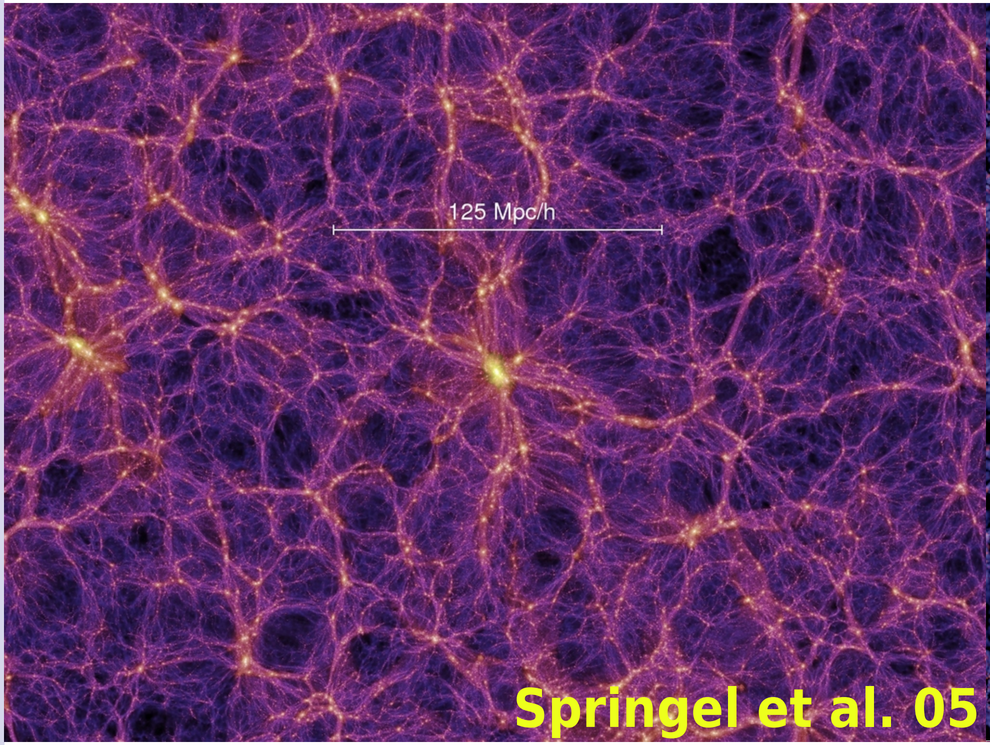
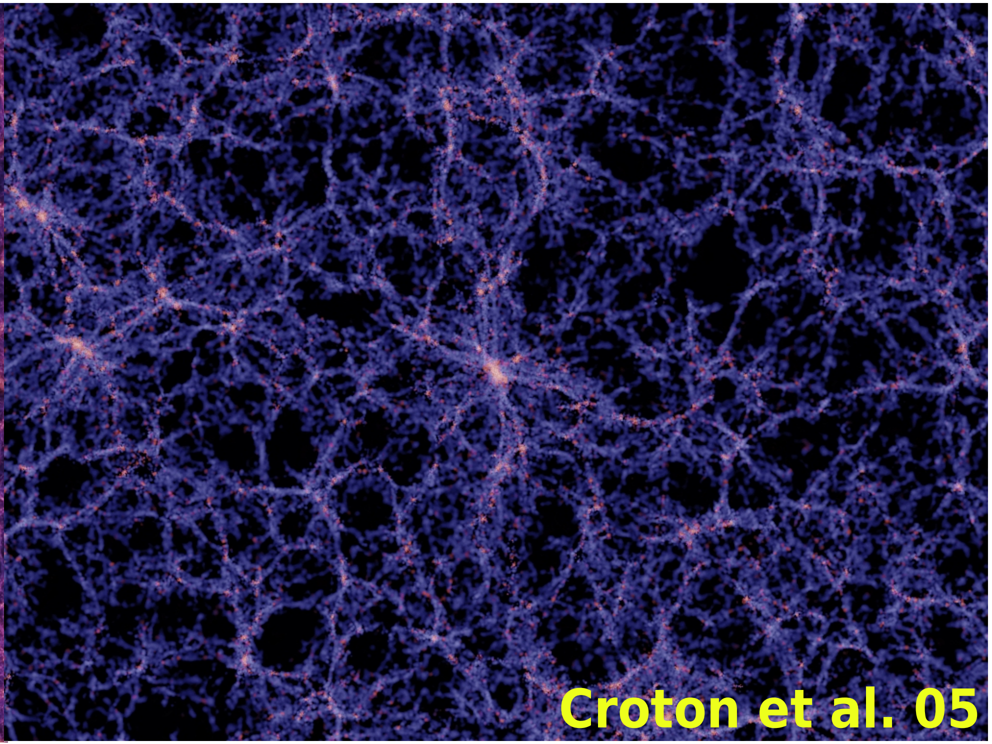
Galaxy And Mass Assembly Survey: the key to a vital CDM model prediction?

Dark Matter: z=0



Galaxy Light: z=0



Peder Norberg

Institute for Astronomy, Royal Observatory Edinburgh

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

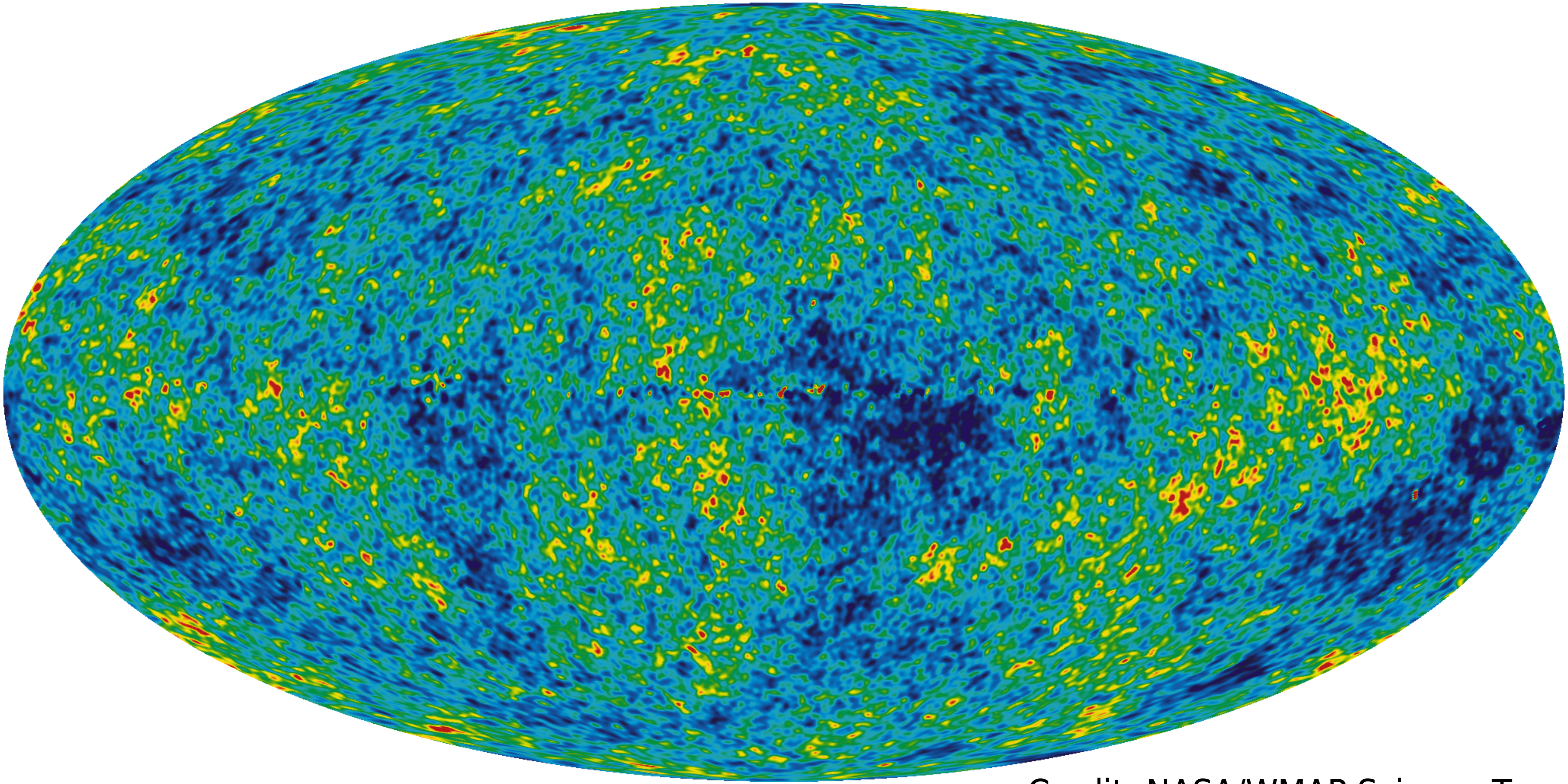
- Brief review of the current state of cosmology
- Biased review of some 2dFGRS & SDSS results
- The Galaxy And Mass Assembly survey
- Preliminary results from GAMA
- A few words about Pan-STARRS...
- Conclusions

Constraints on the Standard Cosmological Model

- Cosmic Microwave Background -> Geometry ...
- Large-Scale Structure -> Matter content ...
- Supernovae Type Ia -> Accelerating Universe ...
- Cepheid Period-Luminosity relation -> H_0
- Weak-Lensing, ... -> Matter content ...

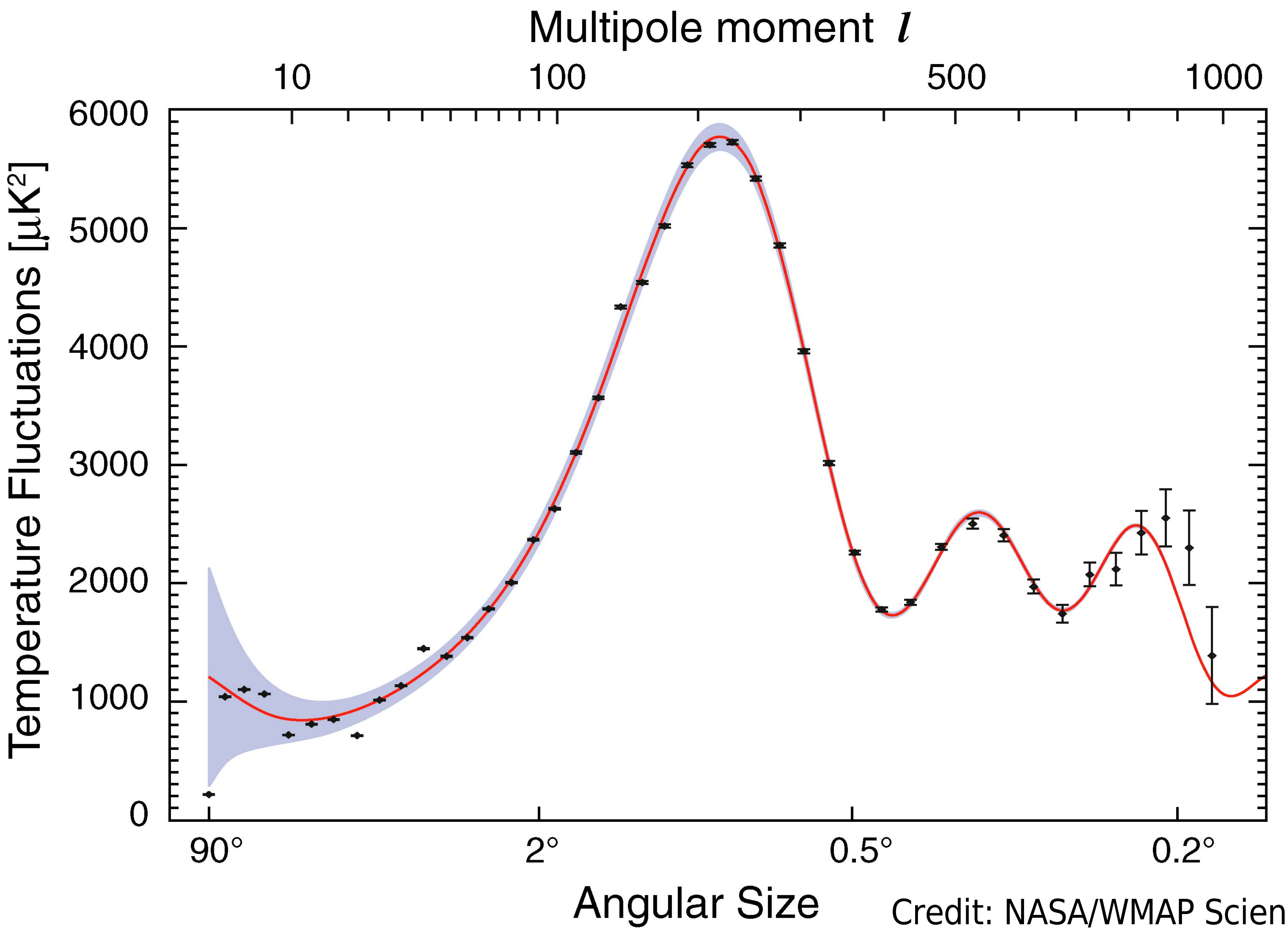
Cosmic Microwave Background: Temperature Fluctuations

