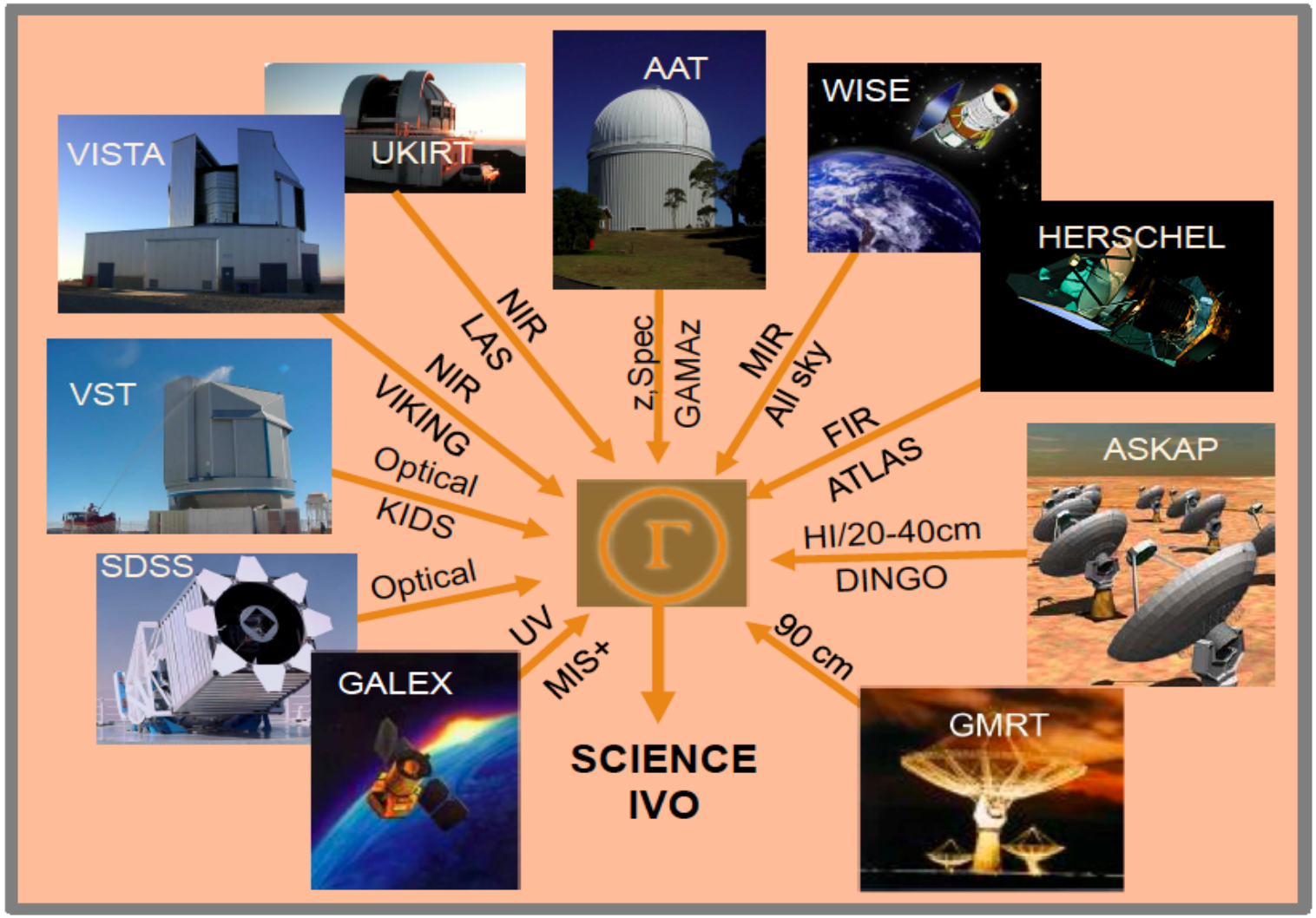
Galaxy And Mass Assembly Survey:
the key to a vital CDM model prediction?



Peder Norberg

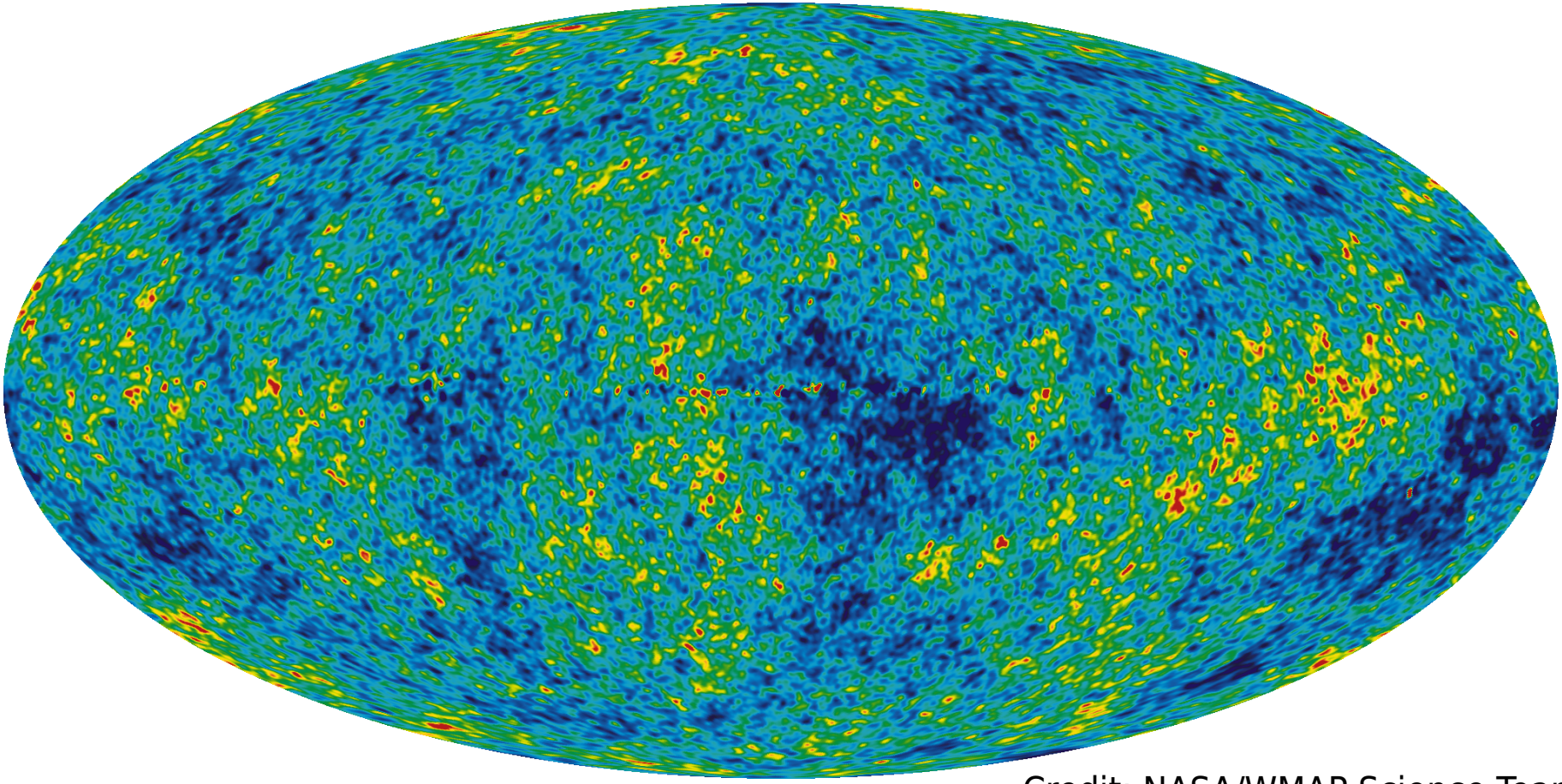
Institute for Astronomy, Royal Observatory Edinburgh

Galaxy And Mass Assembly Survey: the key to a vital CDM model prediction?

- Brief review of the current state of cosmology
- Biased review of some 2dFGRS results
- The Galaxy And Mass Assembly survey
- Preliminary results from GAMA
- Next step: GAMA-II !
- Conclusions

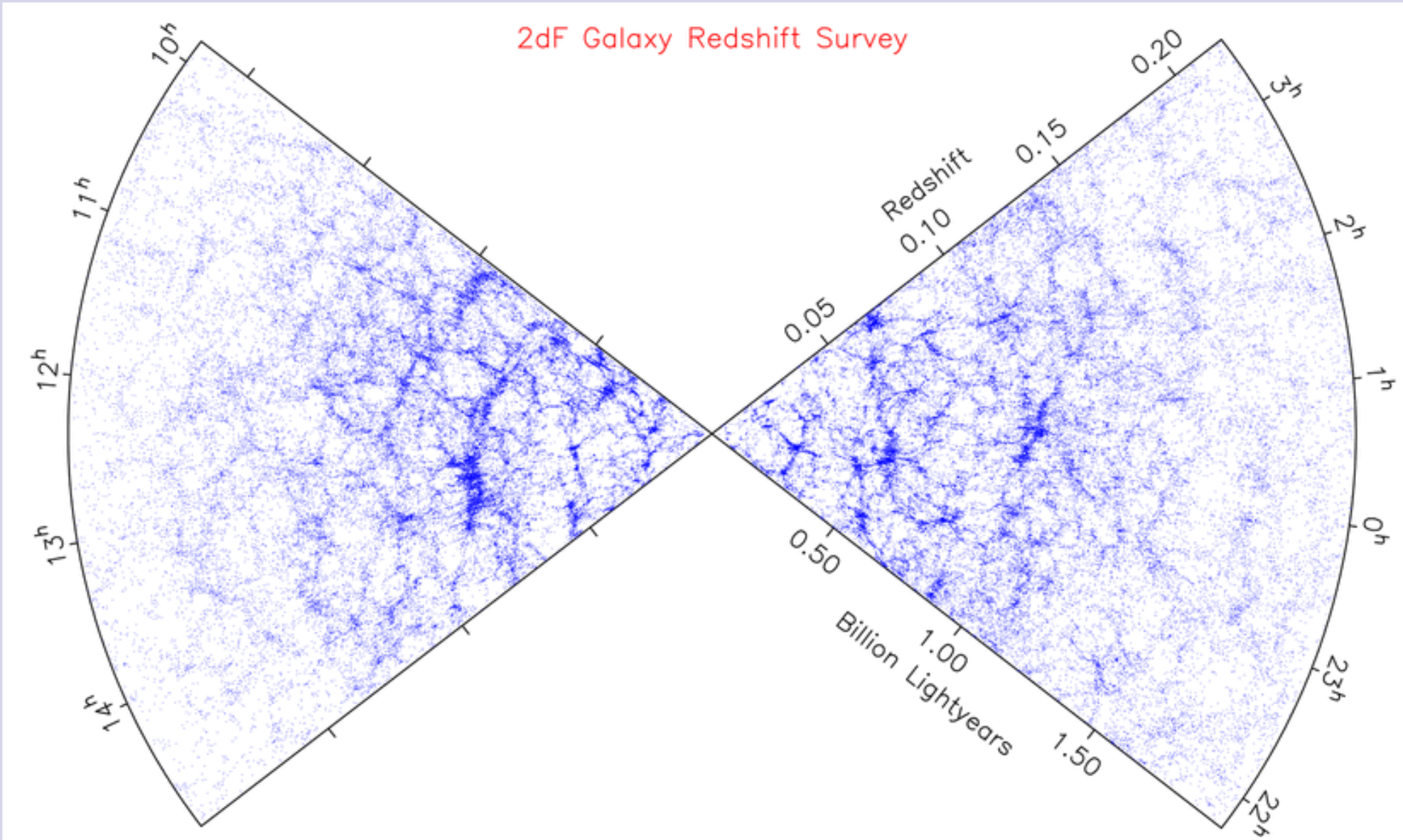
Cosmic Microwave Background: Temperature Fluctuations

Satellite & ground based experiments (COBE, WMAP, Boomerang, ...) have led to precision cosmology:



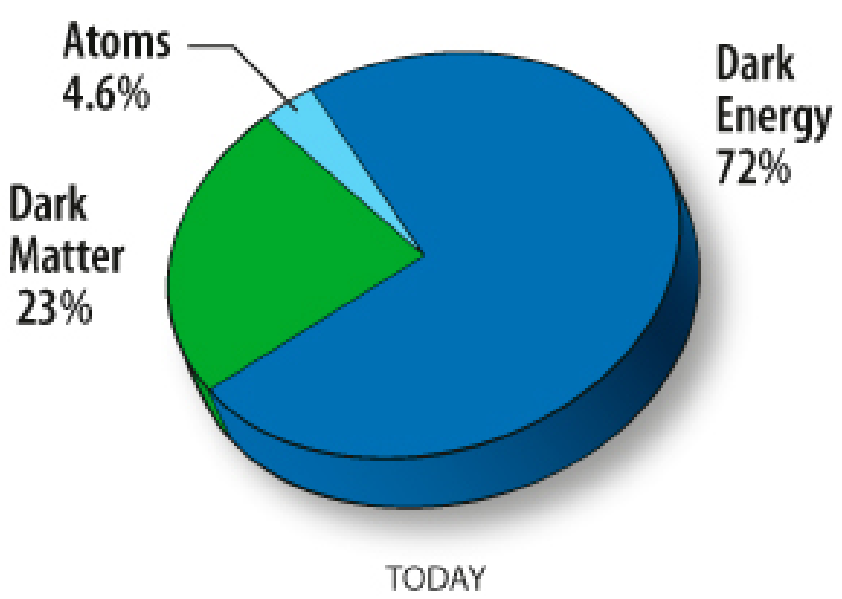
Credit: NASA/WMAP Science Team

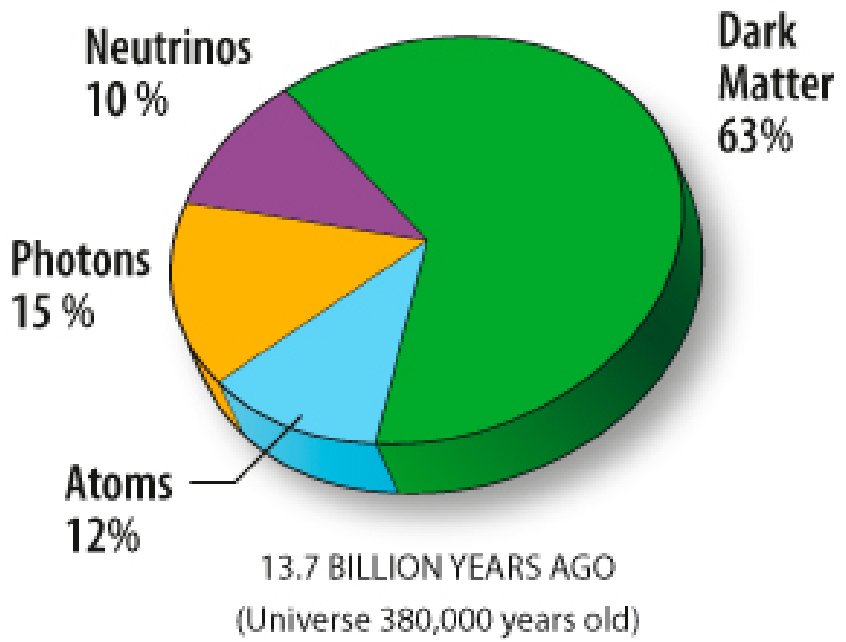
Large-Scale Structure: Galaxy Distribution



CDM: standard cosmological model

Combined with H_0 & SN Ia measurements, CMB & LSS confirm a standard cosmological picture:





Credit: NASA/WMAP Science Team

CDM: standard cosmological model

Two fundamental questions for the very successful CDM model:

- nature of cold dark matter (CDM)
- nature of Dark Energy ( )

Observational / Survey cosmology:

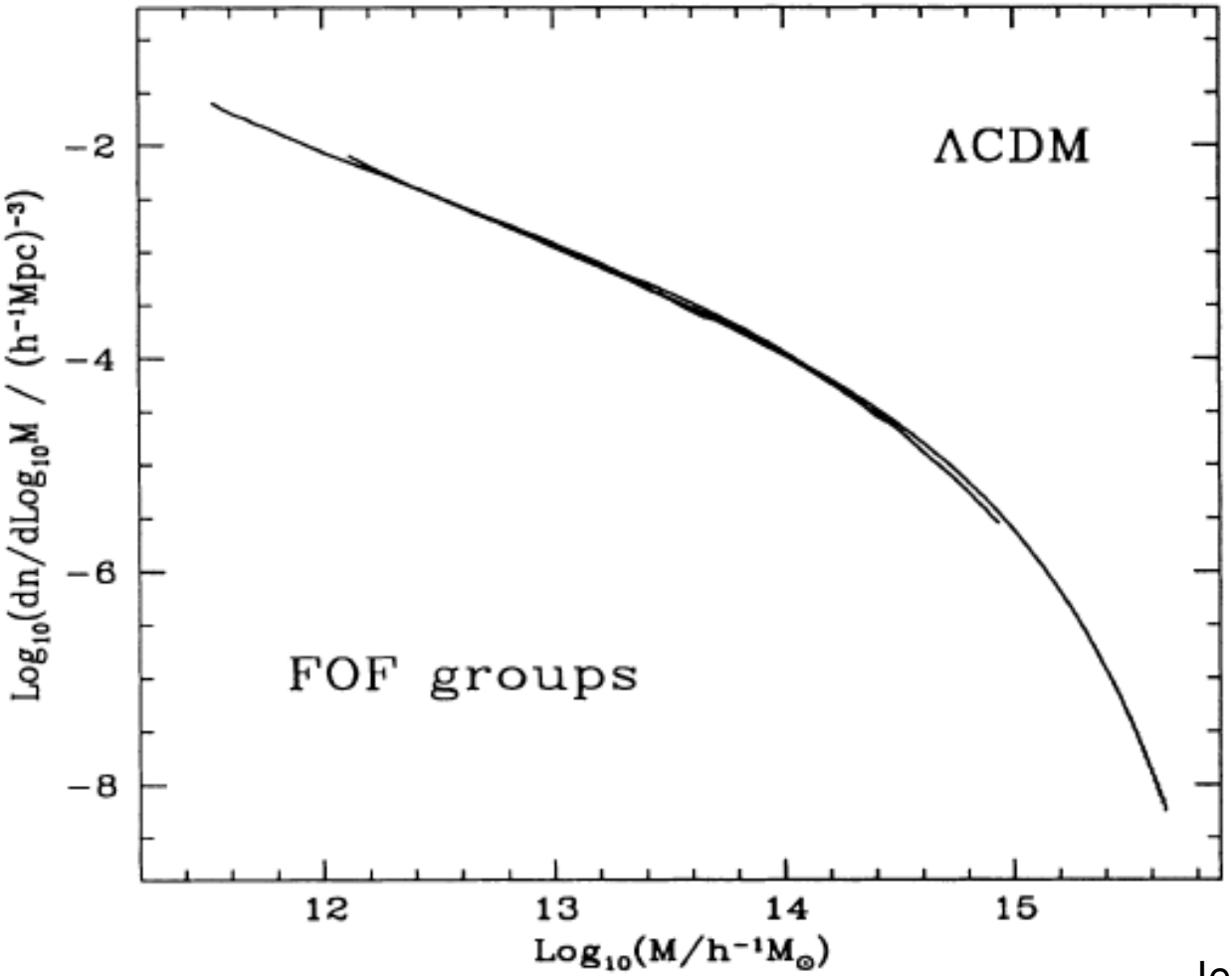
- unlikely to explain the nature of DE or CDM
- key in providing unique model constraints

Robust theoretical predictions exist / are needed:

- shape of cold dark matter halo mass function → GAMA
- evolution of the DE equation of state → e.g. Pan-STARRS

CDM halo mass function

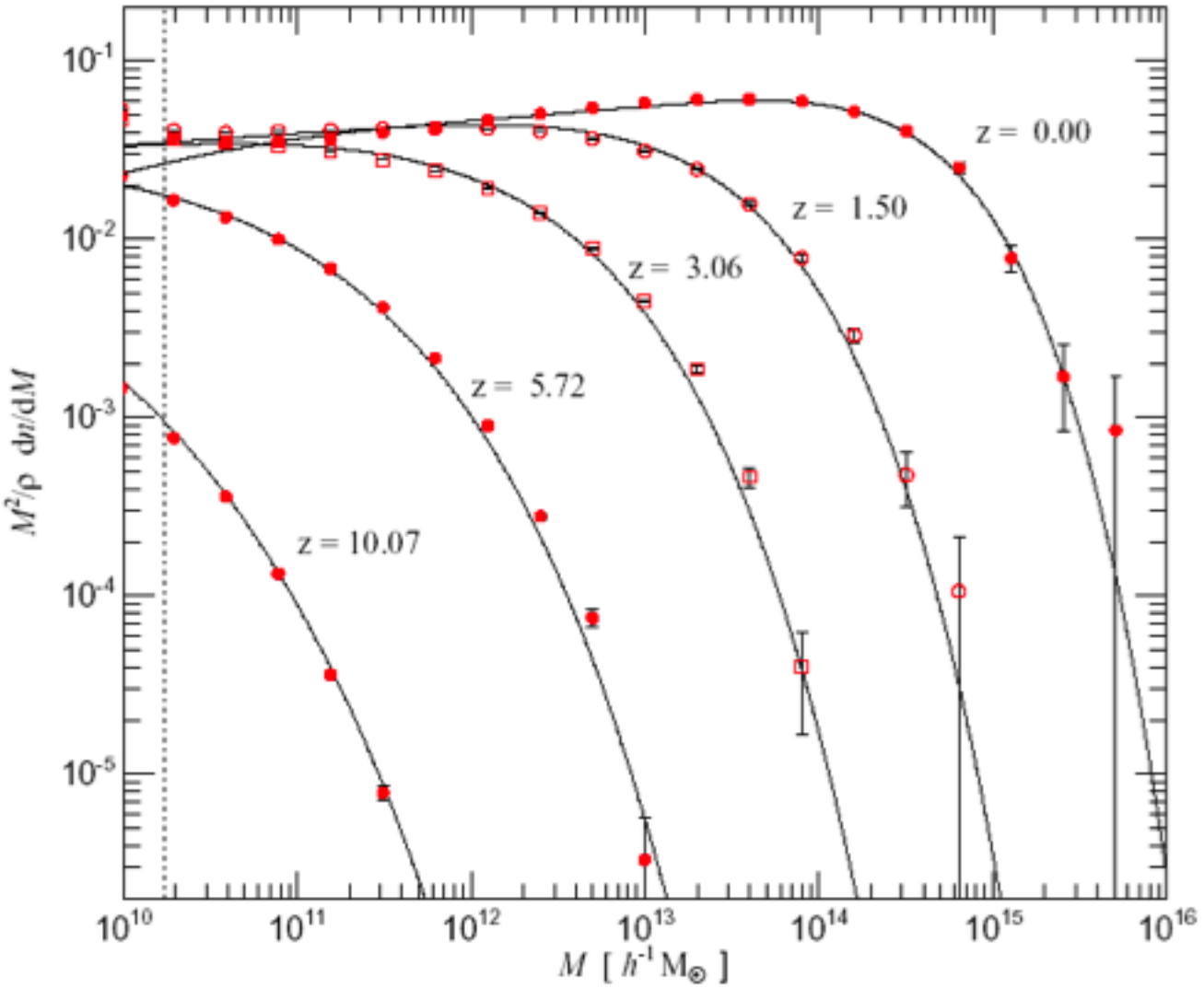
For a given cosmology, the CDM halo mass function is very well predicted (~10% accuracy), but not tested...



