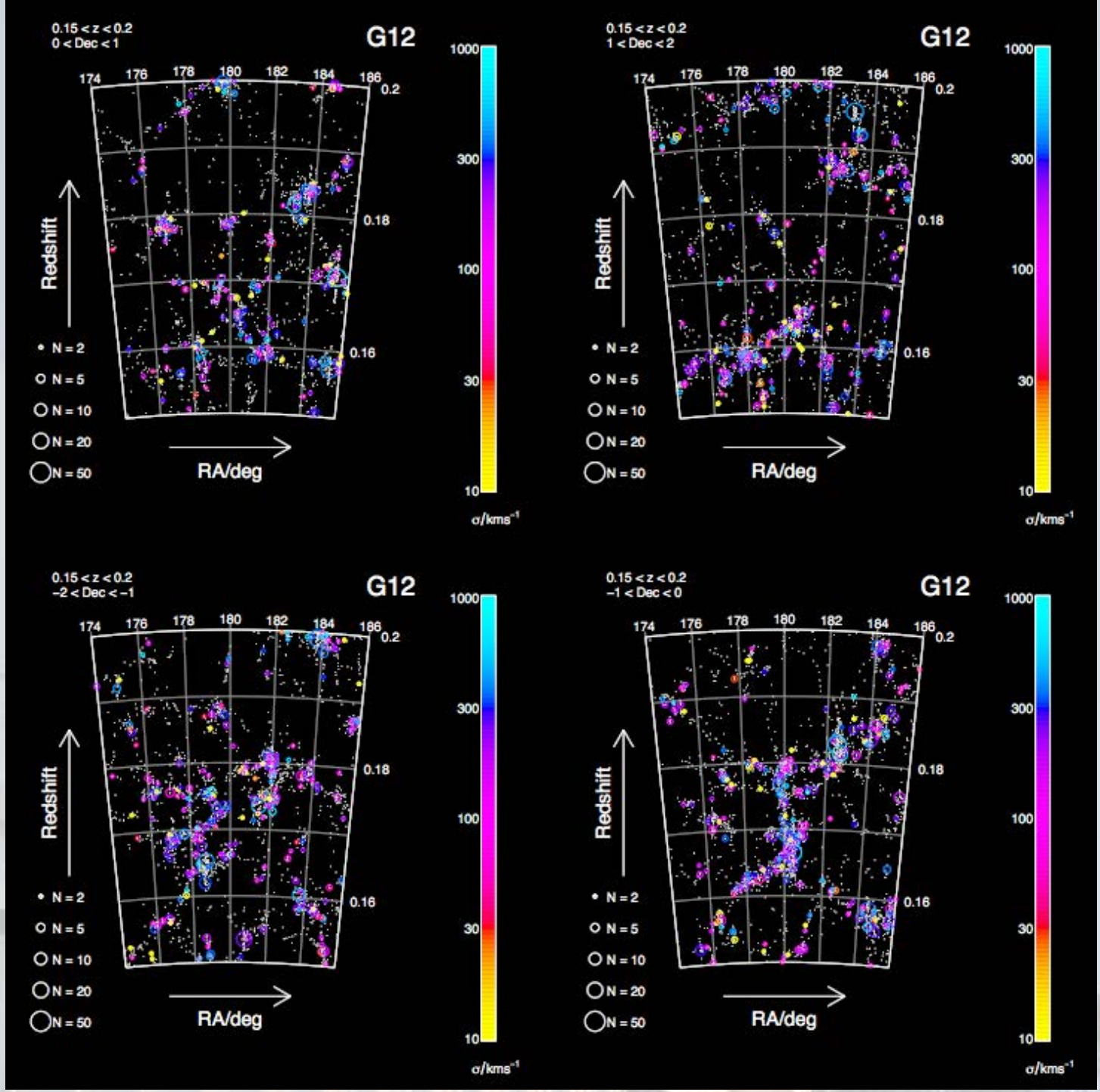
Actual Halo Group = 1, 5, 6

Radial FoF Group = 1, 2, 5, 6, 7

Projected FoF Group = 1, 3, 4, 5, 6

Final Common FoF Group = 1, 5, 6

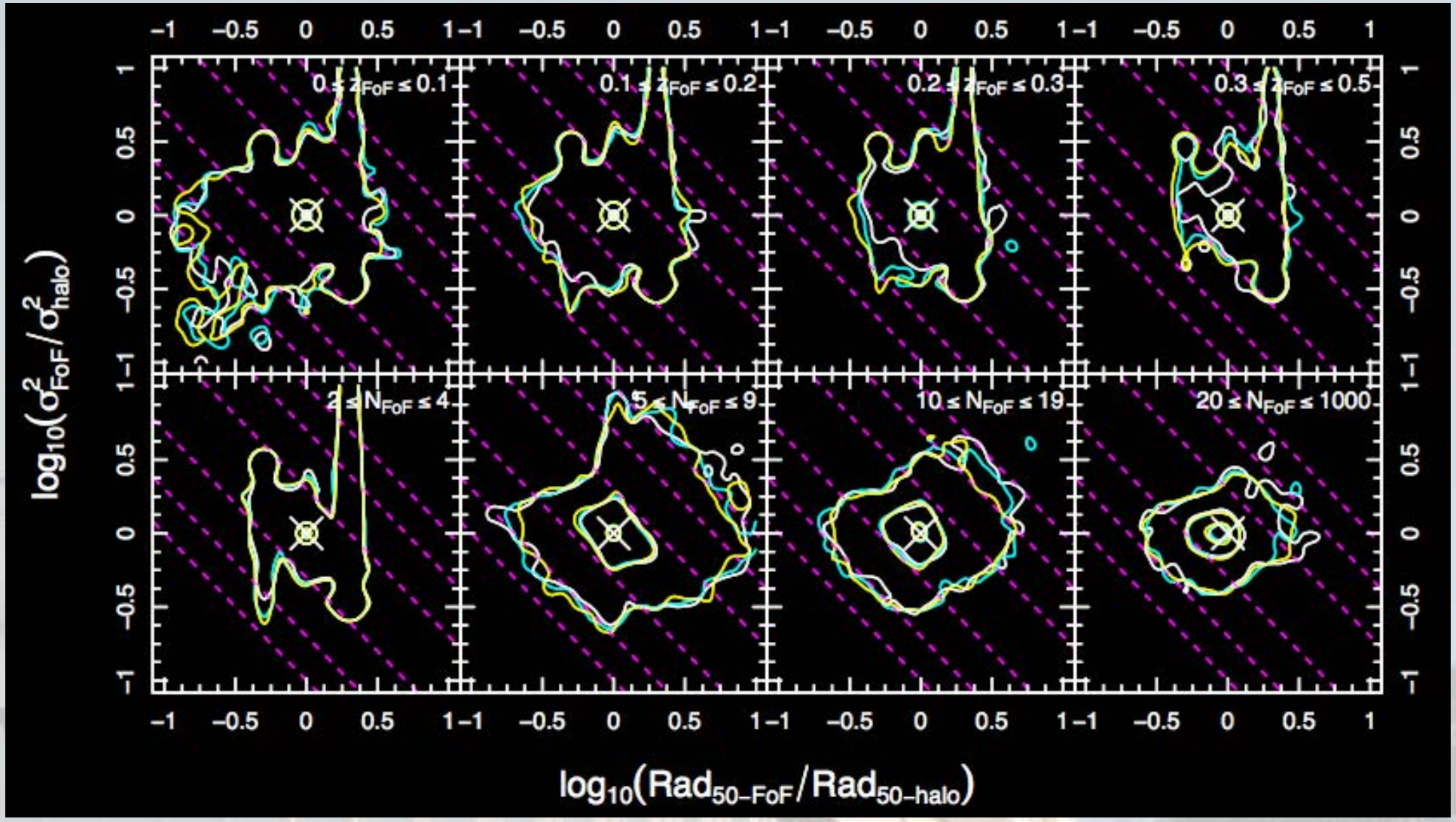

N = 2
N = 5
N = 10
N = 20
N = 50
Redshift
0.1
0.2
0.3
0.4
0.5
G09
r<19.4
130
135
140
G12
r<19.8
175
180
185
G15
r<19.4
215
220
10
30
100
300
1000
σ/kms⁻¹