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



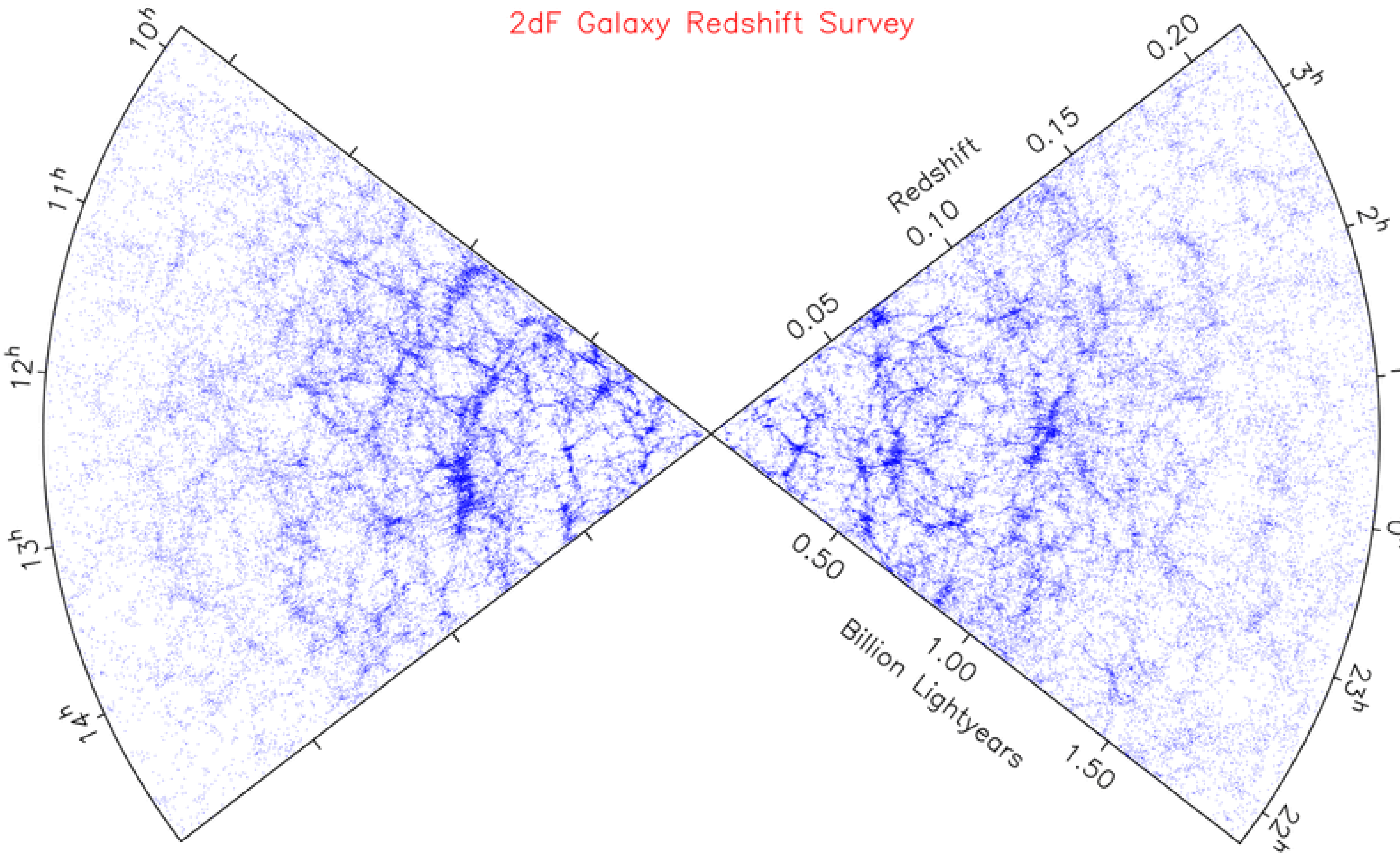
Credit: NASA/WMAP Science Team

Cosmic Microwave Background: Temperature Power Spectrum

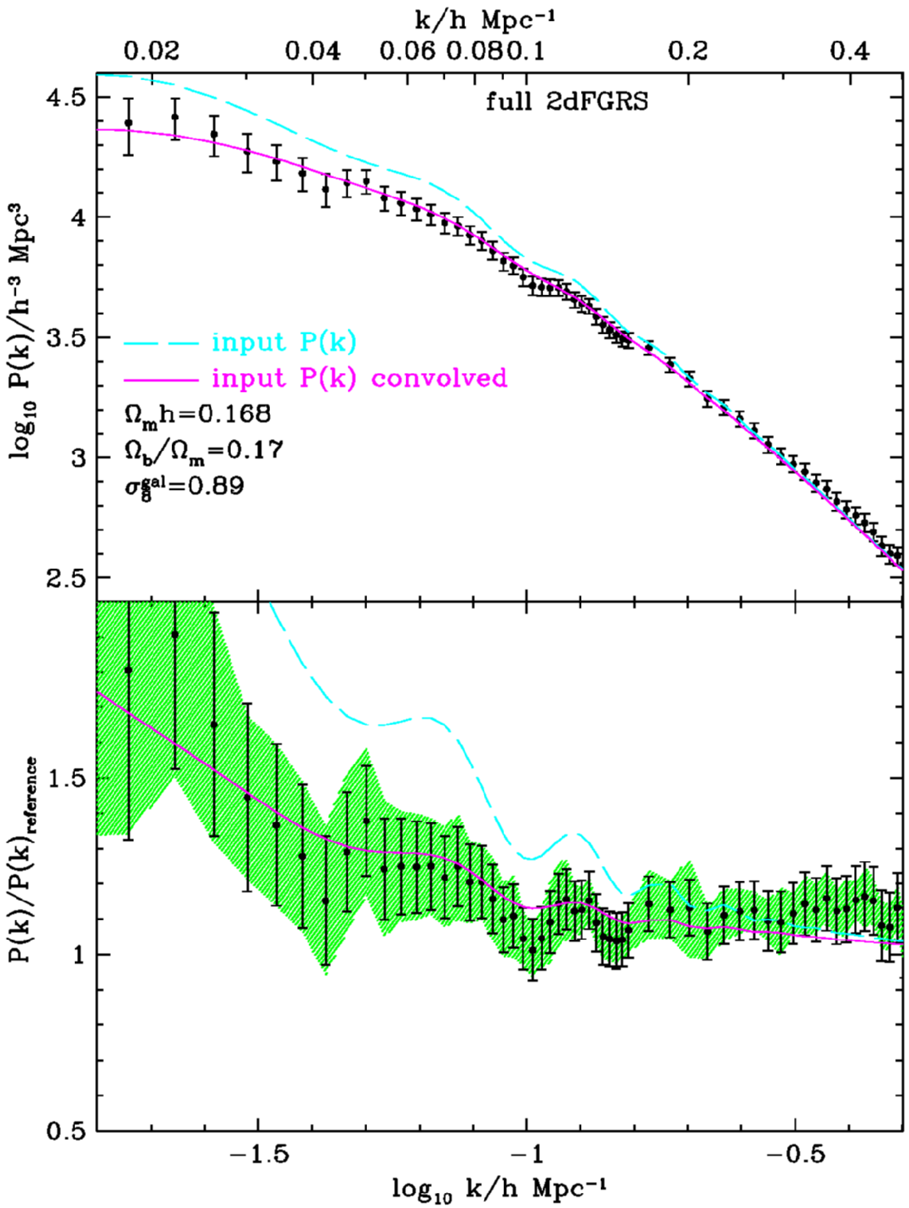


Credit: NASA/WMAP Science Team

Large-Scale Structure: Galaxy Distribution



Large-Scale Structure: Galaxy Power Spectrum

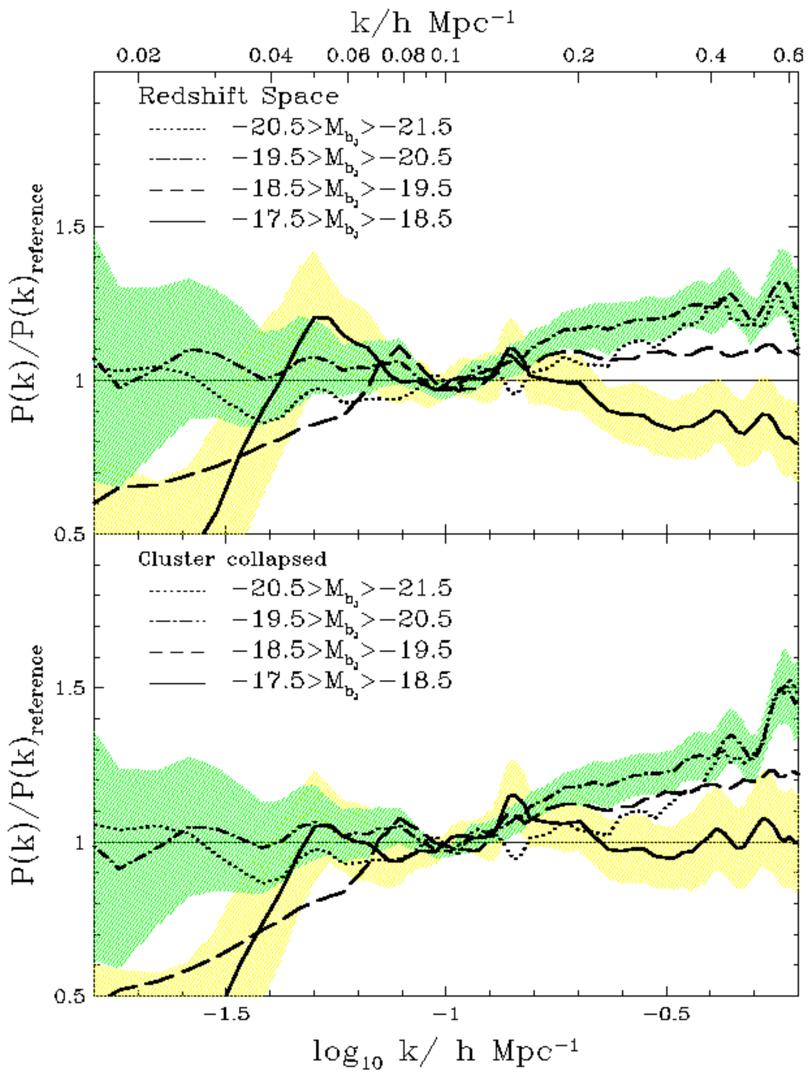


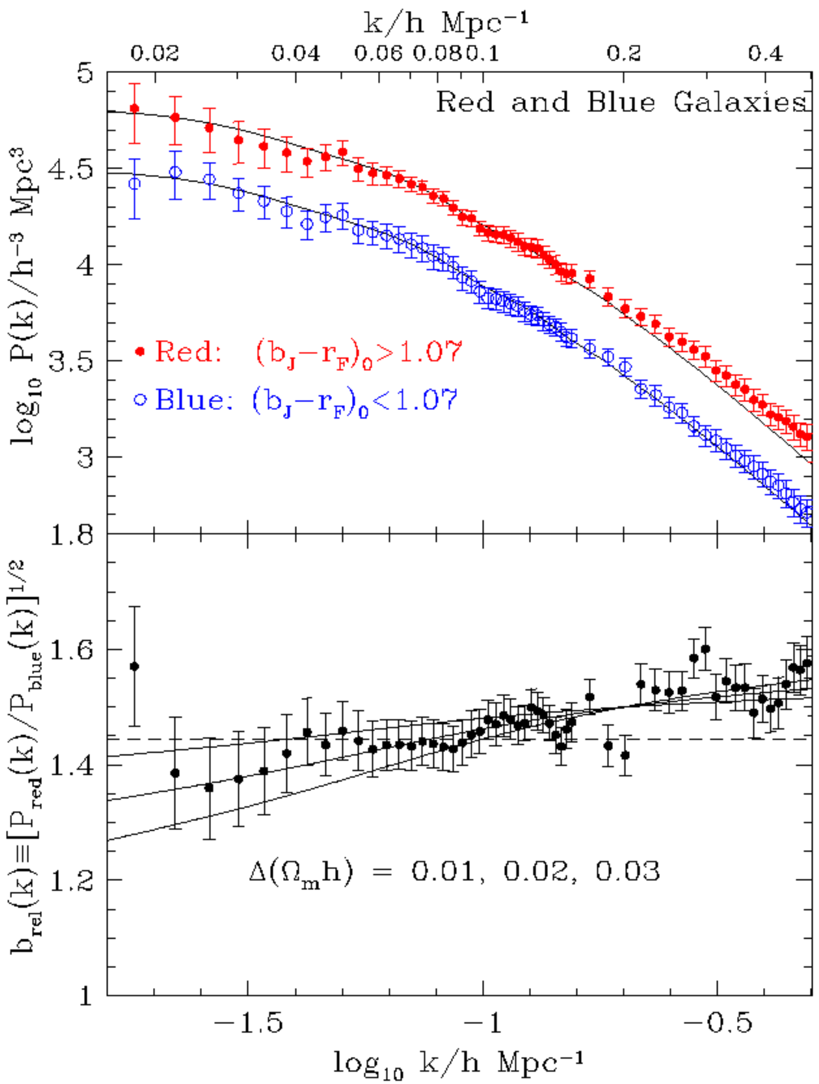
Large galaxy surveys, like SDSS & 2dFGRS, allow precise galaxy power spectrum measurements:

in redshift space & convolved with the survey window function

Cole, Percival, Peacock, Norberg, et al. (the 2dFGRS Team) (2005)

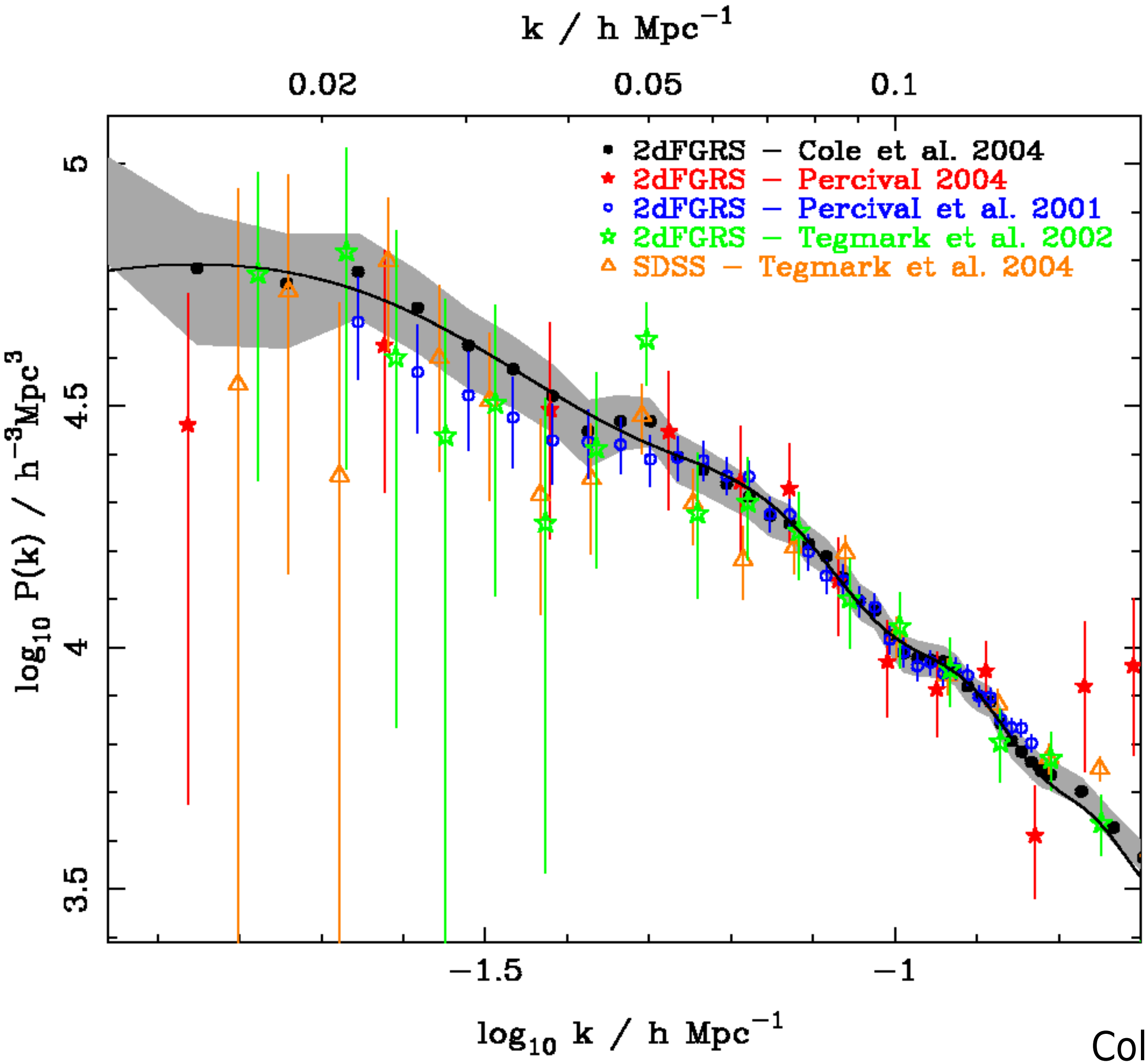
Large-Scale Structure: power spectrum by colour & luminosity





Cole, Percival, Peacock, Norberg, et al.
(the 2dFGRS Team) (2005)

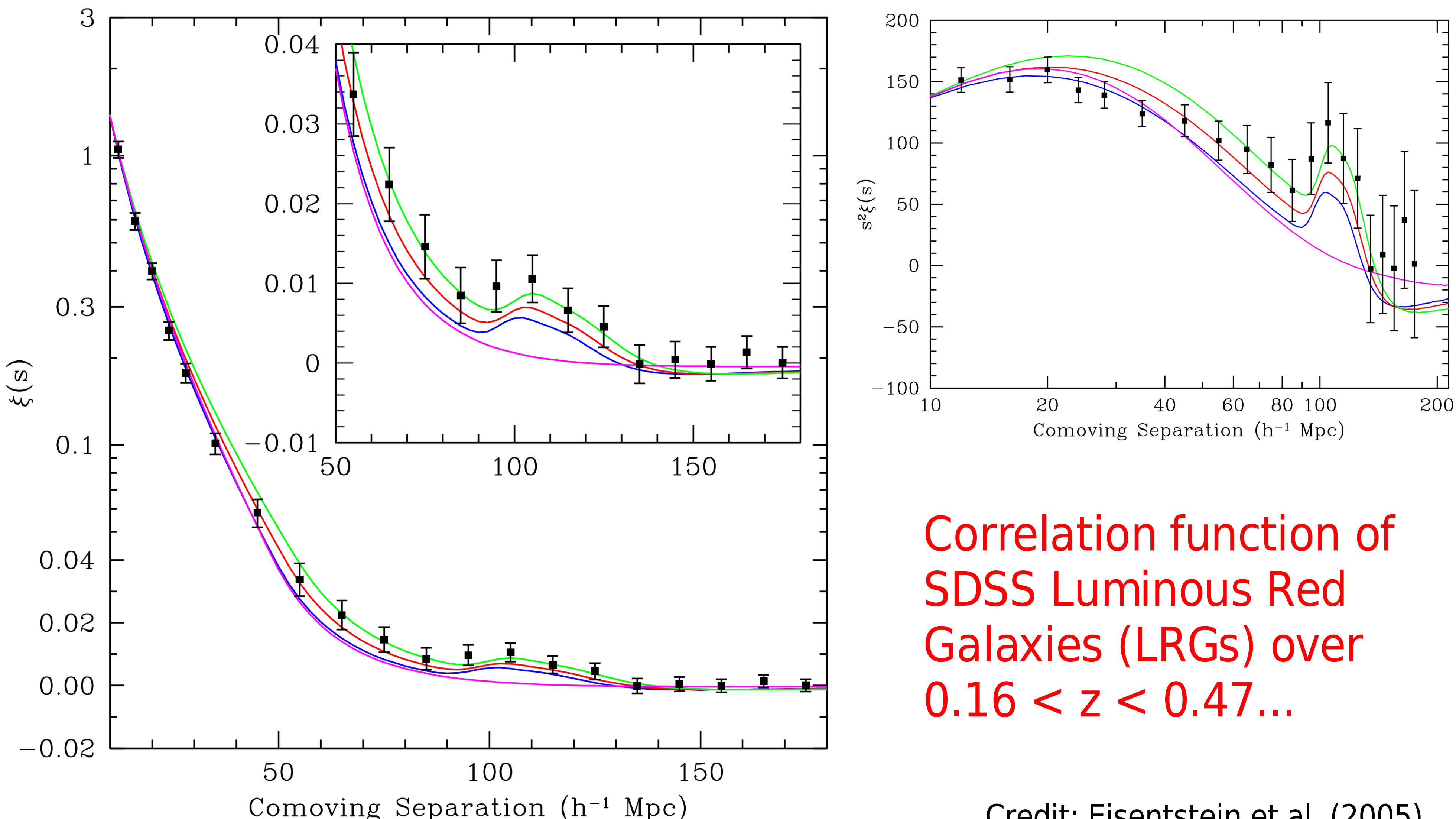
Large-Scale Structure: comparison between SDSS & 2dFGRS



Comparison between different P(k) estimates: agreement to within the errors!

Cole, Percival, Peacock, Norberg, et al. (the 2dFGRS Team) (2005)

Large-Scale Structure: baryonic accoustic oscillations



Correlation function of SDSS Luminous Red Galaxies (LRGs) over $0.16 < z < 0.47$...

Credit: Eisentstein et al. (2005)

ΛCDM: standard cosmological model

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

- flat universe: $\Omega_m + \Omega_\Lambda \simeq 1$
  - Ω_m: matter energy density
  - Ω_Λ: vacuum energy density –> Dark Energy
- $\Omega_m \simeq \Omega_{CDM} + \Omega_b + \Omega_\nu$ (today)
  - Ω_{CDM}: Cold Dark Matter
  - Ω_b , Ω_ν: baryons & neutrinos
- $H_0 = 72 \pm 8$ km s^{-1} Mpc^{-1} (NB: $h = H_0$ / 100 km s^{-1} Mpc^{-1})

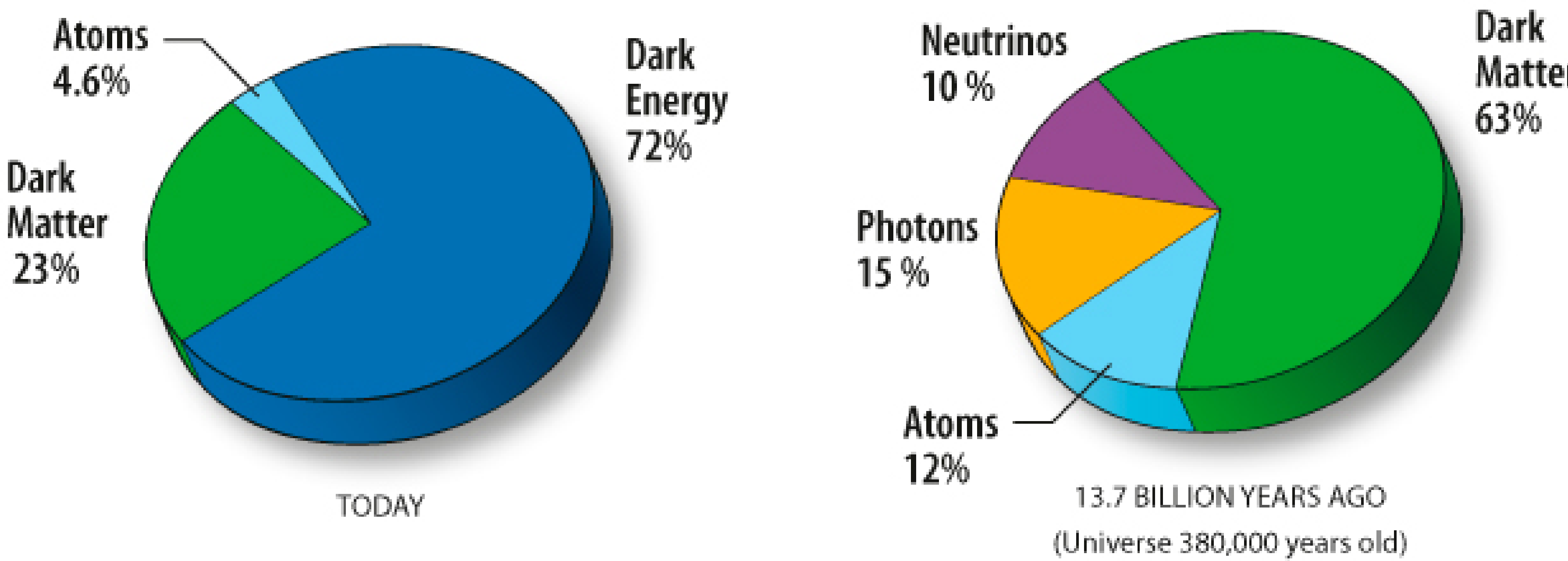
ΛCDM: standard cosmological model

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

- flat universe: $\Omega_m + \Omega_\Lambda \simeq 1$
  - $\Omega_m h \simeq 0.17 \pm 0.02$: matter energy density
  - $\Omega_\Lambda \simeq 0.75 \pm 0.03$ (vacuum energy density –> DE)
- $\Omega_m \simeq \Omega_{CDM} + \Omega_b + \Omega_\nu$ (today)
  - $\Omega_{CDM} \simeq 0.19 \pm 0.05$ (Cold Dark Matter energy density)
  - $\Omega_b / \Omega_m \simeq 0.185 \pm 0.046$ (baryon fraction)
- $H_0 = 72 \pm 8$ km s^{-1} Mpc^{-1} (NB: $h = H_0$ / 100 km s^{-1} Mpc^{-1})

ΛCDM: standard cosmological model

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



Credit: NASA/WMAP Science Team

ΛCDM: standard cosmological model

Two fundamental questions for the very successful ΛCDM model:

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

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 -> Pan-STARRS

ΛCDM: standard cosmological model

Two fundamental questions for the very successful ΛCDM model:

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

Observational / Survey cosmology:

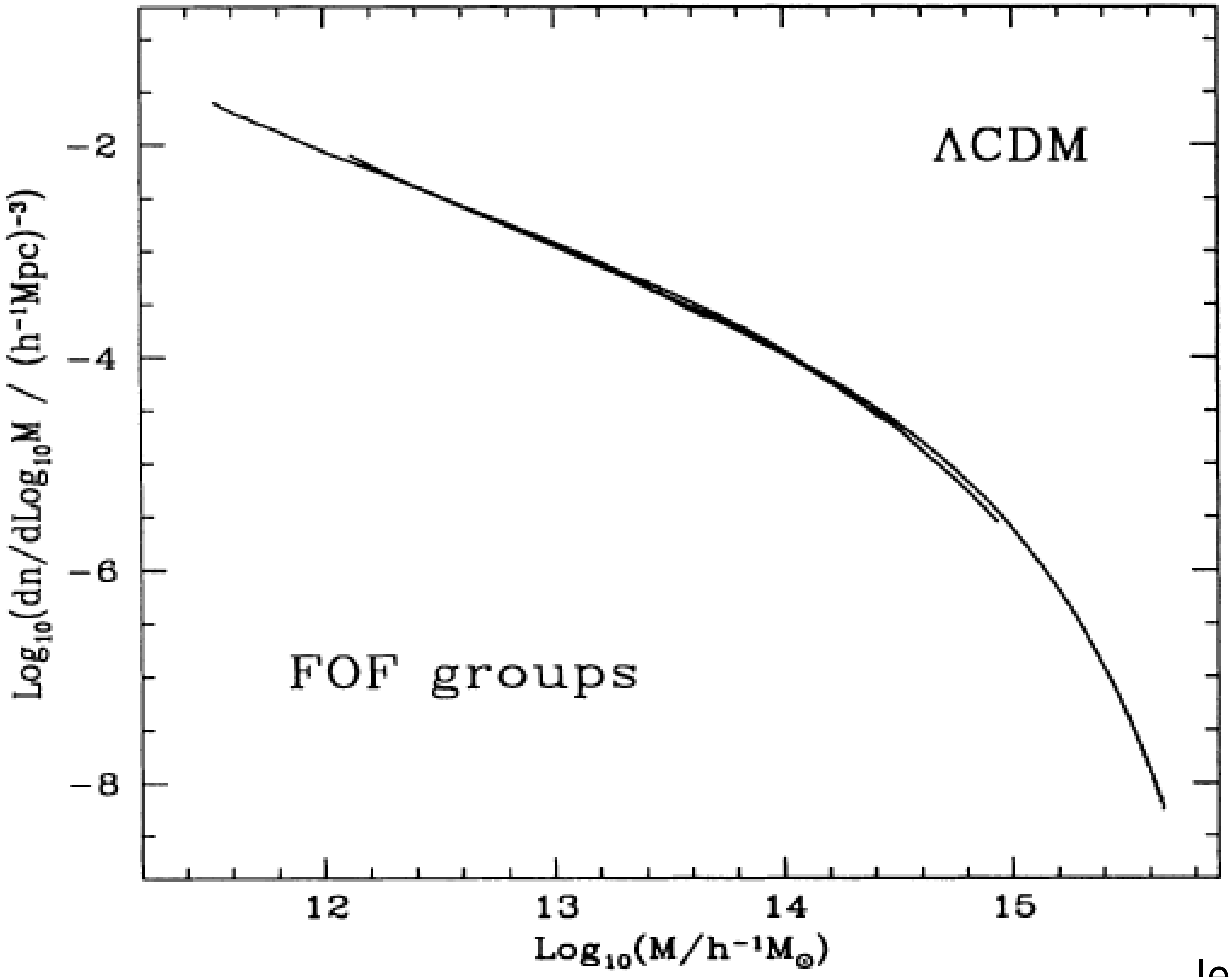
- unlikely to explain the nature of DE or CDM
- key in providing unique model constraints

Robust theoretical predictions exist / are needed:

- shape of cold dark matter halo mass function -> GAMA
- evolution of the DE equation of state -> Pan-STARRS