Jenkins et al. (2001)

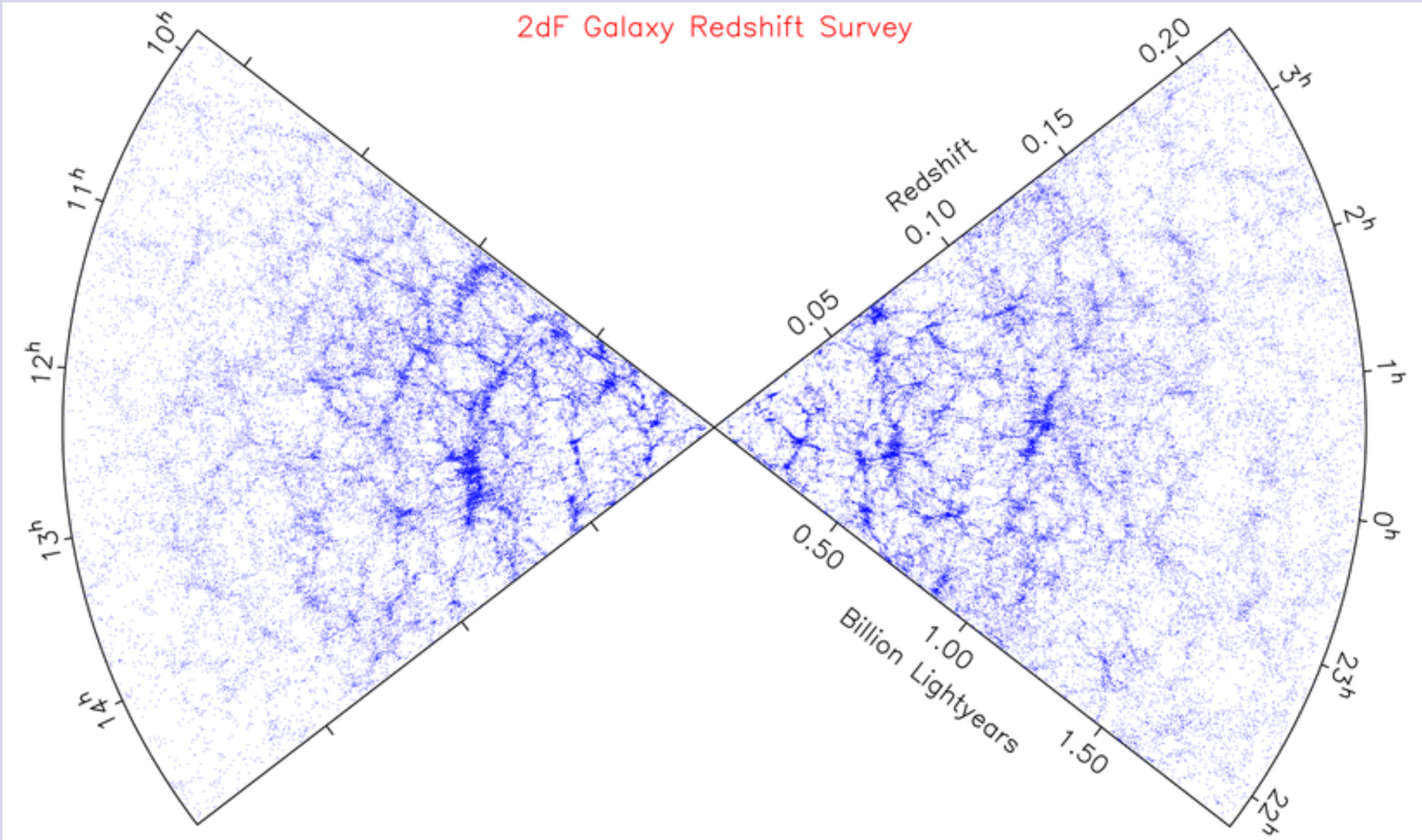
CDM halo mass function

Multiplicity Function



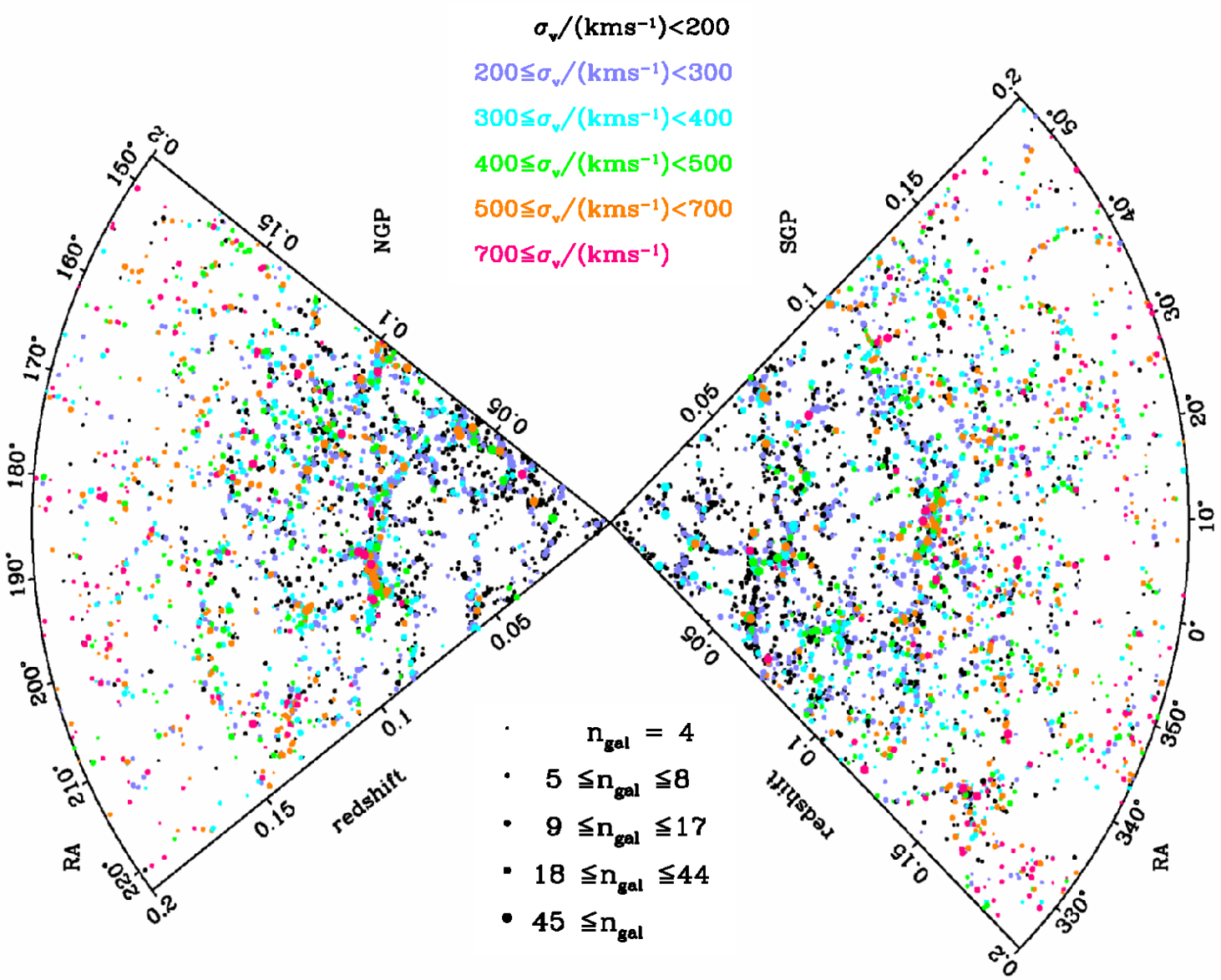
Springel et al. (2005)

2dF Galaxy Redshift Survey: a short summary



Peder Norberg Institute for Astronomy, Royal Observatory Edinburgh Leicester, February 2010

2dFGRS Percolation Inferred Galaxy Group Catalogue (2PIGG)



Dynamical group mass estimator:

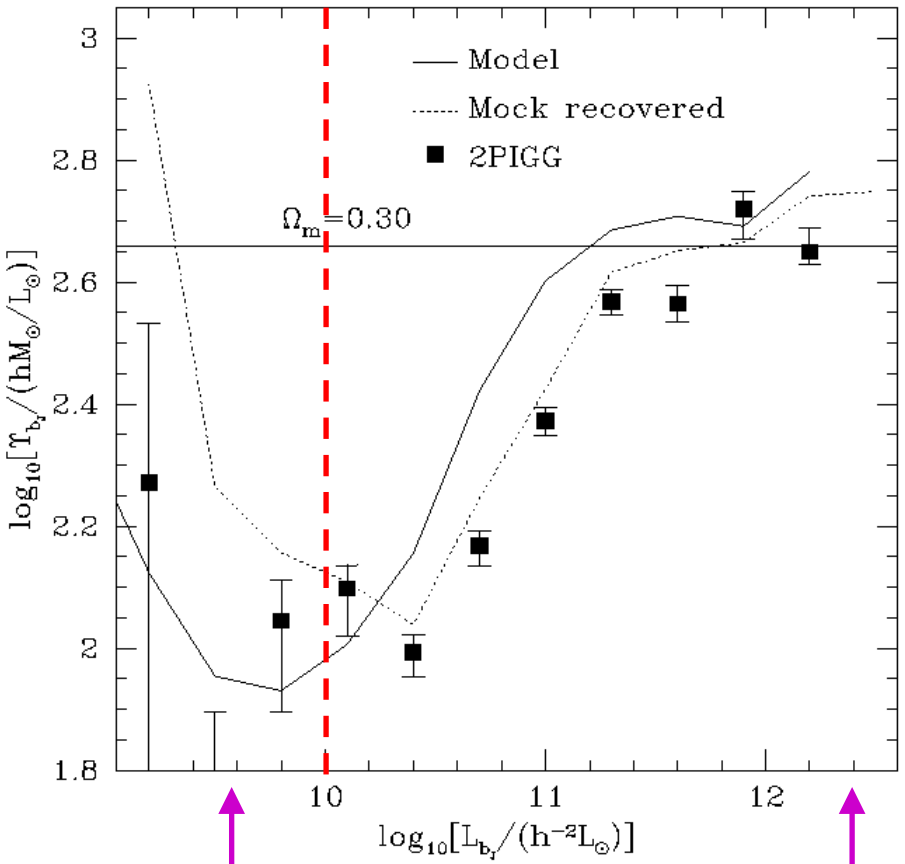
$$\sigma^2 = \sigma^2_{gap}\left(\frac{N}{N-1}\right) - \sigma^2_{err}$$

$$M = \frac{5\, r\, \sigma^2}{G}$$

with 5 so as to match DM FOF b=0.2 halo masses. σ_{gap} see Beers, Flynn & Gebhardt (1990).

(Eke et al. 2004)

2PIGG Mass-to-Light ratio: measure of galaxy formation efficiency



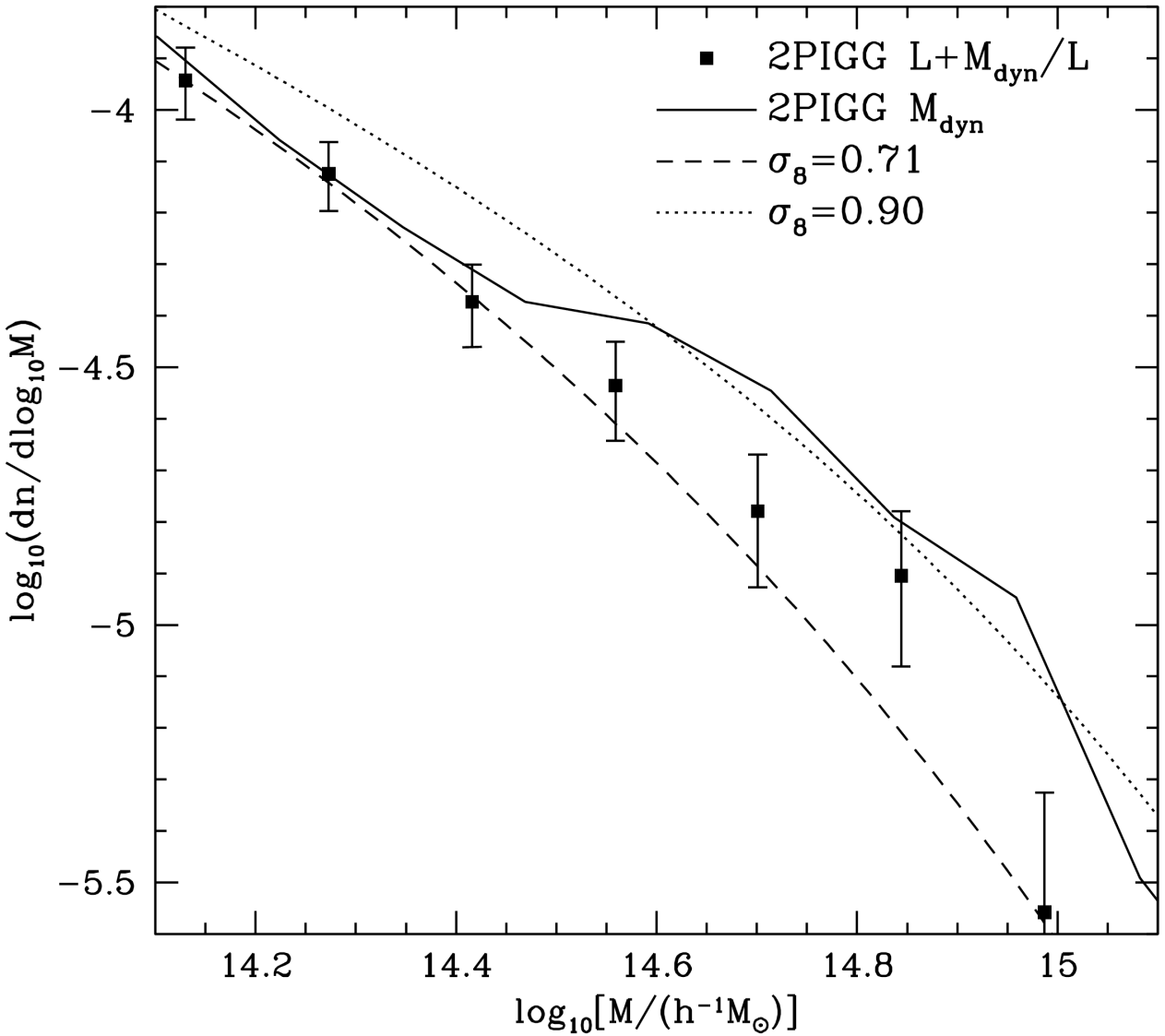
Mass-to-light ratio

Galaxy formation most efficient

Galaxy formation least efficient

(Eke et al. 2004)

2PIGG Group Mass Function: some constraint on CDM...



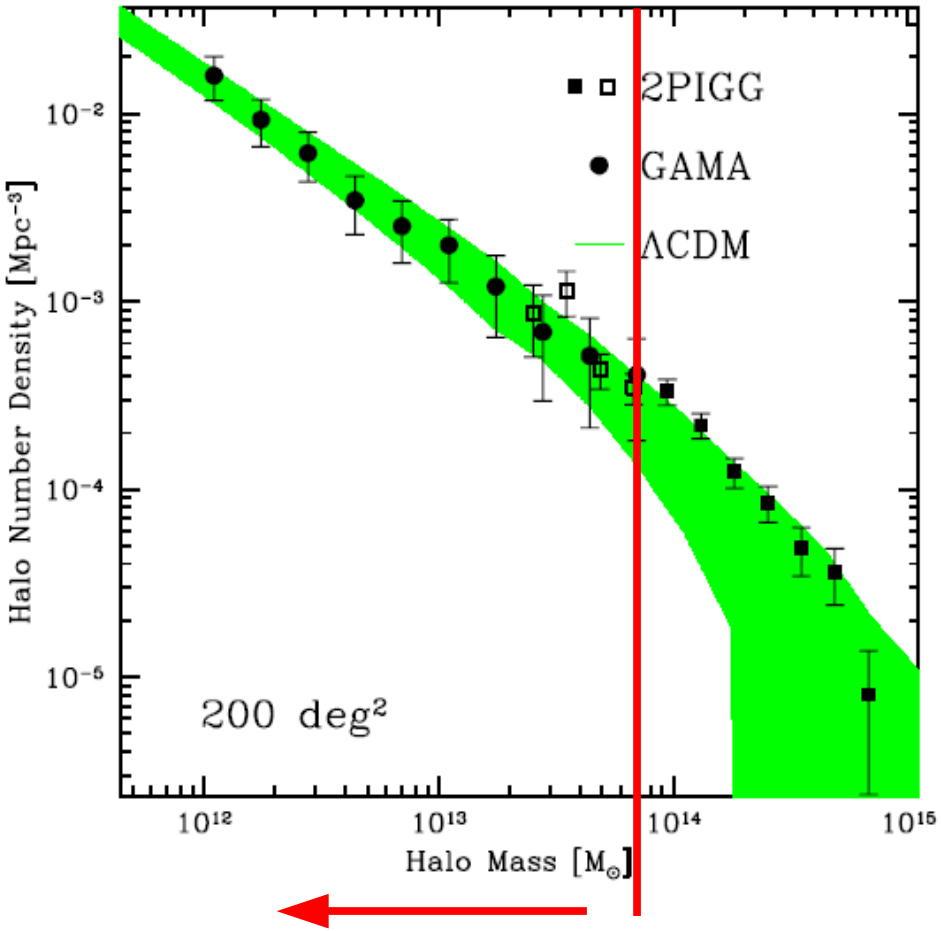
- 2dFGRS (like SDSS): unable to provide firm constraints on the CDM halo mass function:
- Too small halo mass range probed.
- Too large influence from error on σ_8 over that halo mass range.
- Only one redshift slice.

(Eke et al. 2006)

GAMA: la raison d'être

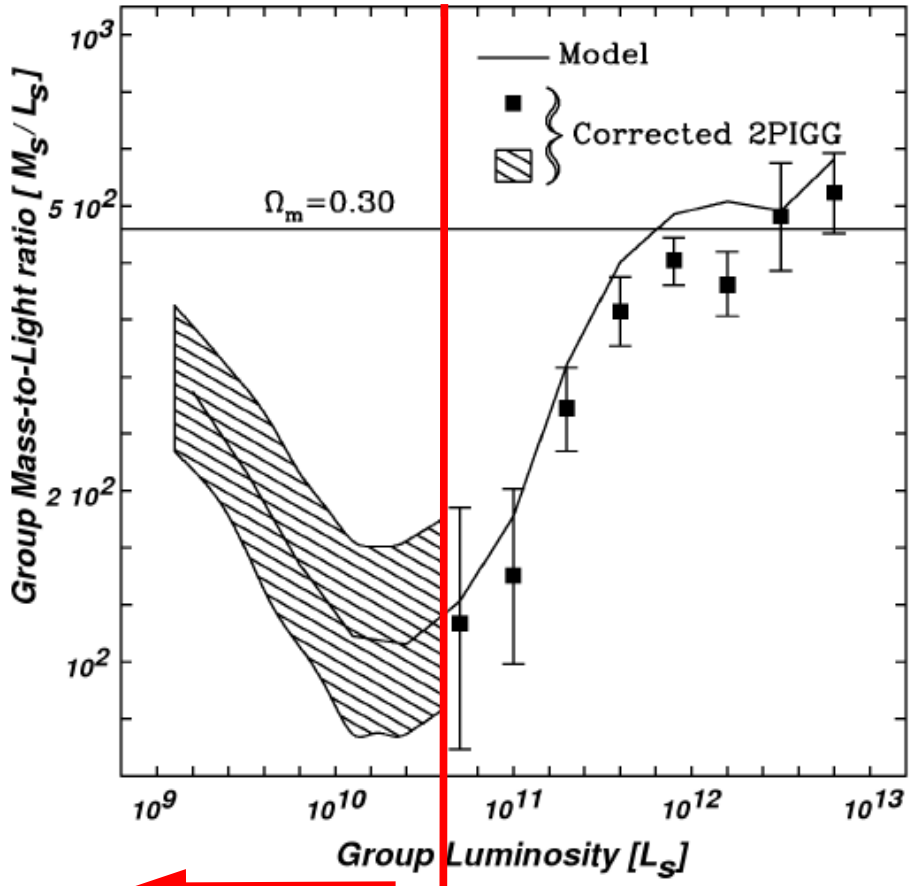
(with predictions from semi-analytic galaxy formation models)

Dark Matter Halo Mass Function



Unprobed so far by galaxy surveys...