G³C: Robotham et al. 2011, MNRAS

GAMA

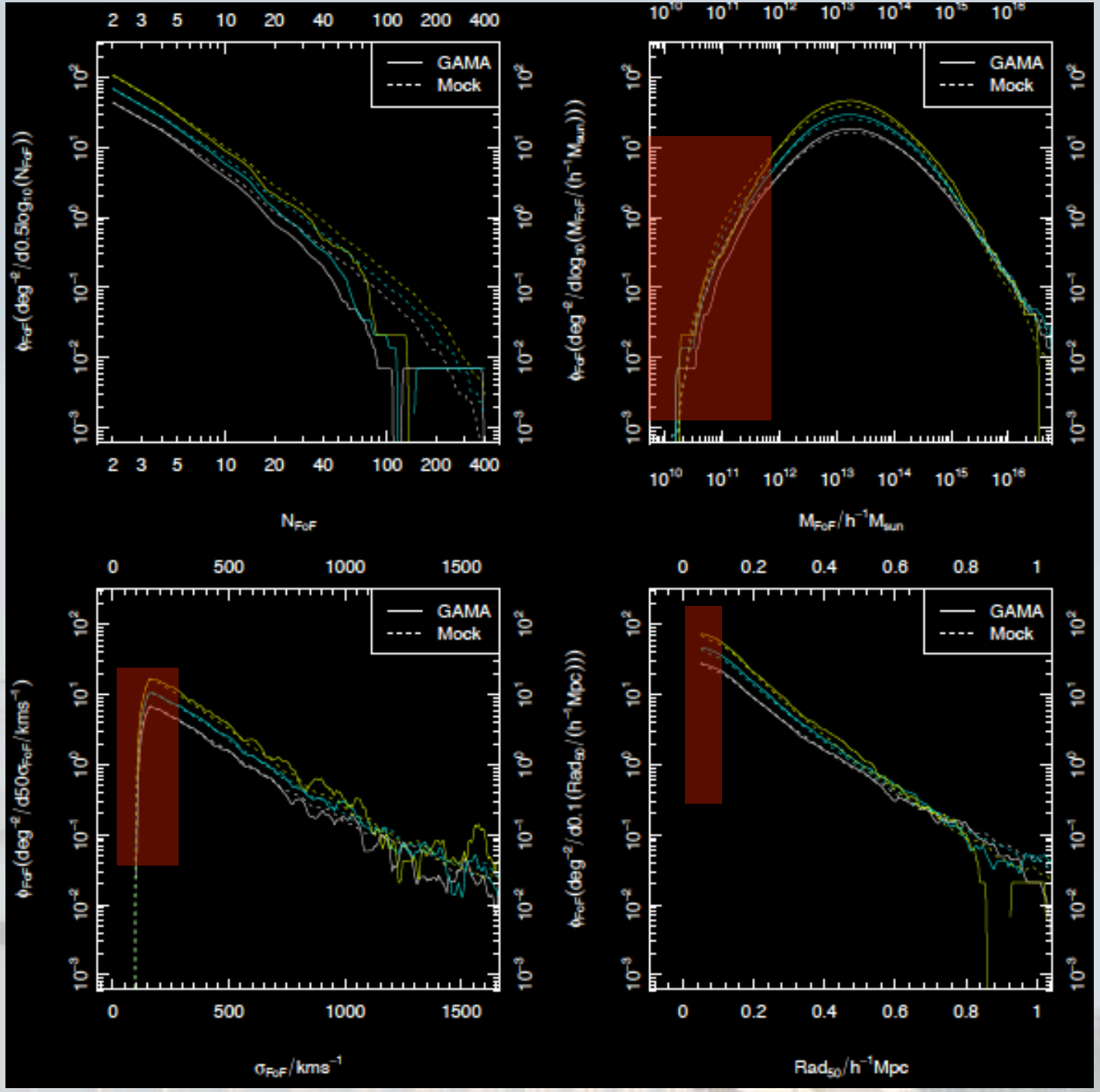
$$M \propto \sigma^2 r$$



 Robotham et al. 2011 MNRAS

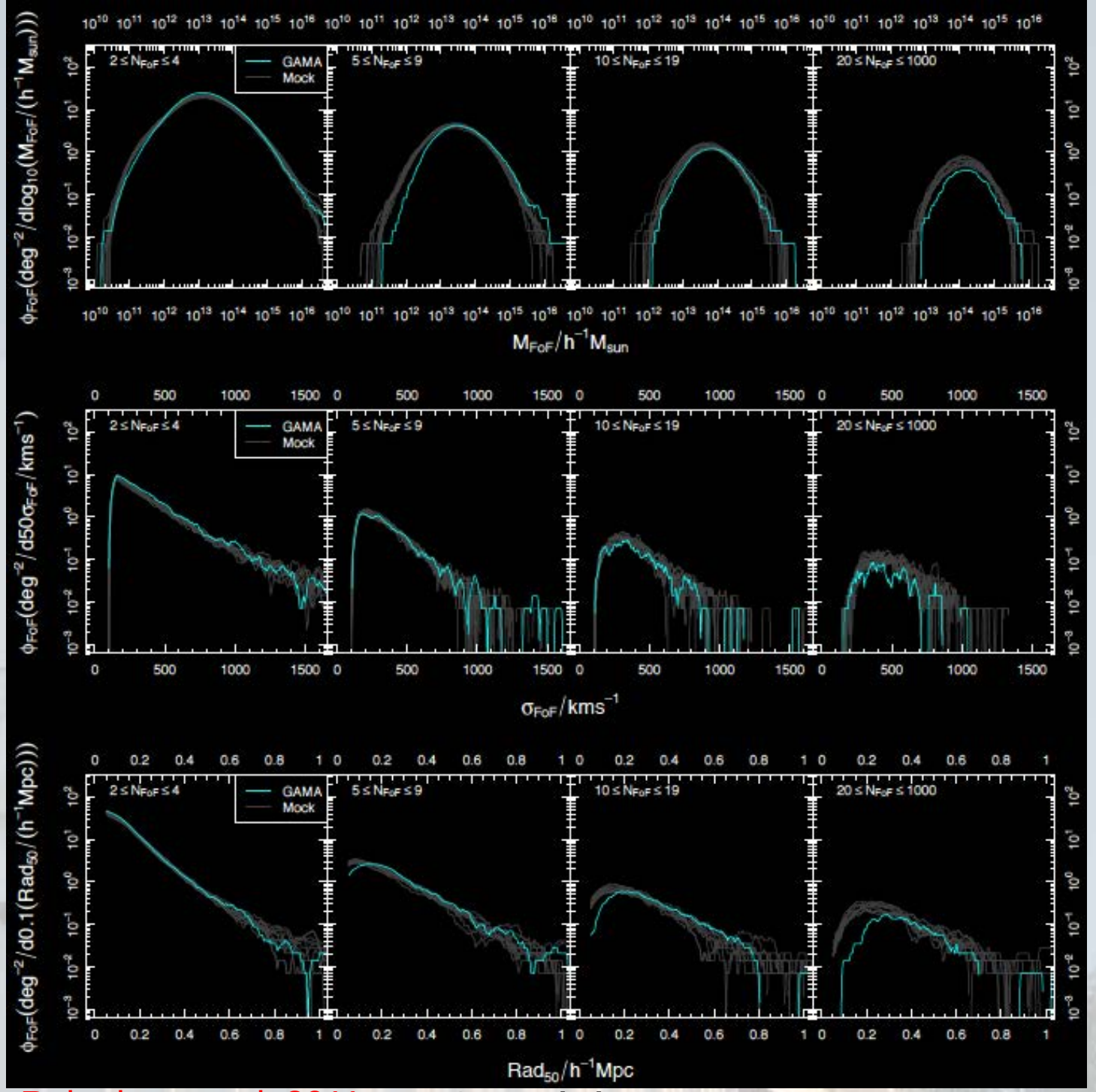
University of St Andrews

GAMA



25 March 2013 Robotham et al. 2011 MNRAS Aaron Robotham

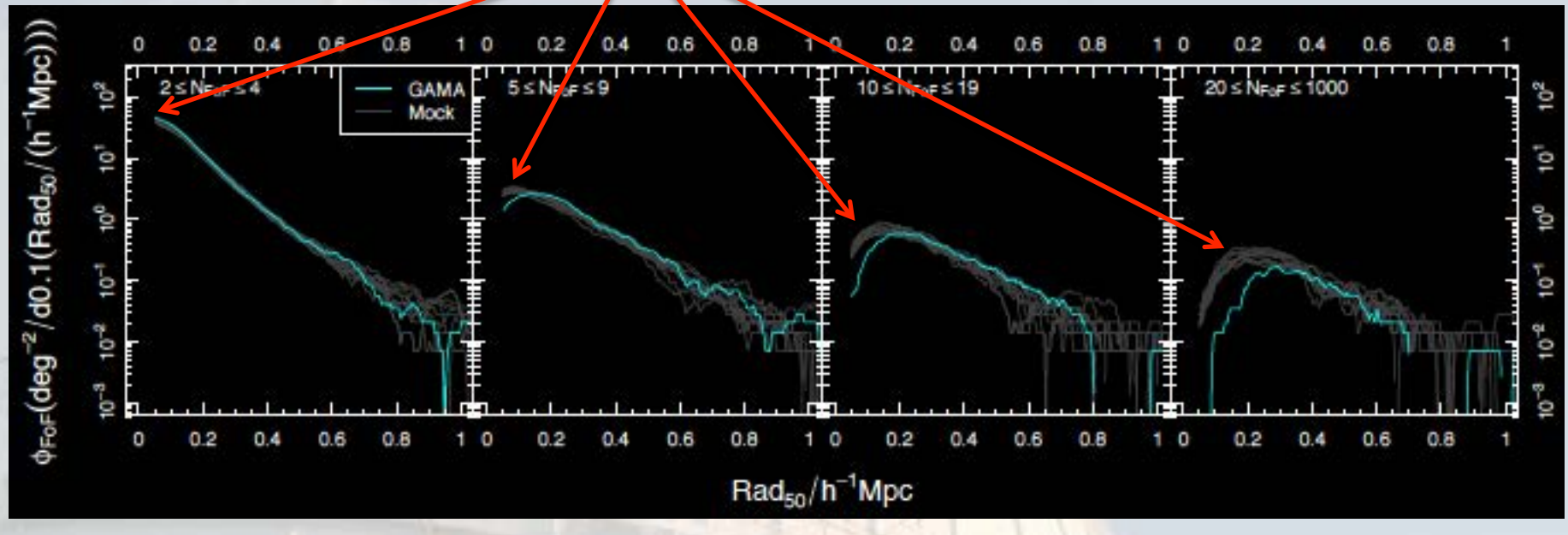
University of St Andrews



Robotham et al. 2011
MNRAS in press

So what is going on at low mass?

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



- A few possibilities:
  - CDM accretion history
  - Dynamical friction recipe

Robotham et al, MRNAS, 2012

Monthly Notices of the ROYAL ASTRONOMICAL SOCIETY

Mon. Not. R. Astron. Soc. **424,** 1448–1453 (2012) doi:10.1111/j.1365-2966.2012.21332.x

Galaxy And Mass Assembly (GAMA): in search of Milky Way Magellanic Cloud analogues

A. S. G. Robotham,[1,2★] I. K. Baldry,[3] J. Bland-Hawthorn,[4] S. P. Driver,[1,2] J. Loveday,[5] P. Norberg,[6] A. E. Bauer,[7] K. Bekki,[2] S. Brough,[7] M. Brown,[8] A. Graham,[9] A. M. Hopkins,[7] S. Phillipps,[10] C. Power,[2] A. Sansom[11] and L. Staveley-Smith[2]

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[4]*Sydney Institute for Astronomy, School of Physics, University of Sydney, NSW 2006, Australia*
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[7]*Australian Astronomical Observatory, PO Box 296, Epping, NSW 1710, Australia*
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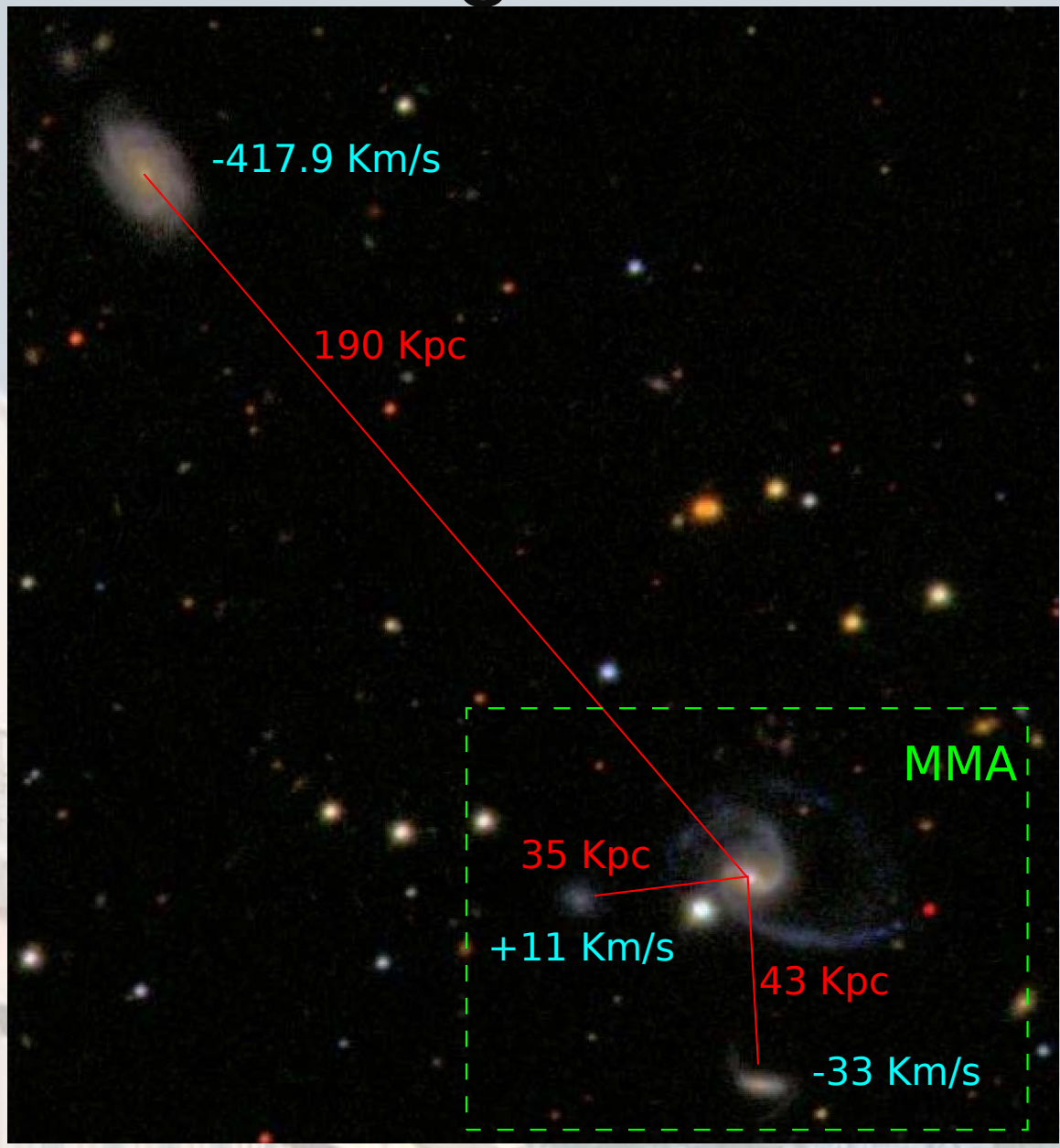
[9]*Centre for Astrophysics and Supercomputing, Swinburne University of Technology, Hawthorne, Victoria 3122, Australia*
[10]*HH Wills Physics Laboratory, University of Bristol, Tyndall Avenue, Bristol BS8 1TL*
[11]*Jeremiah Horrocks Institute, University of Central Lancashire, Preston PR1 2HE*

Looking for the Magellanics

• We searched within 0.3 dex of the stellar mass of the MW

• We look for close pairs that are within 70kpc in projection and 400 km/s in radial separation. This conservatively picks up MW-Magellanic systems.

- 11.9% (11.2 -> 12.8) chance of L* galaxy having one or more LMC mass (or more massive) galaxy.
- 3.4% (2.7 -> 4.5) chance of there being at least two SMC mass (or more massive) galaxies (14 systems).
- 0.4% (0.3 -> 1.1) chance of exactly two SMC mass (or more massive) galaxies where all are late-type and star forming. Recast into Gaussian statistics: 2.7σ event.