CDM halo mass function

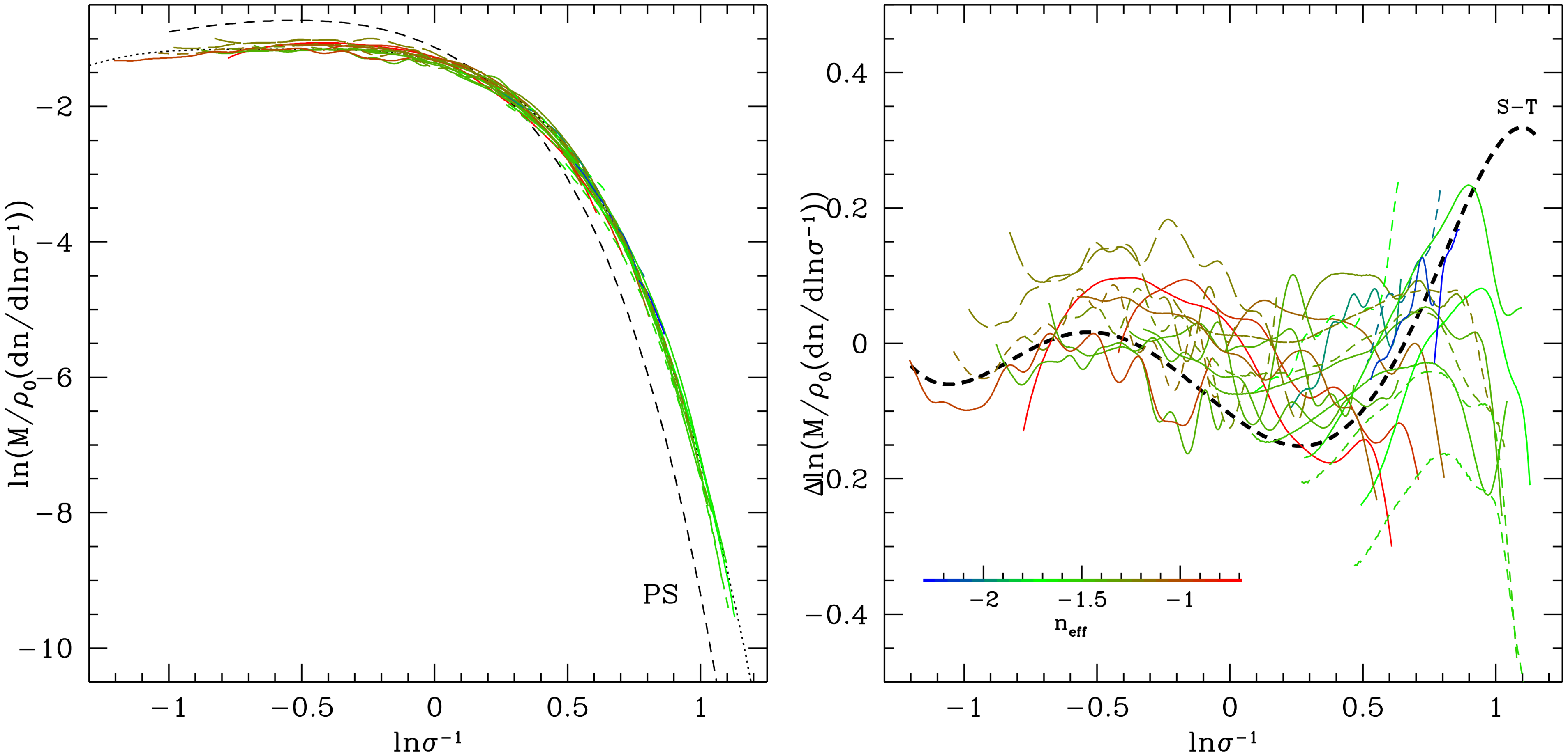
For a given cosmology, the CDM halo mass function is very well predicted (~10% accuracy), but not tested...



Jenkins et al. (2001)

CDM halo mass function

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



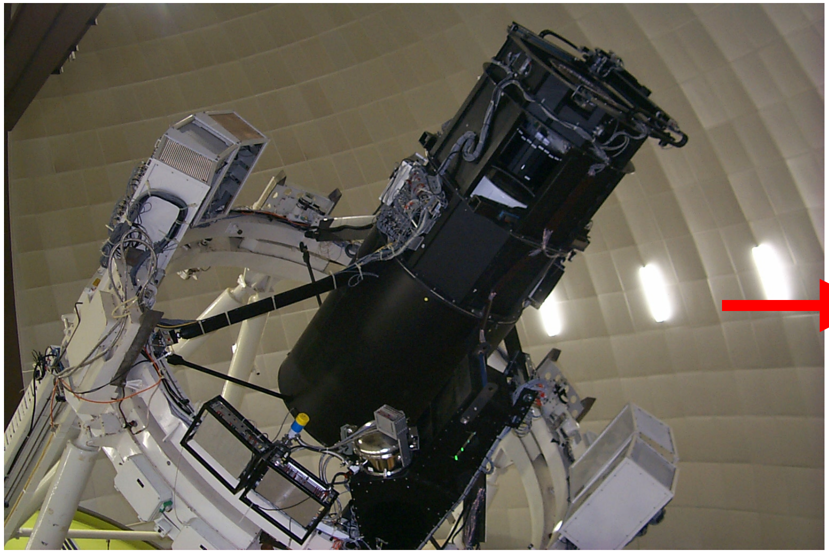
Jenkins et al. (2001)

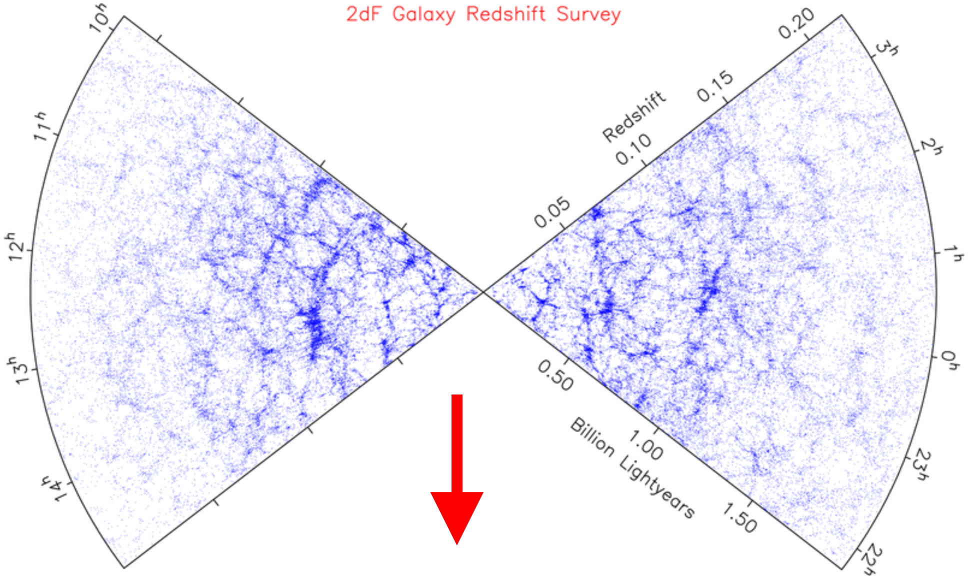
2dFGRS & SDSS: two unique galaxy redshift surveys

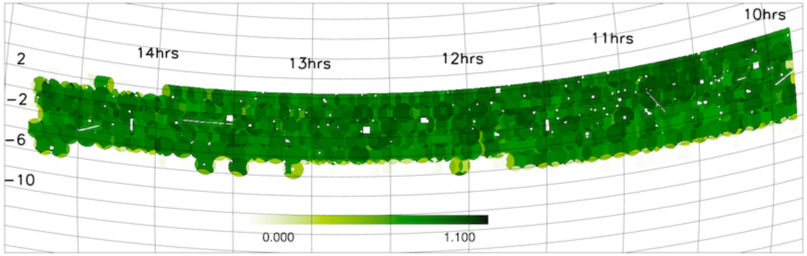
- ~¼ of the sky:
  - SDSS: $r < 17.77$
  - 2dFGRS: $b_J < 19.4$

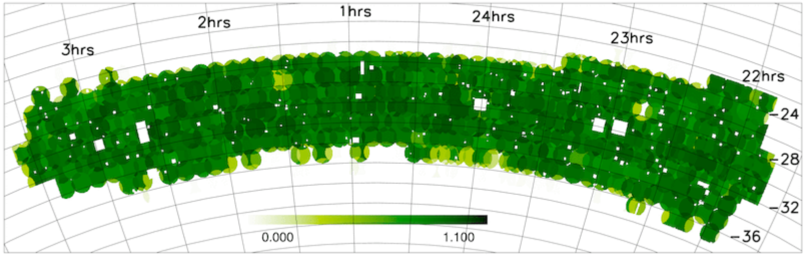
  } L* galaxy at z~0.14 [~400 Mpc/h]
- SDSS 5 band CCD imaging (u, g, r, i, z):
  - essential colour information => galaxy properties
  - photometric redshifts, for $r > 17.77$
- ~¾ million galaxy spectra & redshifts:
  - main samples: $z_{med} \sim 0.11$ [$z_{95\%} \sim 0.27$]
  - LRG sample: $z_{med} \sim 0.50$ [$z_{5\%} \sim 0.25$ & $z_{95\%} \sim 0.60$]
- Two orders of magnitude improvement wrt. previous redshift surveys (CfA, Stromlo-APM, LCRS, ...)

2dF Galaxy Redshift Survey: a short summary





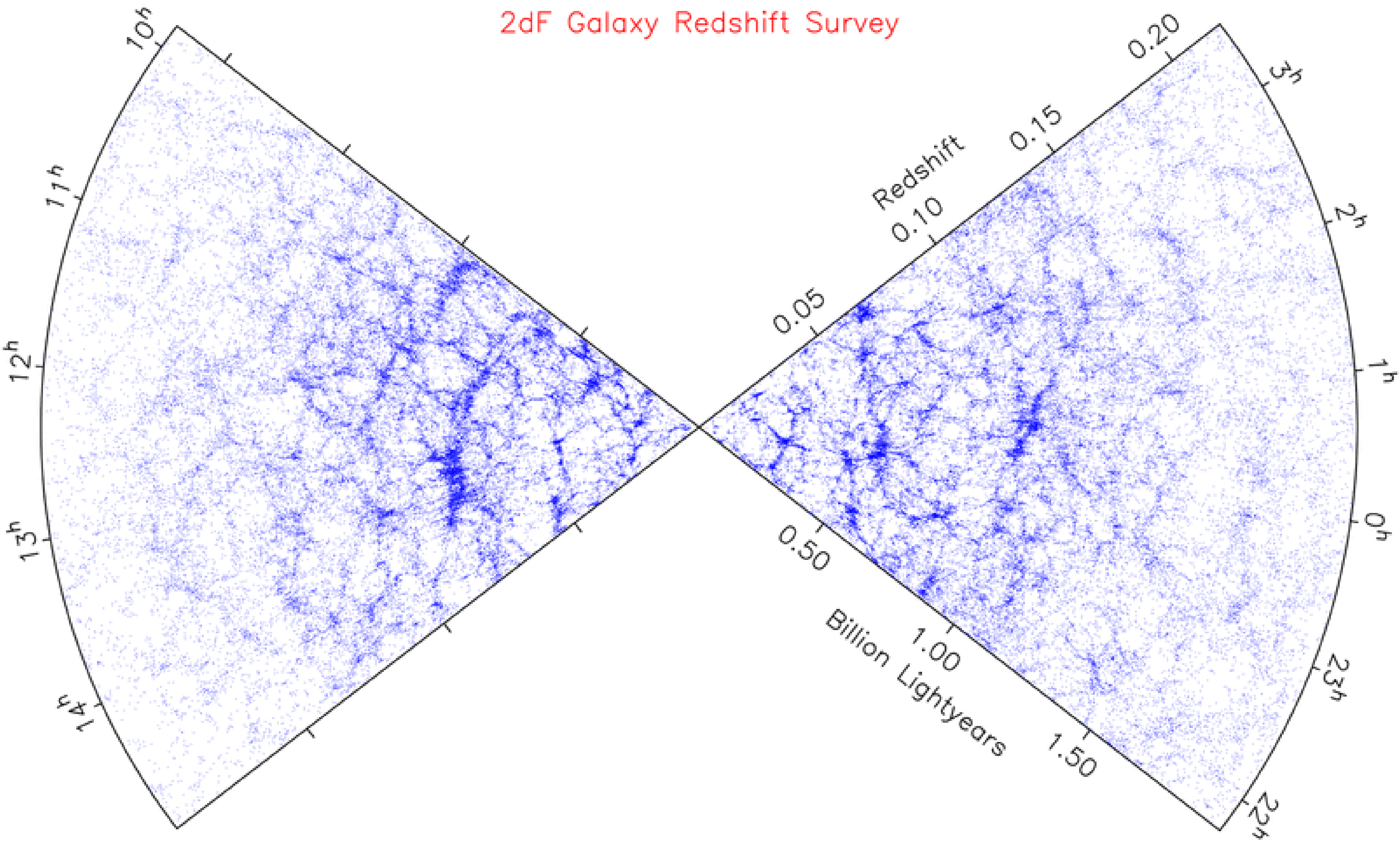




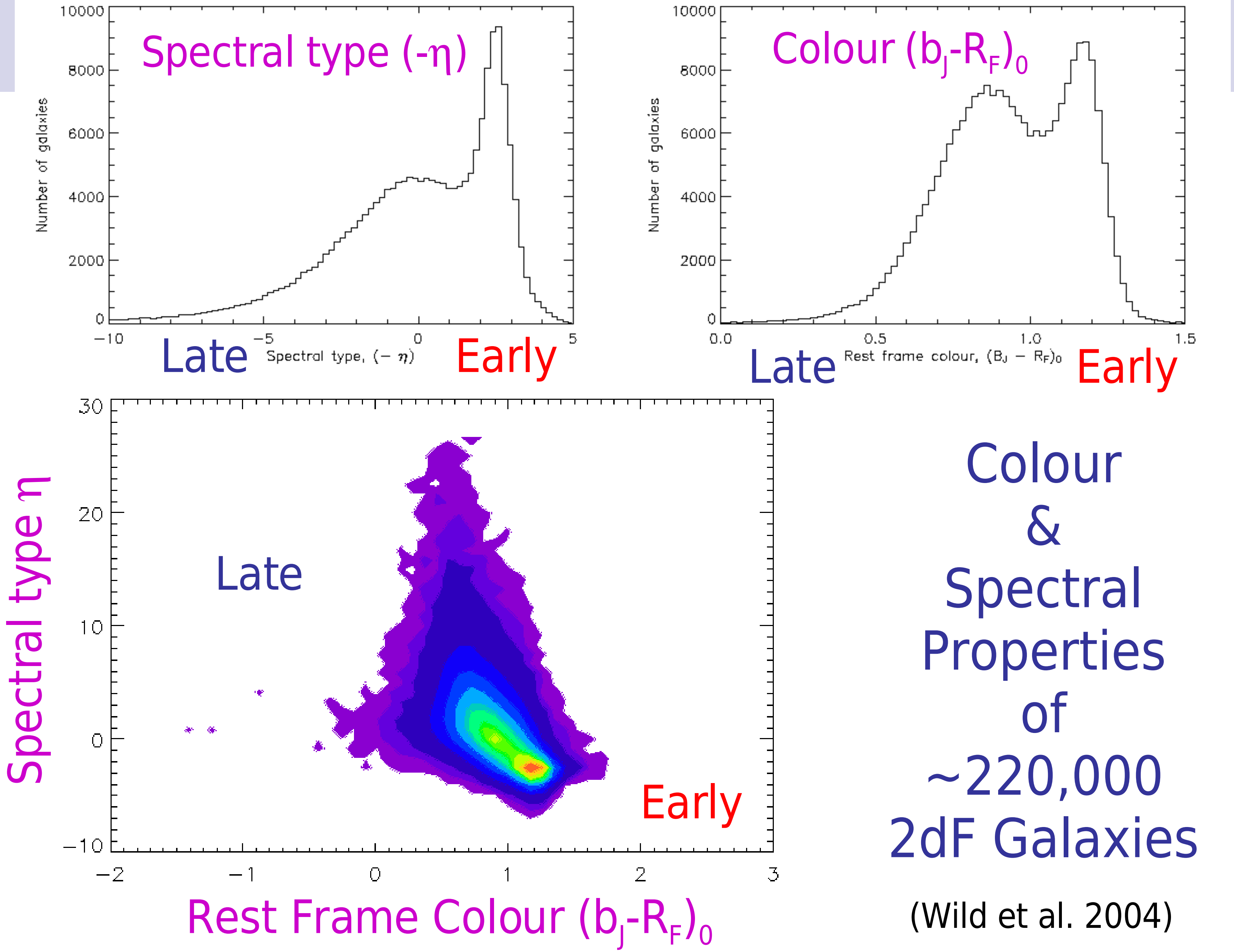
General facts about 2dFGRS:

- **225,000 galaxy spectra, <z> ~ 0.11**
- **probe scales from ~0.1 to ~600 Mpc/h**
- **~1500 sq. deg. down to b_J ~ 19.35**
- **Magnitude limited survey, using UKST photographic plates :**
  - **$14.0 \leq b_J \leq \sim 19.4$, with $\sigma(b_J) \sim 0.12$**
  - **galaxy completeness ~91%**
  - **stellar contamination ~6%**
  - **$(b_J - r_F)$ from SCOS.**

2dF Galaxy Redshift Survey: a short summary



2dF Galaxy Redshift Survey:

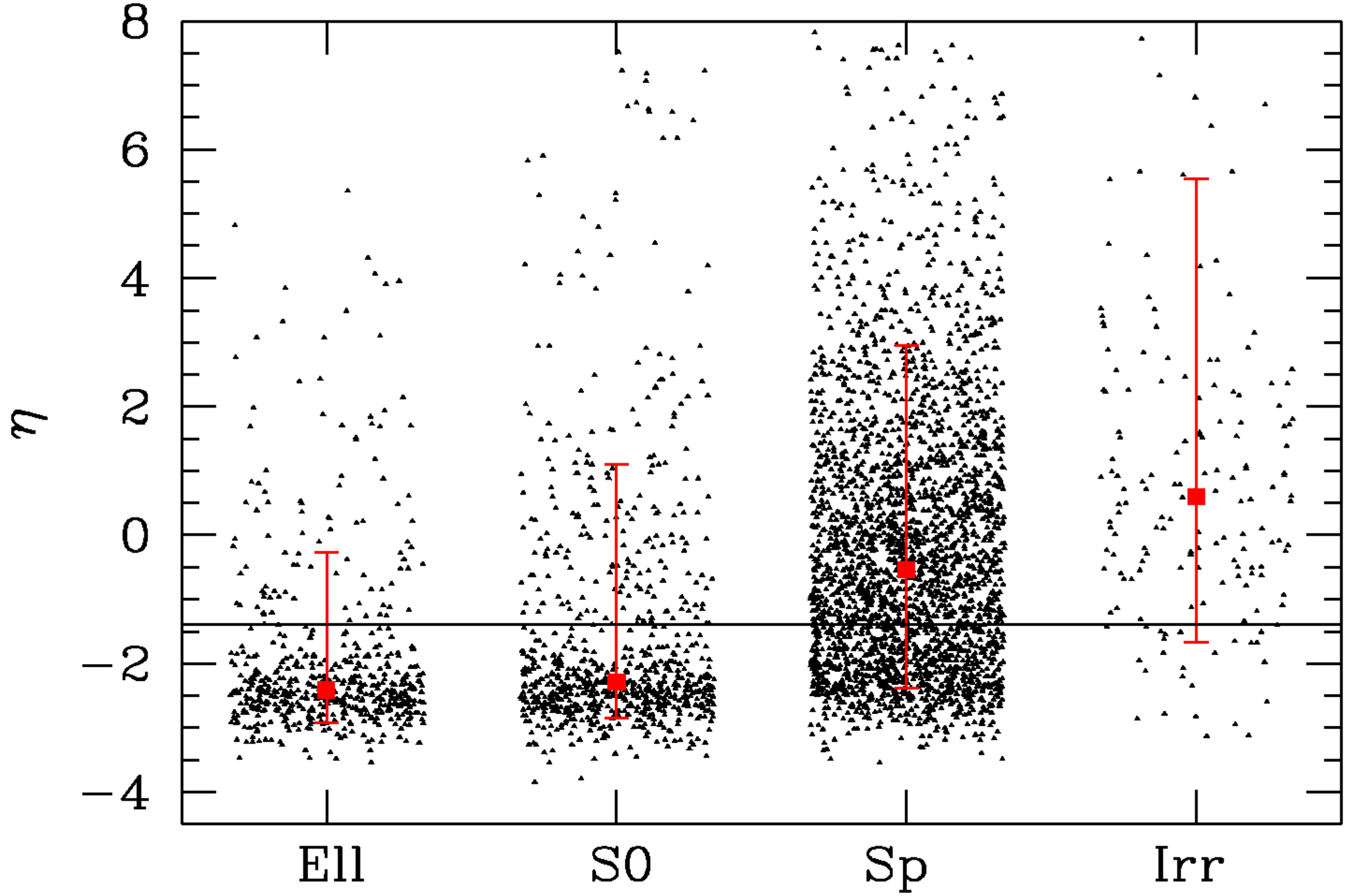


Colour
&
Spectral
Properties
of
~220,000
2dF Galaxies

(Wild et al. 2004)