Galaxy Formation Efficiency



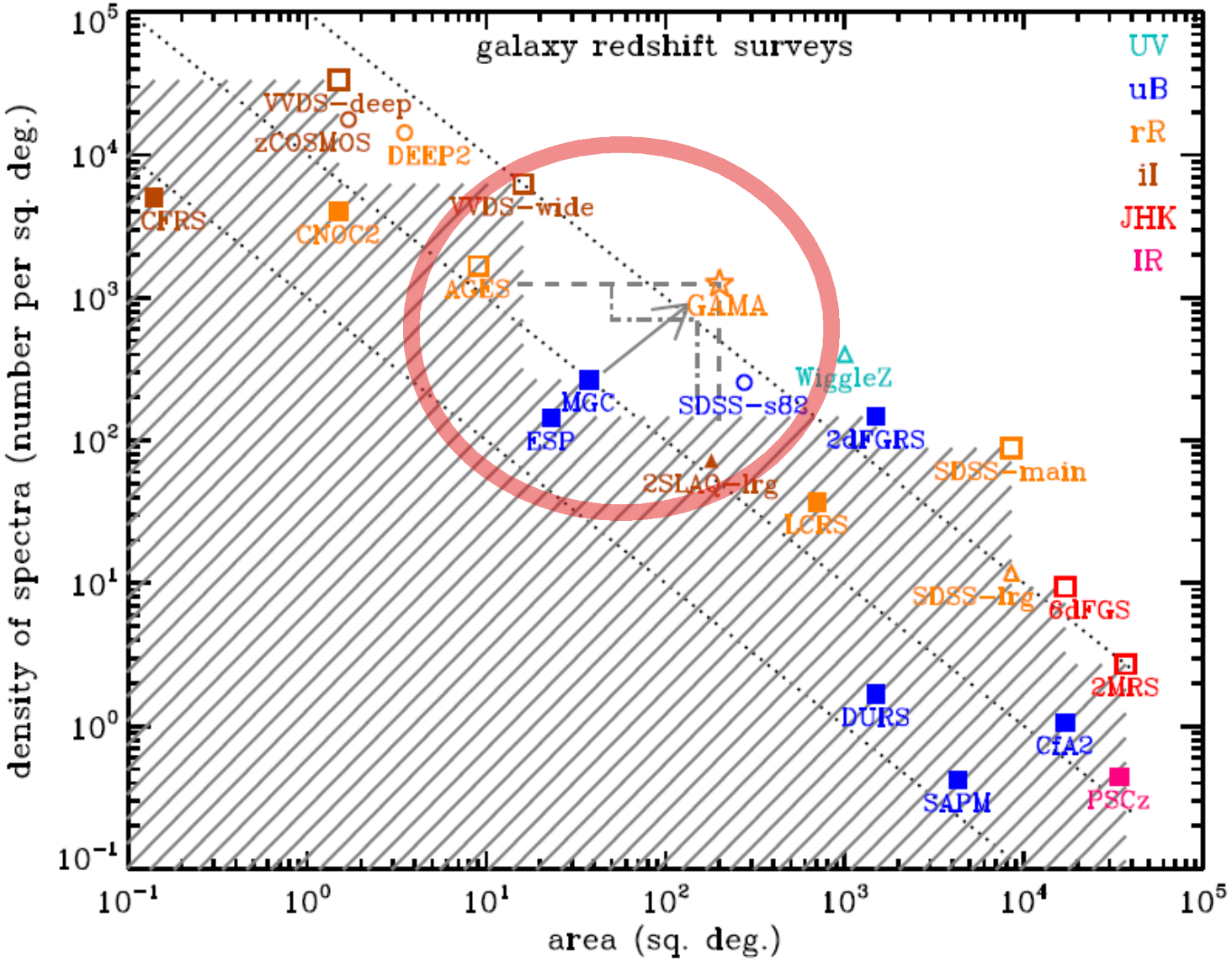
Unprobed so far by galaxy surveys...

Galaxy And Mass Assembly Survey: the key to a vital CDM model prediction?

- Next generation galaxy redshift survey:
  - ~150,000 galaxy spectra to r_{AB}~19.8:
    - 2 mag. fainter than SDSS => L* at z~0.35 [~4 Gyr]
  - 150 sq. deg. wide, overlapping with SDSS and 2dFGRS
  - 66 nights on AAT with AAOmega over 3 years (2008-2010)
  - GAMA is also K-band limited, with K_{AB}<17.6
- GAMA is a unique survey and fills an essential gap in the current generation of redshift surveys, between the very wide low-z and very narrow high-z.

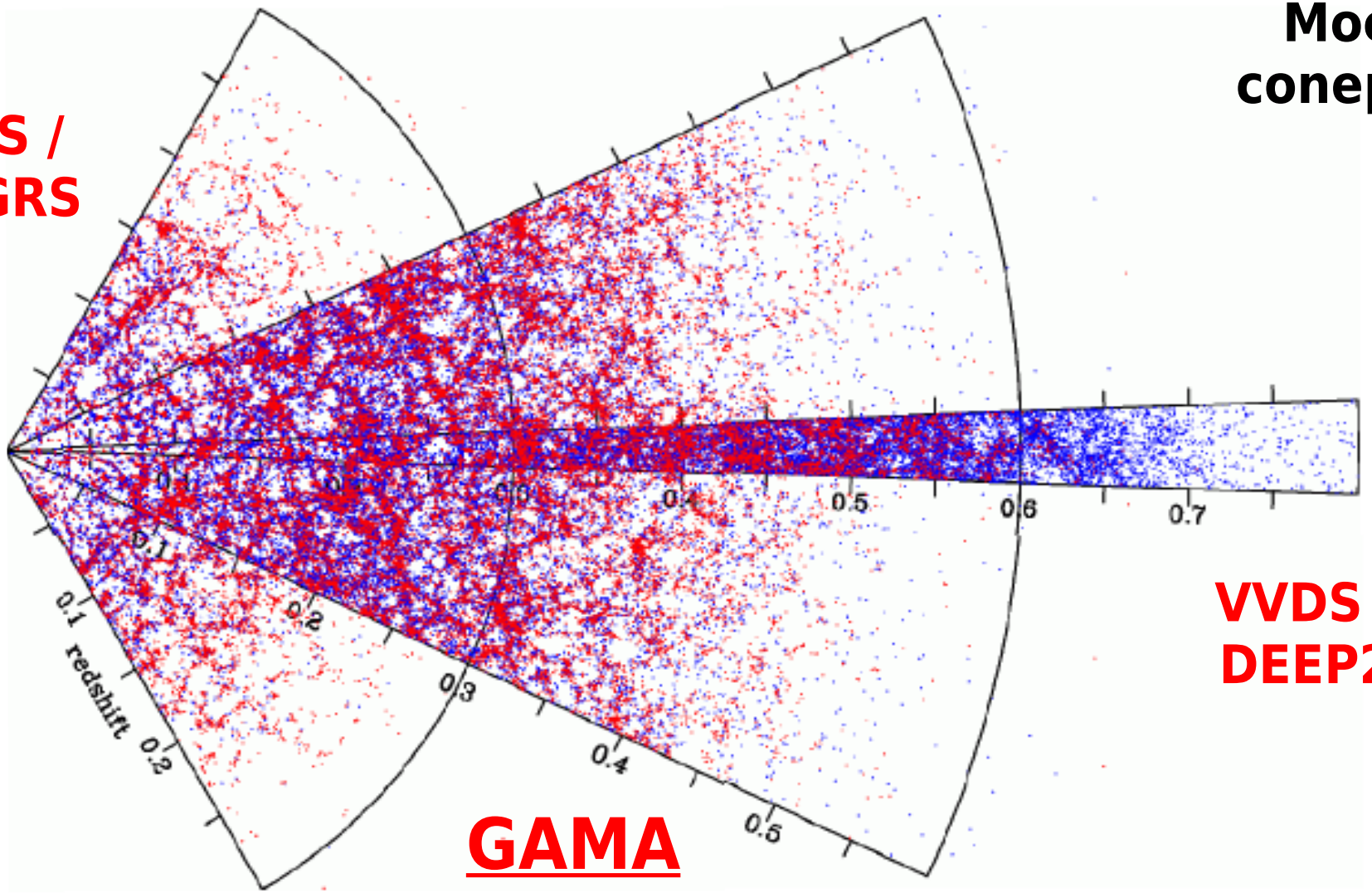
Galaxy And Mass Assembly Survey:

germane connection between shallow-wide & deep-narrow

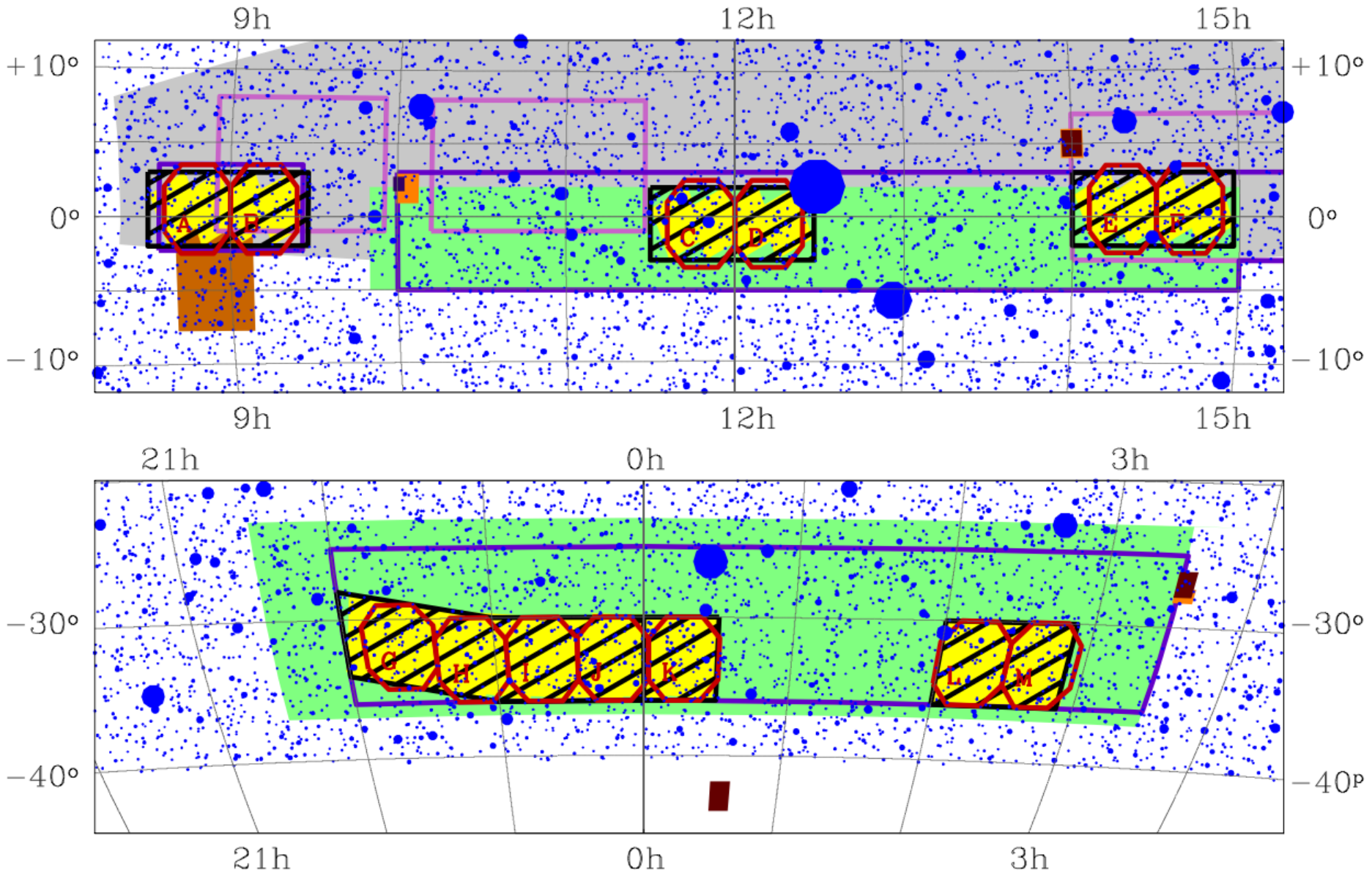


Galaxy And Mass Assembly Survey:

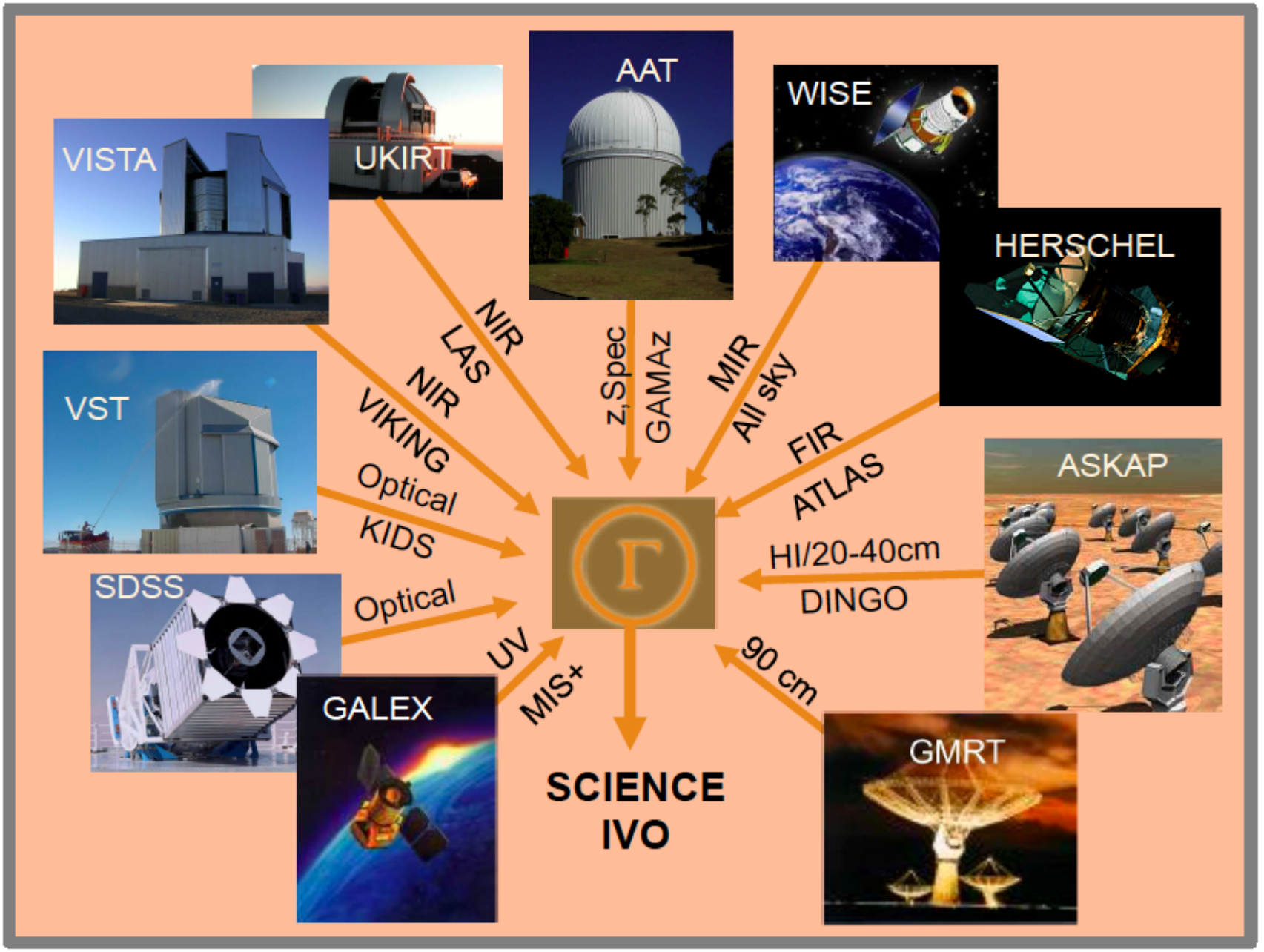
germane connection between shallow-wide & deep-narrow



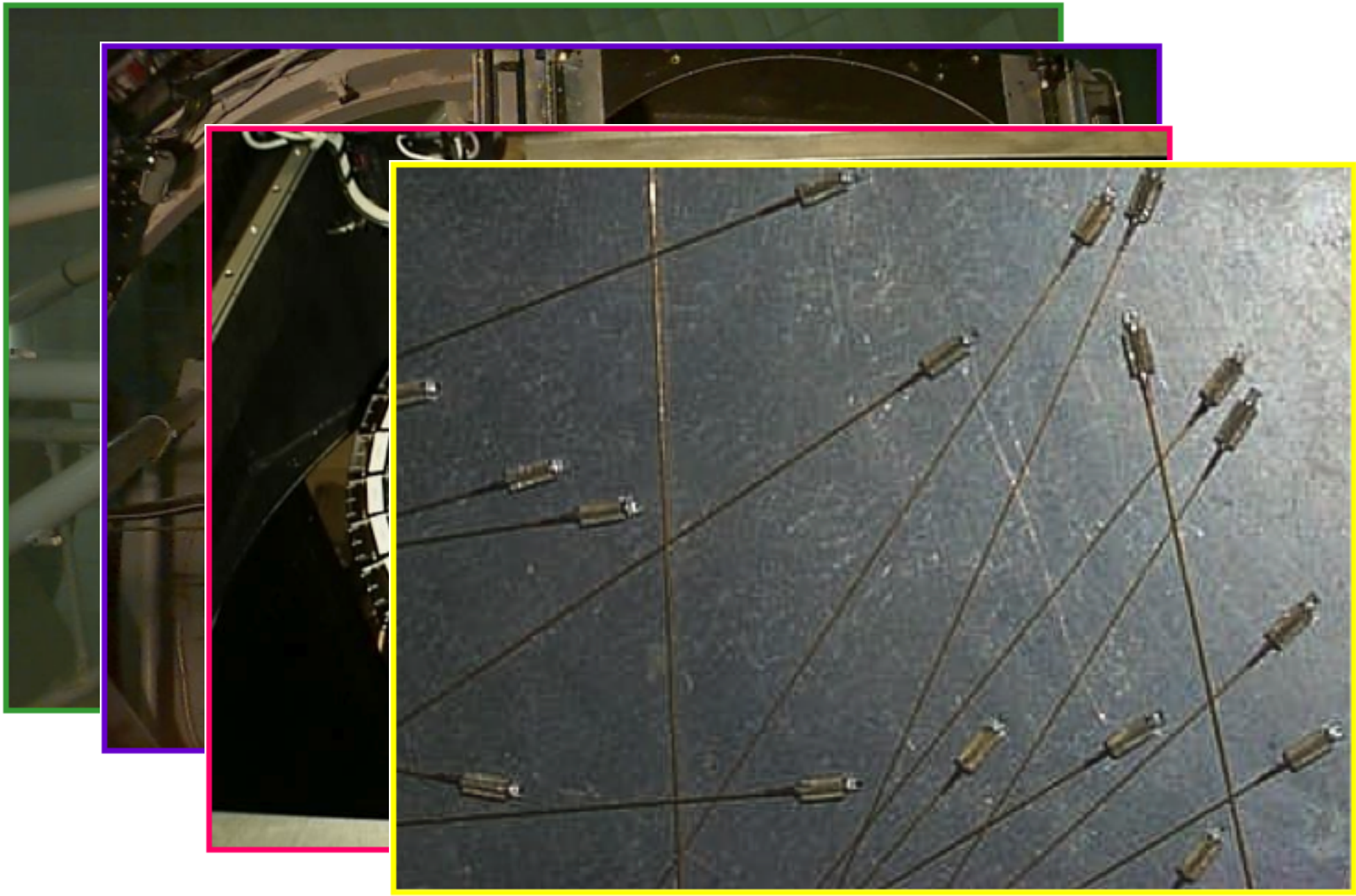
Galaxy And Mass Assembly Survey: where are the fields?



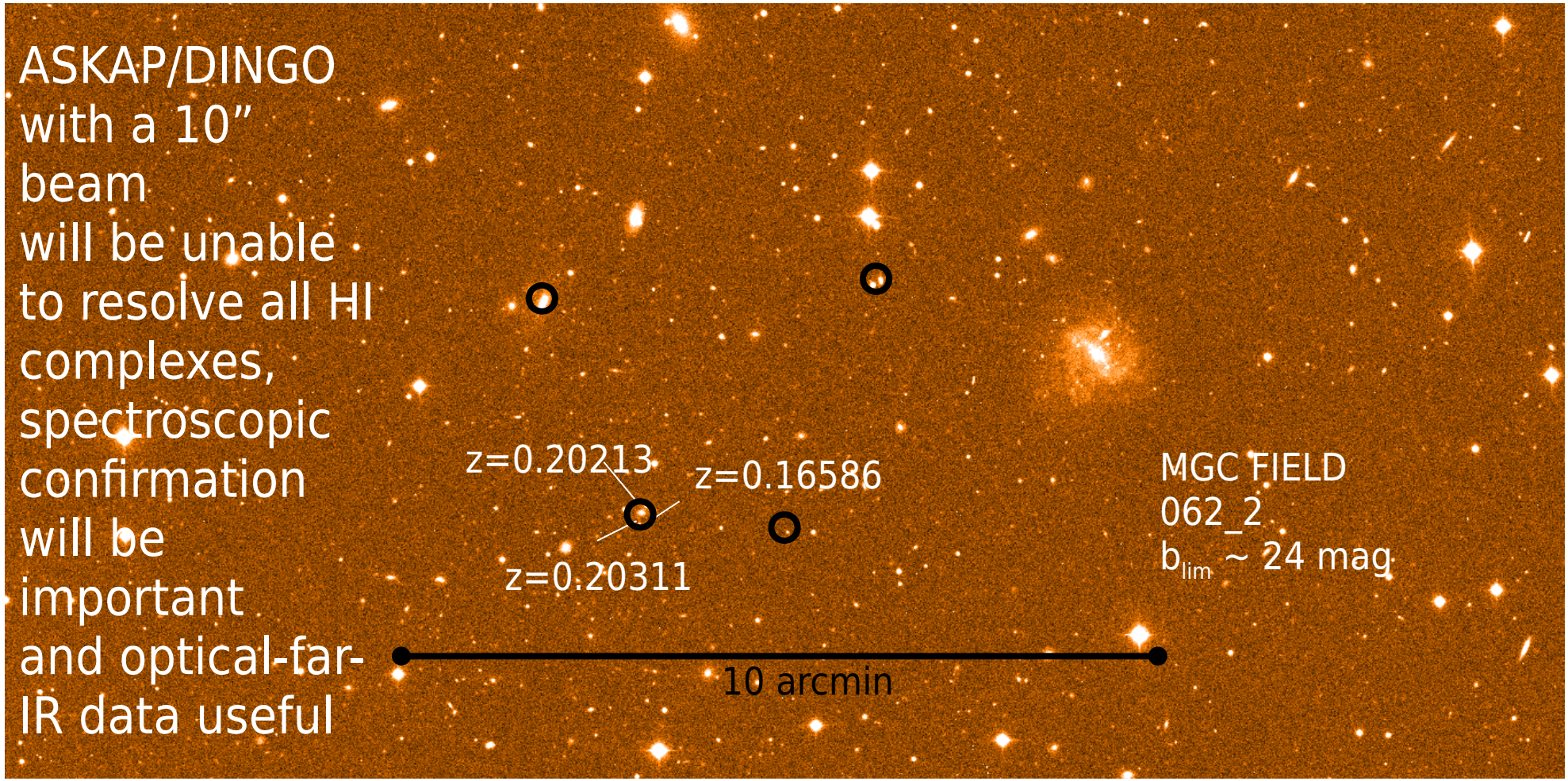
GAMA: Contributing Facilites



GAMA: Contributing Facilites

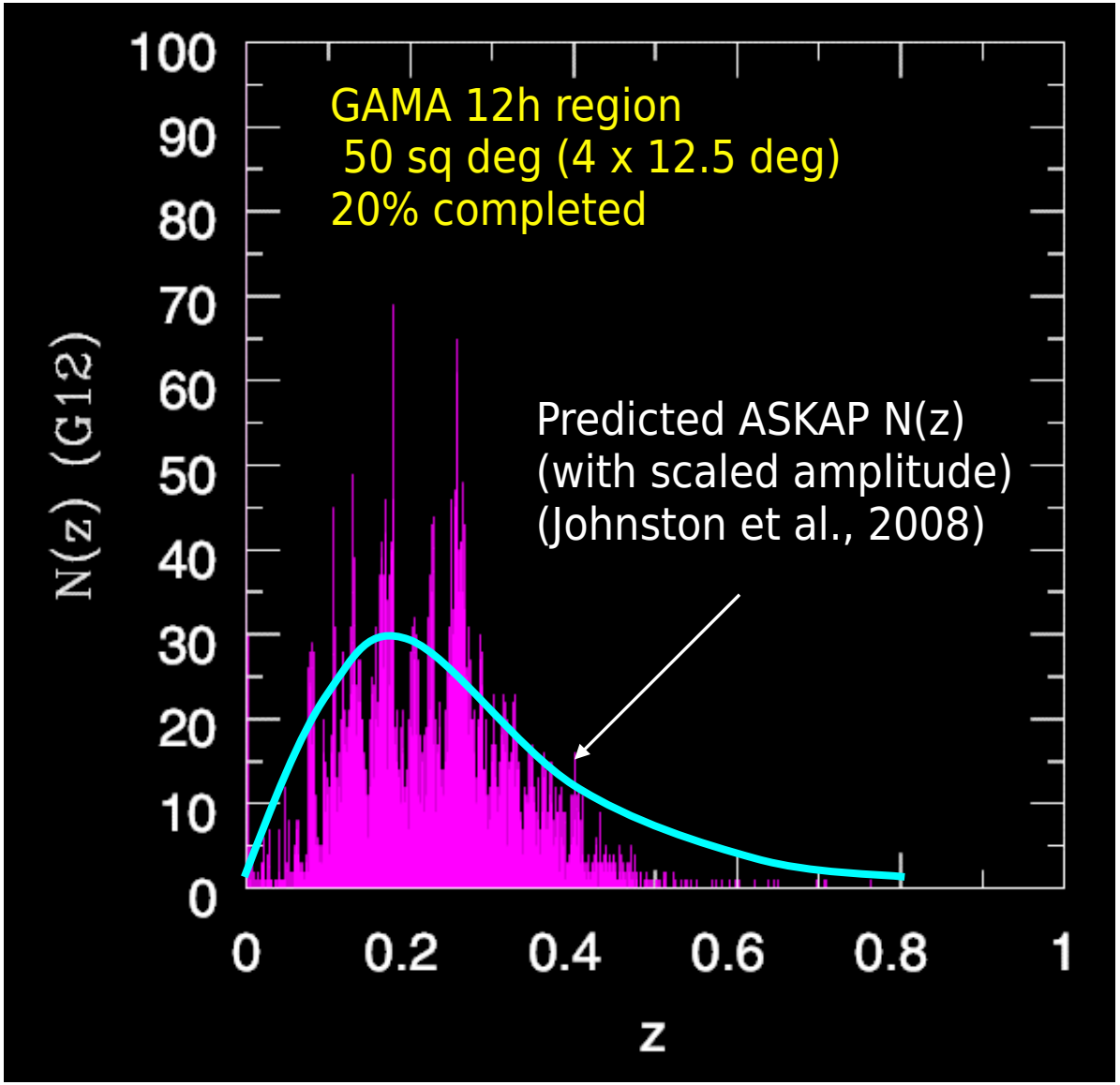


GAMA: Follow up observations
proposed with ASKAP/DINGO...