Robotham et al, MRNAS 2013 (in press)

Galaxy And Mass Assembly (GAMA): The Life and Times of L^* Galaxies

A.S.G. Robotham[1,2⋆], J. Liske[3], S.P. Driver[1,2], A.E. Sansom[4], I.K. Baldry[5], A.E. Bauer[6], J. Bland-Hawthorn[7], S. Brough[6], M.J.I. Brown[8], M. Colless[6], L. Christodoulou[9], M.J. Drinkwater[10], M.R. Grootes[11], A.M. Hopkins[6], L.S. Kelvin,[1,2,12], P. Norberg[13], J. Loveday[9], S. Phillipps[14], R. Sharp[15], E.N. Taylor,[7,16], R.J. Tuffs,[11]

[1] *SUPA†, School of Physics & Astronomy, University of St Andrews, North Haugh, St Andrews, KY16 9SS, UK*
[2] *ICRAR‡, The University of Western Australia, 35 Stirling Highway, Crawley, WA 6009, Australia*
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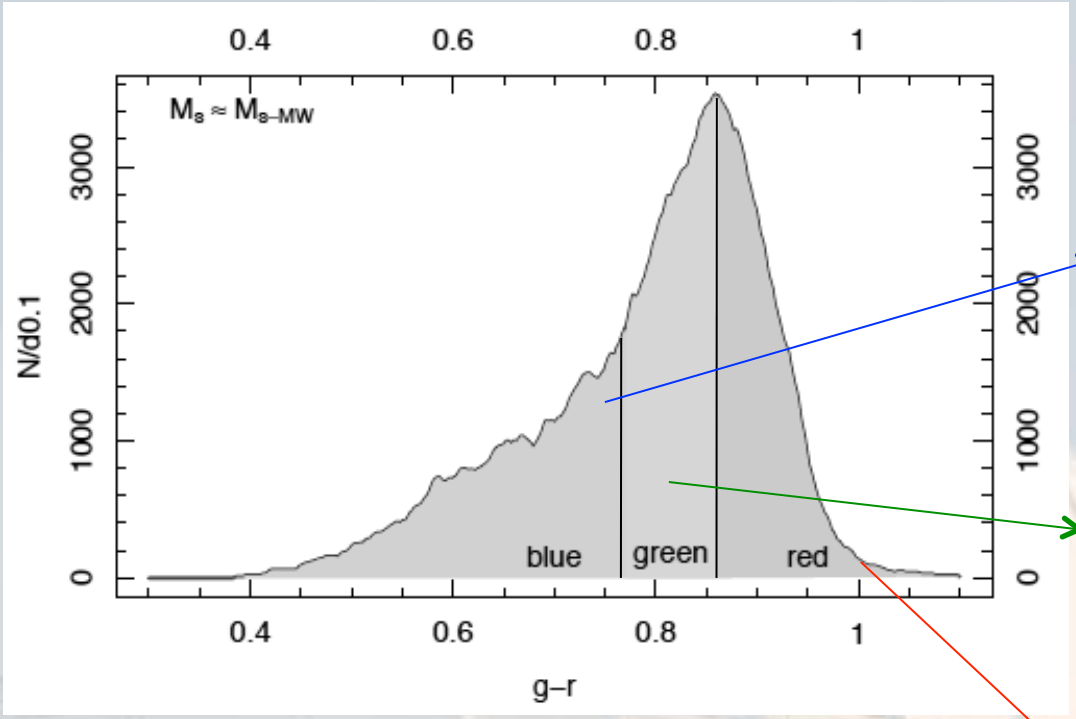
[4] *Jeremiah Horrocks Institute, University of Central Lancashire, Preston PR1 2HE, UK*
[5] *Astrophysics Research Institute, Liverpool John Moores University, Egerton Wharf, Birkenhead, CH41 1LD, UK*
[6] *Australian Astronomical Observatory, PO Box 296, Epping, NSW 1710, Australia*
[7] *Sydney Institute for Astronomy, School of Physics, University of Sydney, NSW 2006, Australia*
[8] *School of Physics, Monash University, Clayton, Victoria 3800, Australia*
[9] *Astronomy Centre, University of Sussex, Falmer, Brighton BN1 9QH, UK*
[10] *Department of Physics, The University of Queensland, Brisbane, QLD 4072, Australia*
[11] *Max Planck Institute for Nuclear Physics (MPIK), Saupfercheckweg 1, 69117 Heidelberg, Germany*
[12] *Institut für Astro- und Teilchenphysik, Universitt Innsbruck, Technikerstrae 25, 6020 Innsbruck, Austria*
[13] *Institute for Computational Cosmology, Department of Physics, Durham University, South Road, Durham DH1 3LE, UK*
[14] *HH Wills Physics Laboratory, University of Bristol, Tyndall Avenue, Bristol, BS8 1TL, UK*
[15] *Research School of Astronomy & Astrophysics, The Australian National University, Cotter Road, Weston Creek, ACT 2611, Australia*
[16] *School of Physics, the University of Melbourne, Parkville, VIC 3010, Australia*

Galaxies are Complicated…



- Main conclusion to draw is that stellar mass alone does a very poor job of predicting the properties of a galaxy.

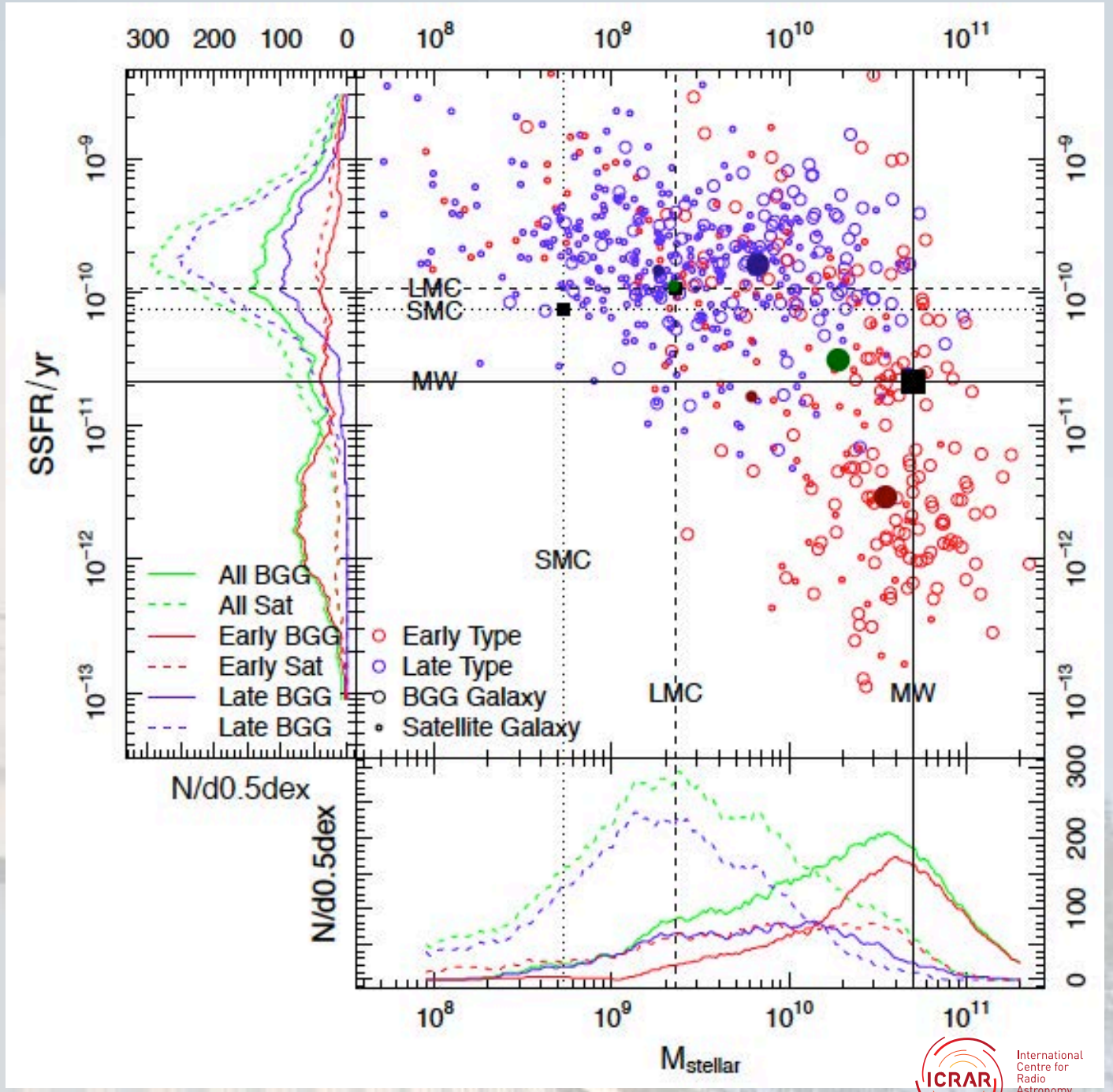
- This is especially true once we move beyond discussions of the “red fraction”. No colour selection (or indeed any of the 4 parameters shown) selects homogenous galaxies.

How typical is the Local Group?

-We selected groups with similar mass to the LG ($2.5 \times 10^{12}\ M_{\odot}$)

- The MW is relatively massive (stellar mass) for its halo mass.

- It would be more typical if it were an early-type galaxy, rather than a late-type spiral.