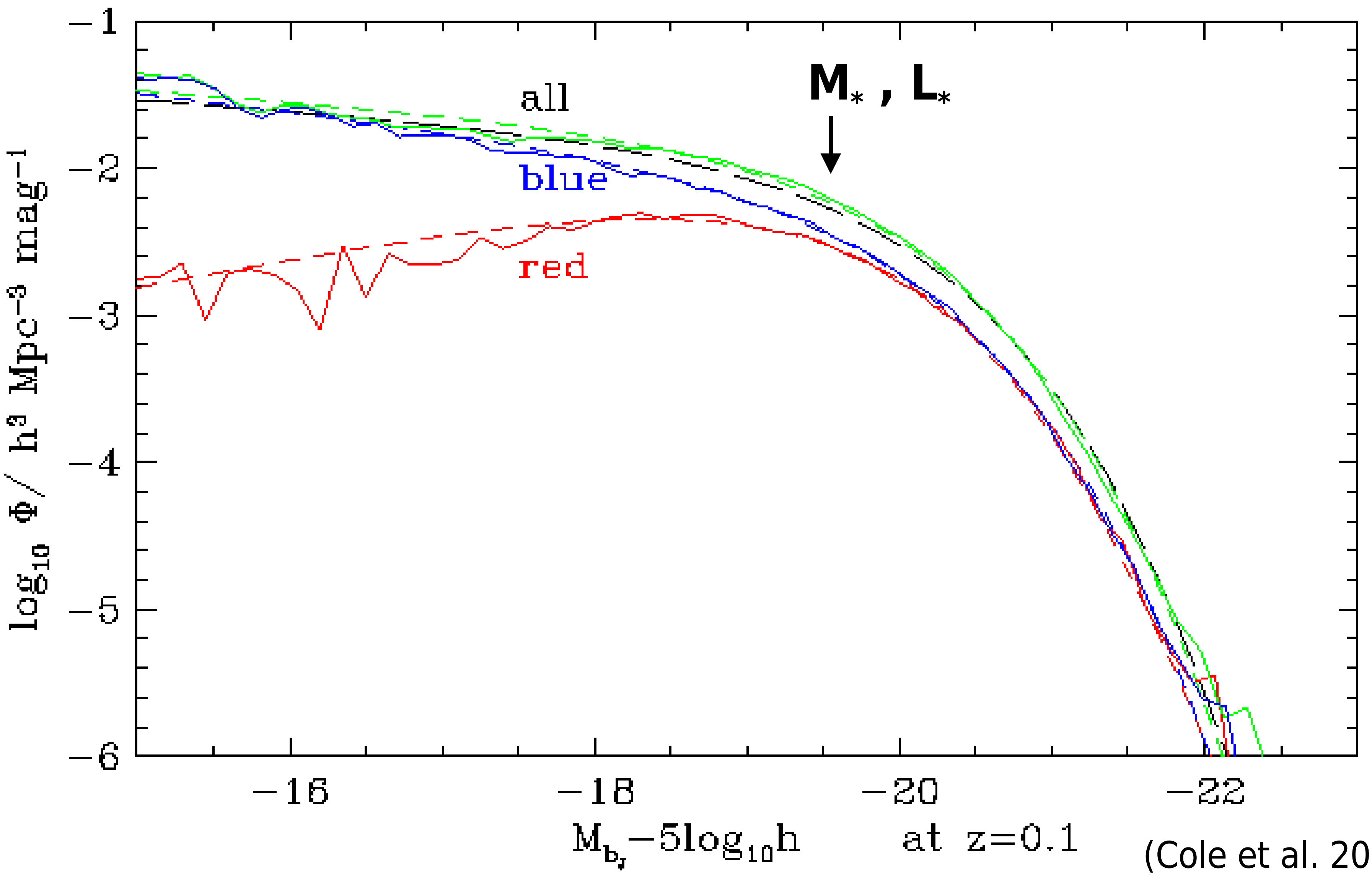
2dF Galaxy Redshift Survey: a short summary

Connection between spectral type and galaxy morphology



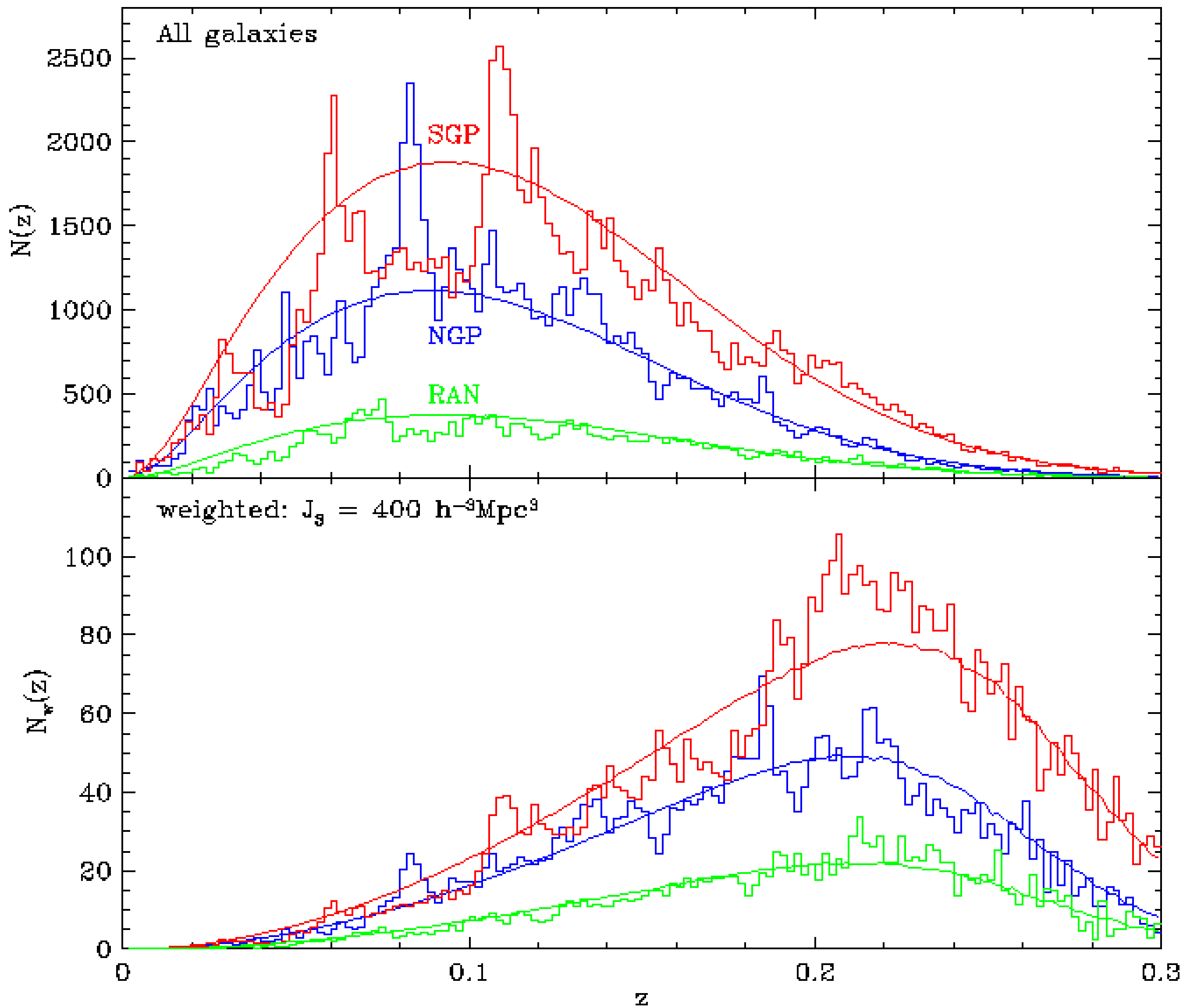
(Norberg et al. 2002a)

2dF Galaxy Redshift Survey: optical galaxy luminosity function



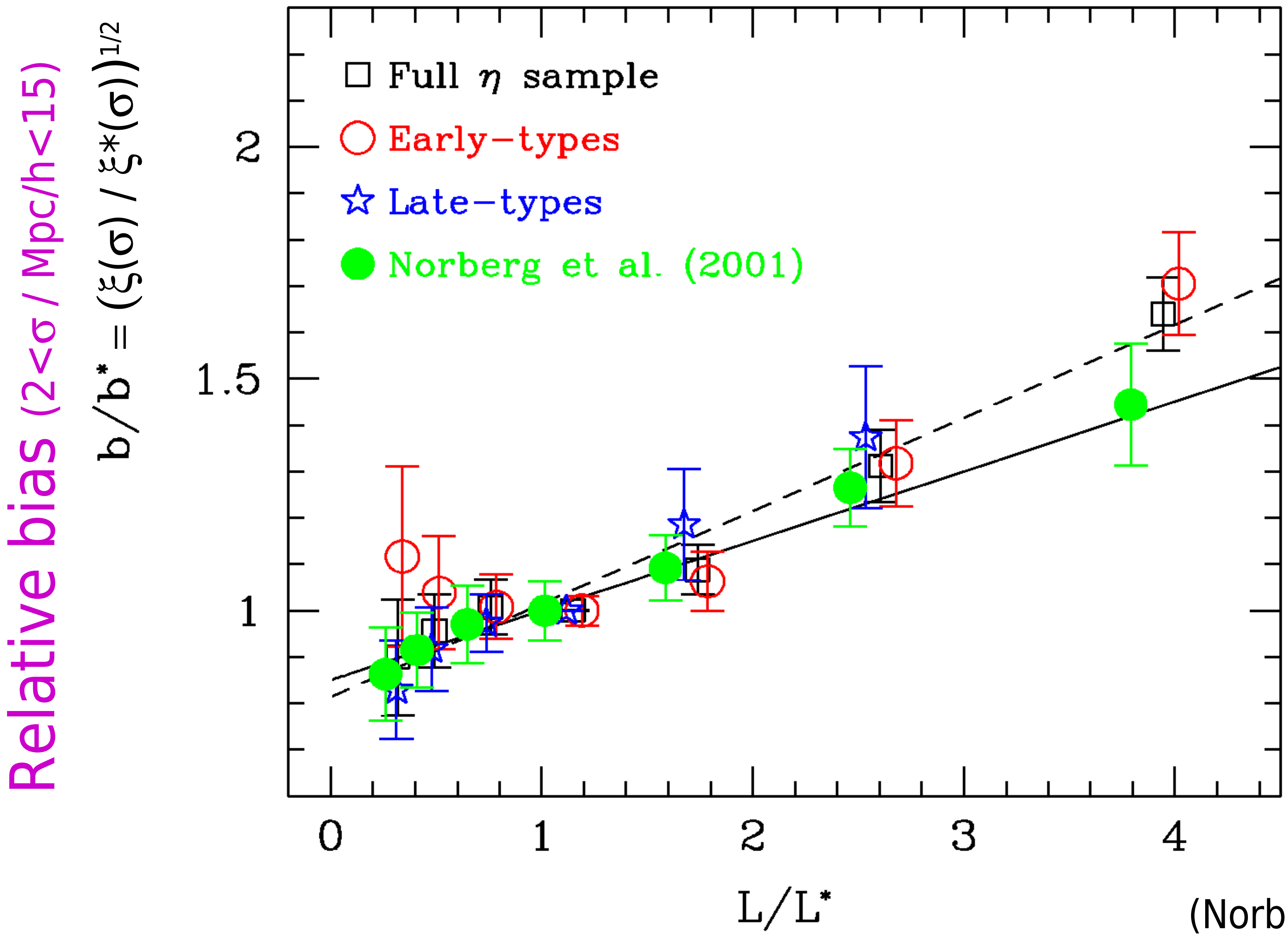
(Cole et al. 2005)

2dF Galaxy Redshift Survey: survey selection function



(Norberg et al. 2002b)

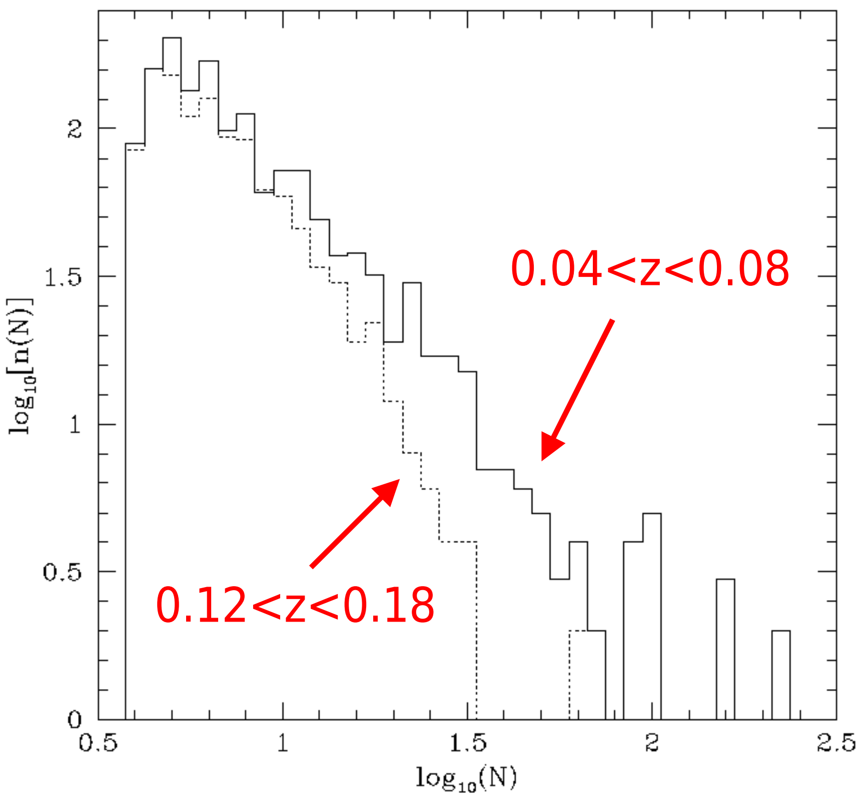
2dF Galaxy Redshift Survey: luminosity & type dependent clustering



(Norberg et al. 2002a)

2dFGRS Percolation Inferred Galaxy Group Catalogue (2PIGG)

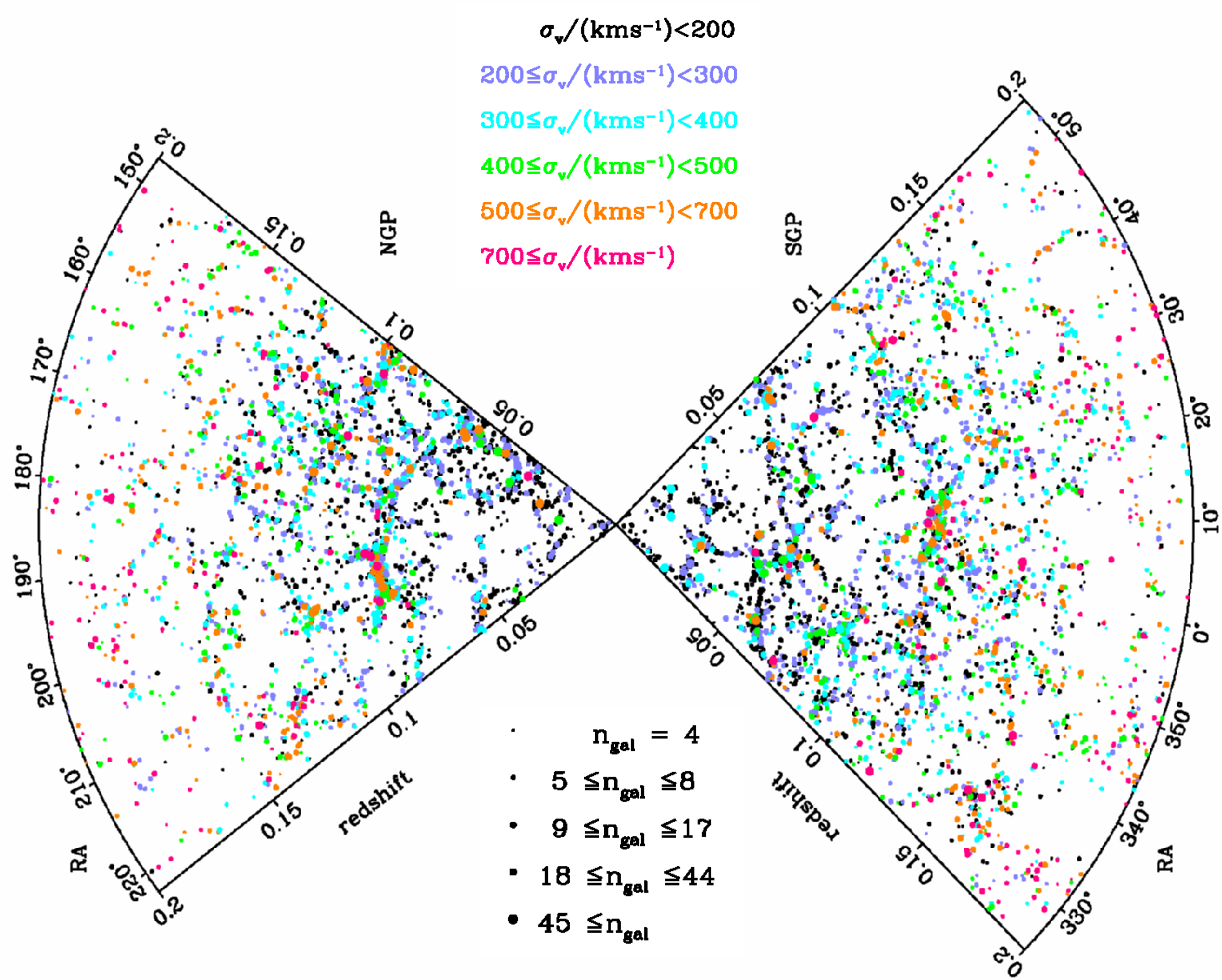
- ~29,000 groups with 2 or more members
- ~7,000 groups with at least 4 members



Weighted Group Number

(Eke et al. 2004)

2dFGRS Percolation Inferred Galaxy Group Catalogue (2PIGG)



Dynamical group mass estimator:

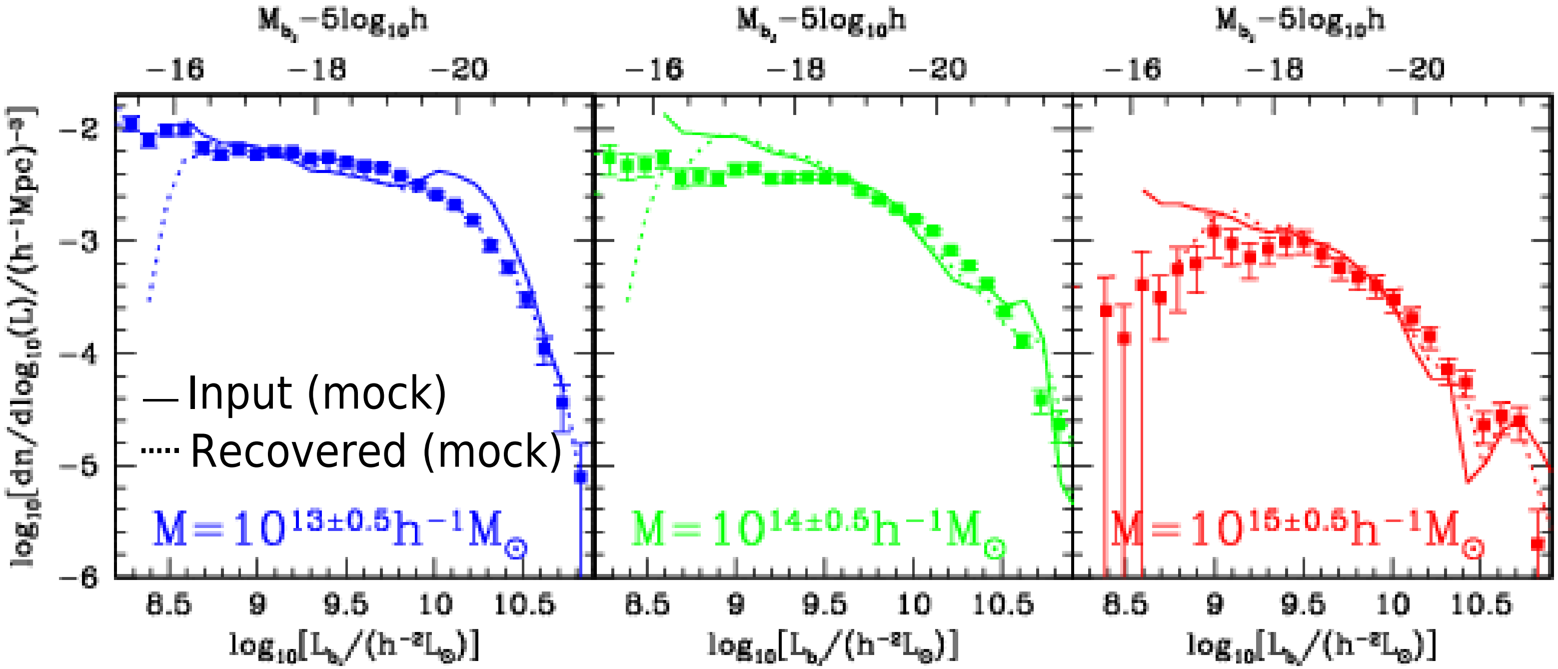
$$\sigma^2 = \sigma_{gap}^2 \left(\frac{N}{N-1} \right) - \sigma_{err}^2$$