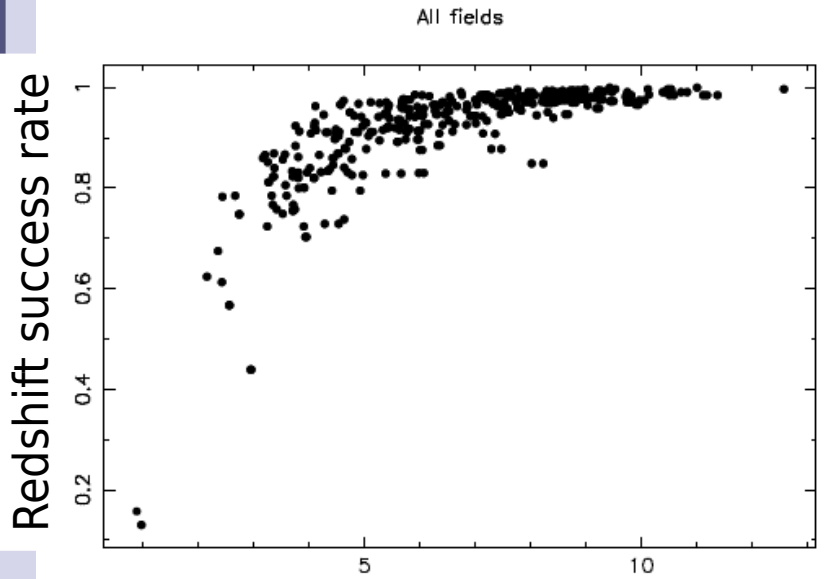


GAMA: Follow up observations
GAMA proposed for ASKAP DINGO follow up

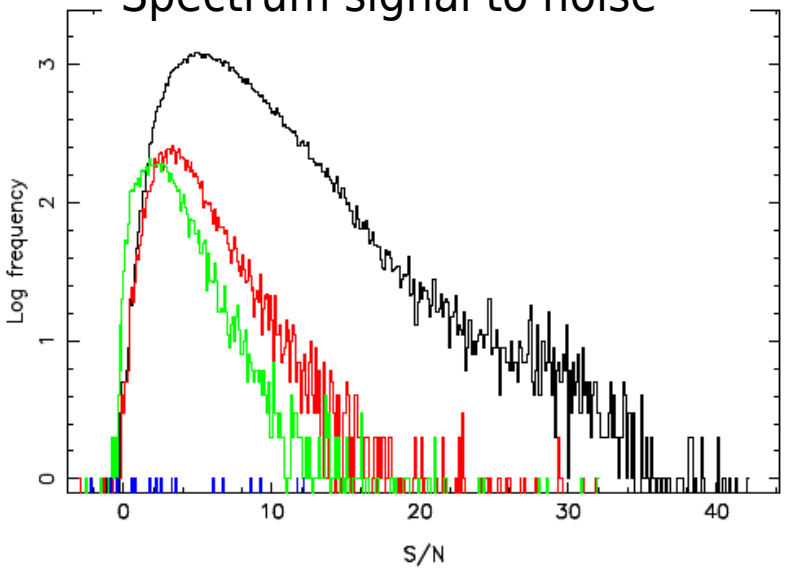
- GAMA depth and area well matched to the proposed ASKAP deep field (DINGO)

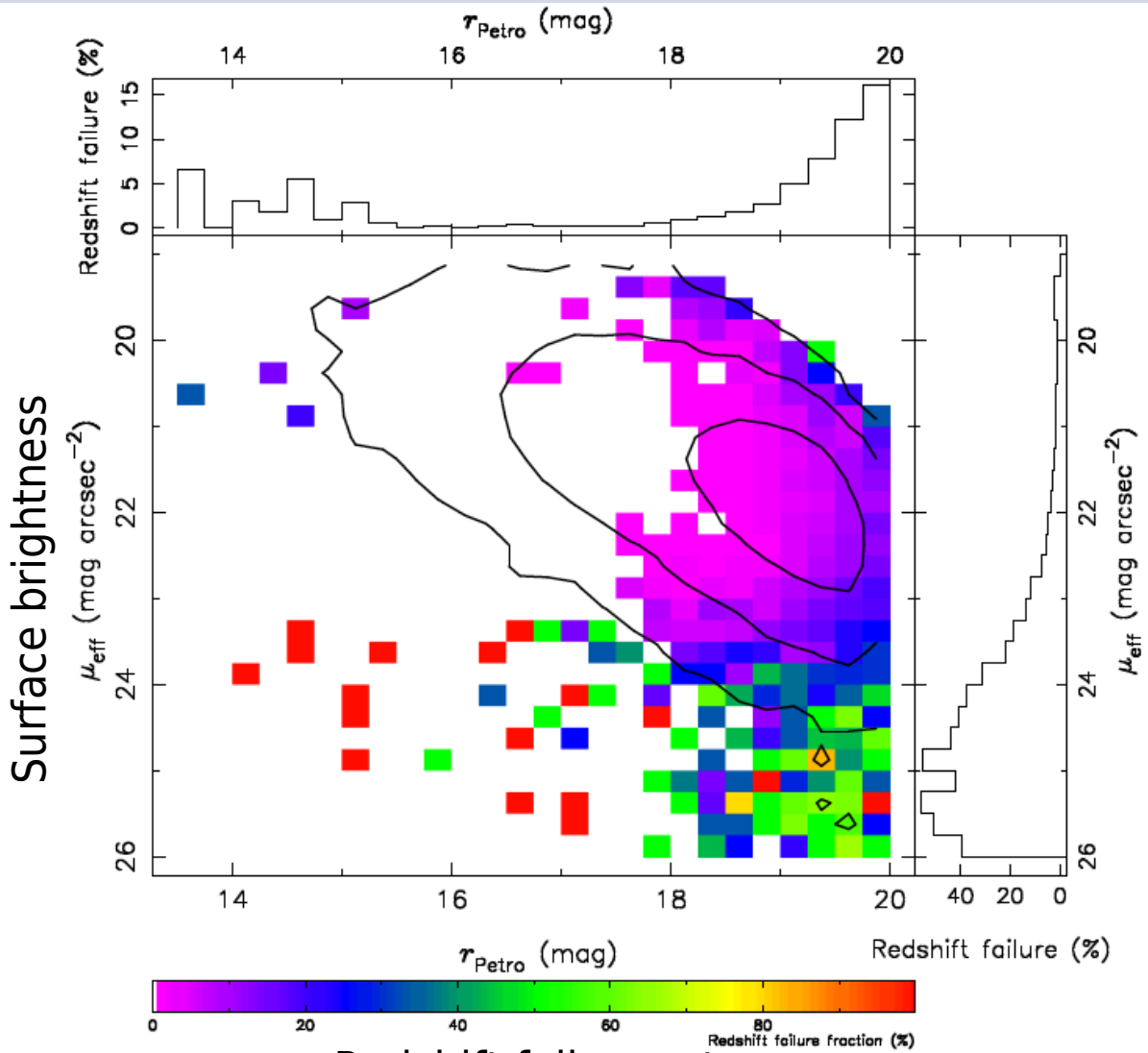


GAMA: Preliminary Results
spectra quality & redshift success rate...



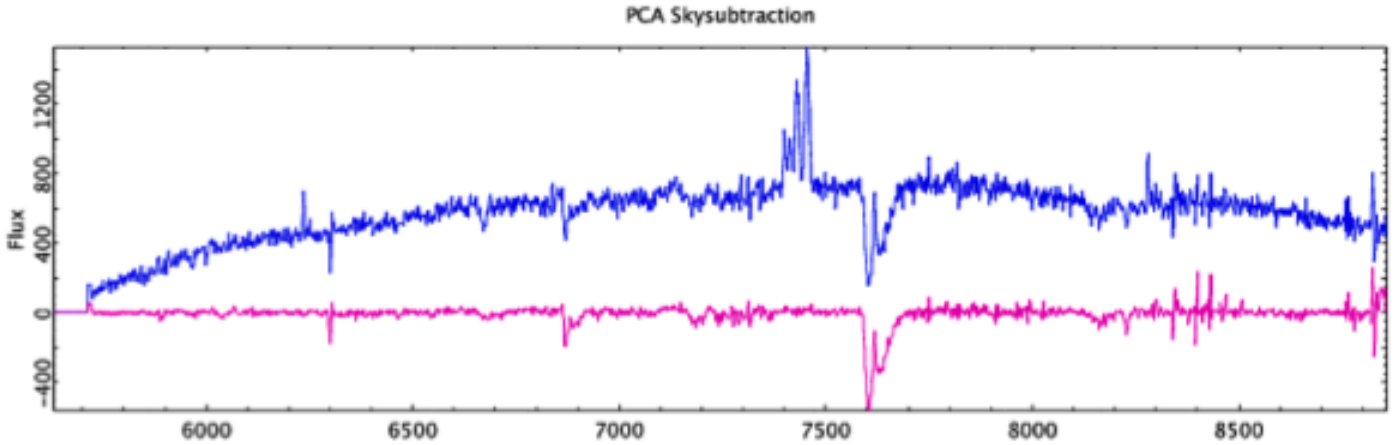
Spectrum signal to noise





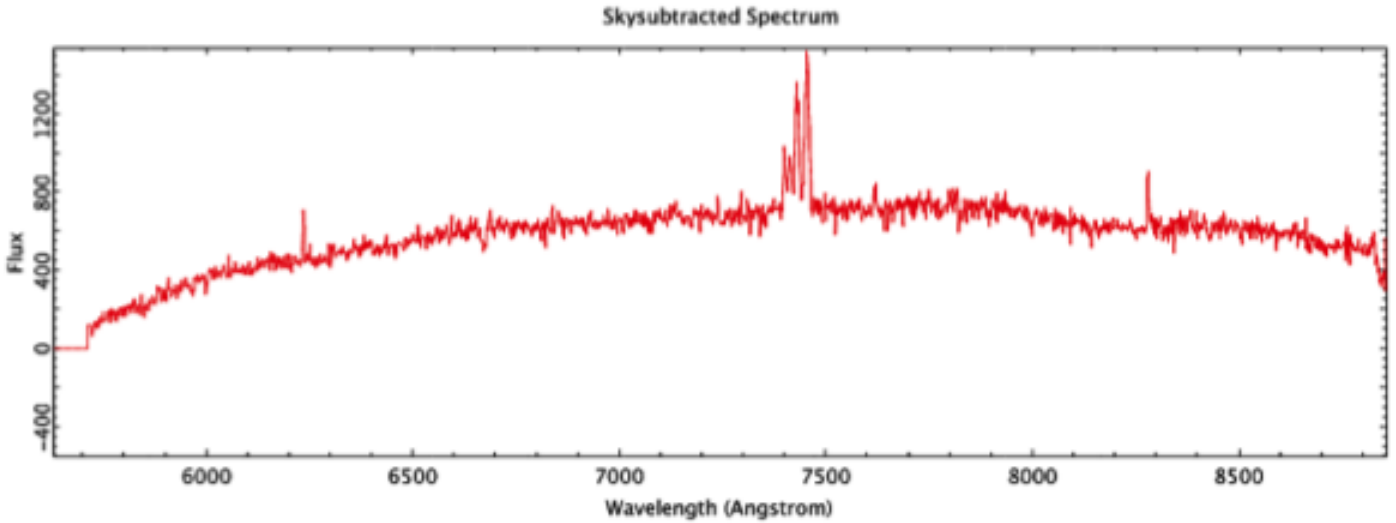
Redshift failure rate

GAMA: Preliminary Results
improved sky-subtraction with PCA



Before Sky-subtraction

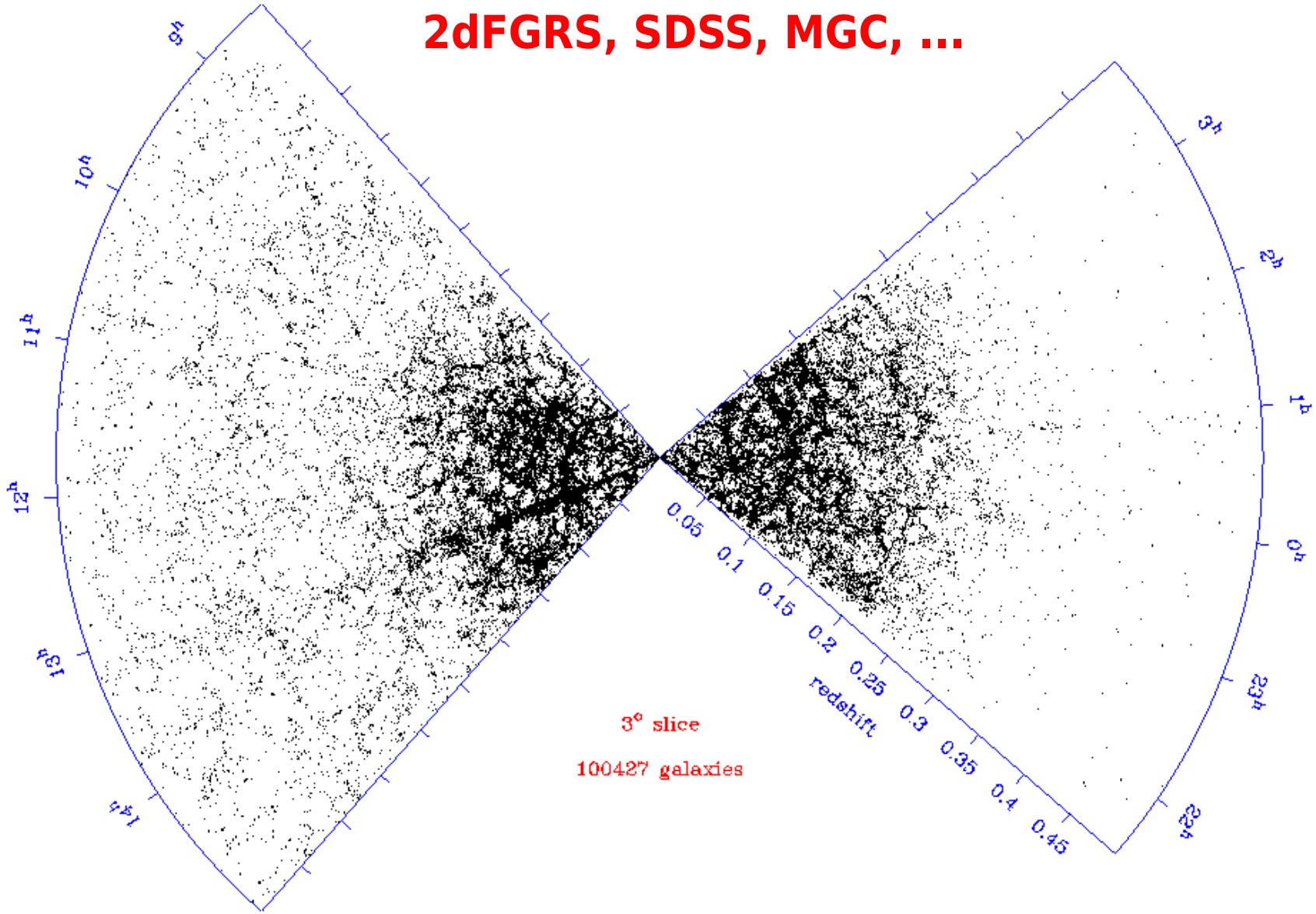
PCA sky



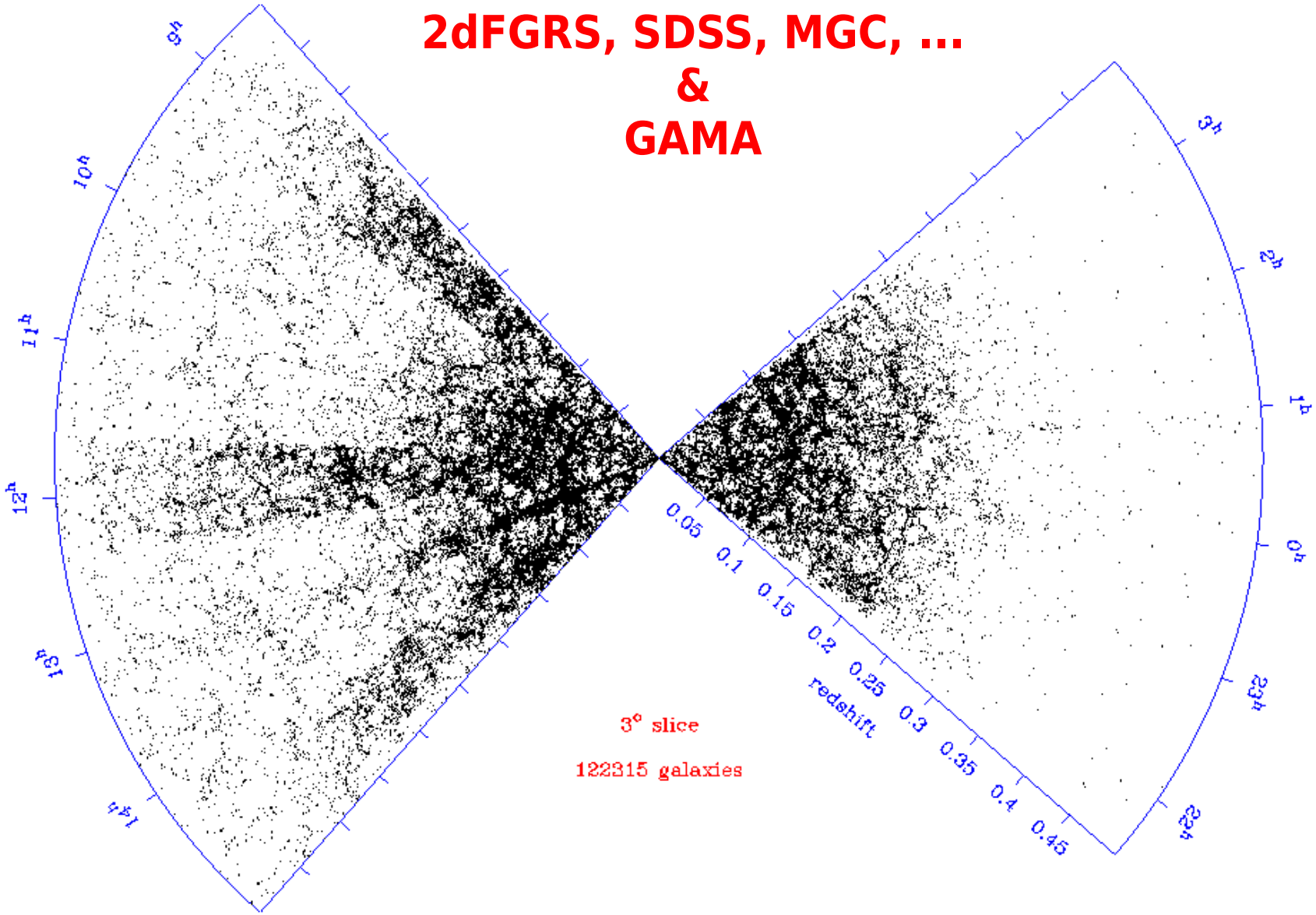
Properly Sky-subtracted Galaxy spectrum

Parkinson et al.