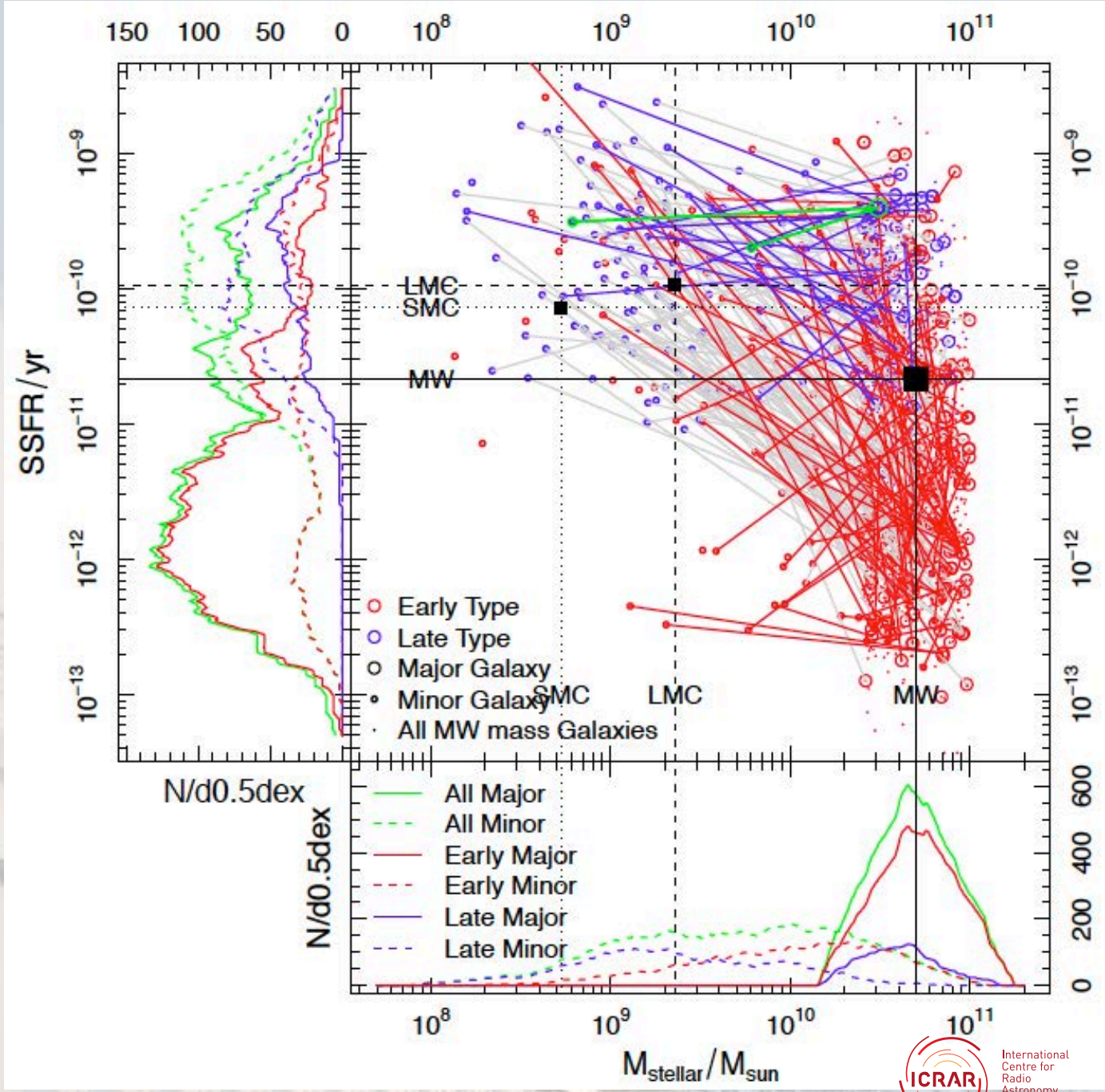


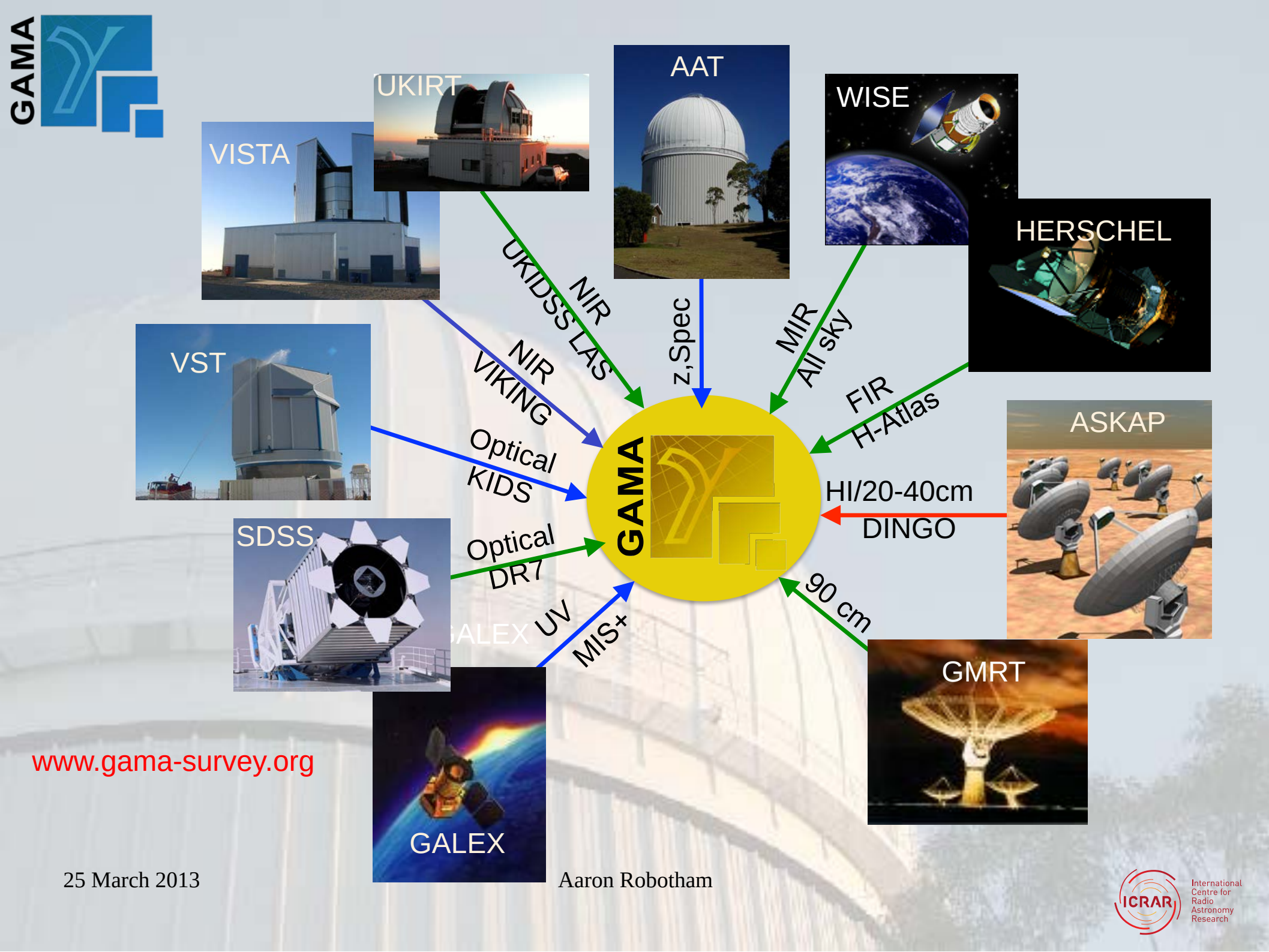
How typical is the MW-LMC?

-We selected close pairs that would detect close passage pair systems like the MW and LMC.

- The MW and the LMC are in a well populated part of stellar mass-SSFR parameter space for all galaxies in the sample.

- Given it is a late-type dominant pair galaxy, the MW has an unusually low SSFR.




GAMA
UKIRT
AAT
WISE
VISTA
HERSCHEL
UKIDSS LAS
NIR
z,Spec
MIR
All sky
NIR
VIKING
FIR
H-Atlas
VST
Optical
KIDS
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90 cm
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MIS+
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GALEX
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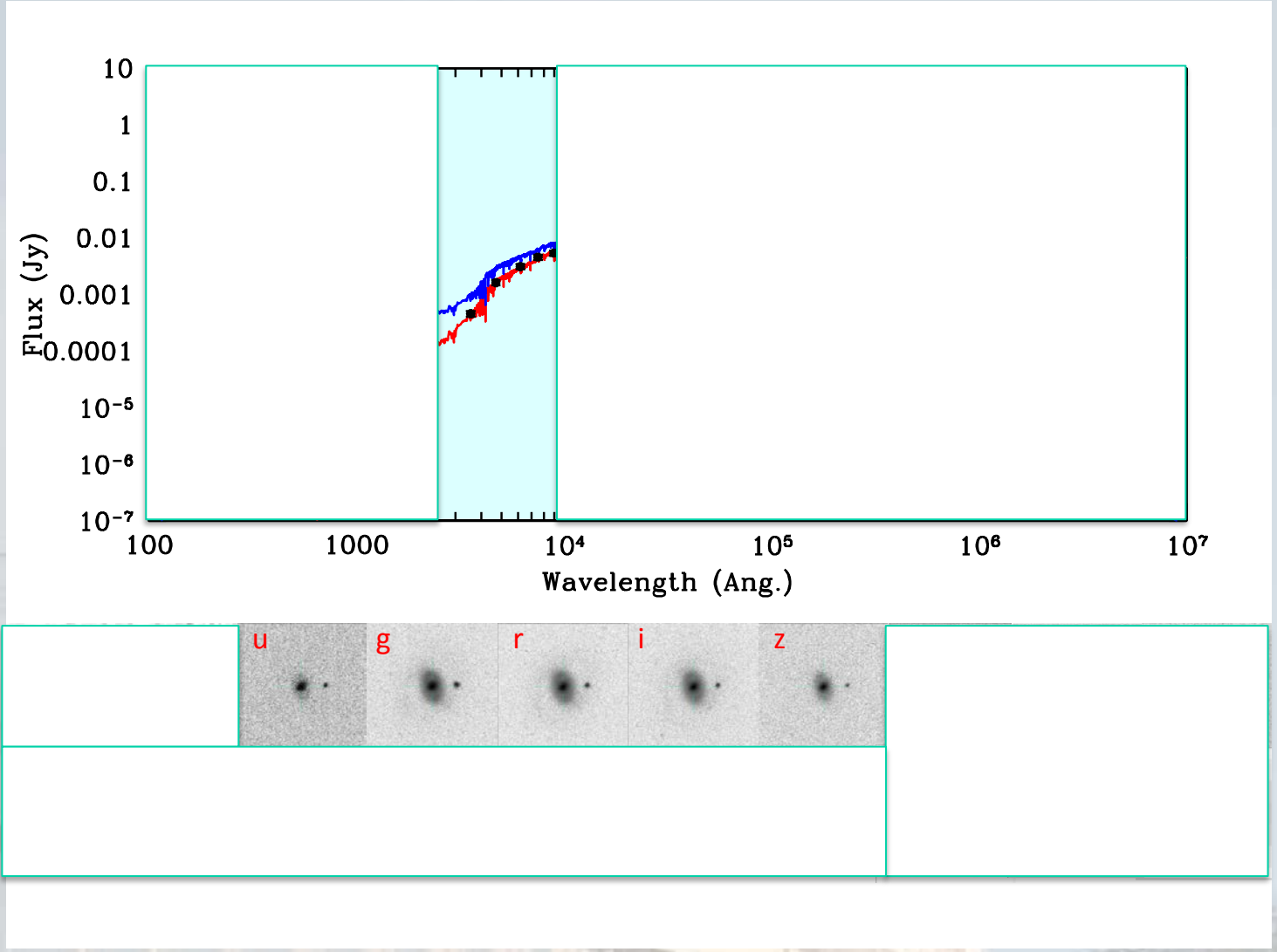
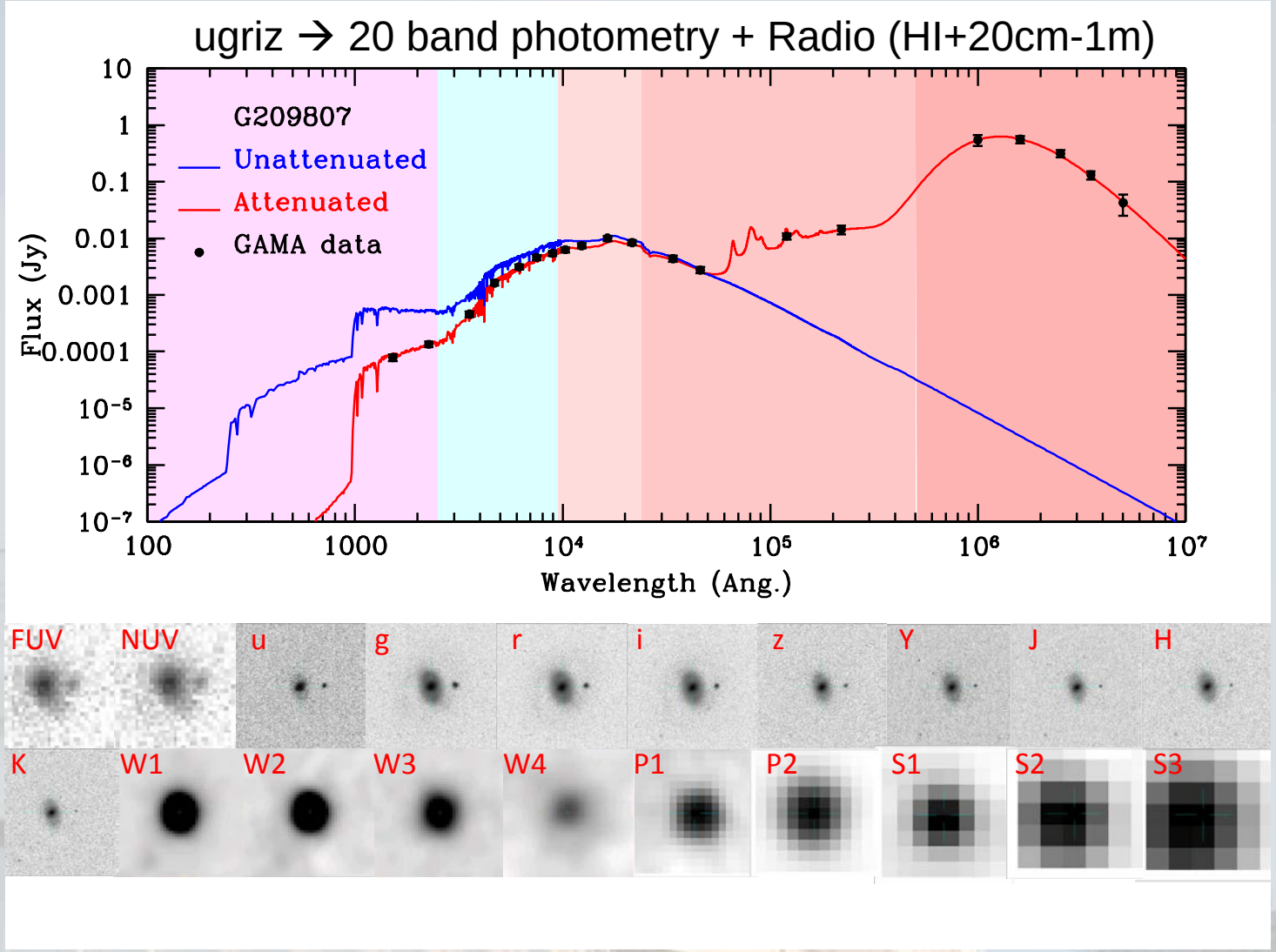
25 March 2013
Aaron Robotham
ICRAR
International Centre for Radio Astronomy Research

Why go multi-wavelength…?



GAMA:20 band photometry



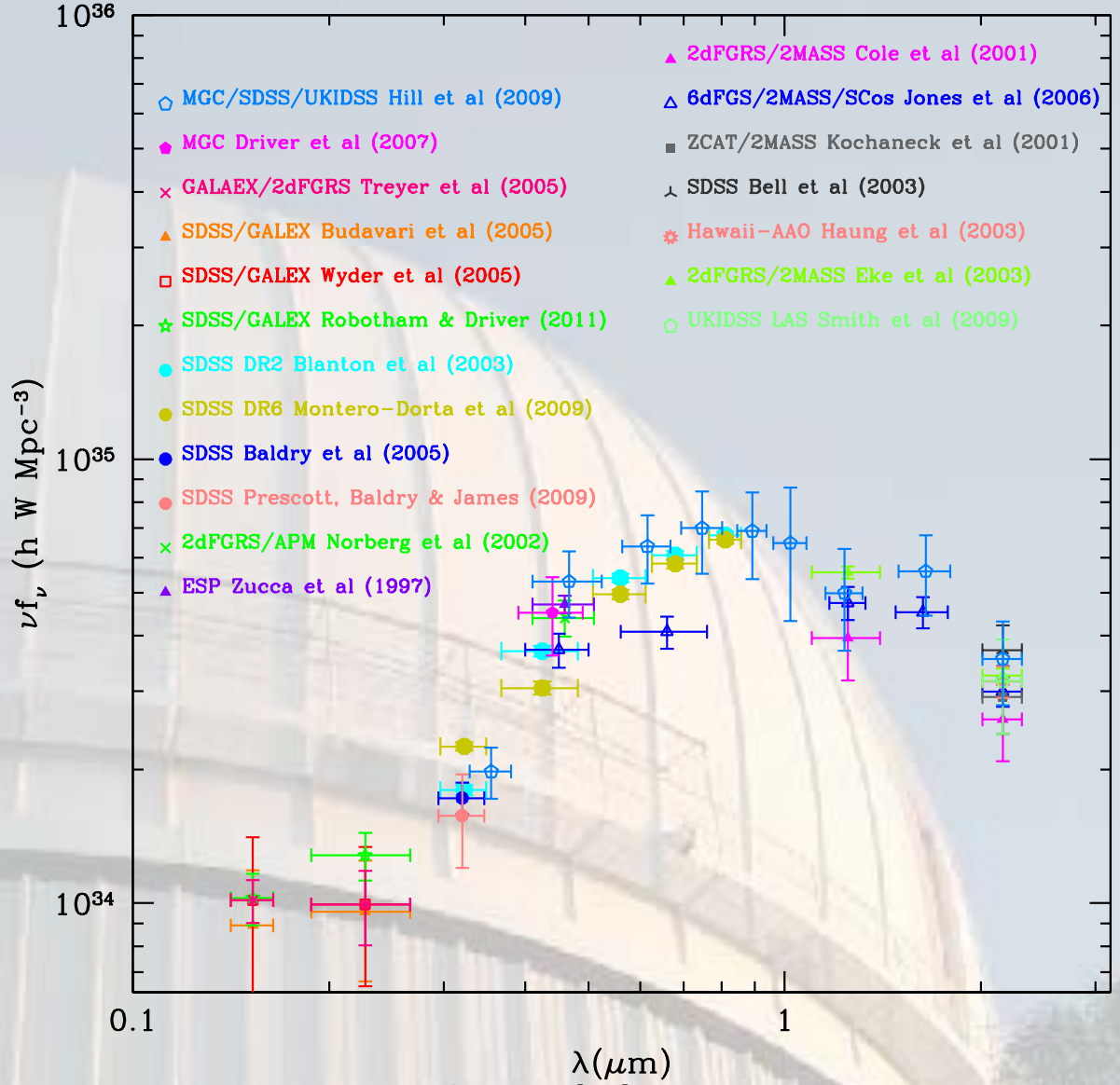
Mon. Not. R. Astron. Soc. **000**, 000–000 (0000) Printed 4 September 2012 (MN LATEX style file v2.2)