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

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

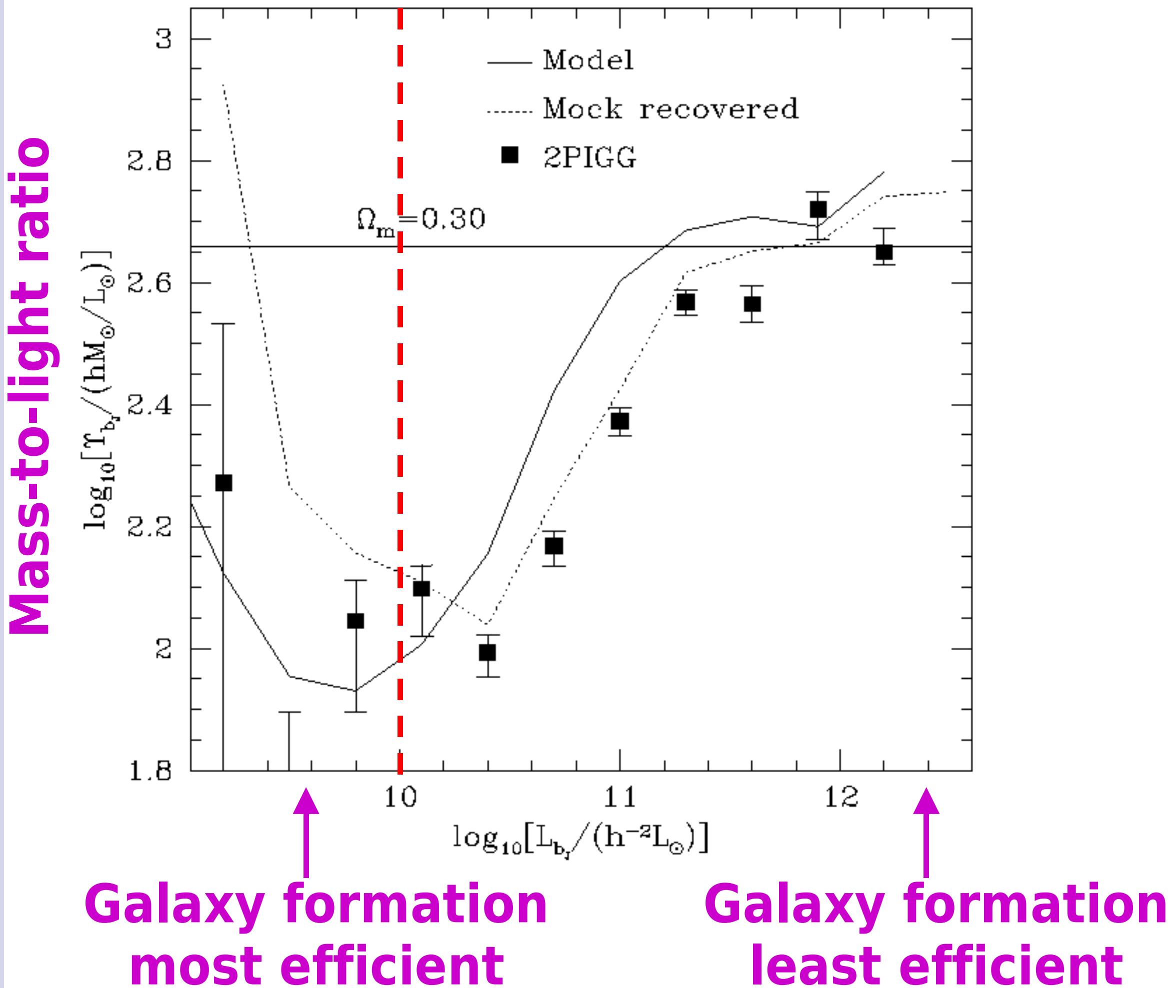
(Eke et al. 2004)

2PIGG Luminosity Functions: split by dynamical group mass



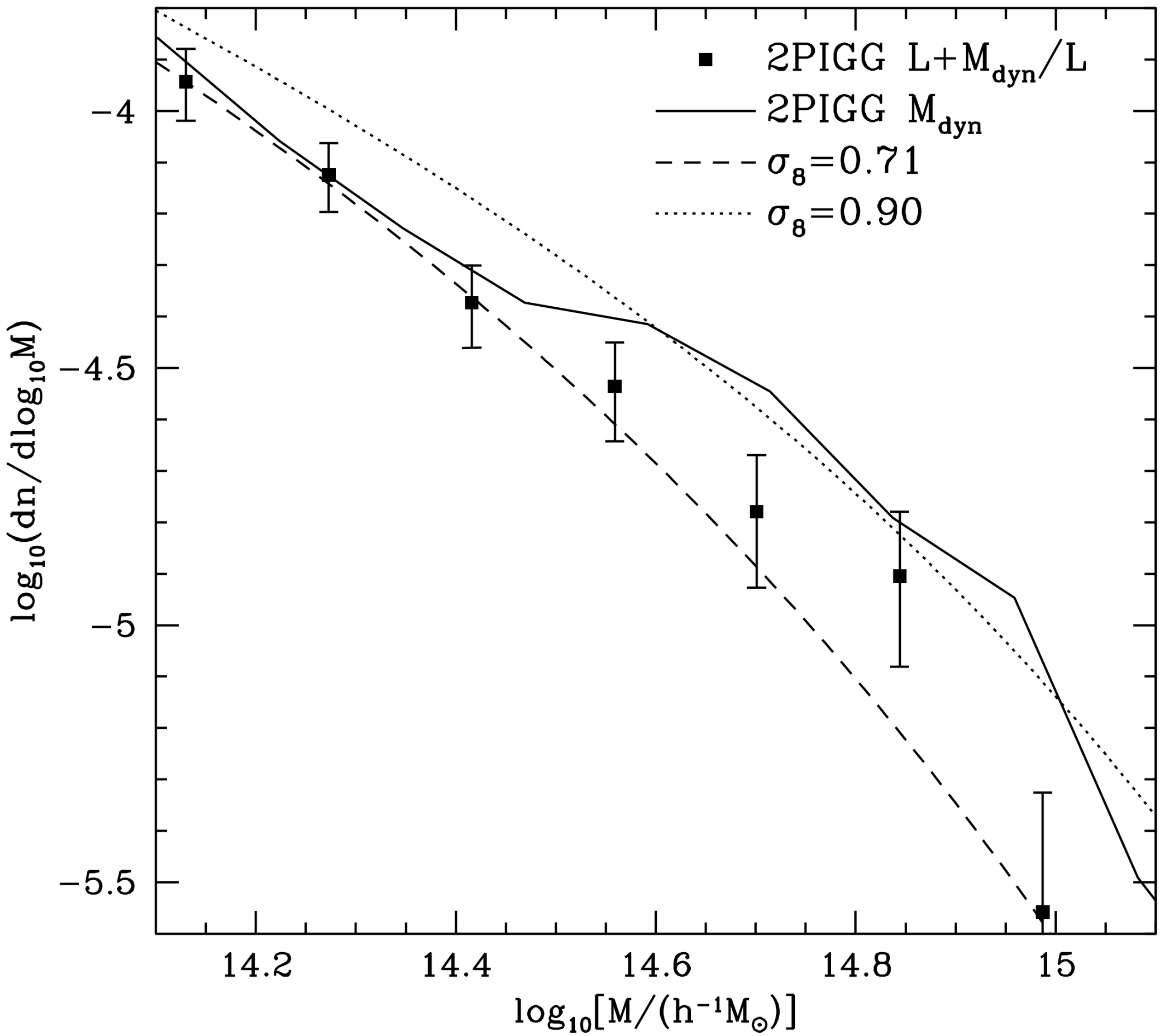
(Eke et al. 2004)

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



(Eke et al. 2004)

2PIGG Group Mass Function: some constraint on ΛCDM…



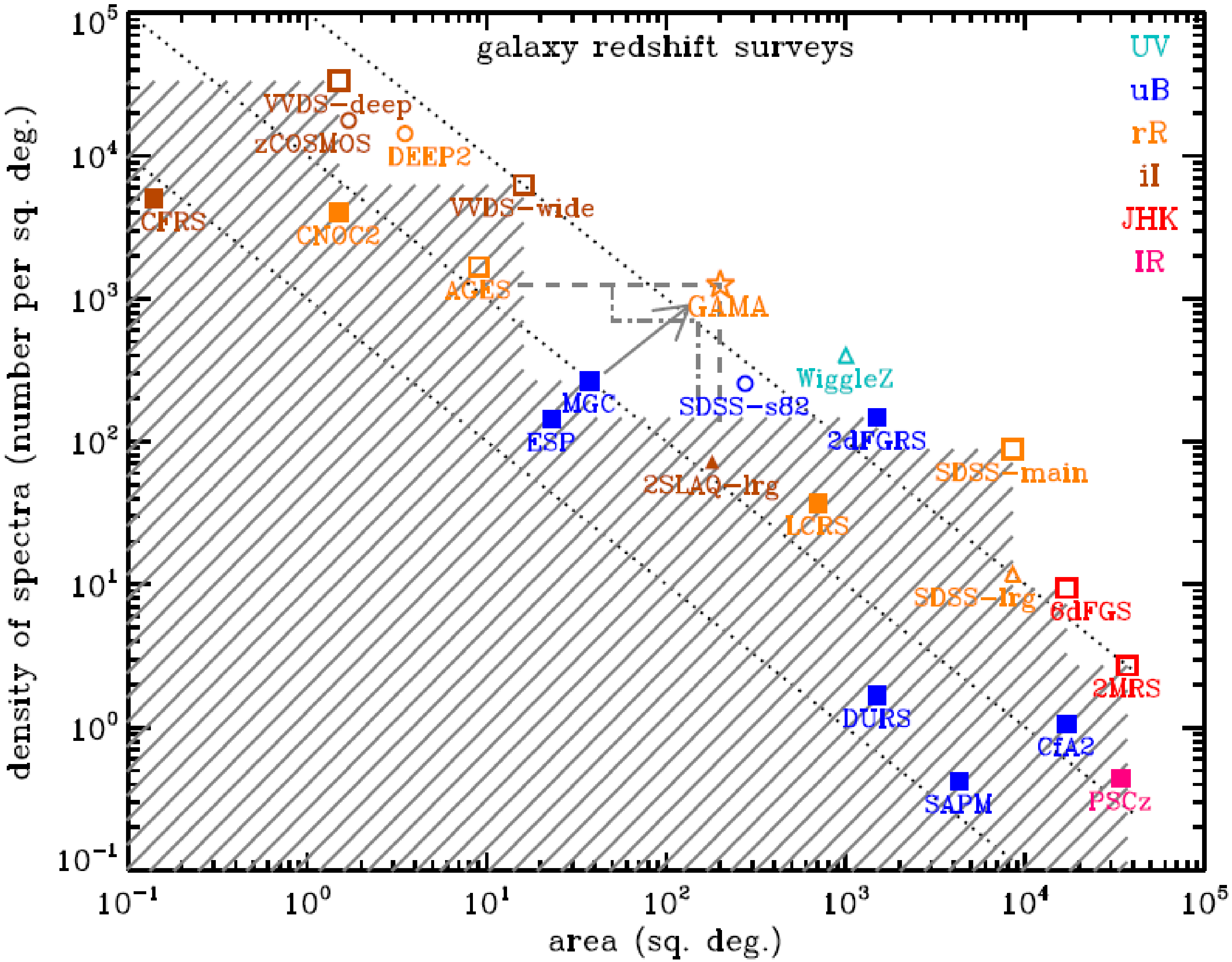
- 2dFGRS (like SDSS): unable to provide any constraints on the CDM halo mass function.
- Too small halo mass range probed!
- Too large influence from error on σ_8 over that halo mass range.

(Eke et al. 2006)

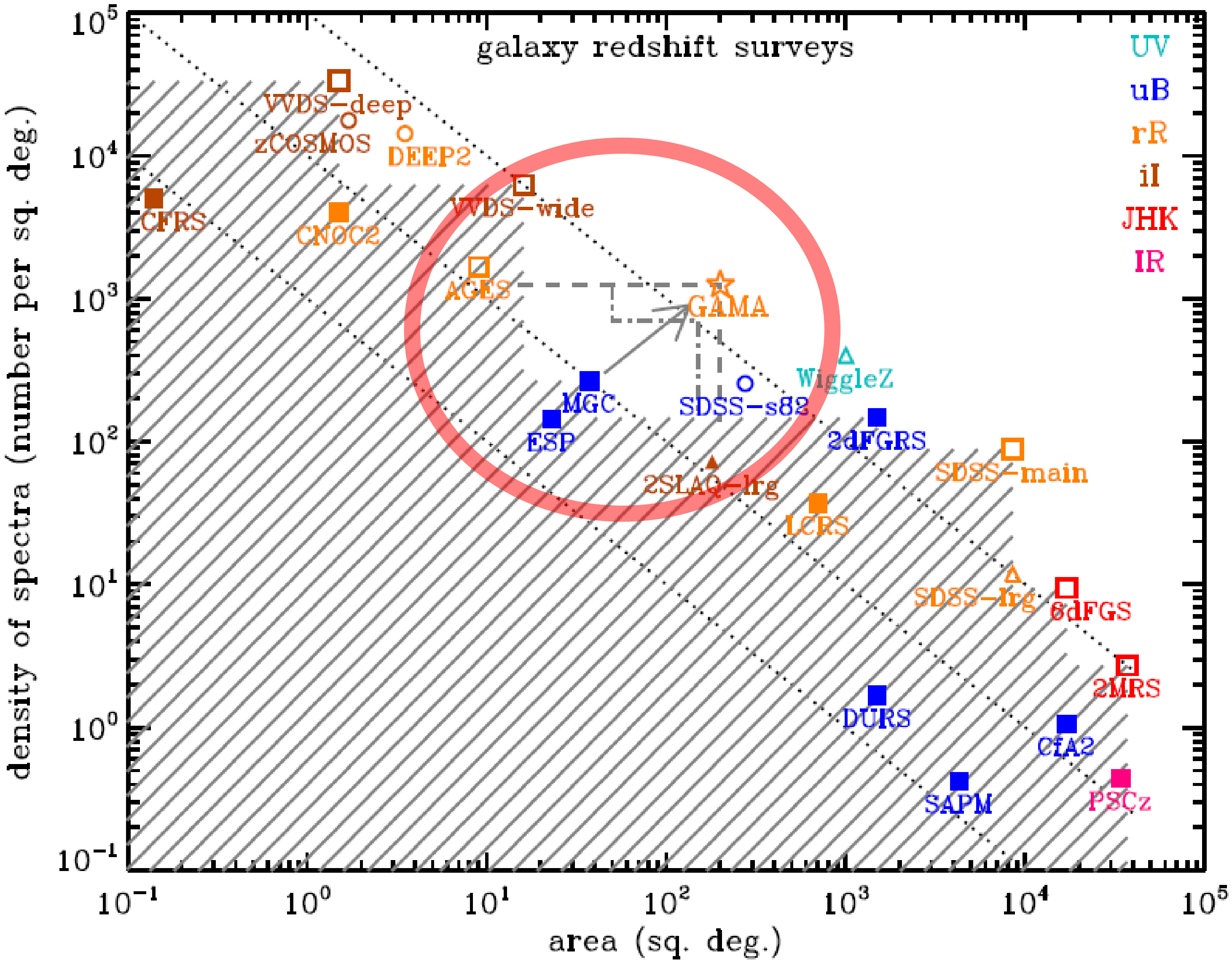
Galaxy And Mass Assembly Survey: the key to a vital CDM model prediction?

- Next generation galaxy redshift survey:
  - ~250,000 galaxy spectra to r~19.8:
    - 2 mag. fainter than SDSS => L* at z~0.35 [~4 Gyr]
  - 250 sq. deg. wide, overlapping with SDSS and 2dFGRS
  - 66 nights on AAOmega over 3 years (2008-2010)
  - large fraction of the survey is also K-band limited
- 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.
- GAMA Team led by S. Driver, with 7 Co-PIs:
  - Baldry, Bamford, Hopkins, Liske, Loveday, Norberg & Peacock
  - ~20 associate members + 5 consortiums (like VISTA/VIKING, ...)

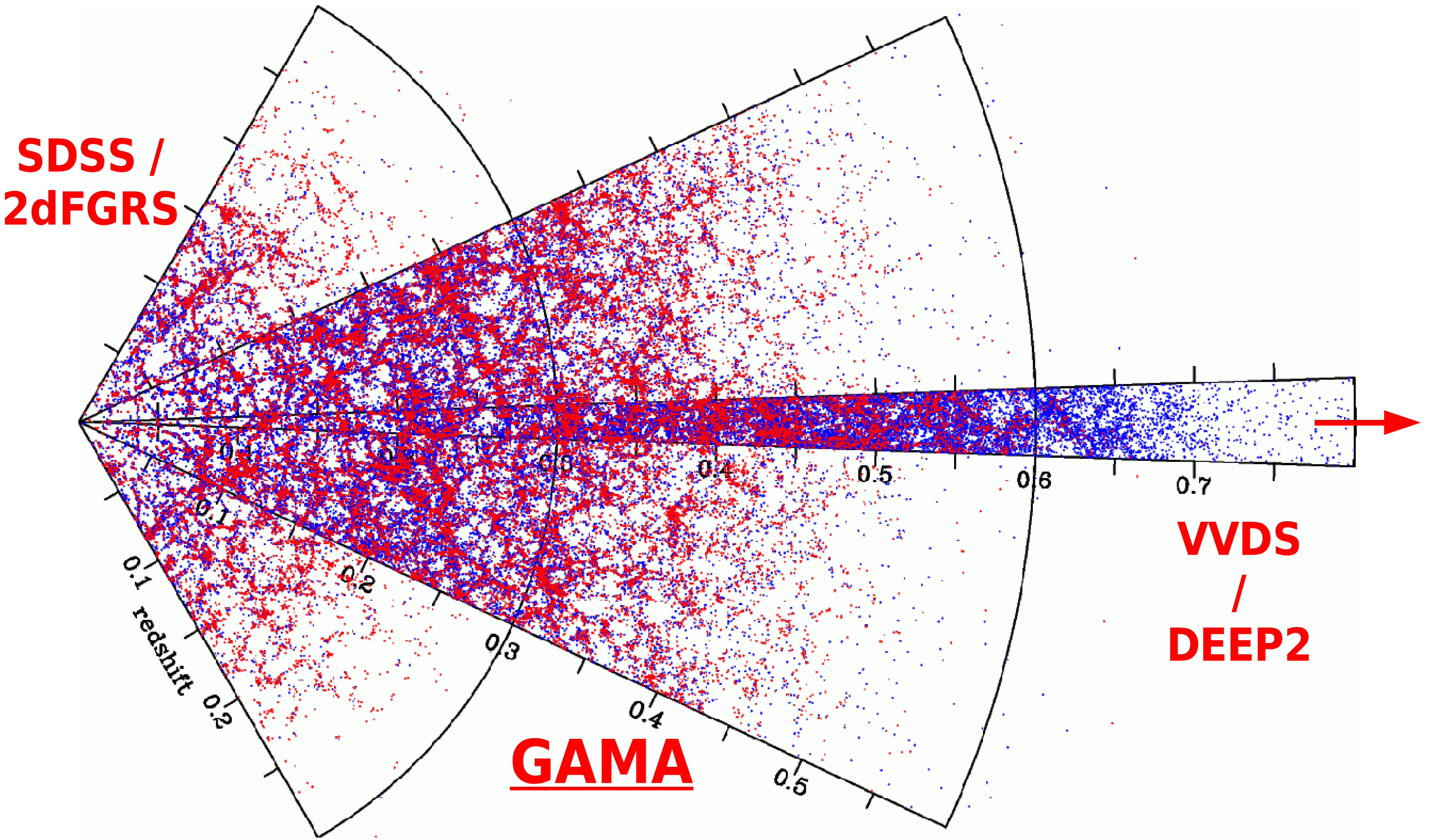
Galaxy And Mass Assembly Survey:
germane connection between shallow-wide & deep-narrow



Galaxy And Mass Assembly Survey:
germane connection between shallow-wide & deep-narrow

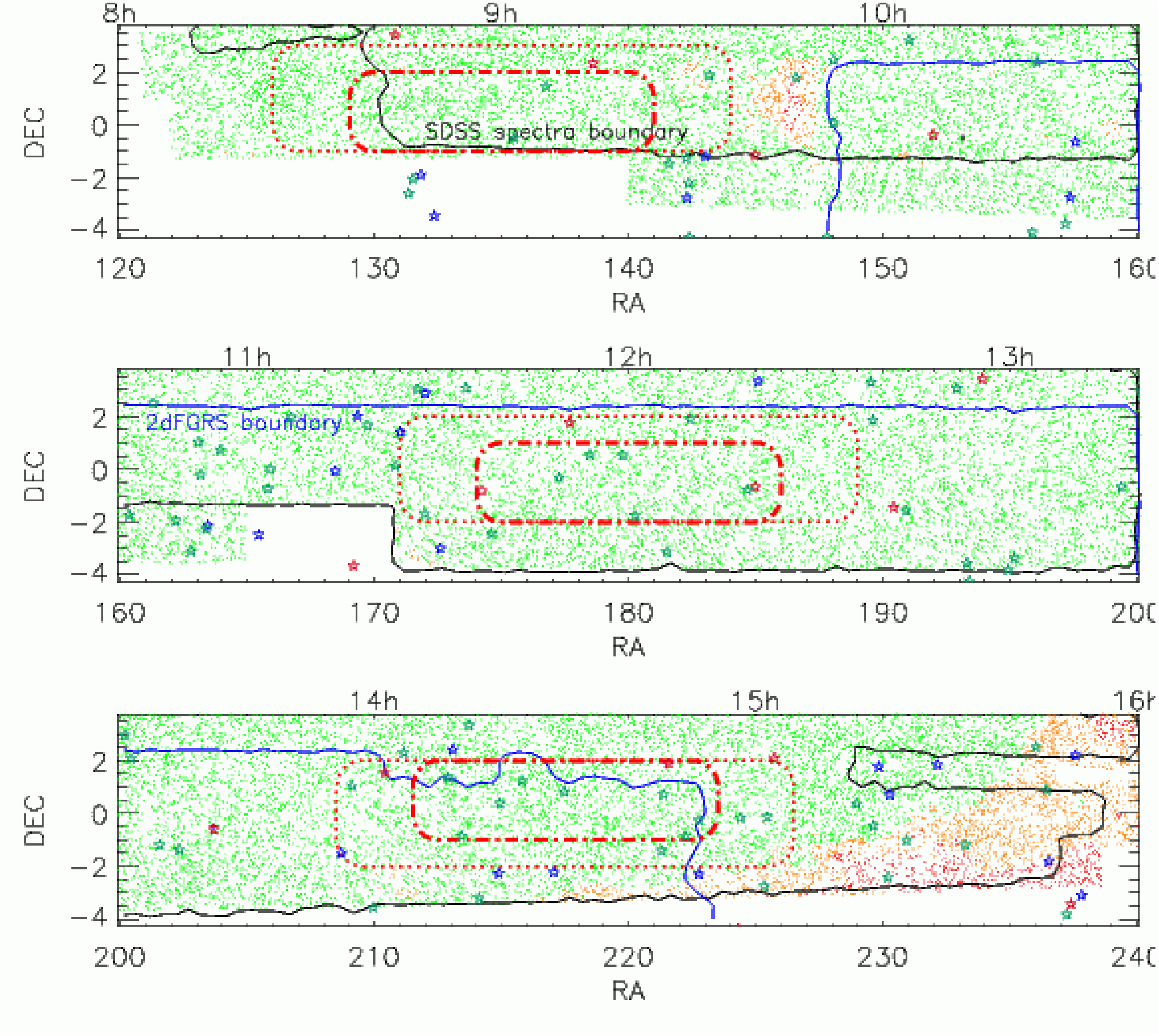


Galaxy And Mass Assembly Survey:
germane connection between shallow-wide & deep-narrow



Peder Norberg   Institute for Astronomy, Royal Observatory Edinburgh   April 2008, Swinburne University

Galaxy And Mass Assembly Survey: where are the fields?