GAMA: Preliminary Results
tracing in detail the large scale structure

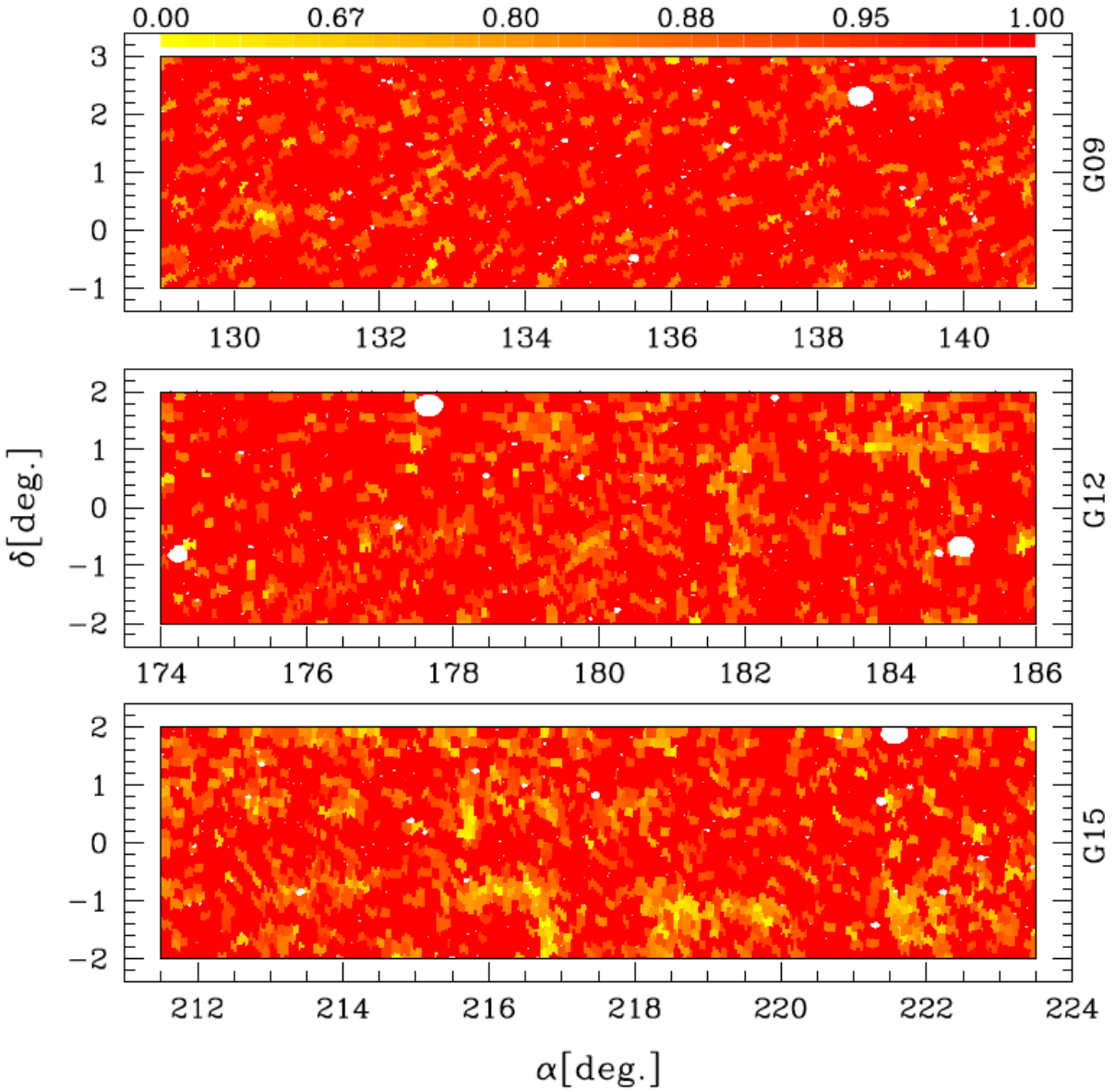


GAMA: Preliminary Results
tracing in detail the large scale structure



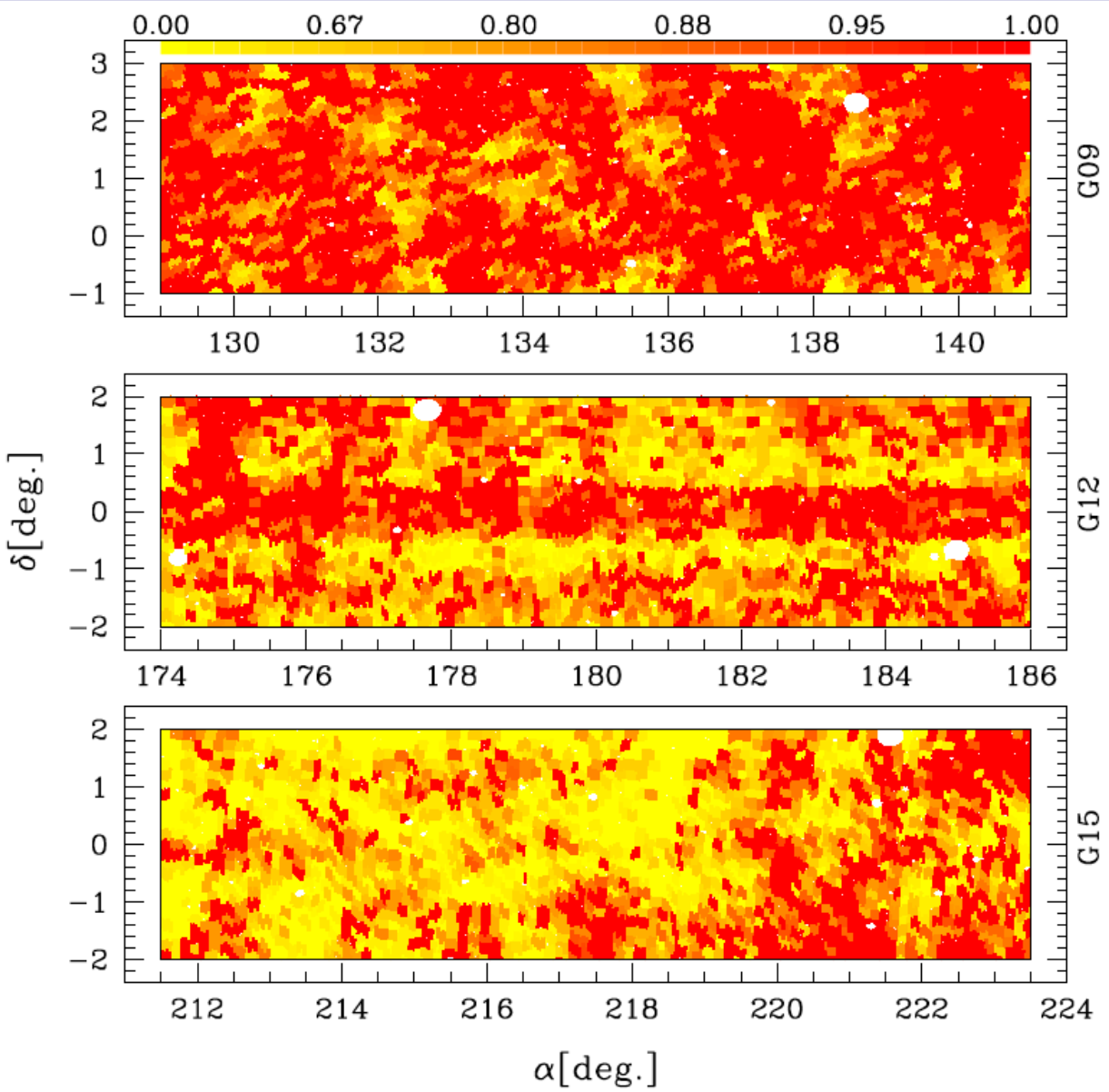
GAMA: Preliminary Results

survey redshift completeness...



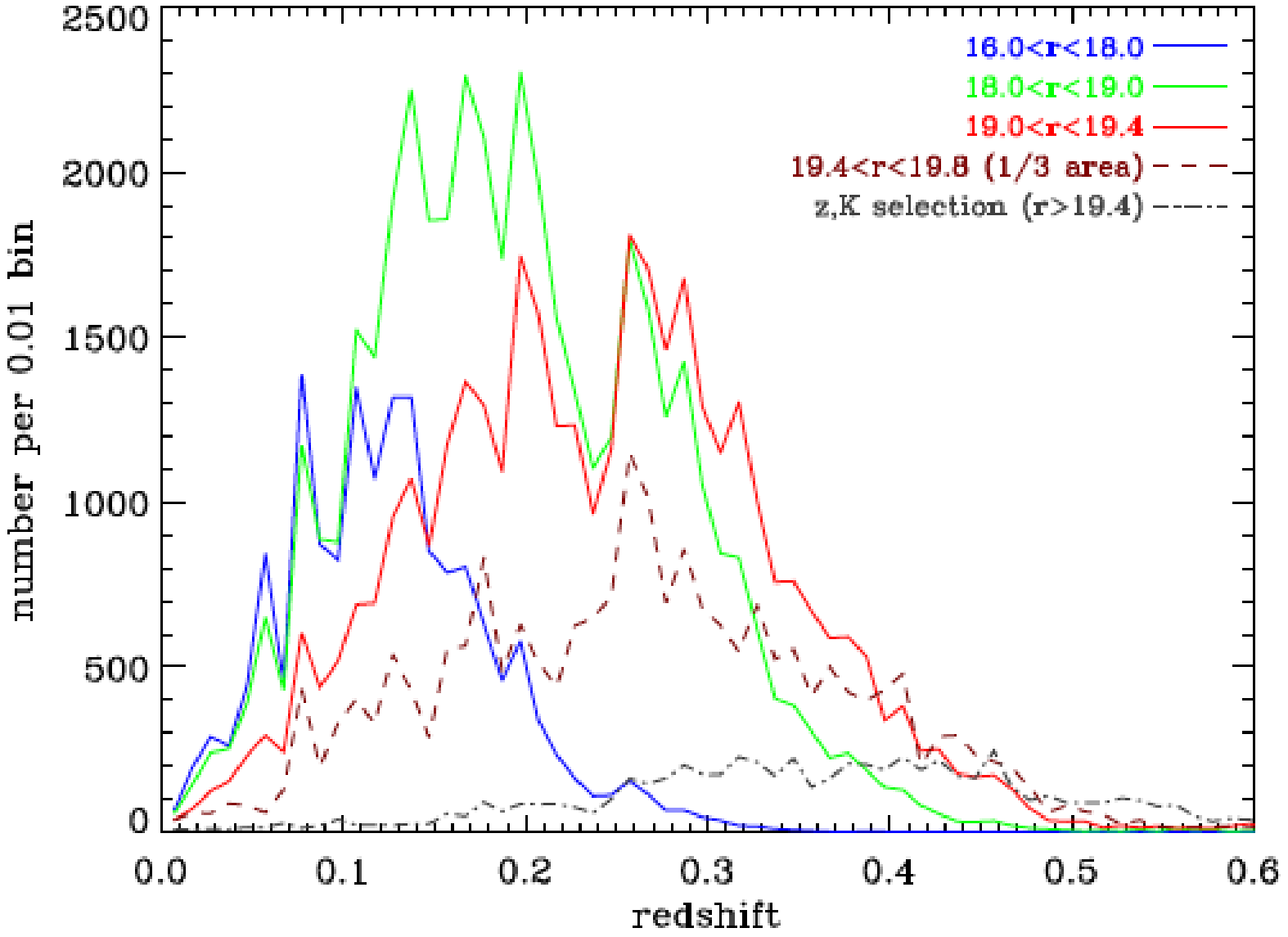
$r_{AB}<19.0$

GAMA: Preliminary Results
survey redshift completeness...

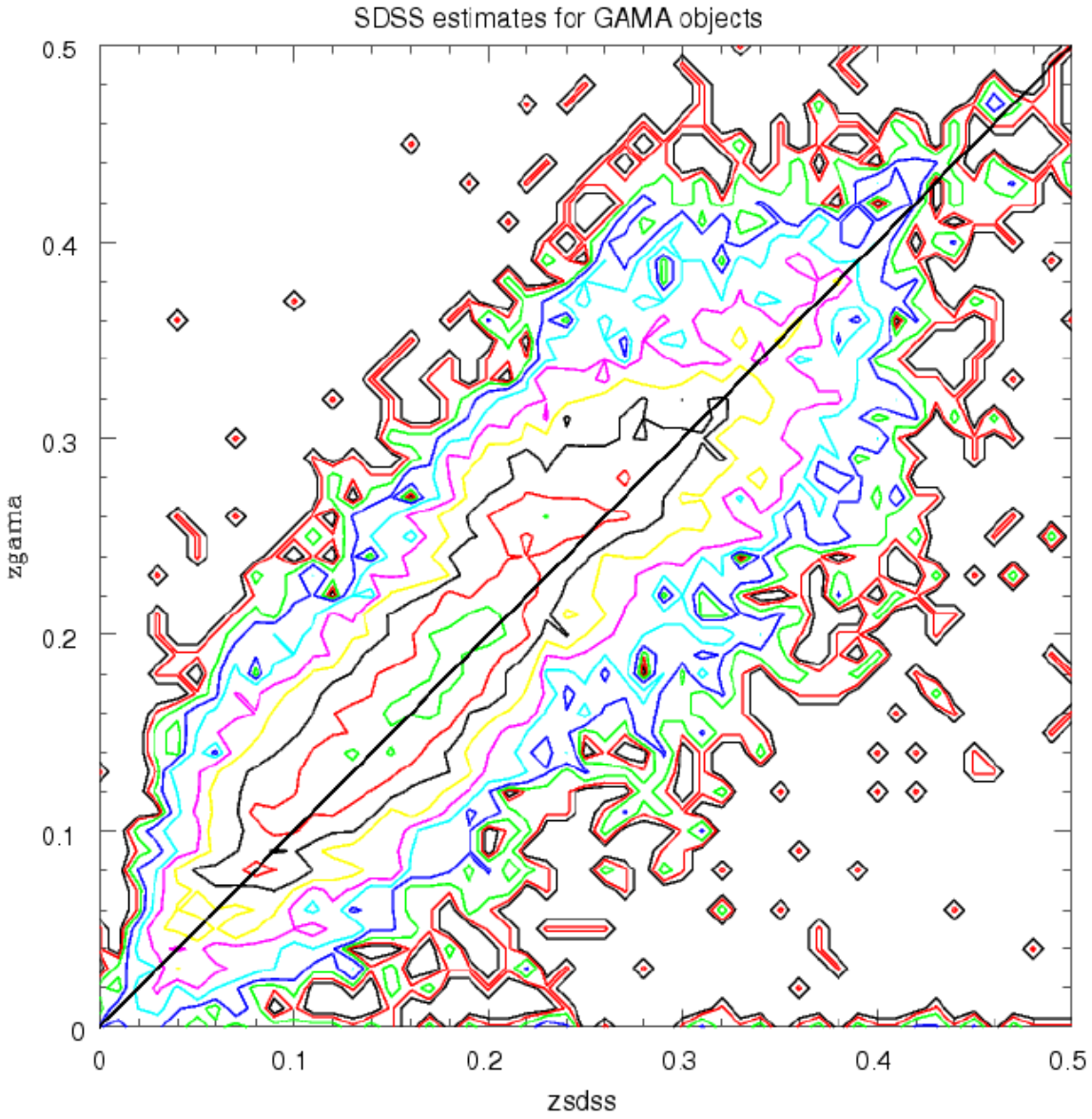


19.0<r$_{AB}$<19.4

GAMA: Preliminary Results
N(z) for different selections



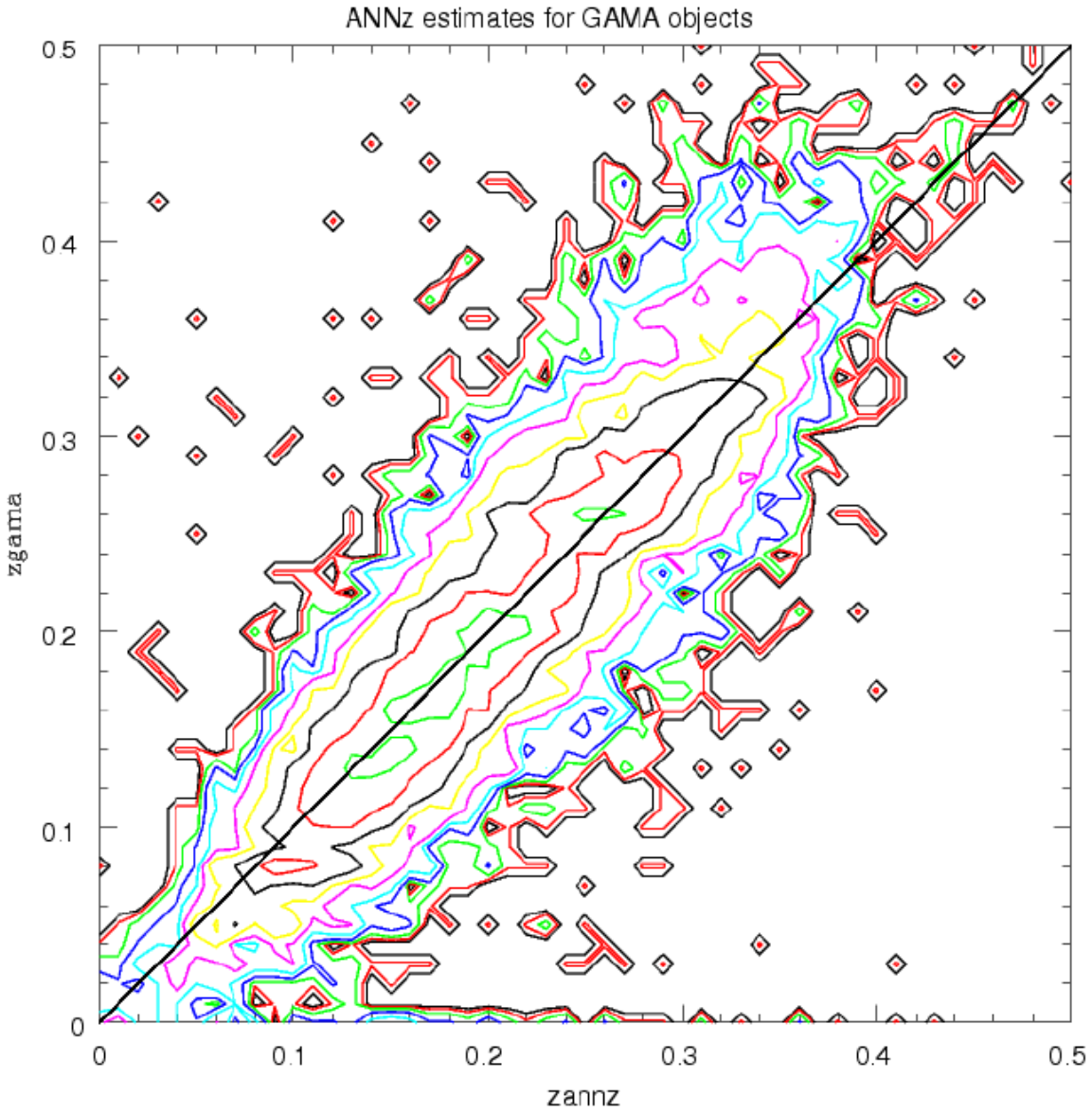
GAMA: Preliminary Results
improved photometric redshifts



SDSS photo-z

Parkinson et al.

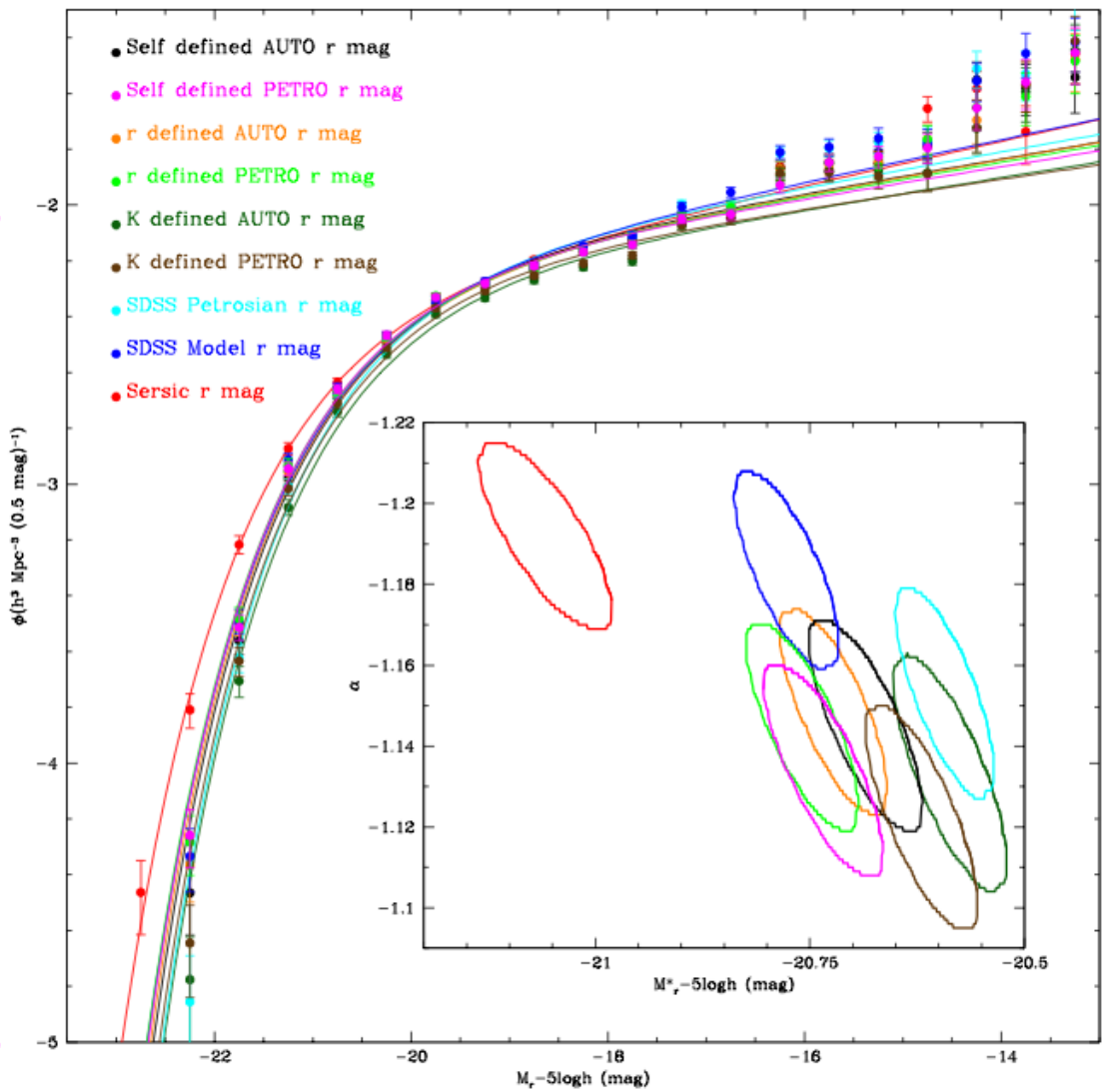
GAMA: Preliminary Results
improved photometric redshifts



GAMA photo-z

Parkinson et al.