Galaxy And Mass Assembly (GAMA): The $0.013 < z < 0.1$ cosmic spectral energy distribution from 0.1 μm to 1 mm

S.P. Driver,[1,2⋆†], A.S.G. Robotham,[1,2] L. Kelvin,[1,2] M. Alpaslan,[1,2] I.K. Baldry,[3] S.P. Bamford,[4] S. Brough,[5] M. Brown,[6], A.M. Hopkins,[5] J. Liske,[7] J. Loveday,[8] P. Norberg,[9] J.A. Peacock,[10] E. Andrae,[11] J.Bland-Hawthorn,[12] N. Bourne,[4] E. Cameron,[13] M. Colless,[5] C.J. Conselice,[4] S.M. Croom,[12] L. Dunne,[14] C.S. Frenk,[9] Alister W. Graham,[15] M. Gunawardhana,[12] D.T. Hill,[2] D.H. Jones,[6] K. Kuijken,[16] B. Madore,[17] R.C. Nichol,[18] H.R. Parkinson,[10] K.A. Pimbblet,[6] S. Phillipps,[19] C.C. Popescu,[20] M. Prescott,[3] M. Seibert,[17], R.G. Sharp,[21] W.J. Sutherland,[22] E.N. Taylor,[12] D. Thomas,[18] R.J. Tuffs,[11] E. van Kampen,[7] D. Wijesinghe,[12] S. Wilkins[23]

The Cosmic Spectral Energy Distribution (pre-GAMA)

Hill et al (2010)

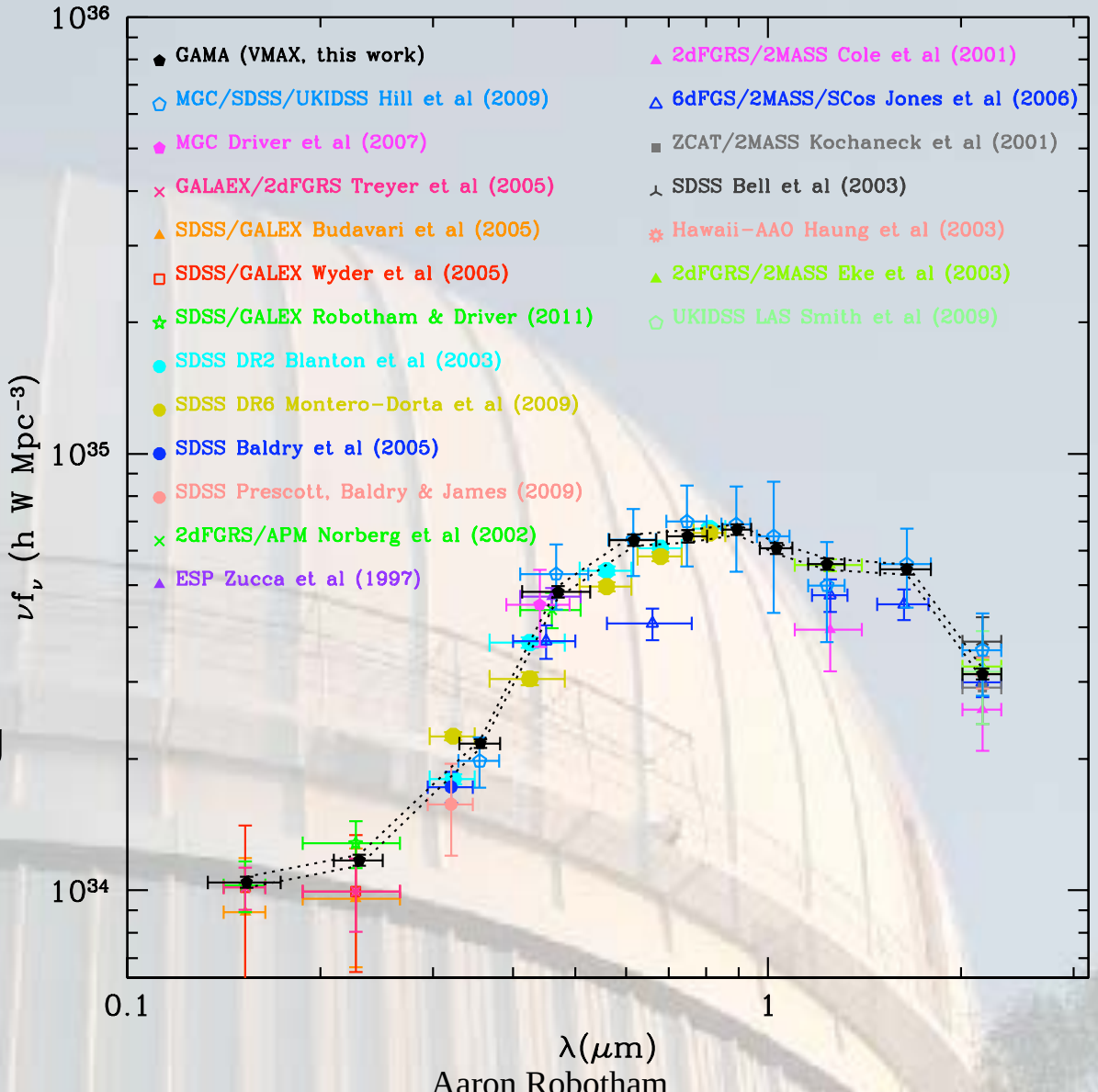


Luminosities densities from FUV to K

Observed energy production of nearby Universe

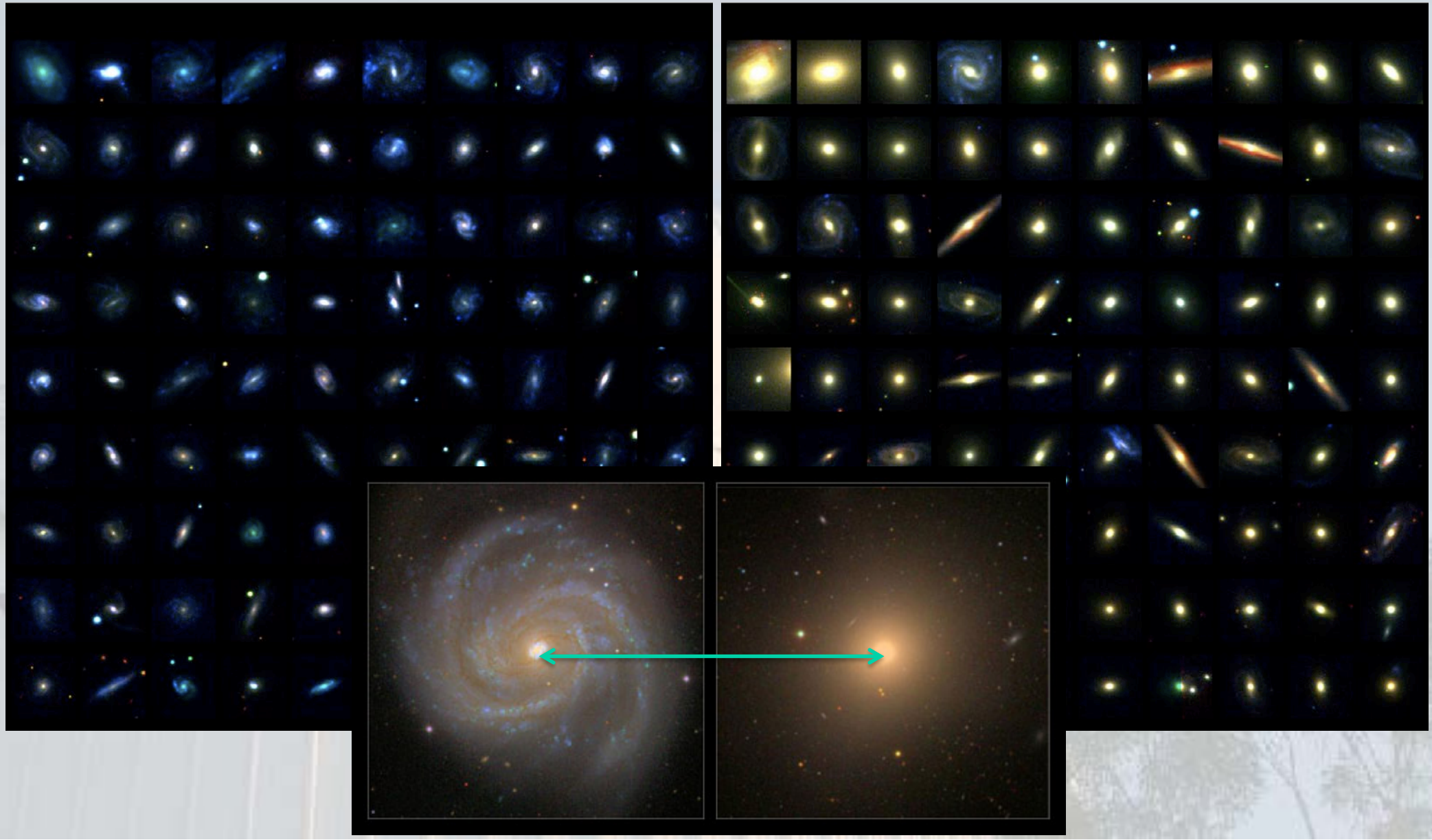
Wavelength dependent cosmic variance removed

Elliptical dust attenuation using photon escape fraction curve (Driver et al 2008)

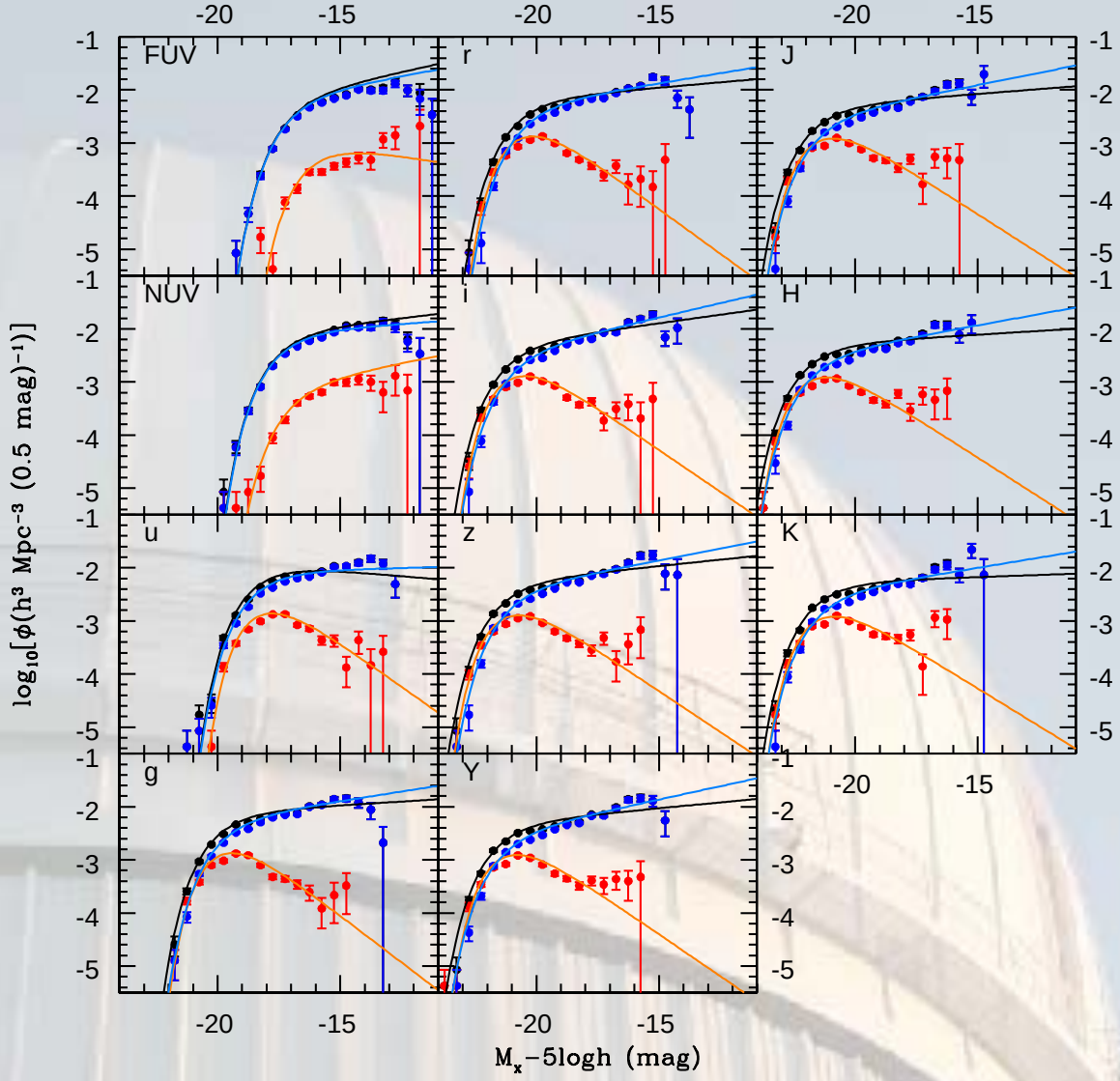


Driver et al 2012

Galaxy bimodality or duality?