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

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

Couch (Swinburne)
Cross (ROE)
Graham (Swinburne)
Lahav (UCL)
Phillipps (Bristol)
Sharp (AAO)
Tuffs (MPIK)

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

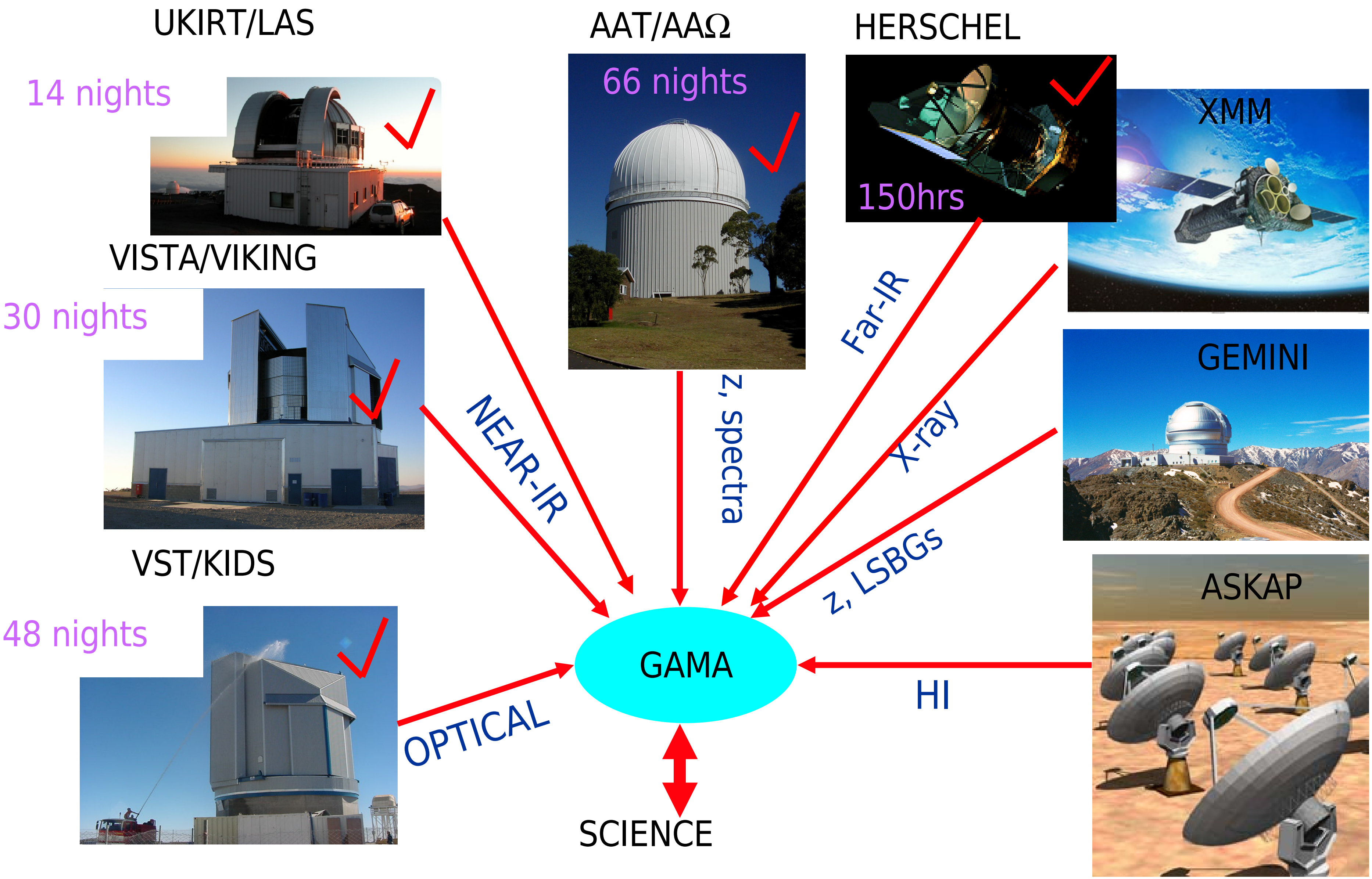
4 PhD students: Cameron (StA), Hill (StA), Parkinson (ROE), Prescott (LJMU)

TEAM AFFILITATIONS

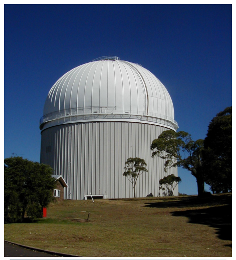
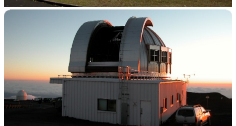
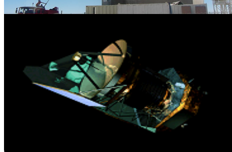
UKIRT/LAS, VST/KIDS, VISTA/VIKING, HERSCHEL-ATLAS, DURHAM ICC

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

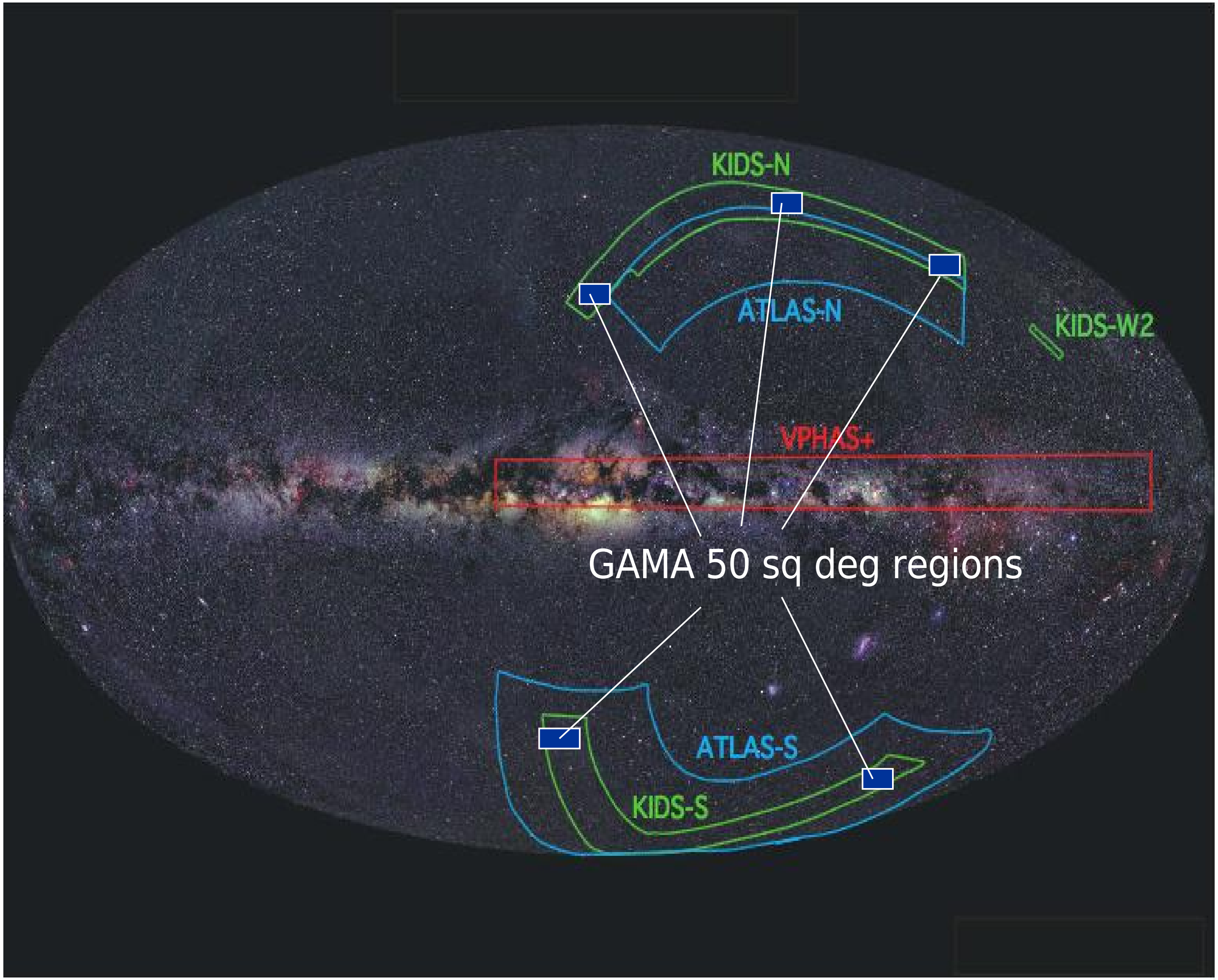
GAMA: Contributing Facilites



GAMA: Follow up observations

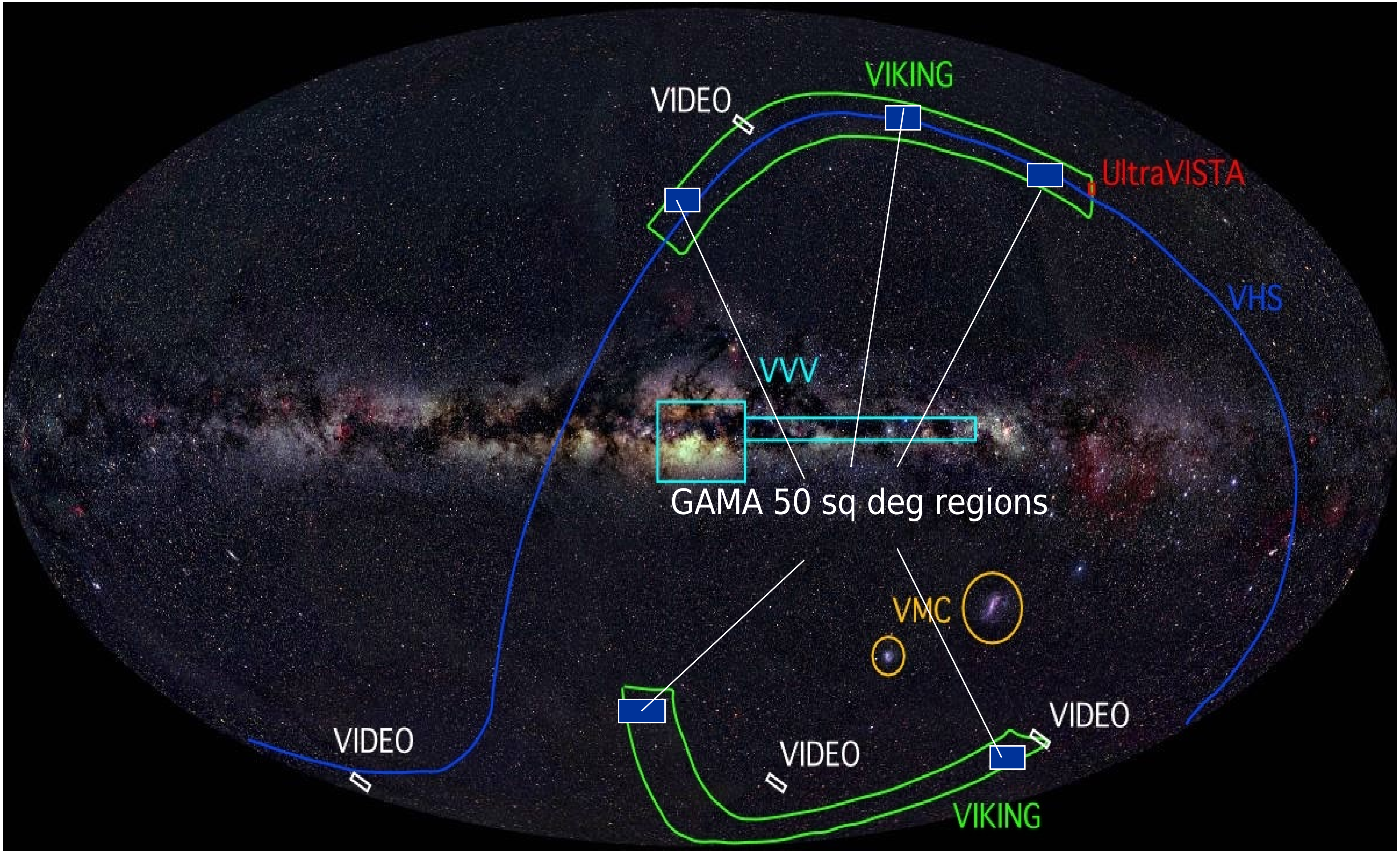
GAMA:	Facility	Wavelength	Time	Depth (on GAMA) (5σ, AB)	Status
	AAT/AAΩ (GAMA I) (GAMA II)	Spectra	66nights ~100nights	r < 19.8, K=19.0 mag	in progress in planification
	UKIRT (LAS)	Near-IR (YJHK)	35nights	Y=22.0, J=20.9, H=20.2, K=20.4	in progress
	VISTA (VIKING)	Near-IR (YJHK)	75nights	Z=23.8, Y=23.0, J=22.8, K=21.9	Mar 09
	VST (VST)	Optical (ugriz)	120nights	u=24.8, g=25.4, r=25.2, i=24.2	Mar 09
	HERSCHEL ATLAS	Far-IR	200hours	100, 160, 250, 350, 500 microns 67, 94, 45, 62, 53 mJy	Mar 09
	XMM	X-Ray	Meeting in Paris (April'08) to discuss 100 sq deg survey		?
	ASKAP DEEP	Radio (21cm)	Meeting in Perth (April'08) to discuss SKA Pathfinders		?

GAMA: Follow up observations
planned VST survey starting March 2009

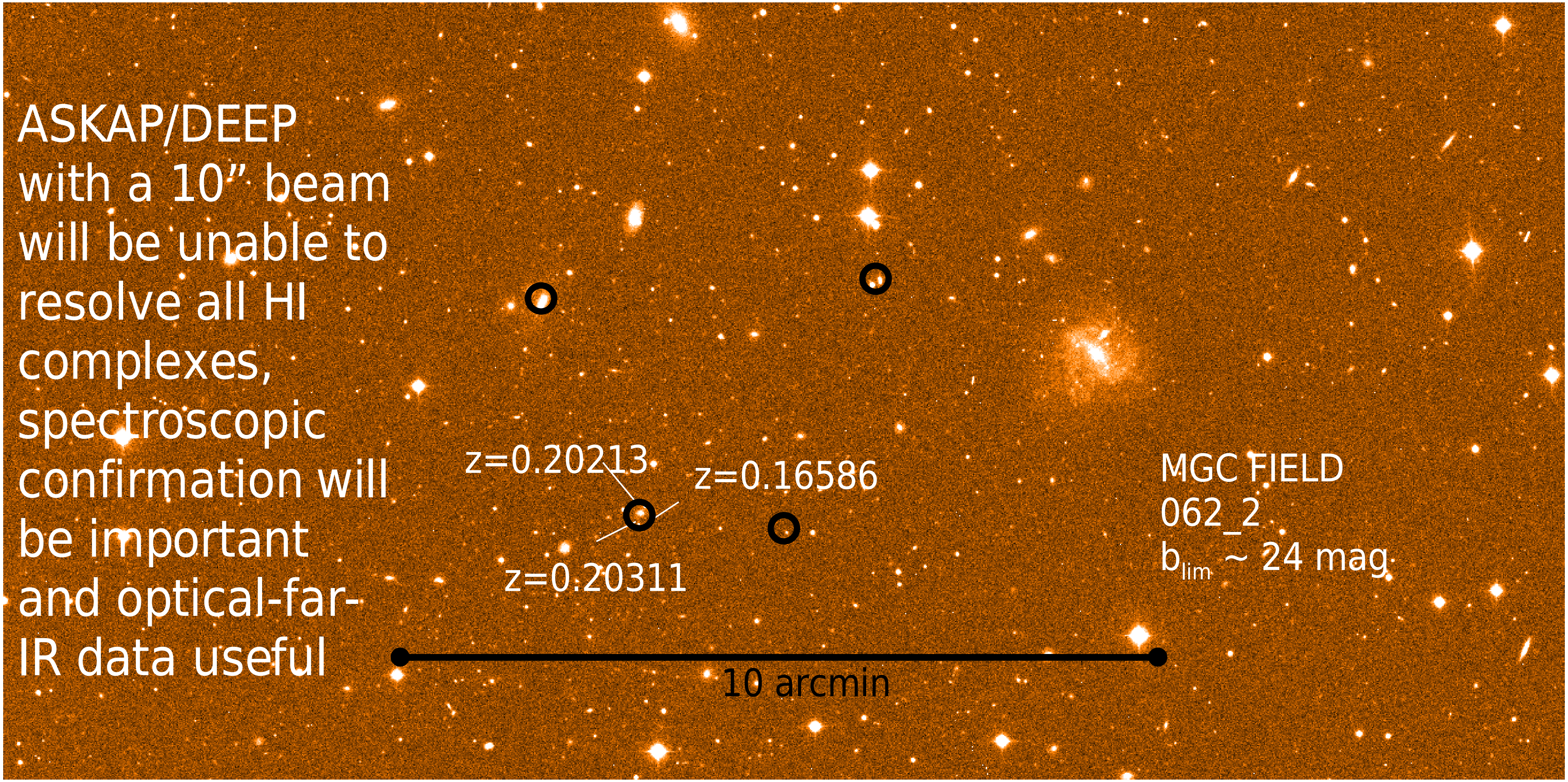


GAMA: Follow up observations

planned VISTA survey starting March 2009



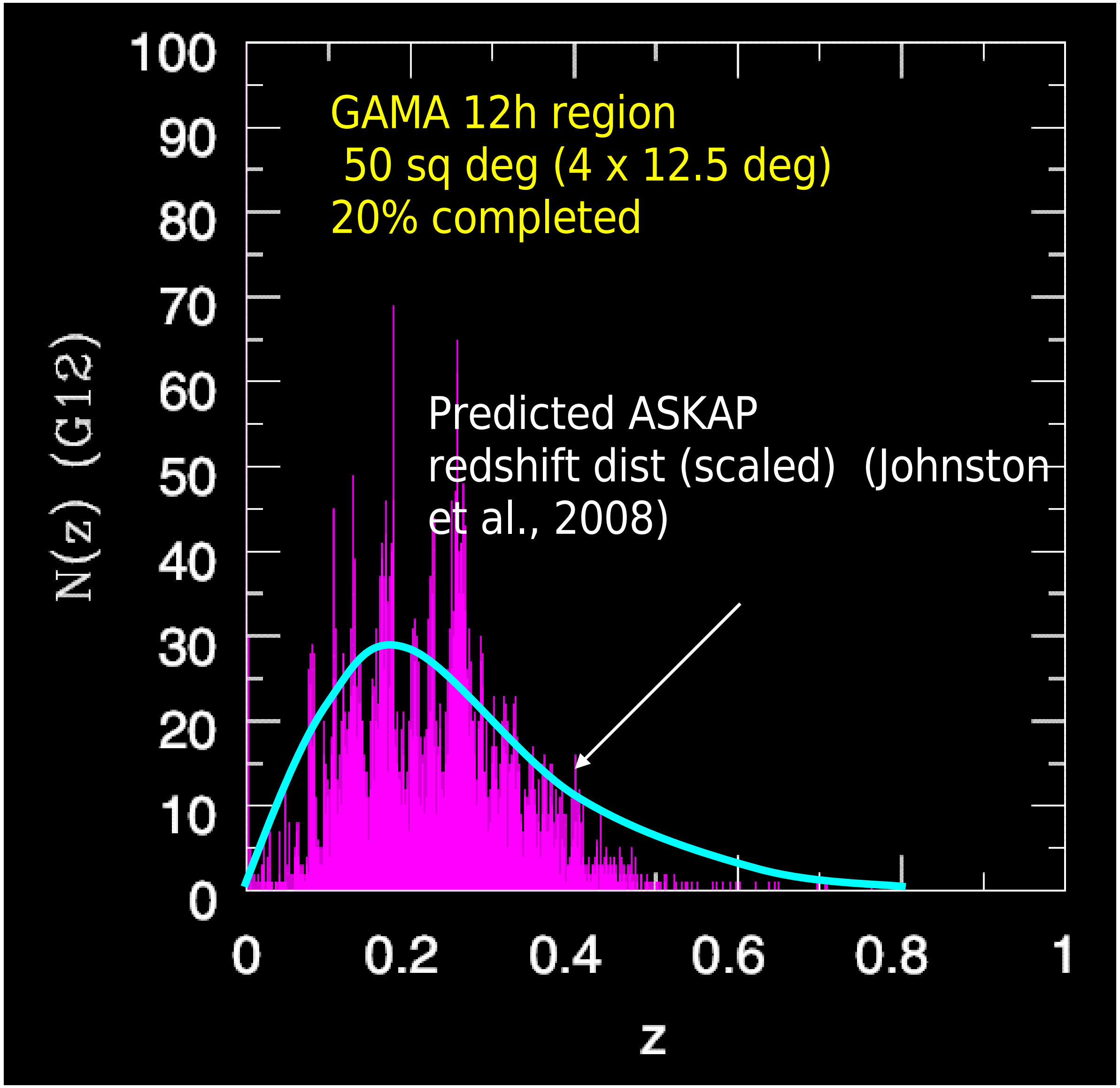
GAMA: Follow up observations
to be proposed ASKAP/Deep...