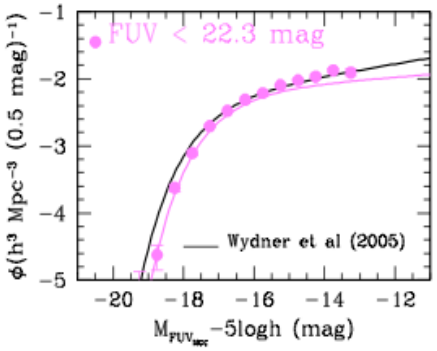
GAMA: Preliminary Results
r-band galaxy luminosity function (z<0.1)

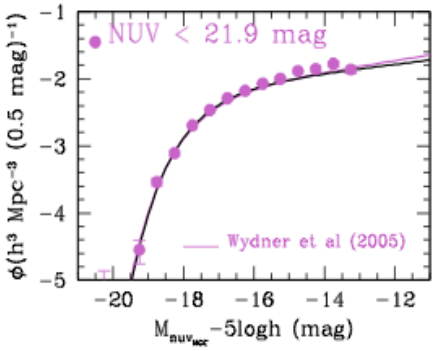


Impact of magnitude definitions

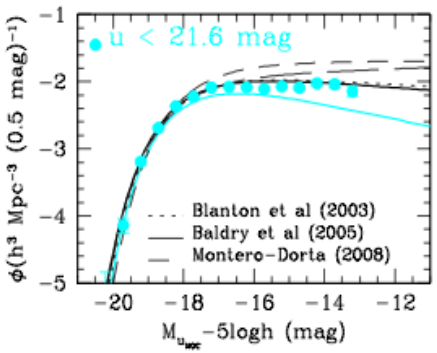
Inset: schechter function maximum likelihood parameters (α,M*)

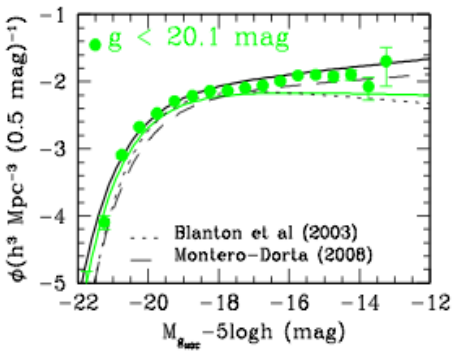
Hill et al.

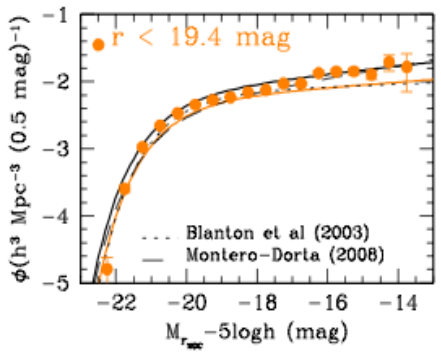


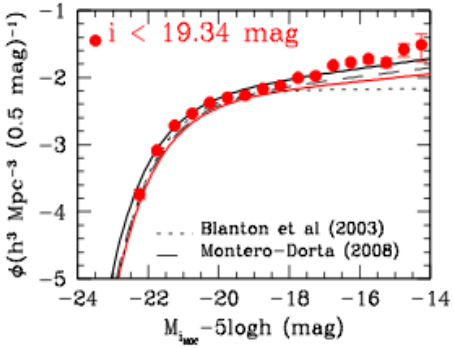


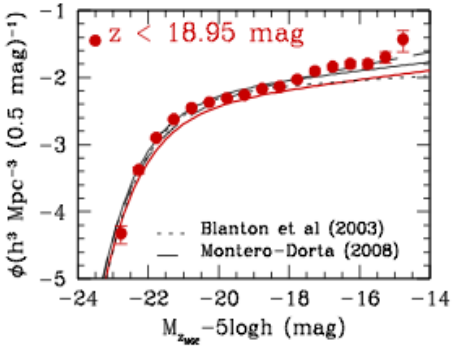
11 band luminosity functions to z < 0.1 over the common GAMA regions (115.14sq deg) to r<19.4 corrected for colour bias and incompletness

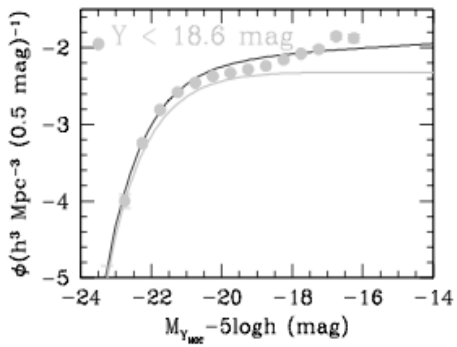


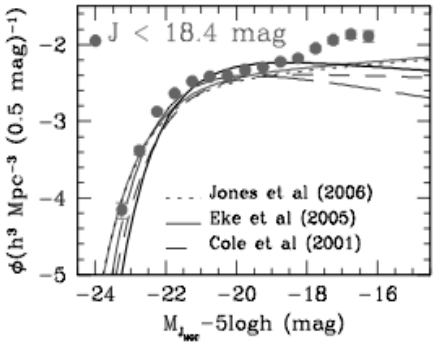


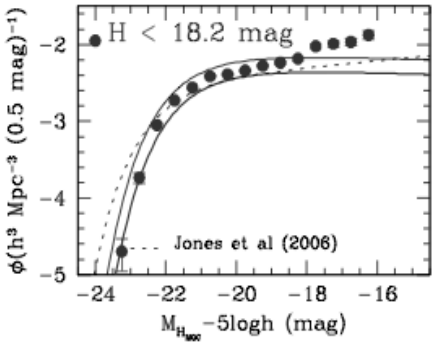


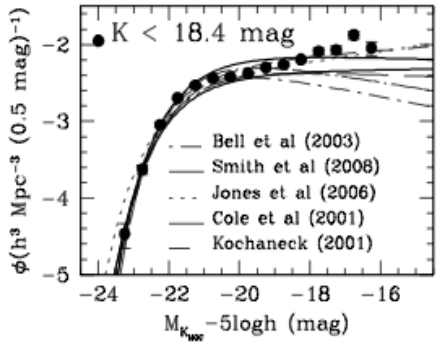






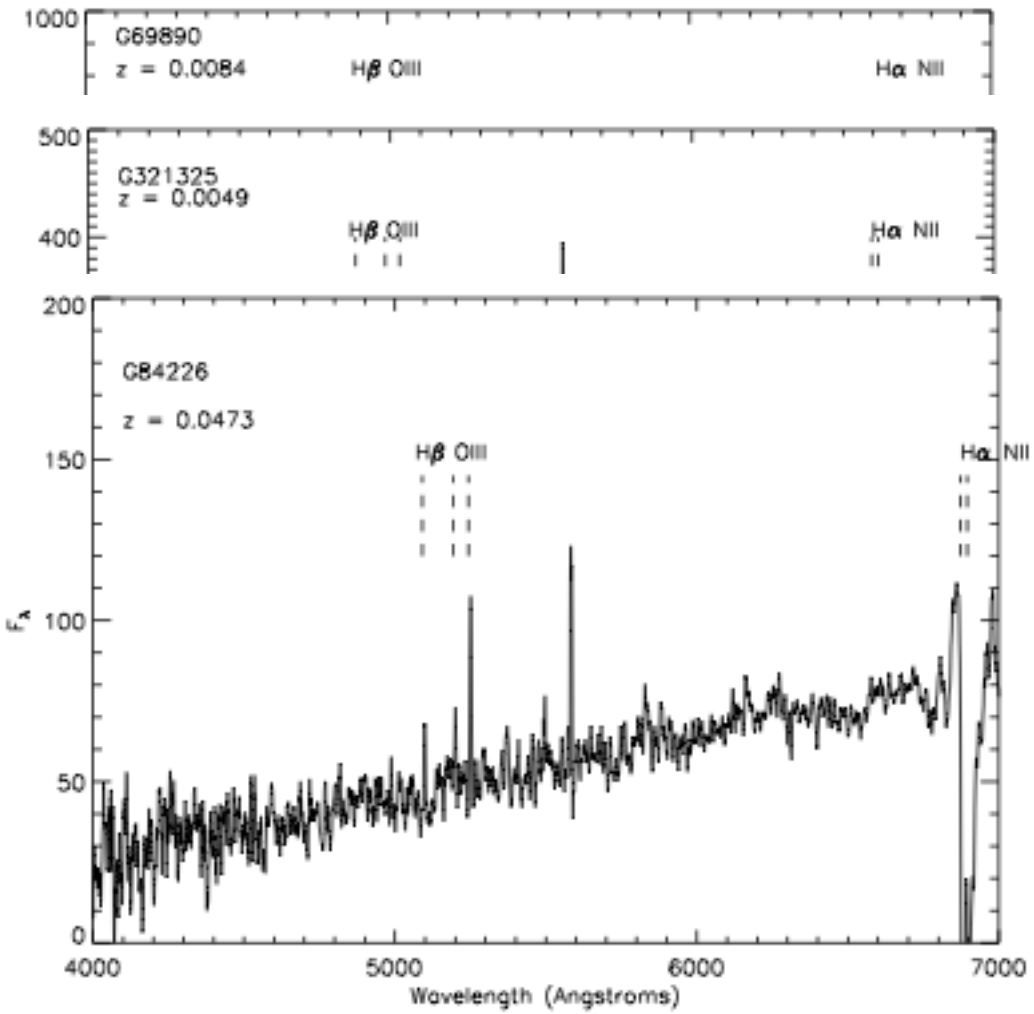


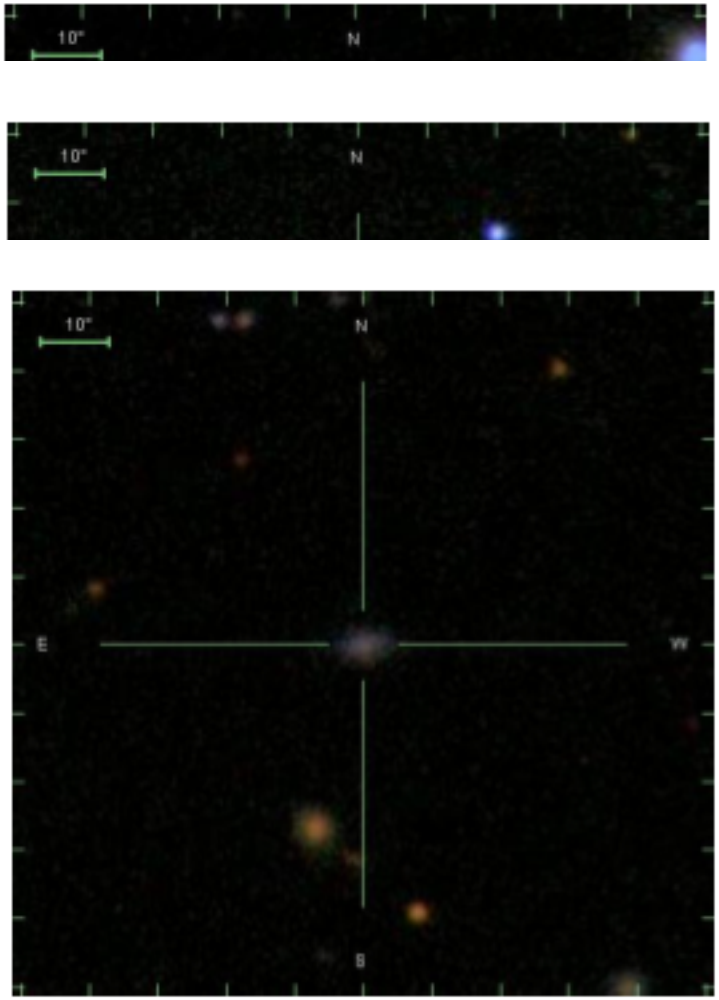




Driver et al.

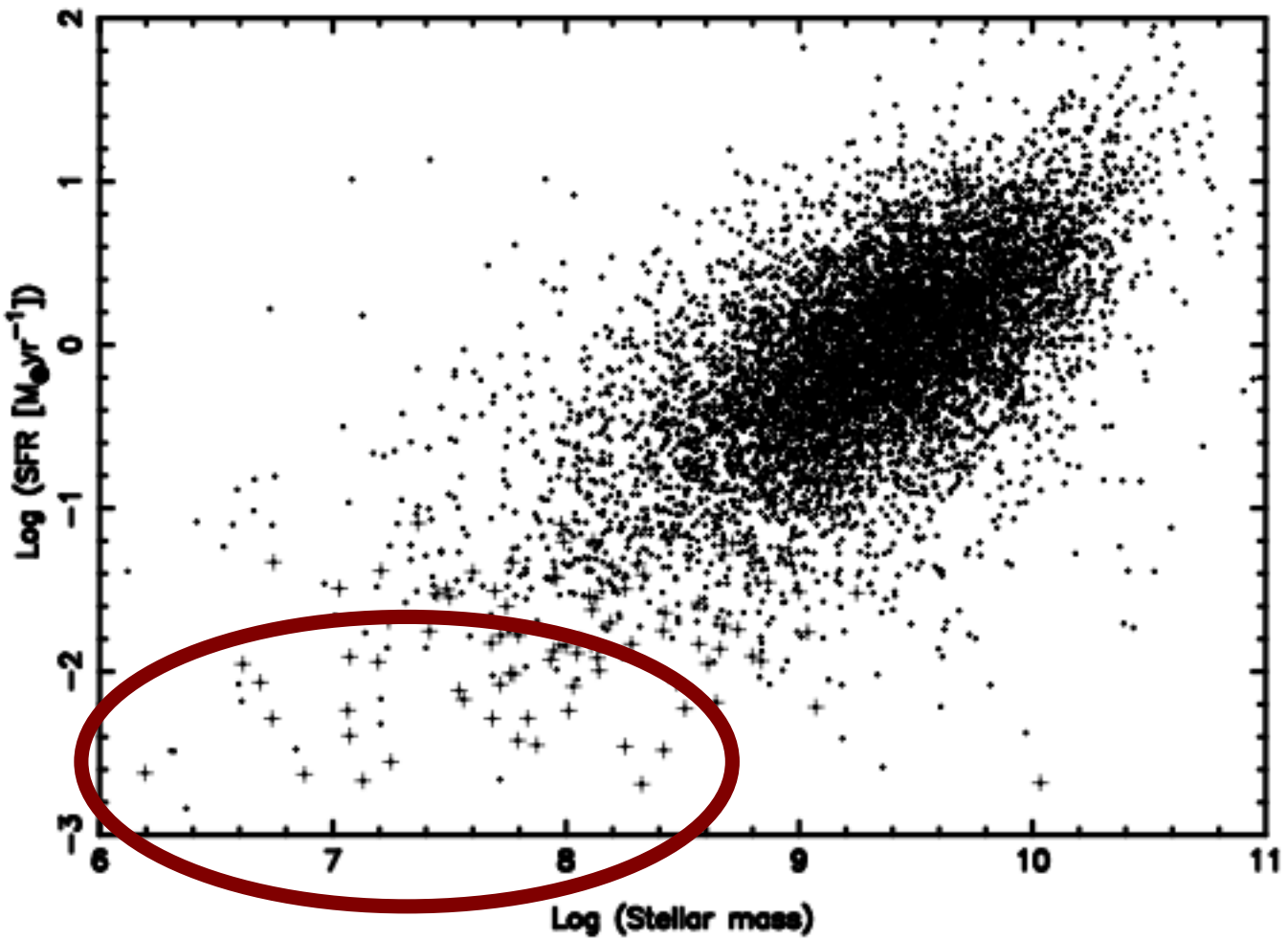
GAMA: Preliminary Results
slowest forming galaxies





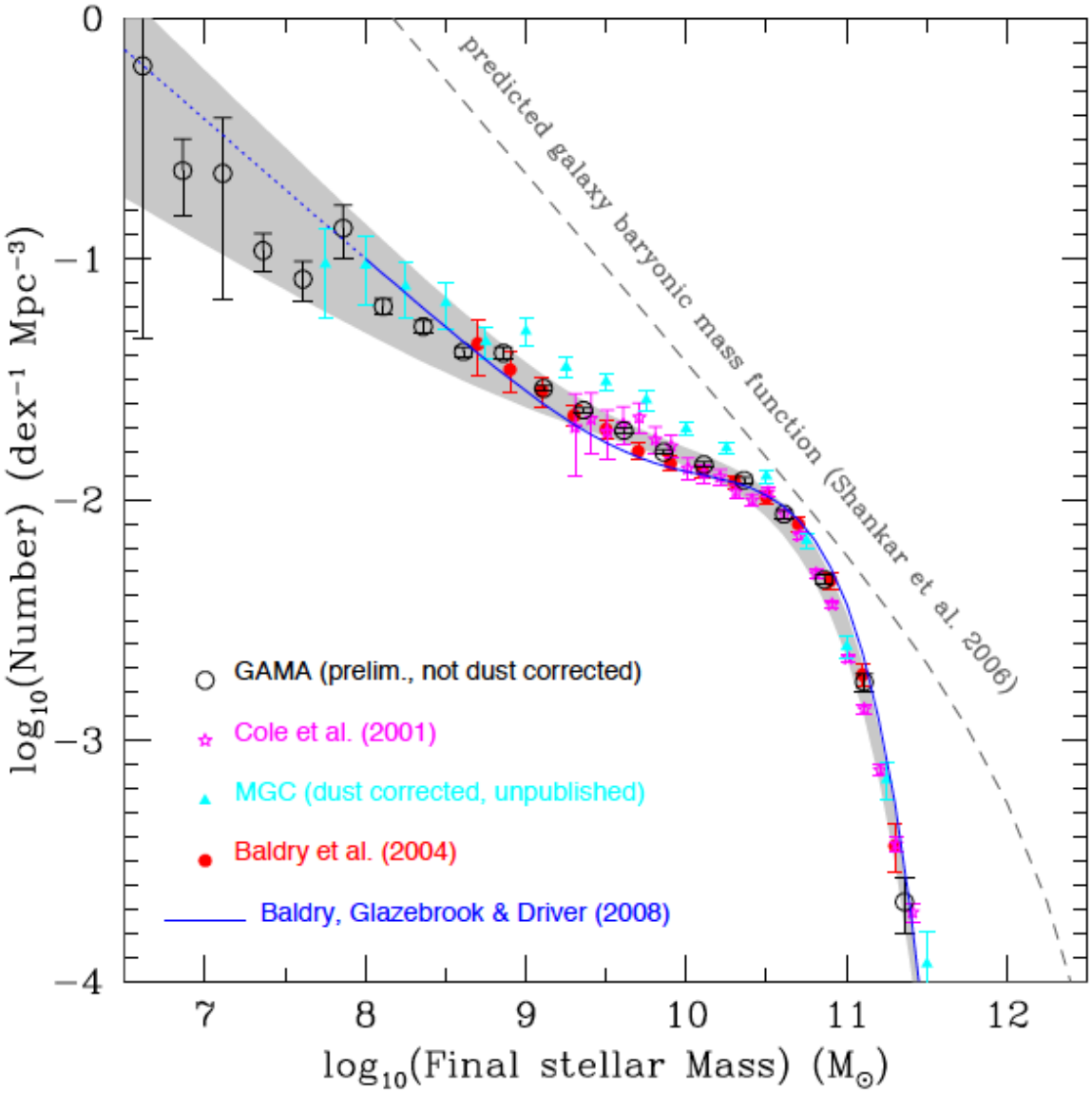
Brough et al.

GAMA: Preliminary Results
slowest forming galaxies



Brough et al.

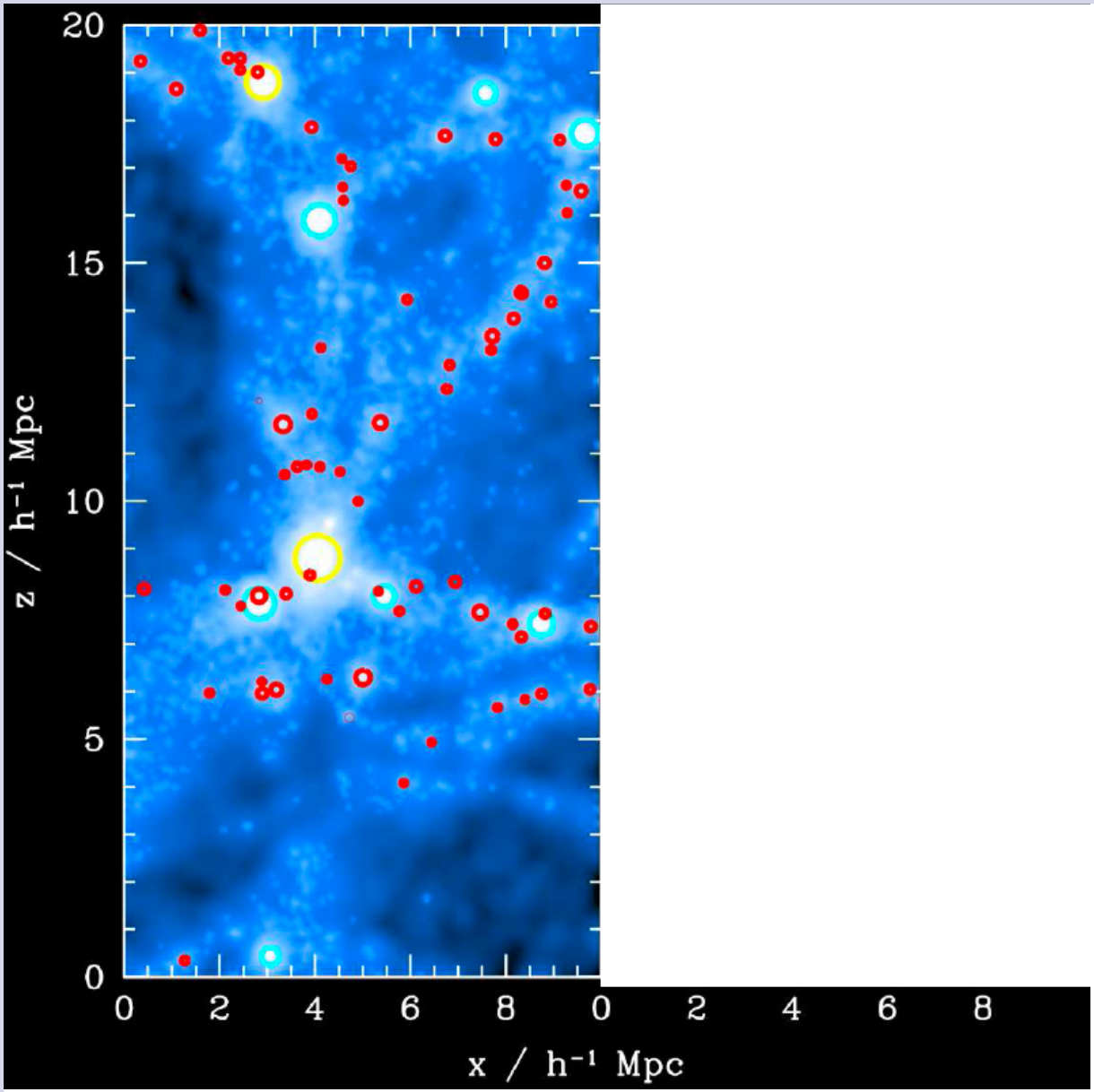
GAMA: Very Preliminary Results
stellar mass function (z<0.1)