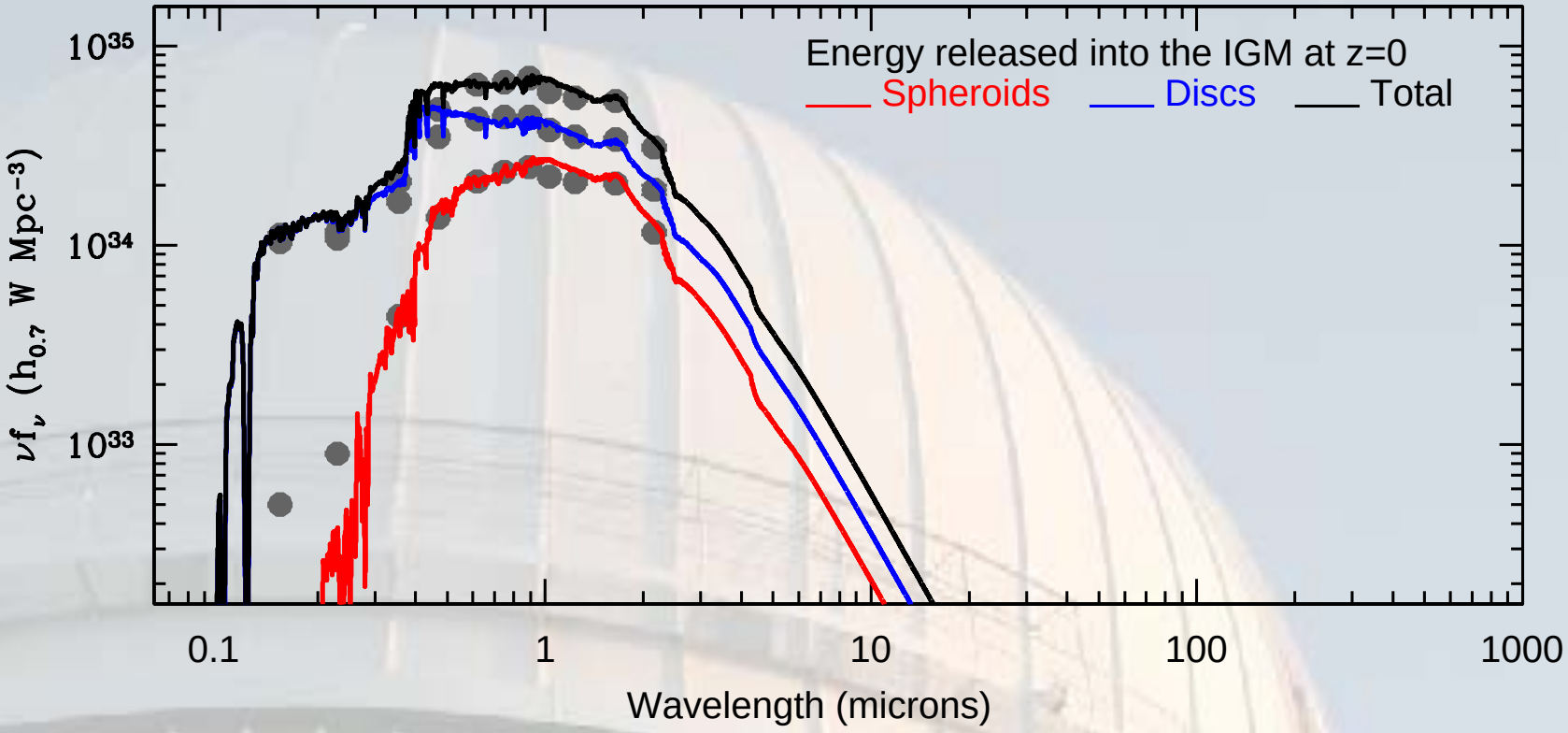


FUV-K LFs by morphological type



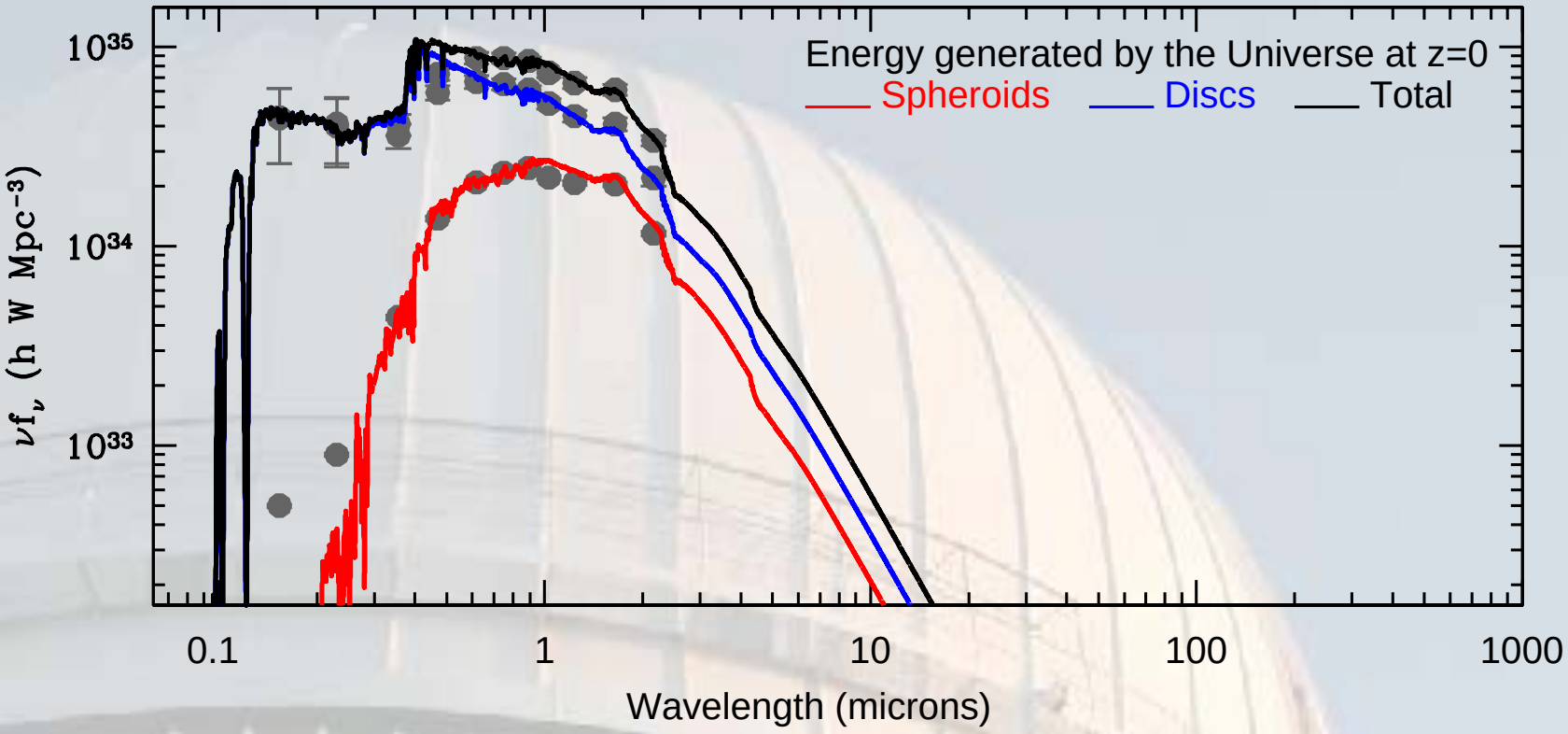
SED of Universe at z=0

Attenuated spectrum for spheroids and discs



SED of Universe at z=0

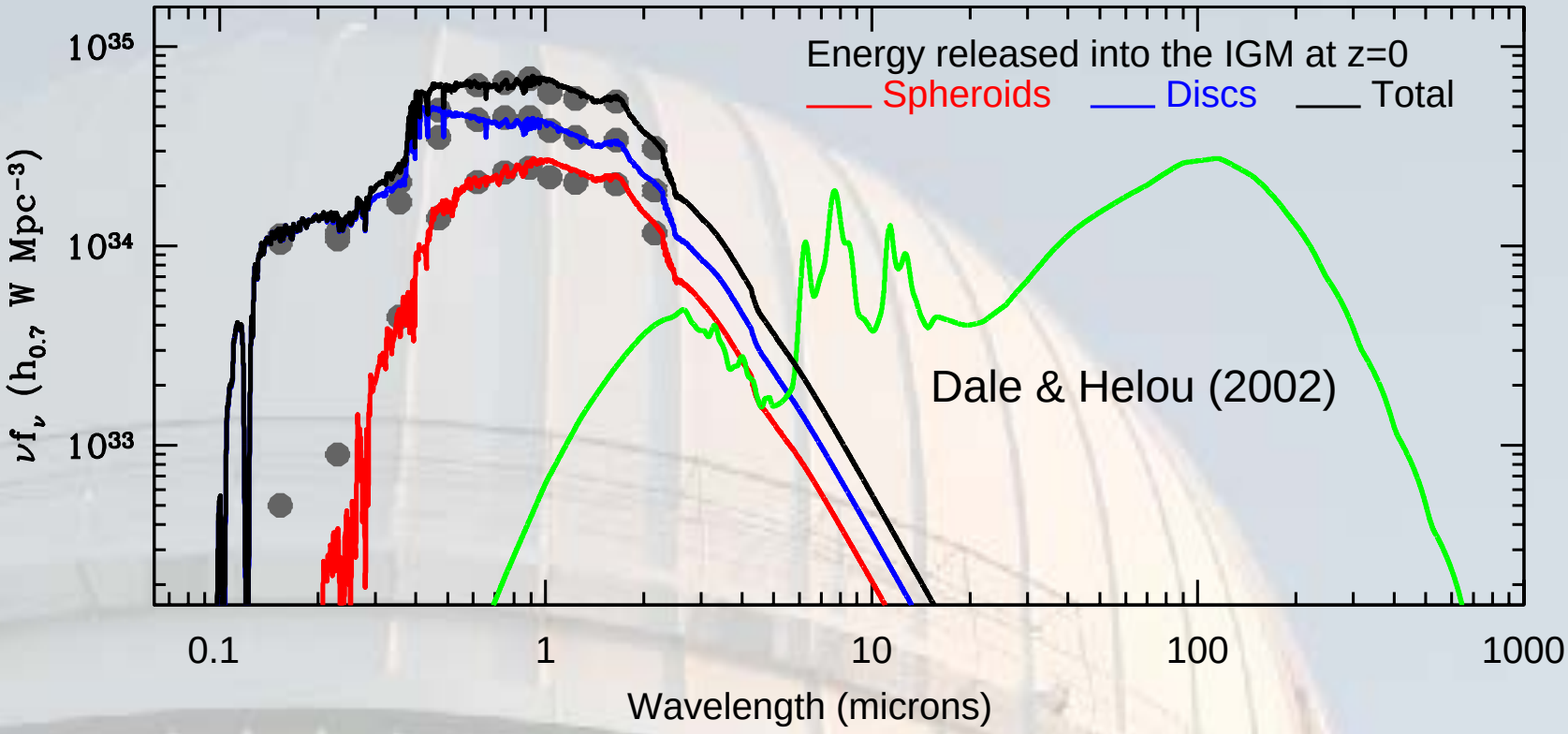
Unattenuated spectrum for spheroids and discs



Using photon escape fraction from Driver et al (2008)