GAMA: Follow up observations

GAMA 12h proposed for ASKAP Deep Observation

- GAMA depth and area well matched to the proposed ASKAP deep field.



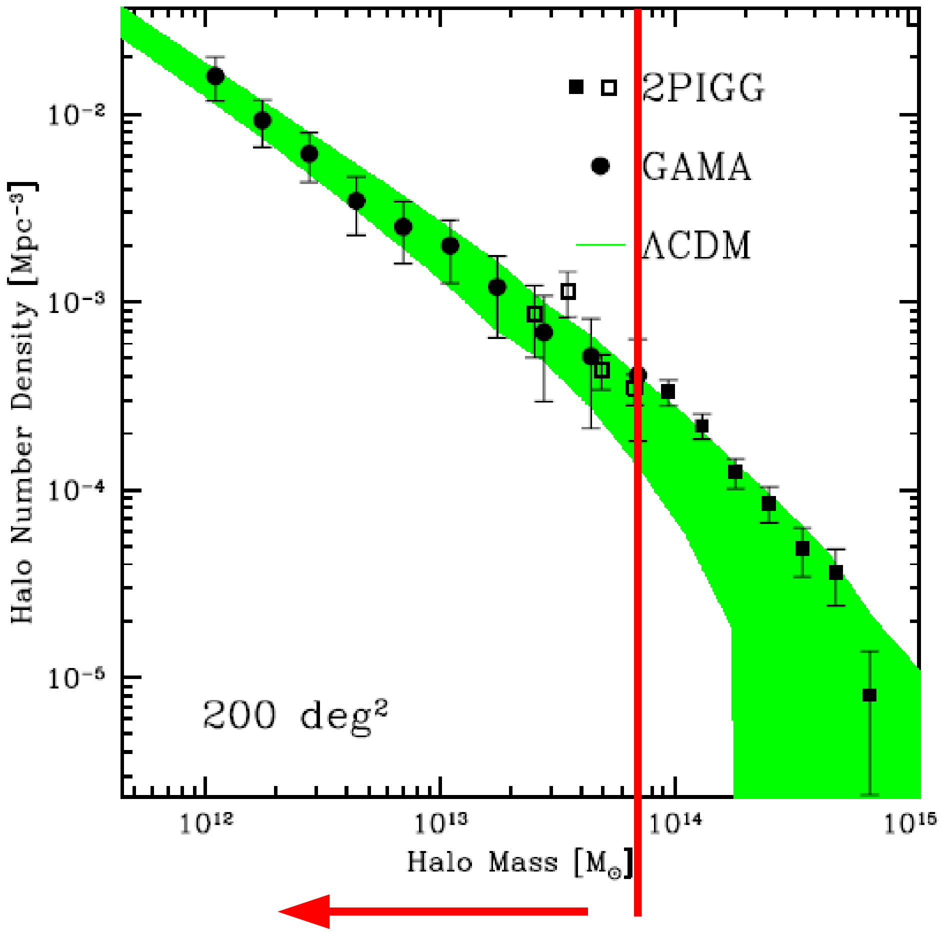
GAMA: Science Goals

- General Aim:
  - **Study the kpc to Mpc scale, where baryon physics is critical**
  - Tracing how “mass” (stars, dust, gas) follows light
  - Provide a definitive low redshift benchmark for JWST and SKA
- Specific science goals:
  - **Determine the CDM Halo Mass function using galaxy groups**
  - Quantify galaxy formation efficiency via group mass-to-light ratios
  - Characterize stellar mass function into the dwarf regime
  - Estimate the HI mass function and associate gas/stellar mass ratios
  - Measure the galaxy merger rate as function of stellar mass ratio
- Provision of a SDSS/2MASS like public database:
  - Optical: ugri (VST), **spectra (AAT)**
  - Near-IR: ZYJHK (VISTA)
  - Far-IR: 100-500 microns (HERSCHEL)
  - Radio: 21cm (ASKAP/DEEP)

GAMA: CDM Mass Function

predictions from semi-analytic galaxy formation models

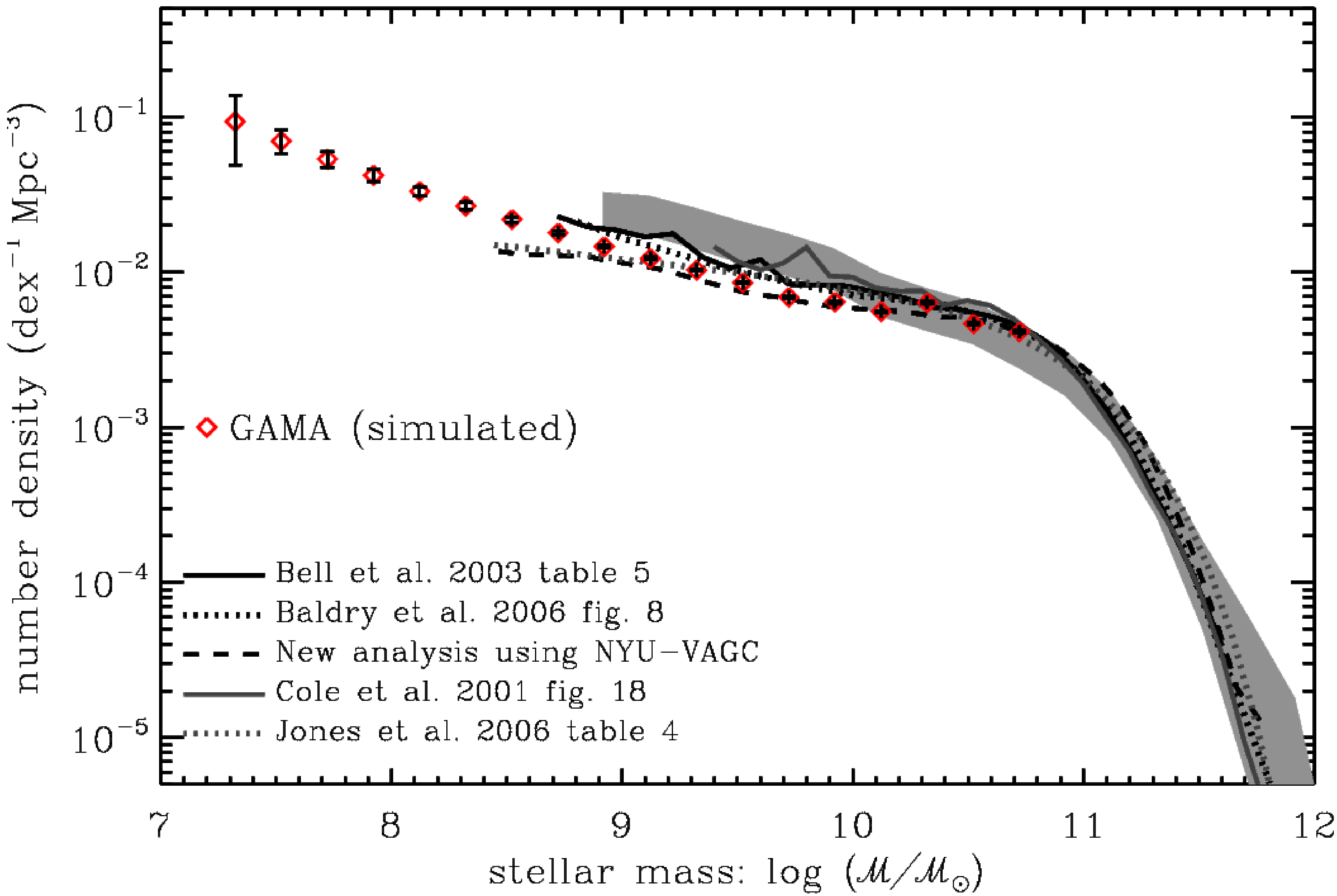
Dark Matter Halo Mass Function



Unprobed so far...

GAMA: Stellar Mass Function

predictions from ....



GAMA: Preliminary Results

after an exceptionally good observing run at the AAT

		A	B	C	D	E	F	G	H	I
G09	X	09_AX 98% (341/347) 100% (327/327)	09_BX 98% (320/325) 98% (344/350)	09_CX 99% (346/350) 97% (316/327)	09_DX 98% (322/327) 99% (346/350)	09_EX 99% (324/327) 99% (346/349)	09_FX 99% (323/327) 99% (346/349)	09_GX 98% (322/327)	09_HX	
	N	09_AN 95% (319/336) 97% (317/326)	09_BN 97% (318/336) 98% (321/326)	09_CN 95% (325/341) 98% (324/331)	09_DN 97% (318/327) 99% (340/342)	09_EN 98% (321/327) 98% (335/342)	09_FN 99% (326/327) 96% (329/342)	09_GN 99% (337/341) 91% (312/342)	09_HN 99% (339/341) 98% (317/325)	09_IN 95% (311/326) 88% (299/339)
	S	09_AS 97% (313/322) 99% (335/339)	09_BS 98% (315/322) 88% (301/344)	09_CS 98% (322/327) 99% (339/342)	09_DS 98% (335/341) 100% (327/328)	09_ES 99% (339/341) 99% (325/328)	09_FS 99% (338/341) 99% (327/328)	09_GS 95% (312/327) 99% (324/329)	09_HS 92% (313/339) 96% (316/328)	09_IS 93% (316/339) 97% (328/339)
G12	X	12_AX 98% (344/350) 99% (325/327)	12_BX 99% (323/325) 99% (348/350)	12_CX 99% (346/350) 98% (322/327)	12_DX 98% (320/327) 98% (344/350)	12_EX 97% (339/349) 97% (338/349)	12_FX 99% (323/327) 98% (342/349)	12_GX	12_HX	
	N	12_AN 91% (298/322)	12_BN 97% (332/341) 99% (340/342)	12_CN 96% (317/327) 99% (325/328)	12_DN 96% (327/341) 99% (324/328)	12_EN 99% (323/326) 93% (317/342)	12_FN 88% (297/339) 95% (313/328)	12_GN 96% (324/339) 95% (310/328)	12_HN 98% (331/339) 97% (333/342)	12_IN 97% (330/339) 99% (325/328)
	D	12_AD: 86% (289/336) 75% (244/326)	12_BD 91% (295/322) 95% (311/326)	12_CD 95% (323/341) 95% (324/342)	12_DD 98% (322/327) 94% (308/328)	12_ED 98% (333/341) 95% (312/328)	12_FD 94% (322/341) 89% (305/342)	12_GD 93% (304/327) 97% (319/328)	12_HD 97% (316/327) 96% (313/325)	12_ID 90% (311/341) 92% (291/318)
	S	12_AS 91% (294/322) 97% (332/344)	12_BS 99% (323/327) 98% (336/342)	12_CS 98% (321/327) 97% (332/344)	12_DS 99% (323/326) 96% (330/342)	12_ES 96% (331/340) 97% (321/331)	12_FS 94% (320/339) 98% (320/328)	12_GS 97% (317/326) 98% (336/342)	12_HS 99% (324/326) 96% (328/342)	12_IS 98% (324/329) 97% (328/339)
G15	N	15_AN 86% (282/328) 98% (336/342)	15_BN 99% (338/341) 98% (336/342)	15_CN 98% (321/327) 98% (320/325)	15_DN 83% (271/326) 98% (340/347)	15_EN 98% (318/326) 99% (342/347)	15_FN 98% (336/342) 100% (323/324)	15_GN 98% (336/342) 100% (323/324)	15_HN 98% (322/328) 98% (341/347)	15_IN 98% (321/328) 99% (345/350)
	S	15_AS 94% (317/336) 97% (317/328)	15_BS 98% (333/341) 97% (319/328)	15_CS 99% (338/341) 100% (347/347)	15_DS 98% (331/339) 85% (274/324)	15_ES 95% (310/326) 99% (344/347)	15_FS 97% (319/329) 99% (322/324)	15_GS 98% (335/342) 100% (349/350)	15_HS 98% (336/342) 87% (281/324)	15_IS 94% (320/342) 98% (322/327)
	X	15_AX 99% (345/350) 95% (308/324)	15_BX 100% (326/327) 98% (343/349)	15_CX 99% (324/327) 99% (344/349)	15_DX	15_EX	15_FX	15_GX 98% (322/327)		

GAMA: Preliminary Results

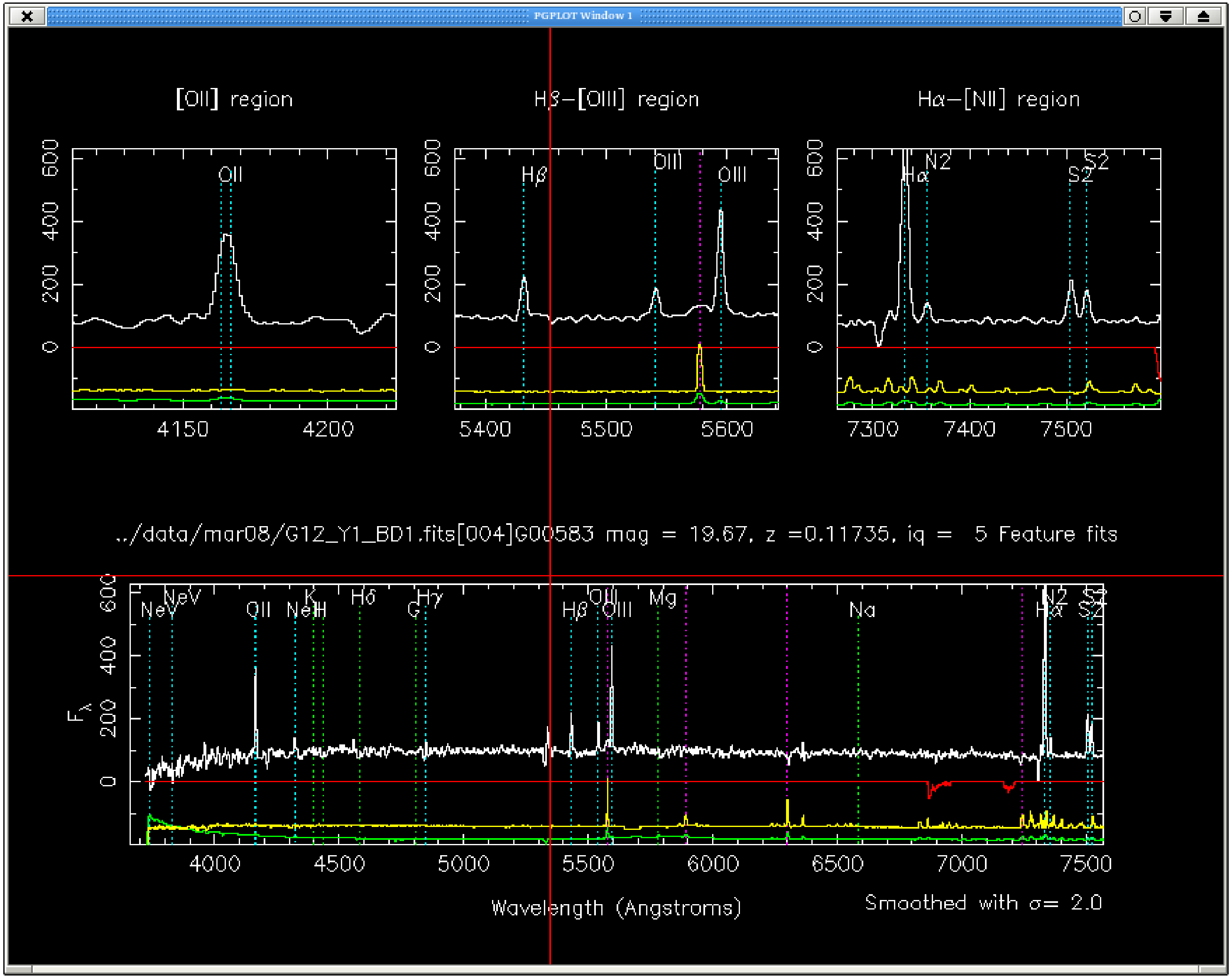
after an exceptionally good observing run at the AAT

```
Sat Apr  5 21:37:22 CEST 2008

159 observations

total: 50746 out of 52557: 96.55%
  jol: 15494 out of 15835: 97.85%
  dth:  5653 out of  5881: 96.12%
  spd:  4924 out of  5266: 93.51%
  evk:  4791 out of  4957: 96.65%
 iprn:  4253 out of  4354: 97.68%
  mxp:  4122 out of  4322: 95.37%
  jon:  4132 out of  4309: 95.89%
  hrp:  3898 out of  3995: 97.57%
  amh:  3209 out of  3318: 96.71%
  rgs:   270 out of   320: 84.38%

Q = 0     1     2     3     4     5     6
   10   126  1675  4450 45099  1077   120
```

		A	H	I
G09	X	09_AX 98% (341/347) 100% (327/327)	09_HX	
	N	09_AN 95% (319/336) 97% (317/326)	09_HN 99% (339/341) 98% (317/325)	09_IN 95% (311/326) 88% (299/339)
	S	09_AS 97% (313/322) 99% (335/339)	09_HS 92% (313/339) 96% (316/328)	09_IS 93% (316/339) 97% (328/339)
G12	X	12_AX 98% (344/350) 99% (325/327)	12_HX	
	N	12_AN 91% (298/322)	12_HN 98% (331/339) 97% (333/342)	12_IN 97% (330/339) 99% (325/328)
	D	12_AD: 86% (289/336) 75% (244/326)	12_HD 97% (316/327) 96% (313/325)	12_ID 90% (311/341) 92% (291/318)
	S	12_AS 91% (294/322) 97% (332/344)	12_HS 99% (324/326) 96% (328/342)	12_IS 98% (324/329) 97% (328/339)
G15	N	15_AN 86% (282/328) 98% (336/342)	15_HN 98% (322/328) 98% (341/347)	15_IN 98% (321/328) 99% (345/350)
	S	15_AS 94% (317/336) 97% (317/328)	15_HS 98% (336/342) 87% (281/324)	15_IS 94% (320/342) 98% (322/327)
	X	15_AX 99% (345/350) 95% (308/324)		