Driver et al. (2009)

GAMA: Preliminary Results

Mock GAMA Galaxy Group (G^3) catalogue

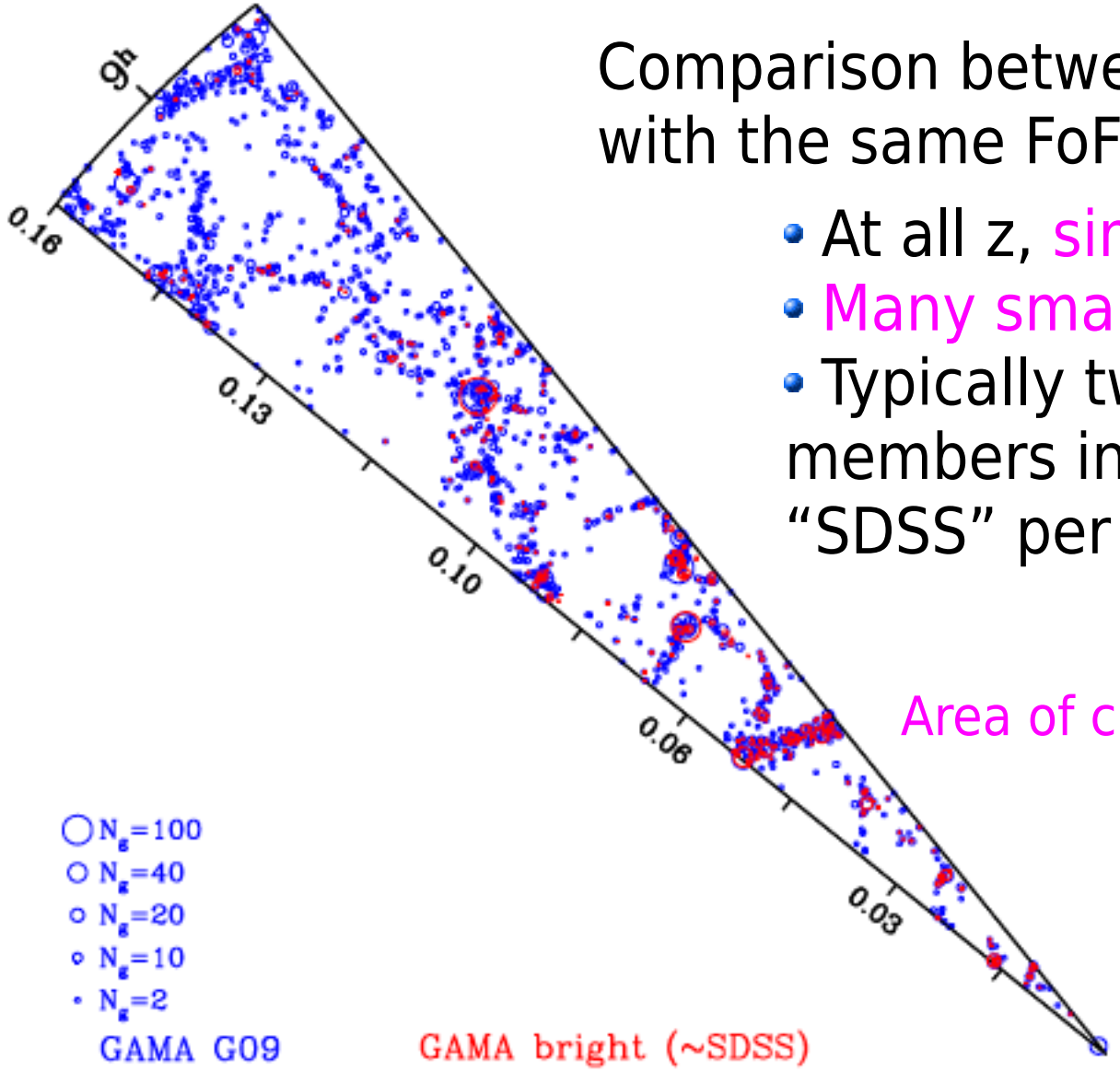


Example of a 4 Mpc/h thick slice of a mock GAMA galaxy catalogue:
- HOD/CLF
- modified semi-analytic (Durham/Munich)

Halo ~ 10^{14} Msol/h
Halo ~ 10^{13} Msol/h
Halo ~ 10^{12} Msol/h
Halo ~ 10^{11} Msol/h

GAMA: Preliminary Results

GAMA Galaxy Group (G^3) catalogue



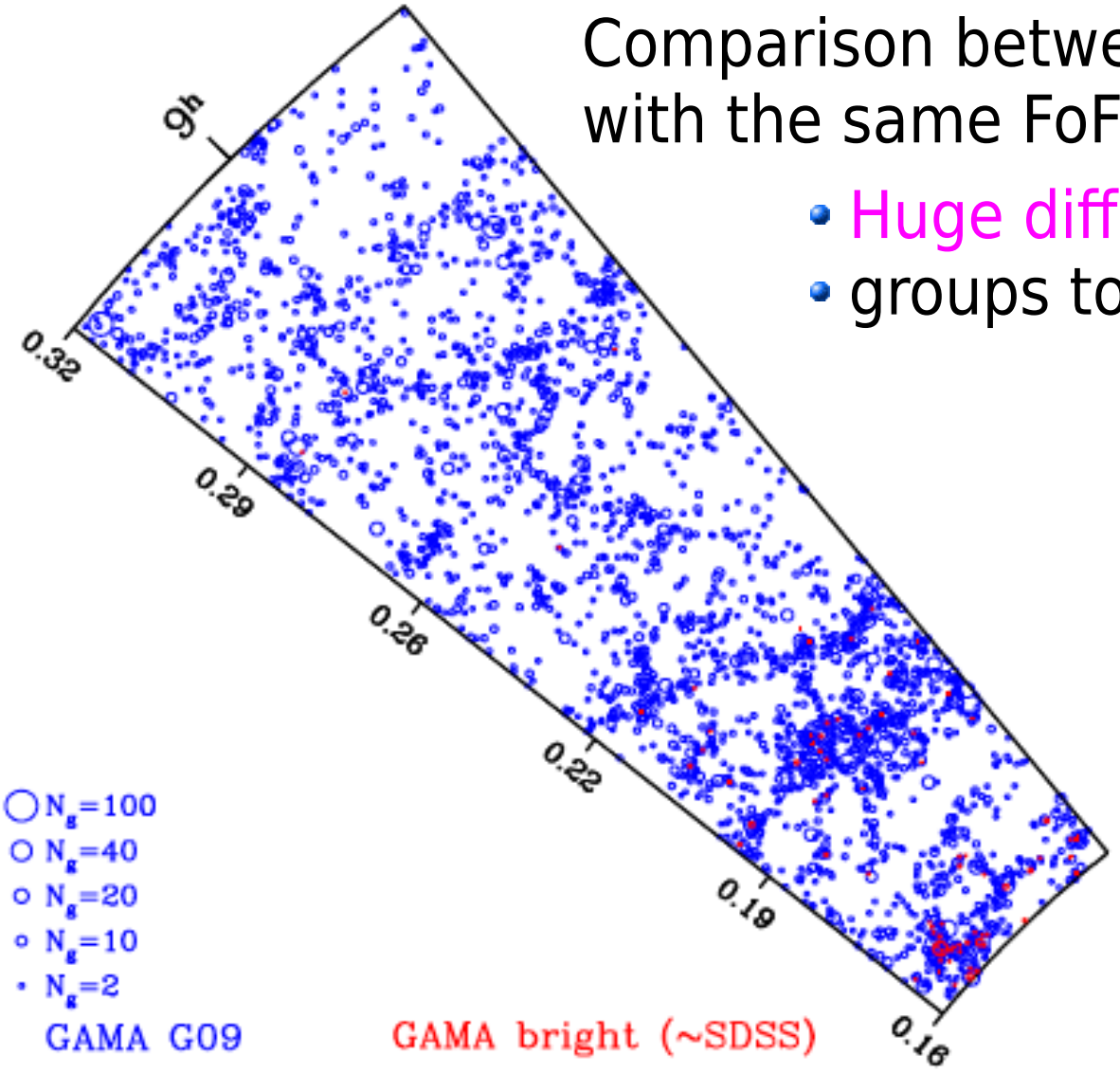
Comparison between GAMA & "SDSS" with the same FoF group finder:

- At all z, similar structures found
- Many smaller groups with GAMA
- Typically twice as many group members in GAMA as with "SDSS" per group.

Area of circle ~ # of group member

GAMA: Preliminary Results

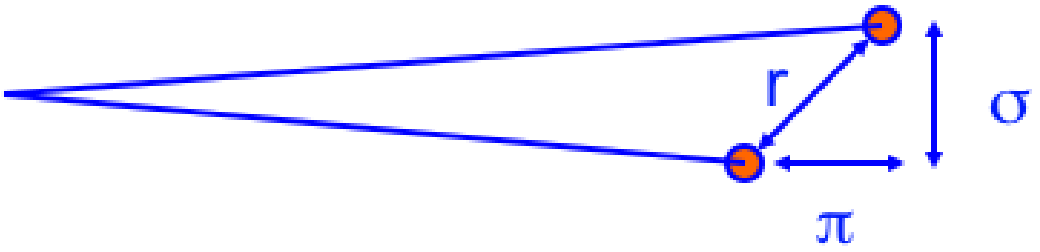
GAMA Galaxy Group (G^3) catalogue



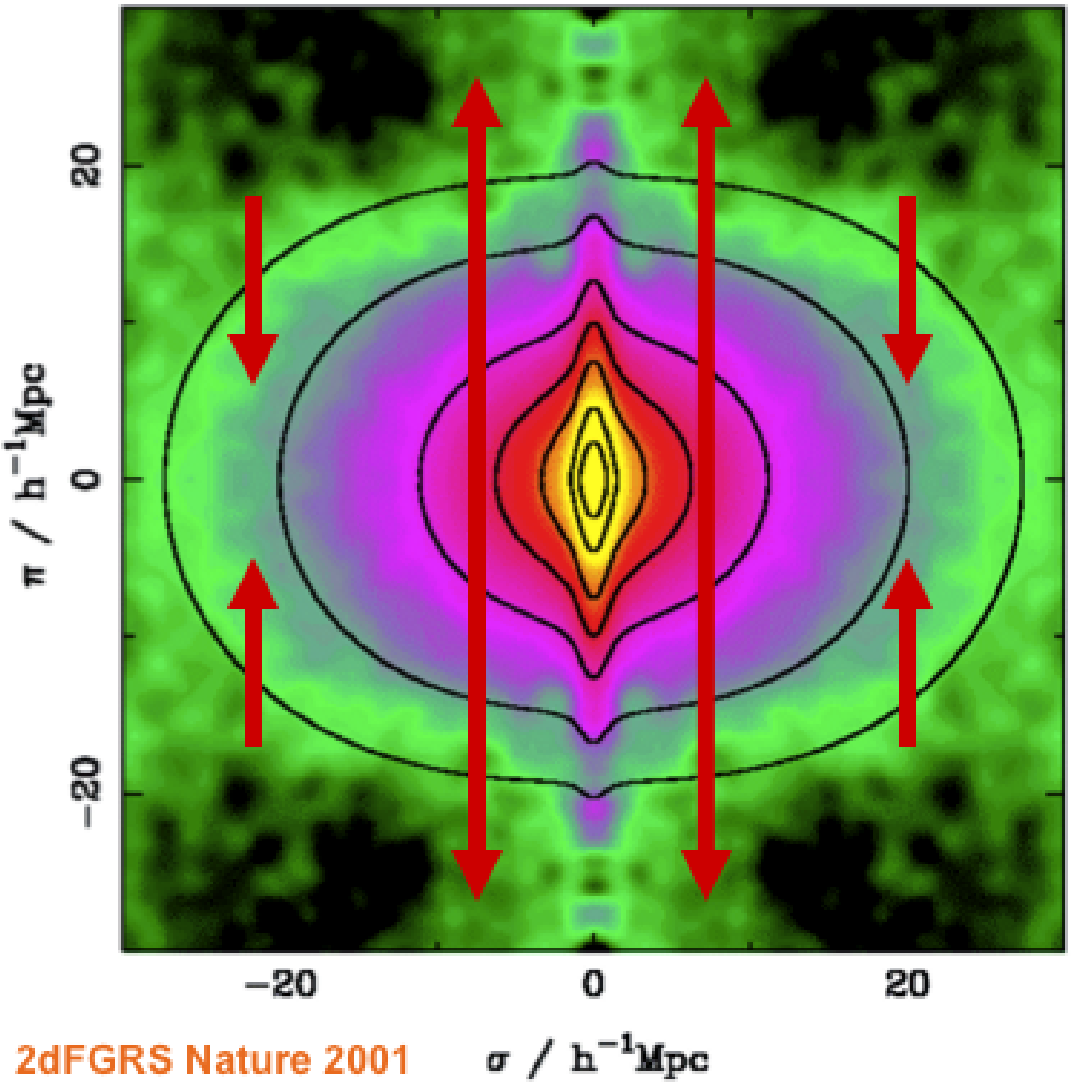
Comparison between GAMA & "SDSS" with the same FoF group finder:

- Huge difference for z>0.15!
- groups to z~0.4 with GAMA.

Redshift-Space Distortions



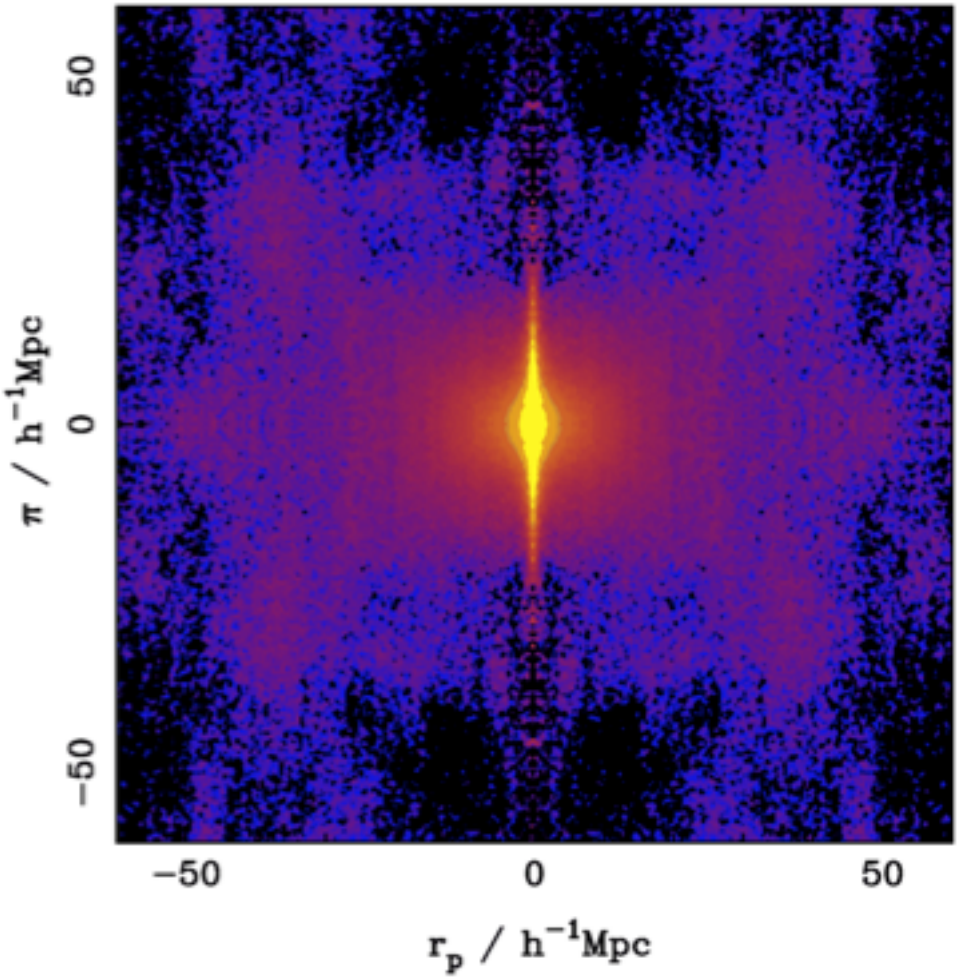
- RSD due to peculiar velocities are quantified by correlation fn $\xi(\sigma,\pi)$.
- Two effects visible:
  - Small separations on sky: 'Finger-of-God';
  - Large separations on sky: flattening along line of sight.

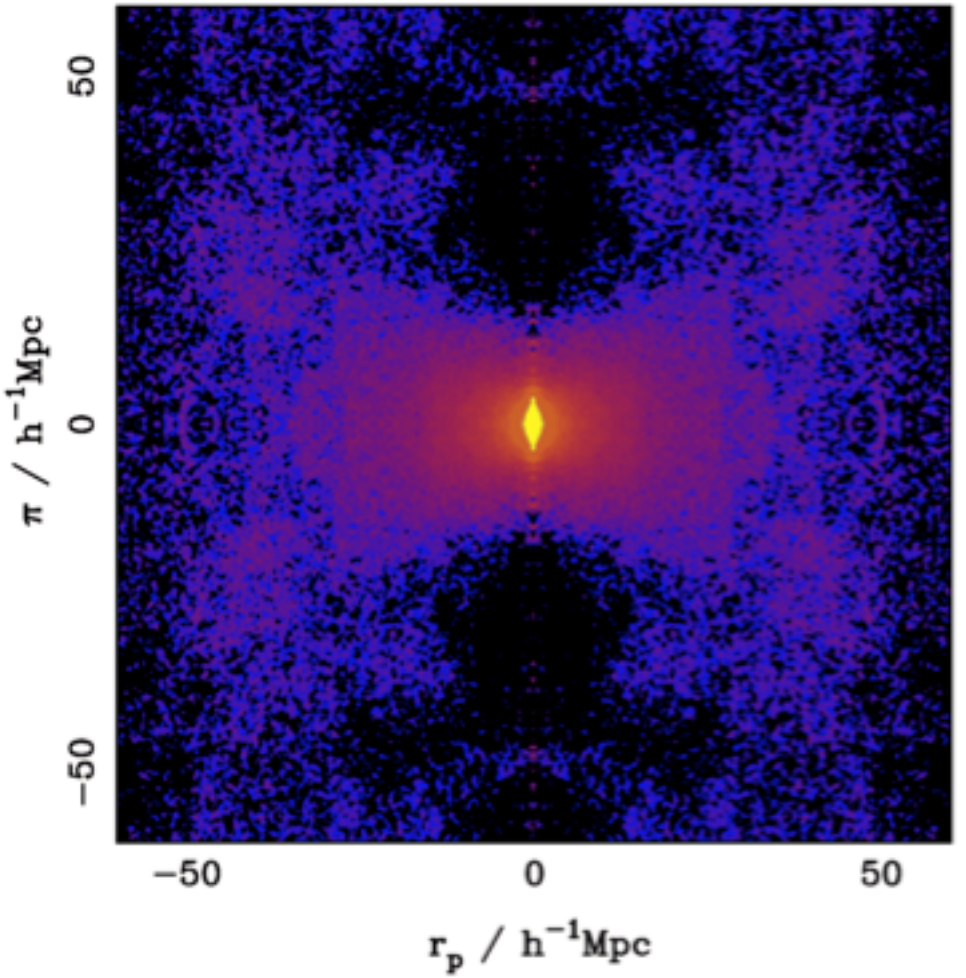


2dFGRS Nature 2001

GAMA: Preliminary Results

Clustering & Redshift Space Distortions

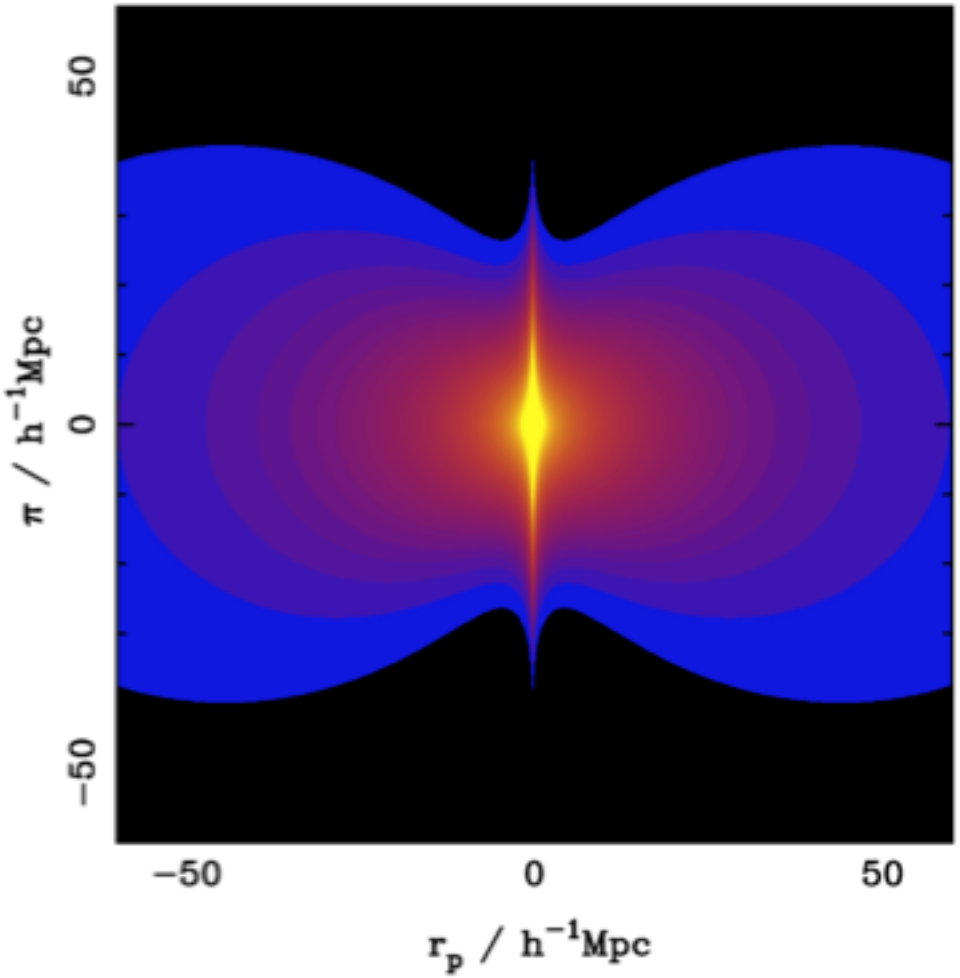




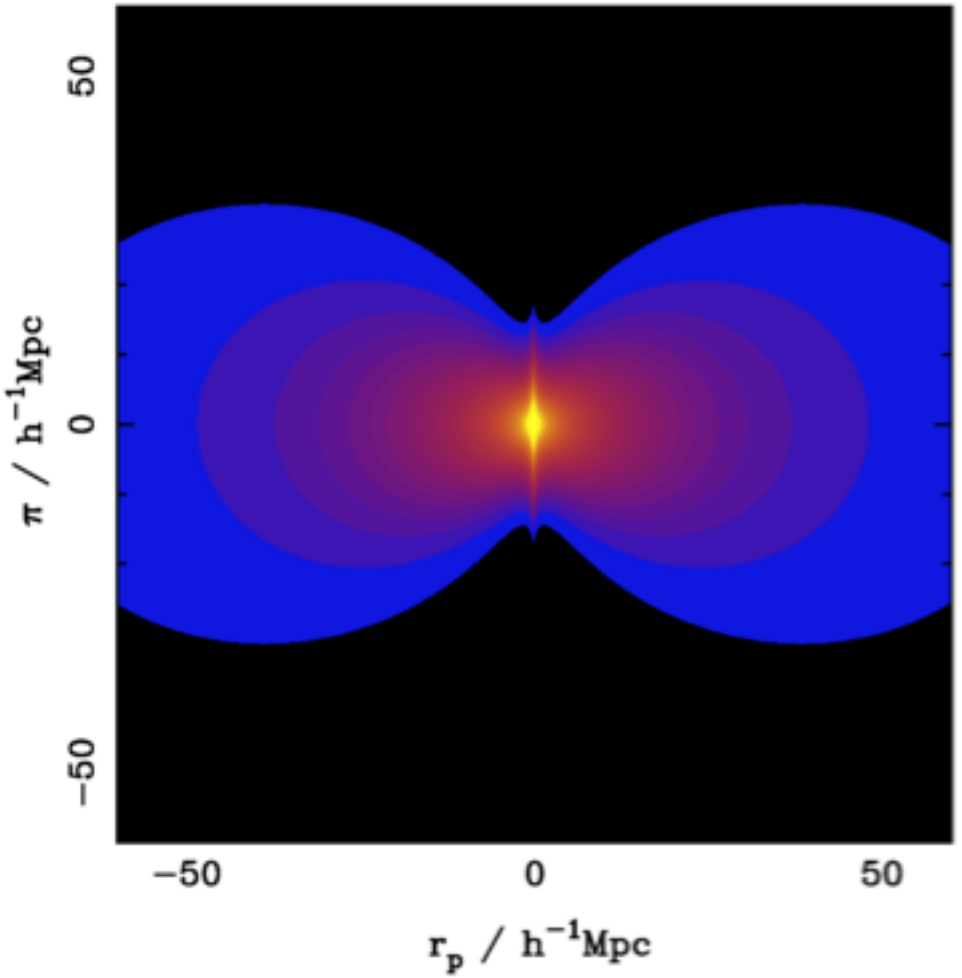
Red **Blue**

GAMA: Preliminary Results

Clustering & Redshift Space Distortions



Red



Blue

GAMA: THE DATABASE (I)