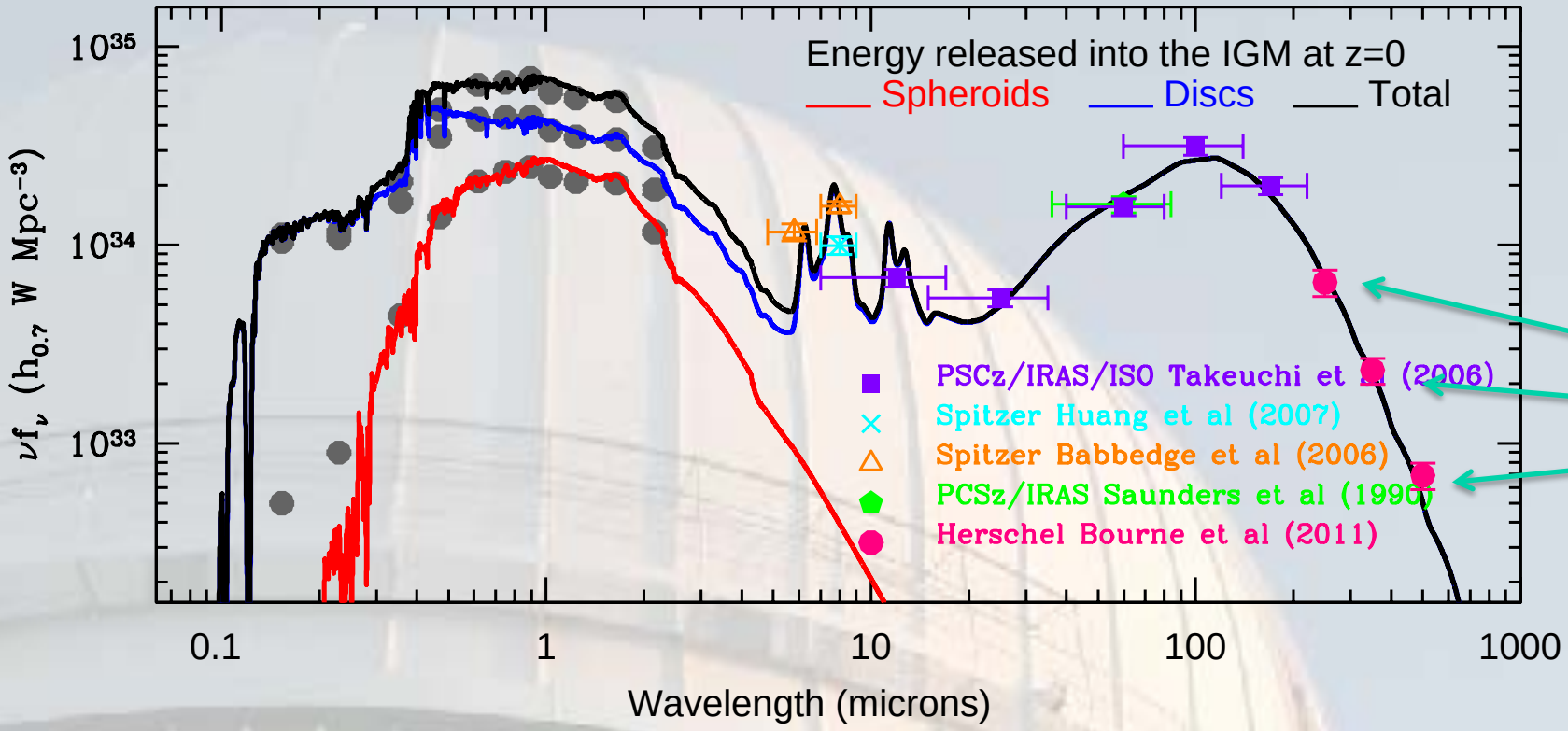
SED of Universe at z=0

Missing energy transferred to dust

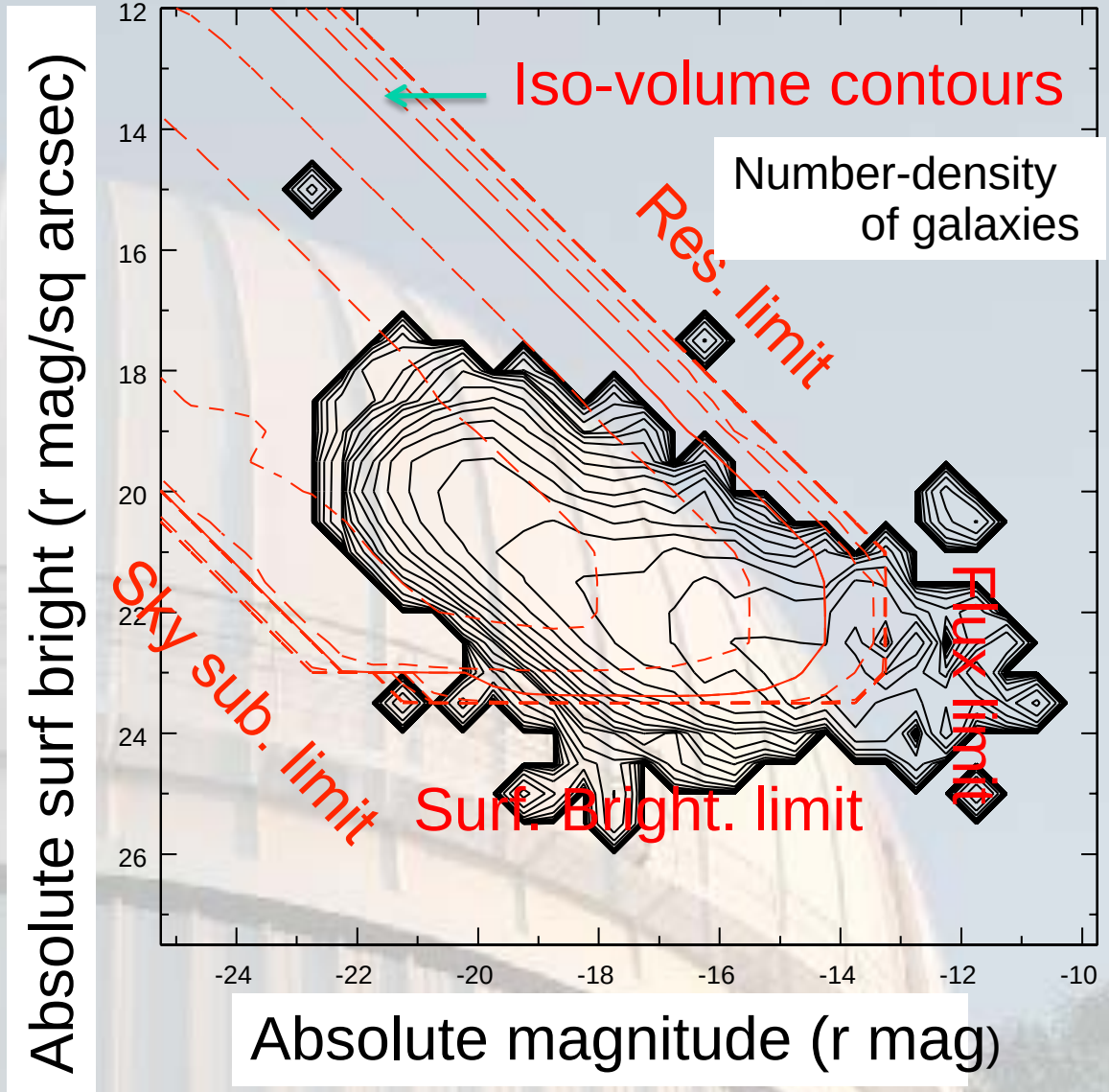


SED of Universe at z=0

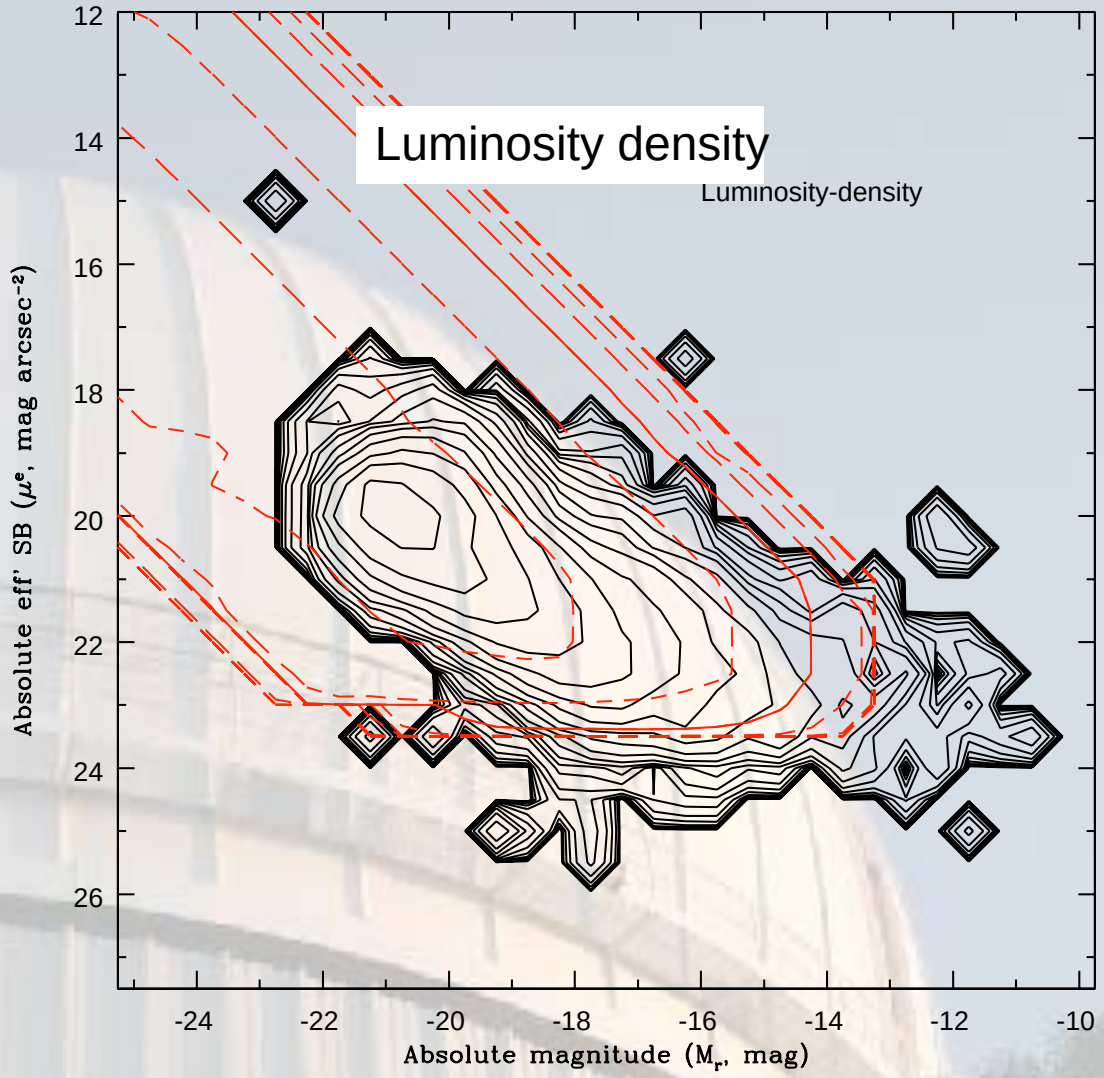
PREDICTION v FIR data



SDSS great but shallow & chunky



Lum. density OK, faint-end slopes not, GAMA not sampling dwarf populations



GAMA

Mon. Not. R. Astron. Soc. **000**, 1–?? (2012) Printed 8 January 2013 (MN LATEX style file v2.2)

Two-phase galaxy evolution: the cosmic star-formation histories of spheroids and discs

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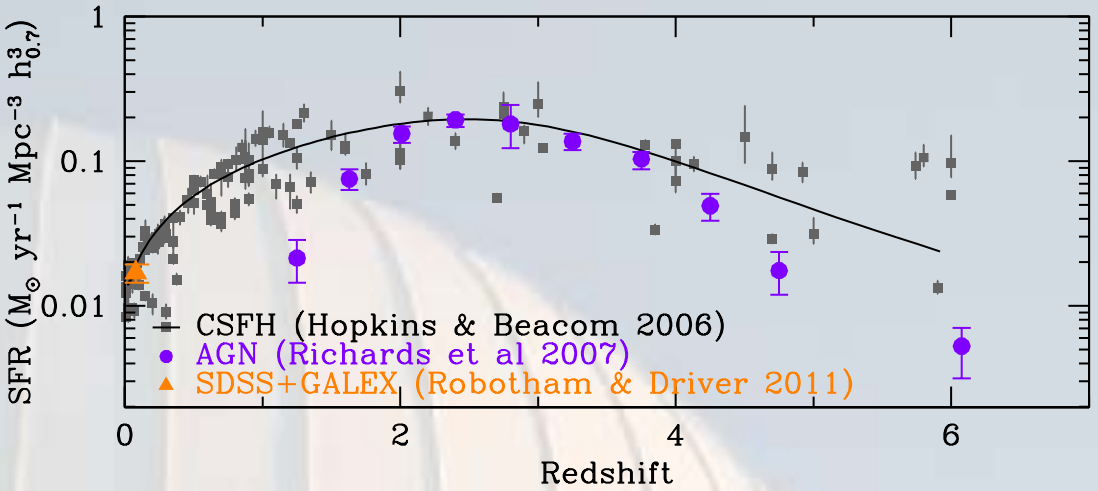
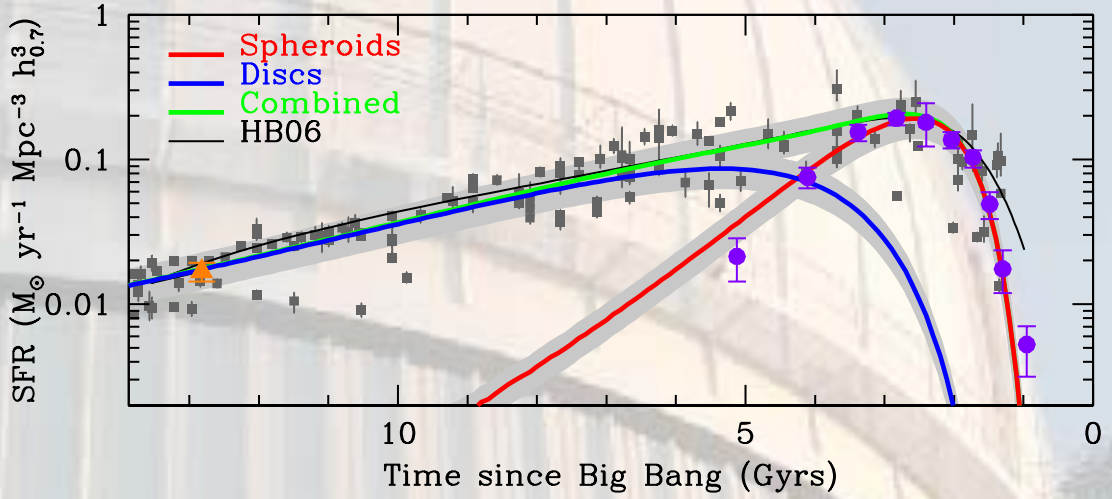
Simplest “Model” for the Cosmic SED