All (~250k):

General: GAMA ID : SDSS ID : **z** (heliocentric) : **z** quality

Flux: UV : optical : near-IR : mid-IR : far-IR : Radio (20,rest-21,30,40,90cm)

Shape: CAS : Sersic index: half-light radii : b/a : PA in *ugrizYJHK*

Opacity: $\tau_{UV,ugriz,YJHK}$

Spectral features: Emission: Hα,Hβ,Hγ,Hδ,OII,OIII,NII

Abs.: Dn4000,Ca4227,Hα,Hβ,Hγ,Hδ,Mgb,Fe

SFR: UV : Hα : far-IR : Radio continuum

Fossil record: Age : SFH : element abundance

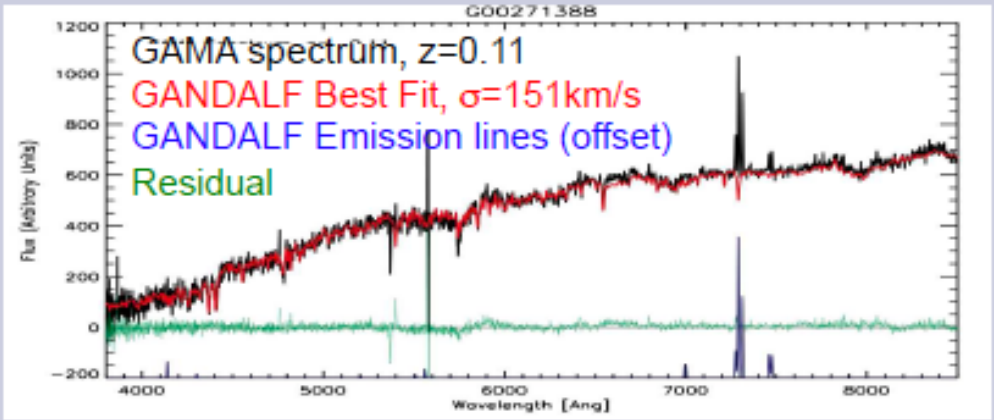
AGN: BPT diagnostics : type : strength : ionisation state

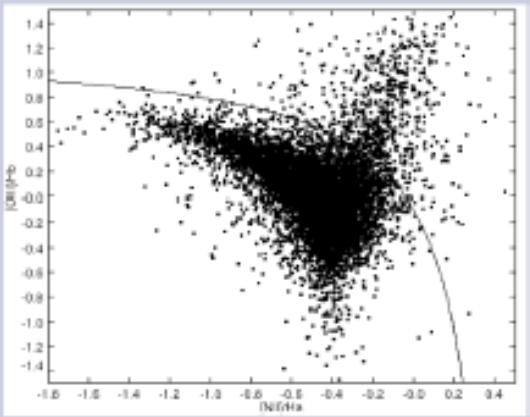
Dynamics: σ_{spec} (GANDALF) : W_{21}: HI line profile

Distances: Tully-Fisher : Faber-Jackson

Masses: Stellar : SMBH : HI : Dust : Baryon : Dynamical

Environment/Halo: Local density : Group membership : Group halo mass





GAMA: THE DATABASE (II)

For z<0.1 (~30k):

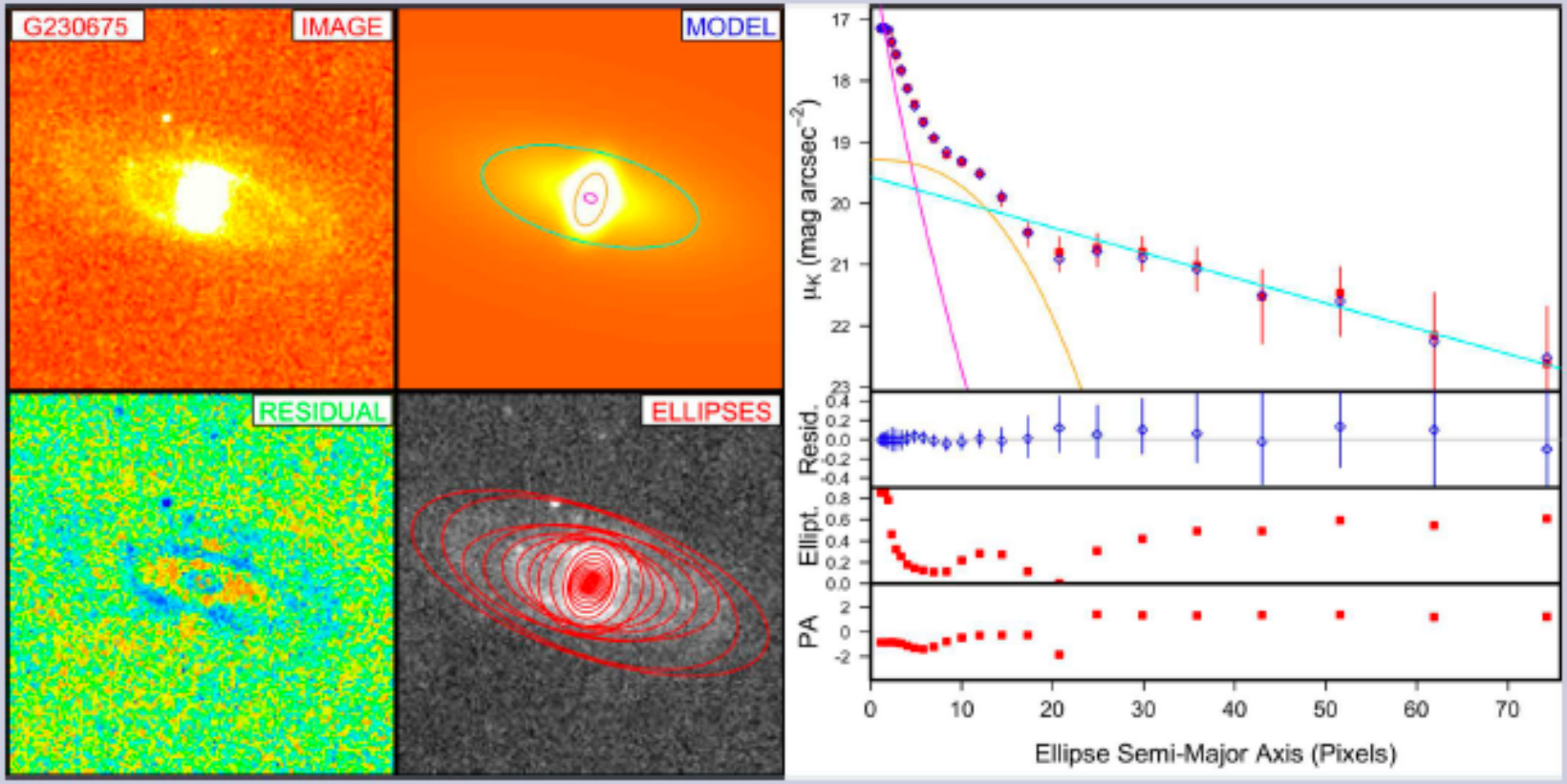
Structural: Bulge/Bar/Disc decomp. in *ugrizYJHK* (GALFIT3)

Bulge: Sersic index, half light radius, Pos. Angle, Ellipticity

Bar: Sersic index, half light radius, scale-length

Disc: Scalelength, PA, b/a

SMBH Mass: via M-σ, M-L , M-n relations



GAMA: Galaxy And Mass Assembly
Team Structure

WORKING GROUPS

SCIENCE	CATS	DATABASE	OBS	MOCK/THEORY	RADIO	SPEC. P.	IMAGE P.
Peacock (ROE)	Baldry (LJMU)	Liske (ESO)	Driver (PI, StA)	Norberg (ROE)	Hopkins (Sydney)	Loveday (Sussex)	Bamford (Nott.)

TEAM MEMBERS (now incomplete...)

Bland-Hawthorn (Sydney)
Croom (Sydney)
Frenk (Durham)
Kuijiken (Leiden)
Nichol (Portsmouth)
Proctor (Swinburne)
Sutherland (QMUL)
Warren (Imperial College)
Cameron (StA, ETH)

Couch (Swinburne)
Cross (ROE)
Graham (Swinburne)
Lahav (UCL)
Phillipps (Bristol)
Sharp (AAO)
Tuffs (MPIK)
Robotham (StA)
Thomas (ICG)

Concelice (Nottingham)
Edmondson (Portsmouth)
Jones (AAO)
Oliver (Sussex)
Popescu (UCLan)
Staveley-Smith (UWA)
van Kampen (Innsbruck)
Ellis (Sydney)
Brough (AAO)....

More than 5 PhD students: Hill & Kelvin (StA), Parkinson (ROE), Prescott (LJMU), Gunawardhana (Macquarie U), Wijesinghe (Sydney)...

TEAM AFFILITATIONS

UKIRT/LAS, VST/KIDS, VISTA/VIKING, HERSCHEL/ATLAS, ASKAP/DINGO, DURHAM ICC

URL: http://www.eso.org/~jliske/gama/

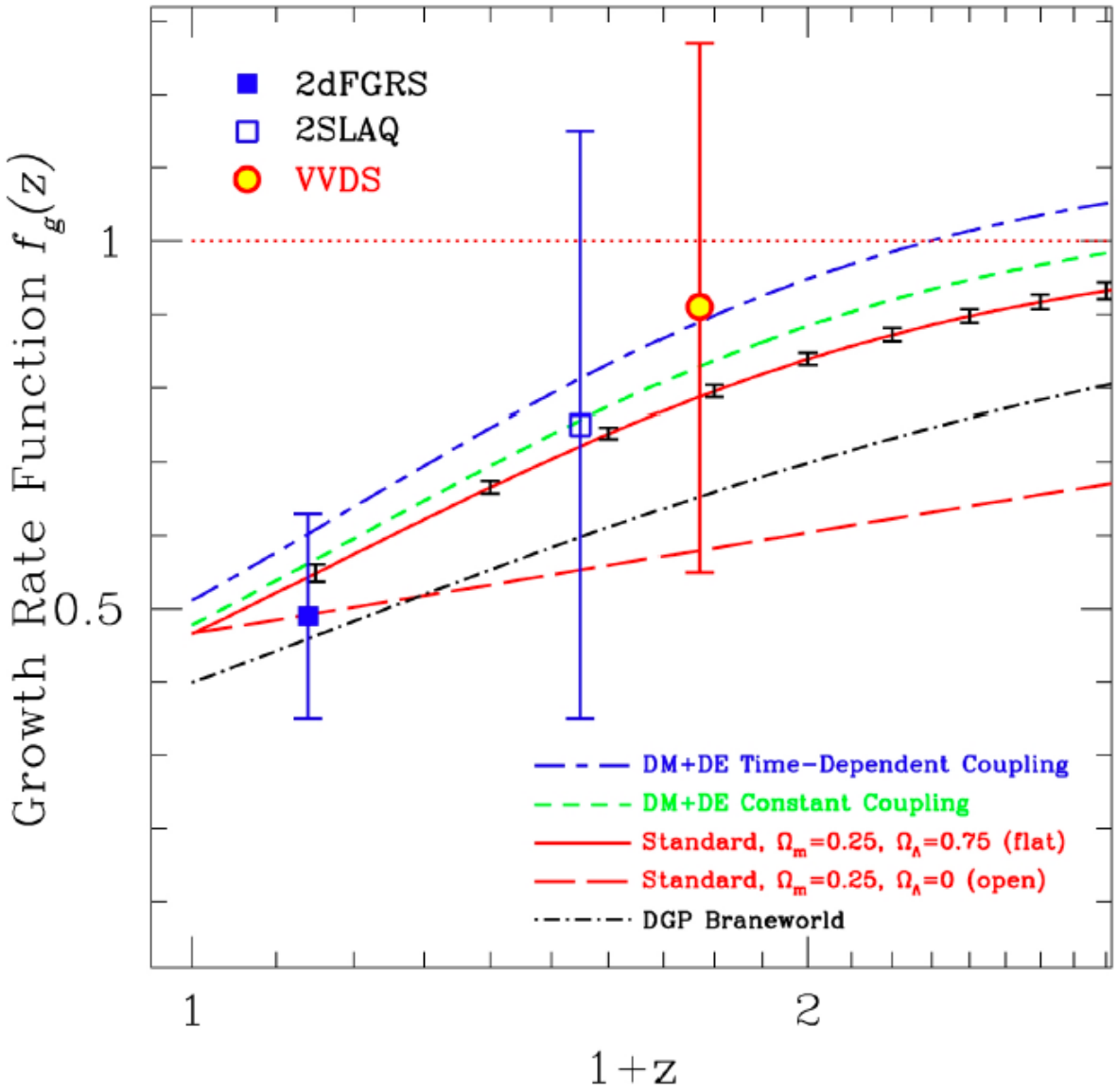
Galaxy And Mass Assembly: The next steps....

- GAMA-II:
  - Galaxy formation and large scale structure survey:
    - ~450 sq. deg.: ~200 sq.deg. at δ~0 (mostly GAMA-I) & ~250 at δ~-30.
    - 2 mags deeper than SDSS & 4 mags deeper than 6dFGS
    - Multi-wavelength: AAT, VST, VISTA, HERSCHEL (XMM, SCUBA II, ASKAP)
  - Comprehensive study of matter and energy on Mpc to kpc scales $z < 0.5$

- GAMA-II and the large scale structure case:
  - Groups: Halo Mass Function, Galaxy Formation Efficiency, X-ray follow up...
  - Environmental studies: from voids to clusters as function of redshift!
  - Growth rate of structure, $f_g(z)$, and $\gamma(z)$ from the GAMA survey!

- GAMA-II and the multi-wavelength case (~15 bands):
  - SMF, SFH, SFR, ... as function of X...
  - Structural decomposition into bulge, bar, disk, ... in multiple (optical) bands
  - Herschel/ATLAS and ASKAP/DINGO fields → Far-IR and H_I Universe

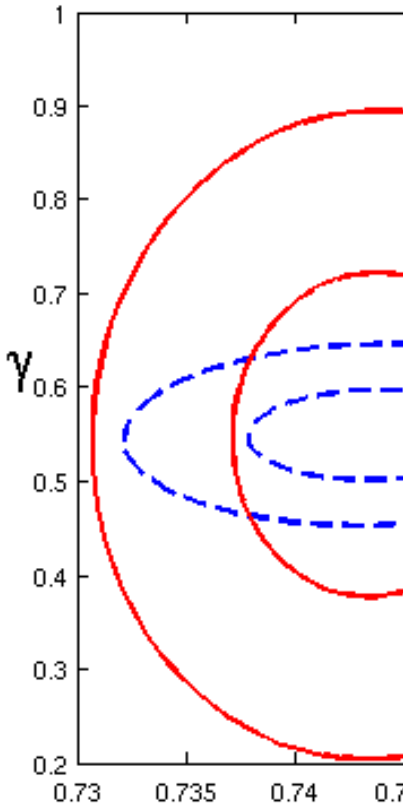
Galaxy And Mass Assembly: Growth rate....

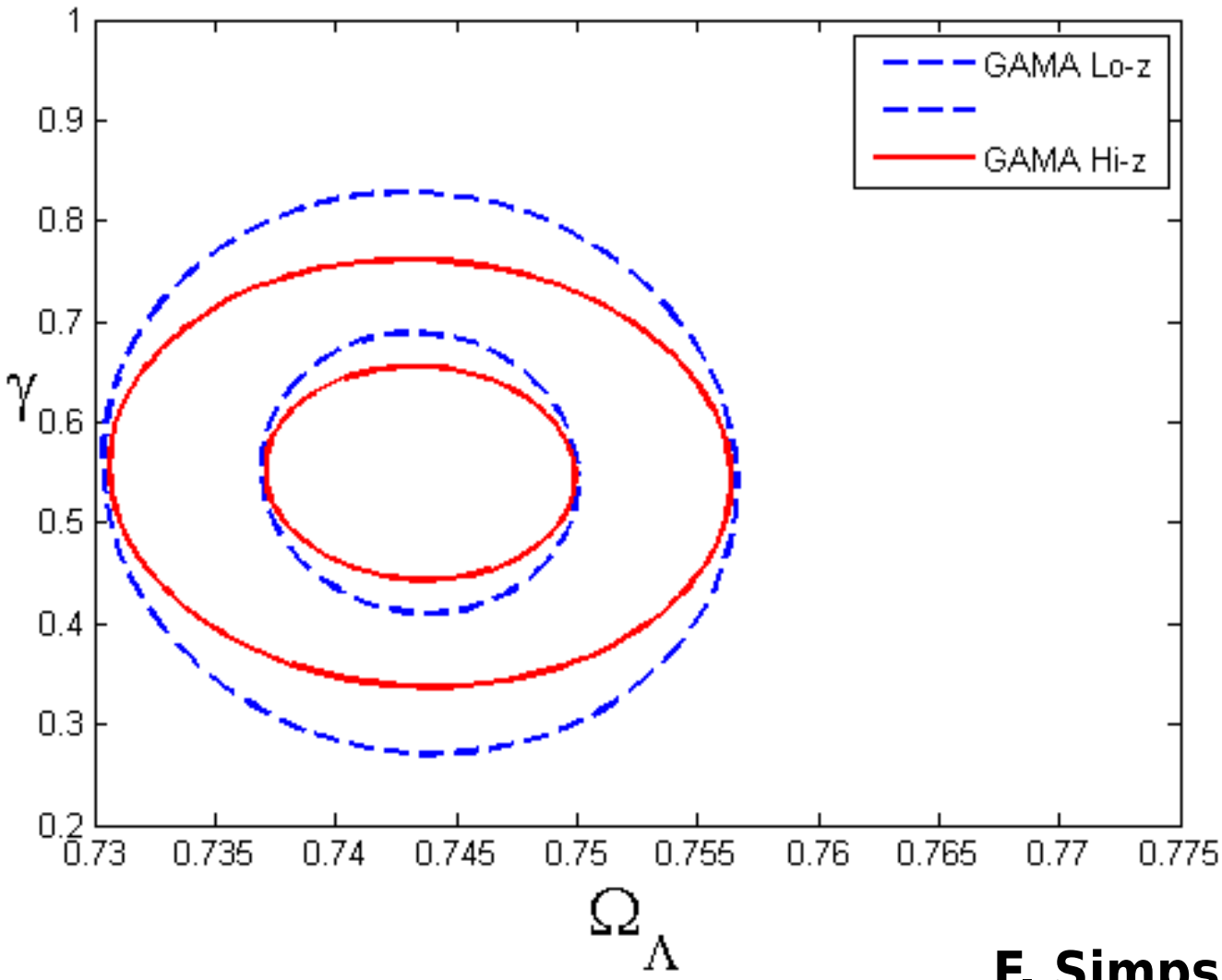


$$f_g(z) = \mathrm{dln}\delta/\mathrm{dln}a \simeq \Omega_m^{\gamma}(z)$$

Guzzo et al. (2008)

Galaxy And Mass Assembly: gravitational growth index γ...





F. Simpson

Galaxy And Mass Assembly: the key to a vital CDM model prediction?

- What is GAMA?
  - Dedicated galaxy formation survey:
    - 150 sq. deg. so far and with GAMA-II → 450 sq.deg.)
    - 2 mags deeper than SDSS & 4 mags deeper than 6dFGS
    - Multi-wavelength: AAT, VST, VISTA, HERSCHEL (XMM, SCUBA II, ASKAP)
  - Comprehensive study of matter and energy on Mpc to kpc scales $z < 0.5$

- GAMA update:
  - GAMA started March 1st 2008
  - >80k new spectra with the AAT's AAΩ: >93% redshift success rate
  - Preliminary science: GLF & SMF, G^3, photo-z calibration, …

- How you can get involved:
  - First data release: June 2010...
  - Website: http://www.eso.org/~jliske/gama/
  - PI: Simon Driver (spd3@st-andrews.ac.uk).