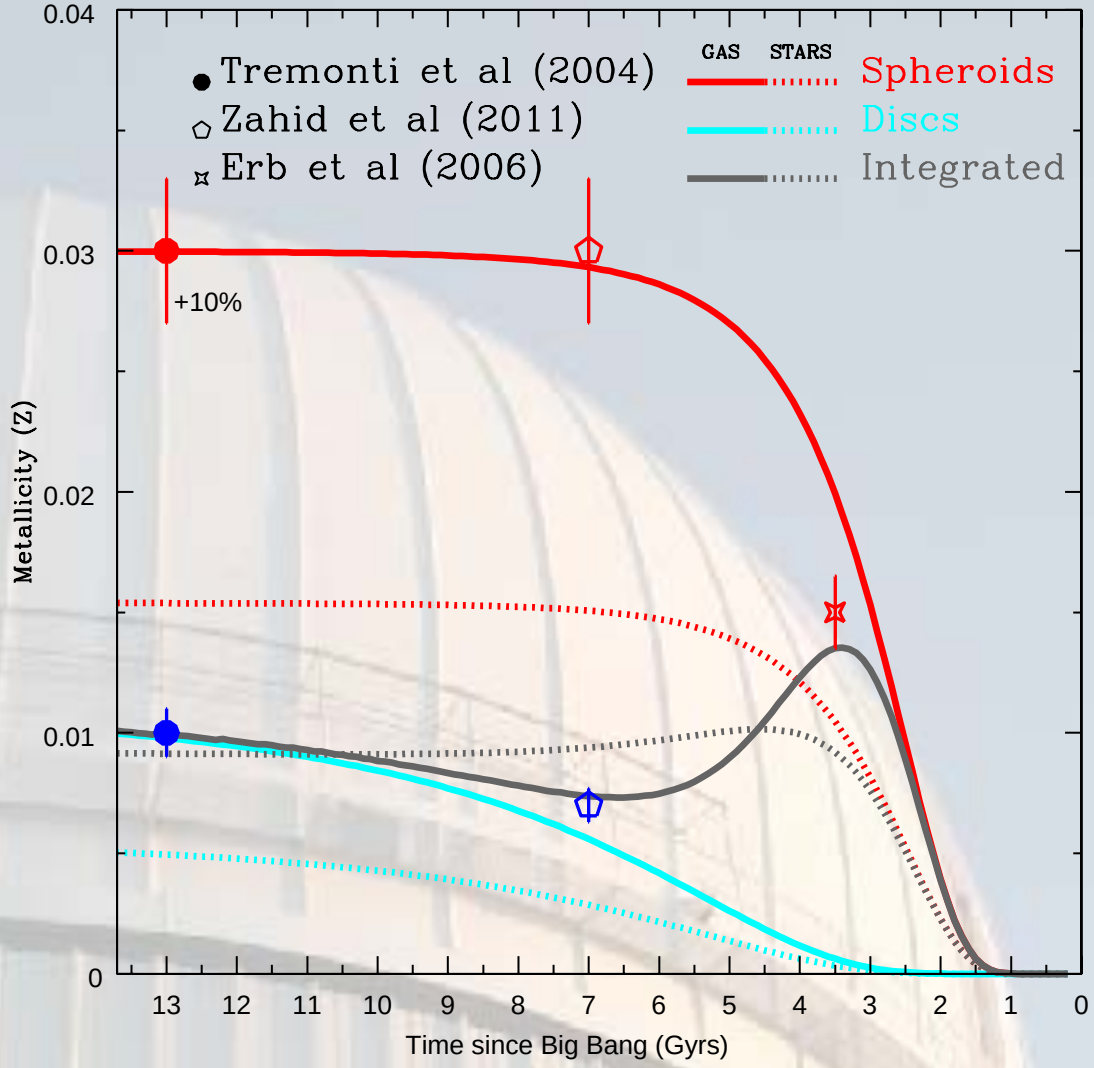
- Two axioms:
  - AGN activity traces spheroid formation
    - SMBH-bulge relations
    - AGN coincident with star-formation
  - Spheroid formation dominates at high-z
    - Ages & metallicities of nearby Ellipticals

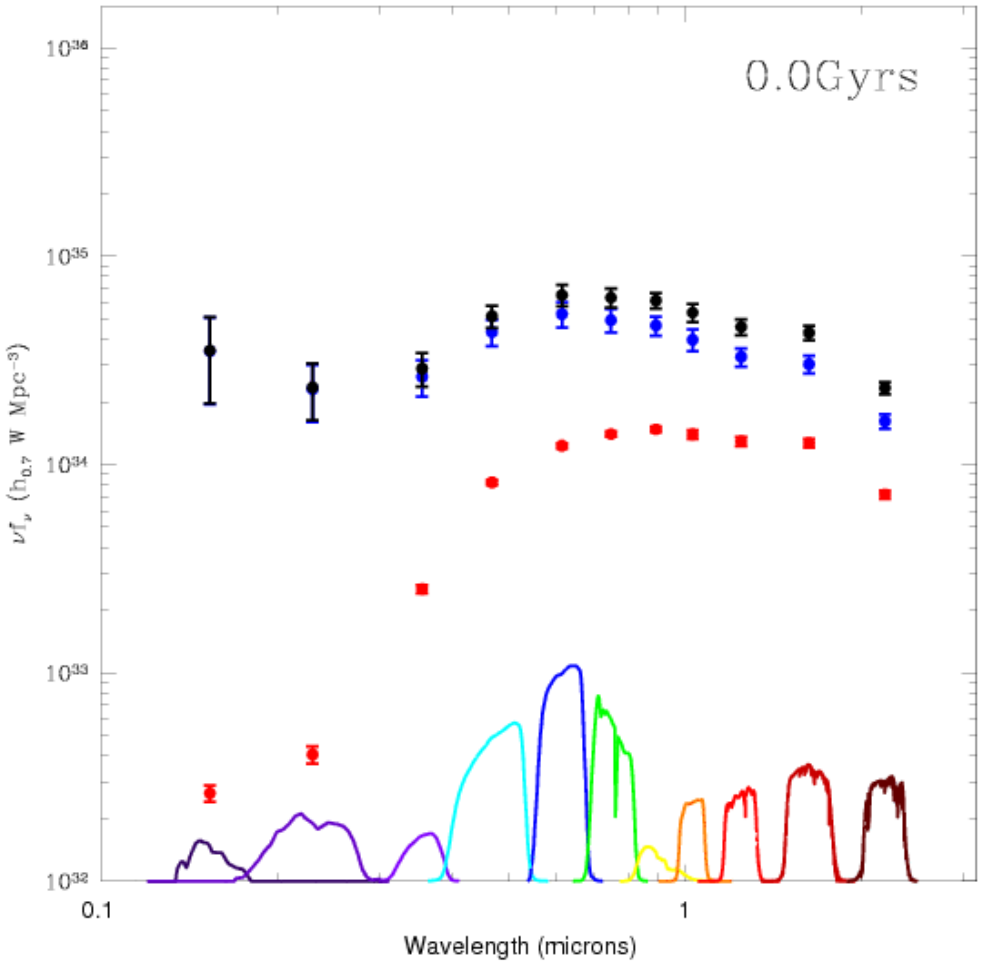
CSFH of galaxies and AGN (scaled)

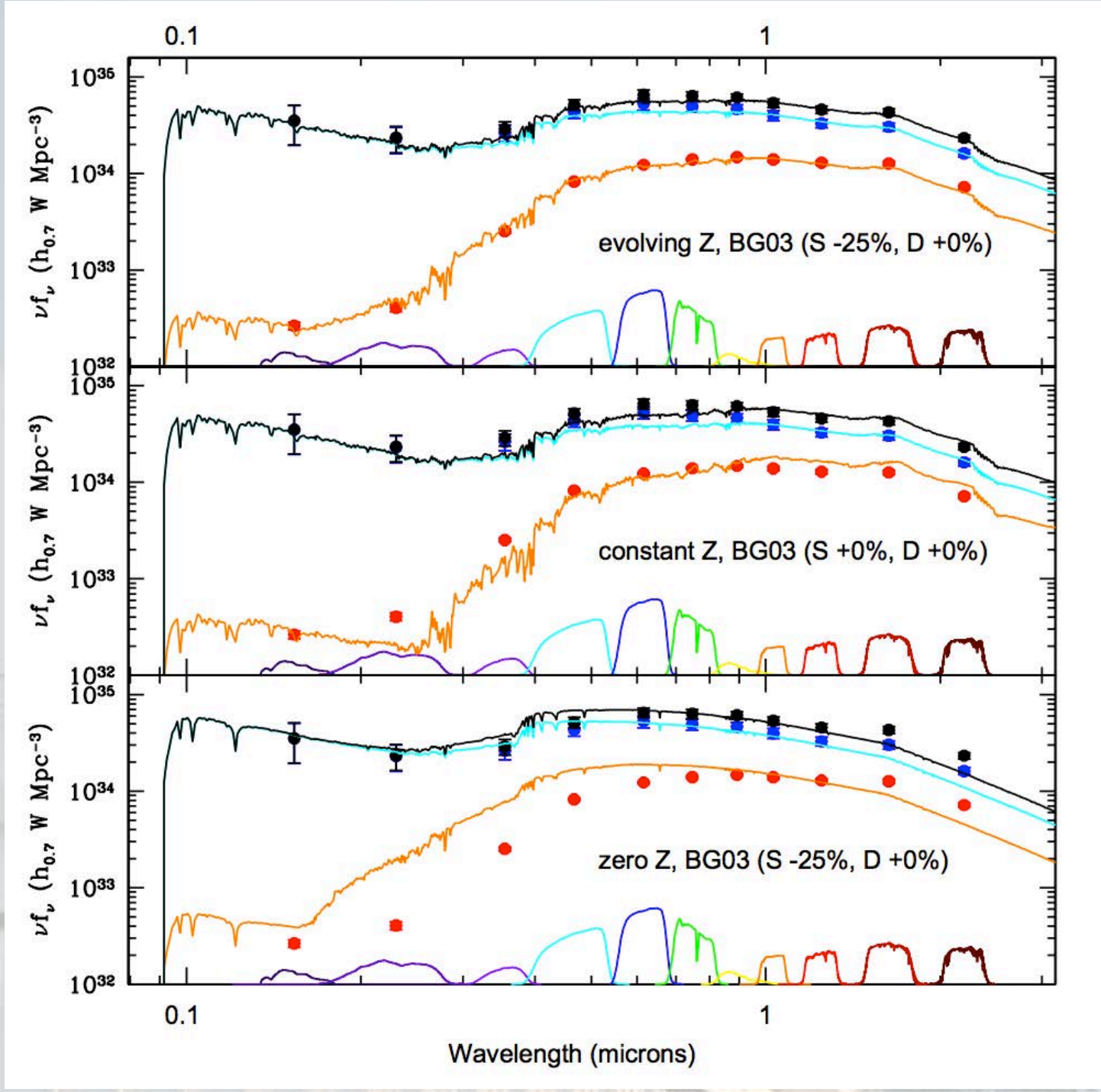




Implied metallicity history




0.0Gyrs
10^{36}
10^{35}
10^{34}
10^{33}
10^{32}
νf_ν ($h_{0.7}$ W Mpc^{-3})
0.1
1
Wavelength (microns)


0.1
1
10^{35}
10^{34}
10^{33}
10^{32}
νf_ν ($h_{0.7}$ W Mpc^{-3})
evolving Z, BG03 (S -25%, D +0%)
constant Z, BG03 (S +0%, D +0%)
zero Z, BG03 (S -25%, D +0%)
Wavelength (microns)

Conclusions

- GAMA is hitting its stride in terms of producing testable results at interesting (small, inter-halo) scales.
- We have enough observational data to do a good job of measuring physical quantities (stellar masses and dust masses). So we can meet sims in the middle.
- Even with this amount of data, some excellent data fits can be achieved with “parameter-less” models.