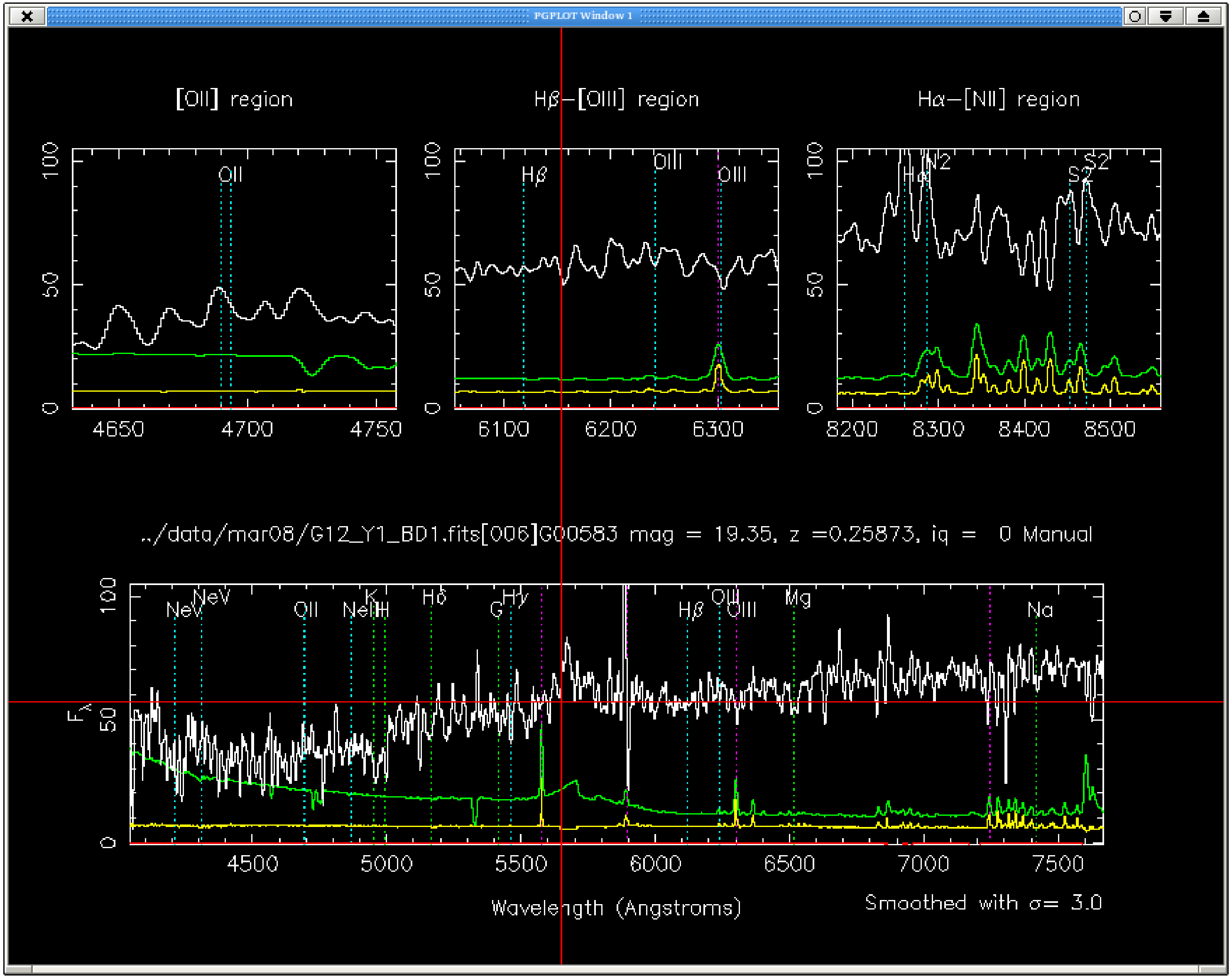
GAMA: Preliminary Results

after an exceptionally good observing run at the AAT



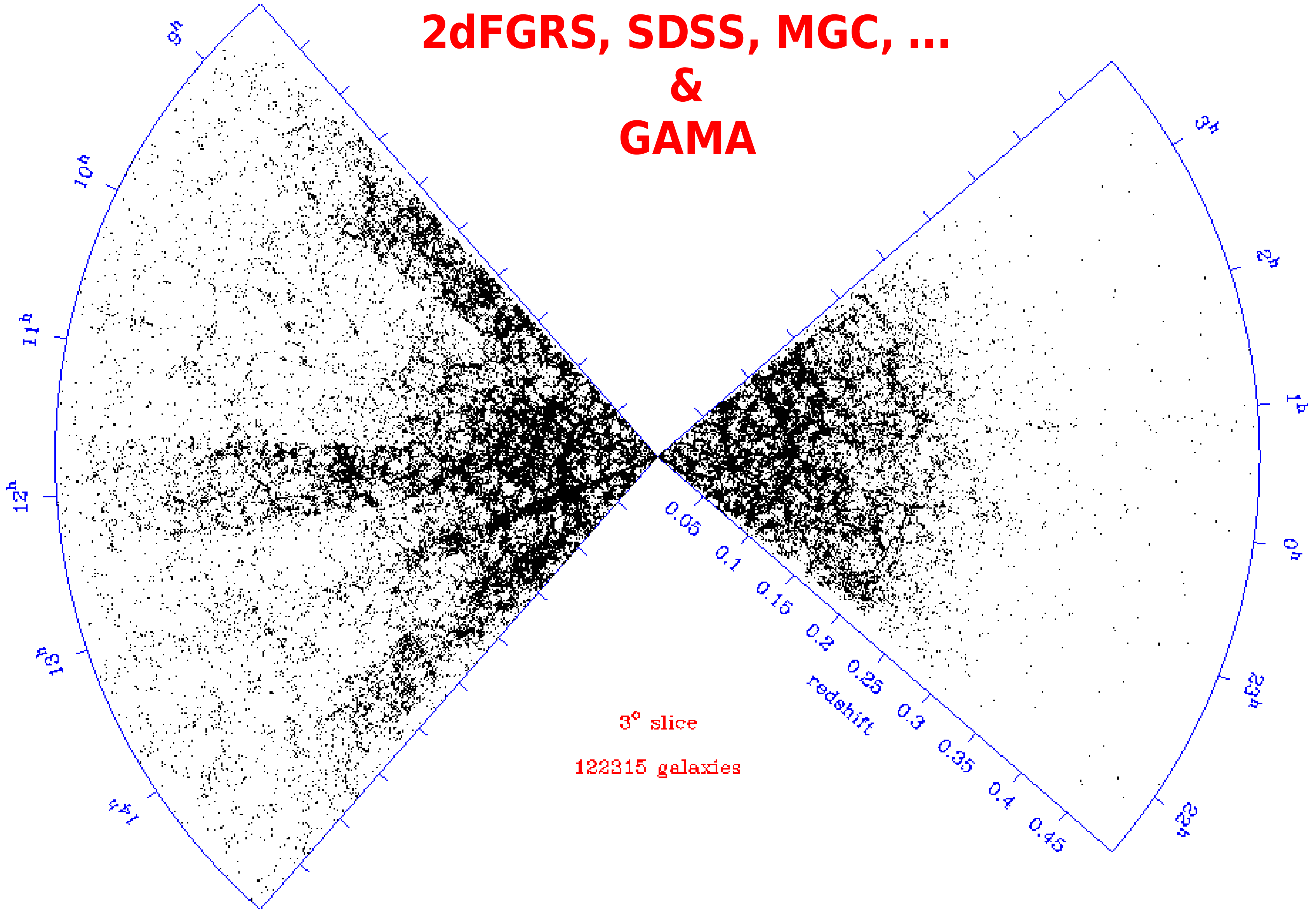
GAMA: Preliminary Results

after an exceptionally good observing run at the AAT

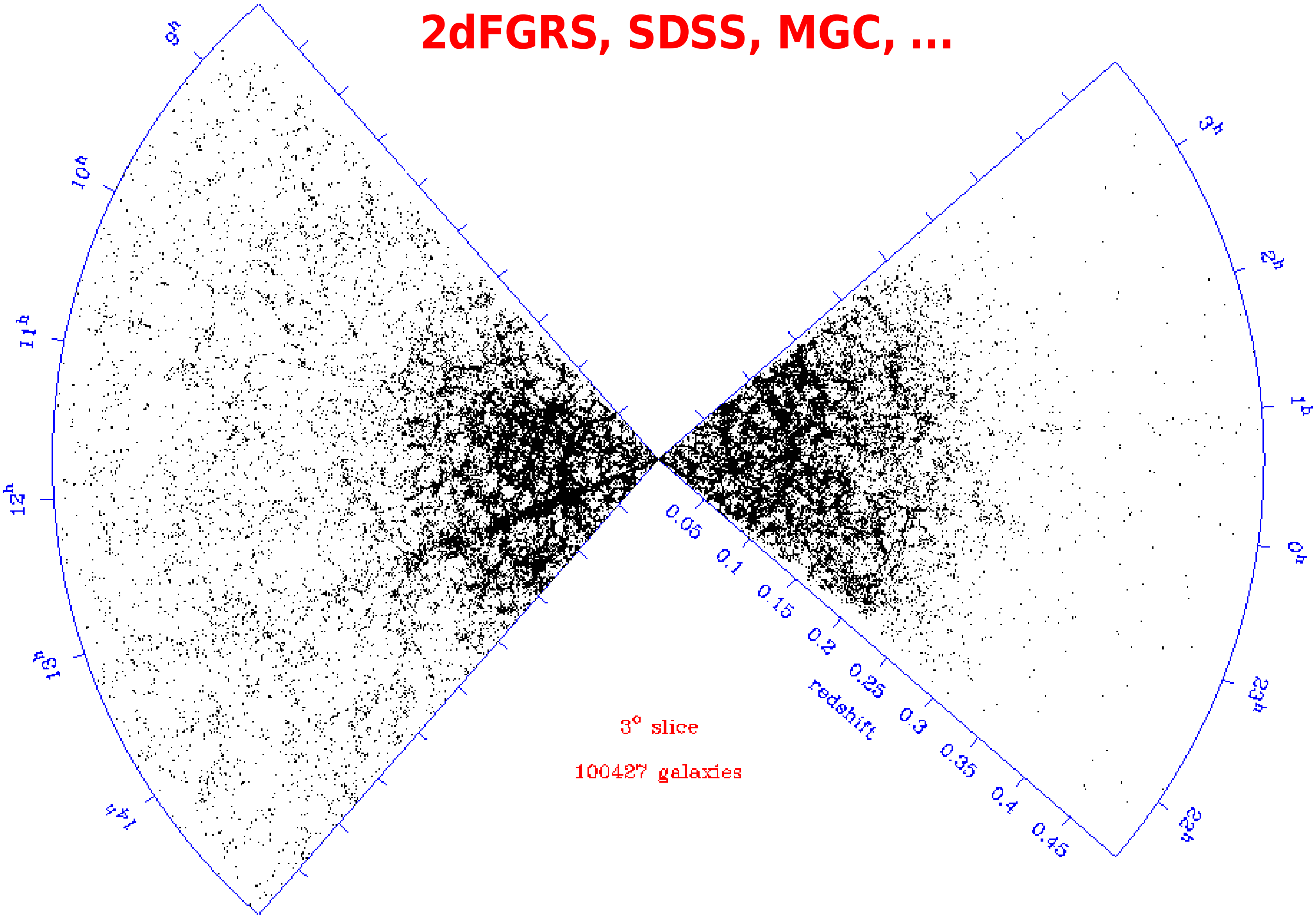


Spectras in bad conditions ...

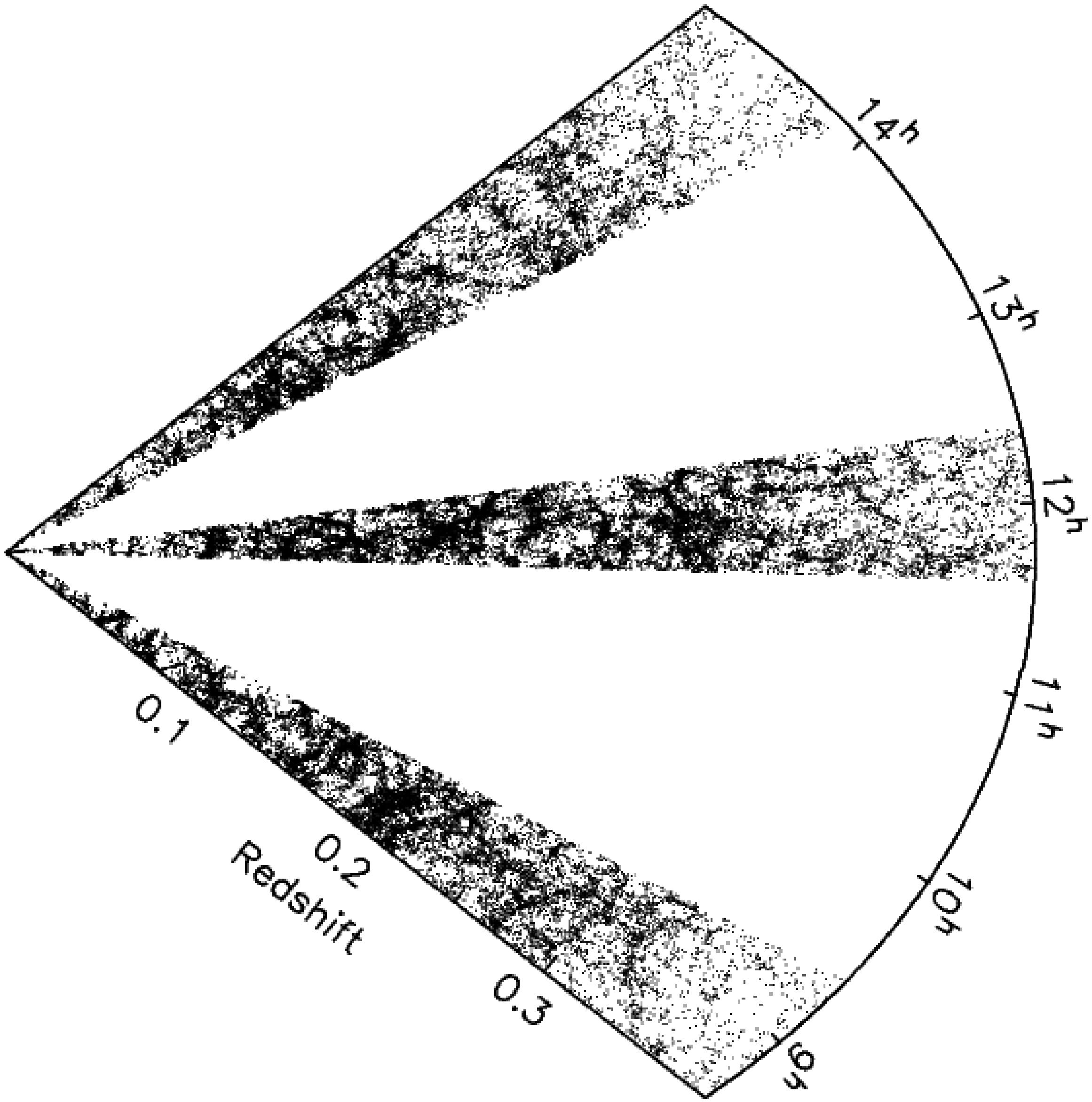
GAMA: Preliminary Results
tracing in detail the large scale structure



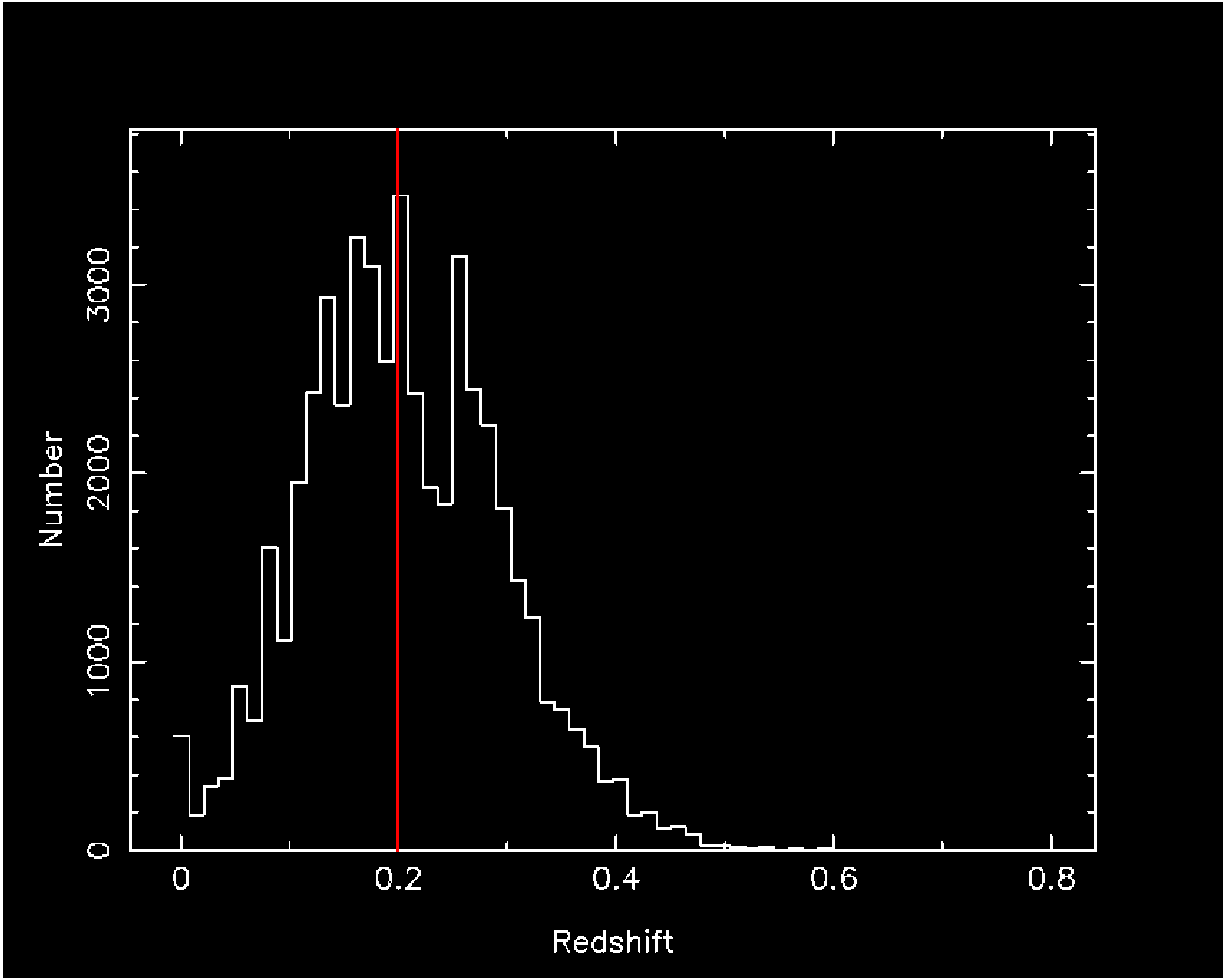
GAMA: Preliminary Results
tracing in detail the large scale structure



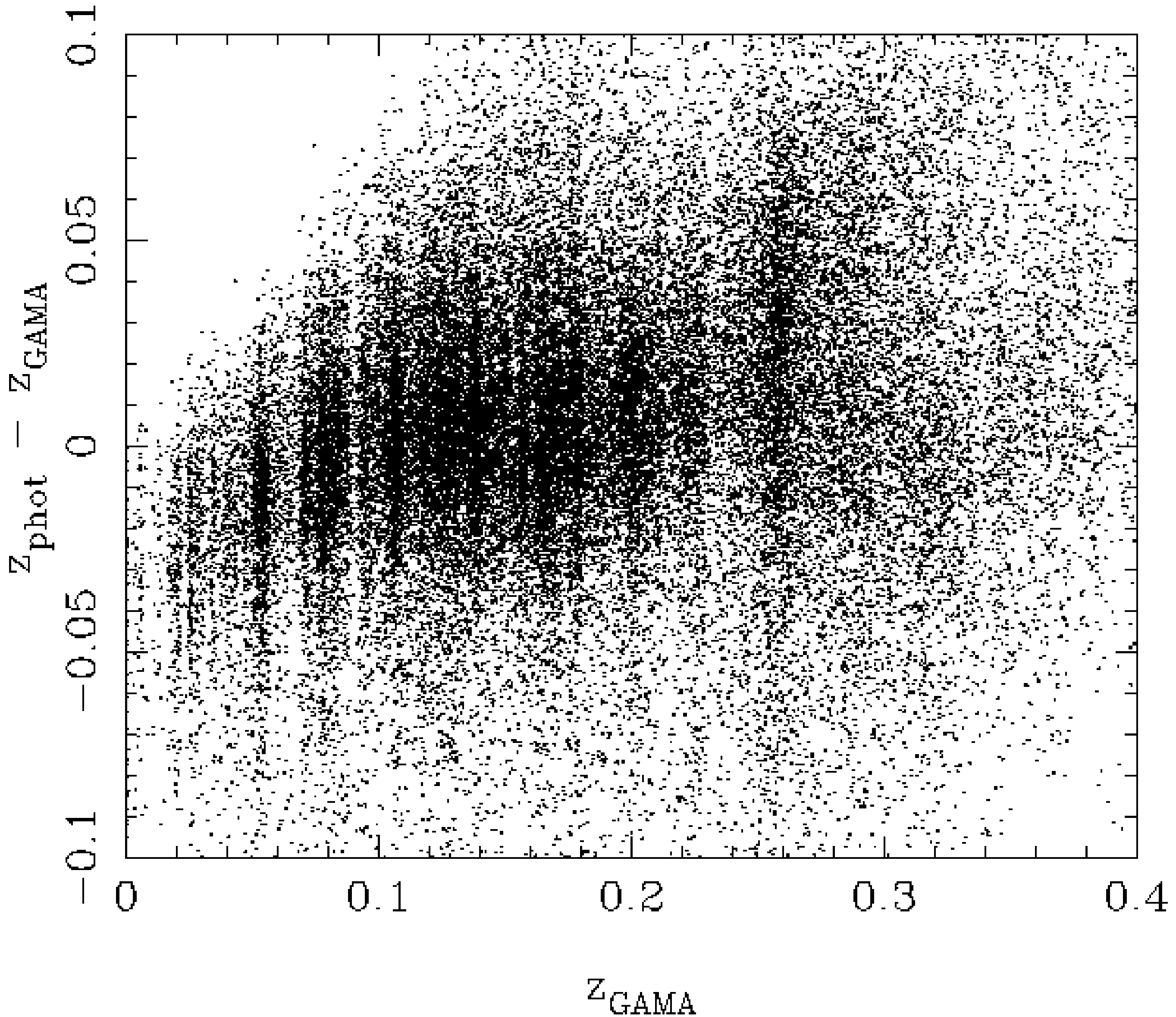
GAMA: Preliminary Results
tracing in detail the large scale structure



GAMA: Preliminary Results
global galaxy redshift distribution



GAMA: Preliminary Results
calibration of SDSS photometric redshifts

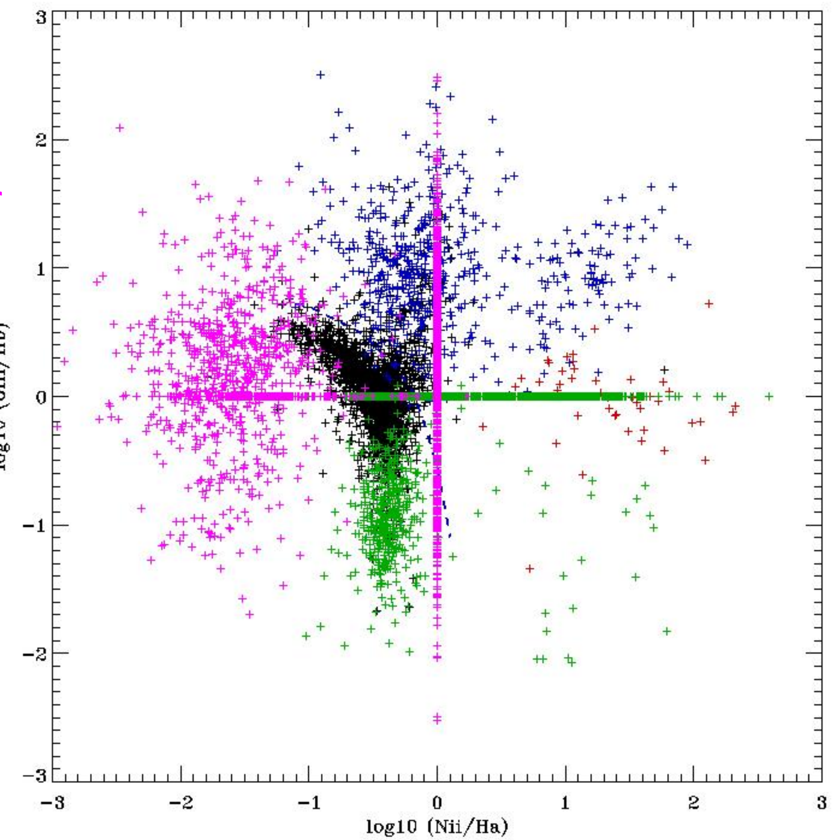


GAMA: Preliminary Results

disentangling AGNs from starbursting galaxies

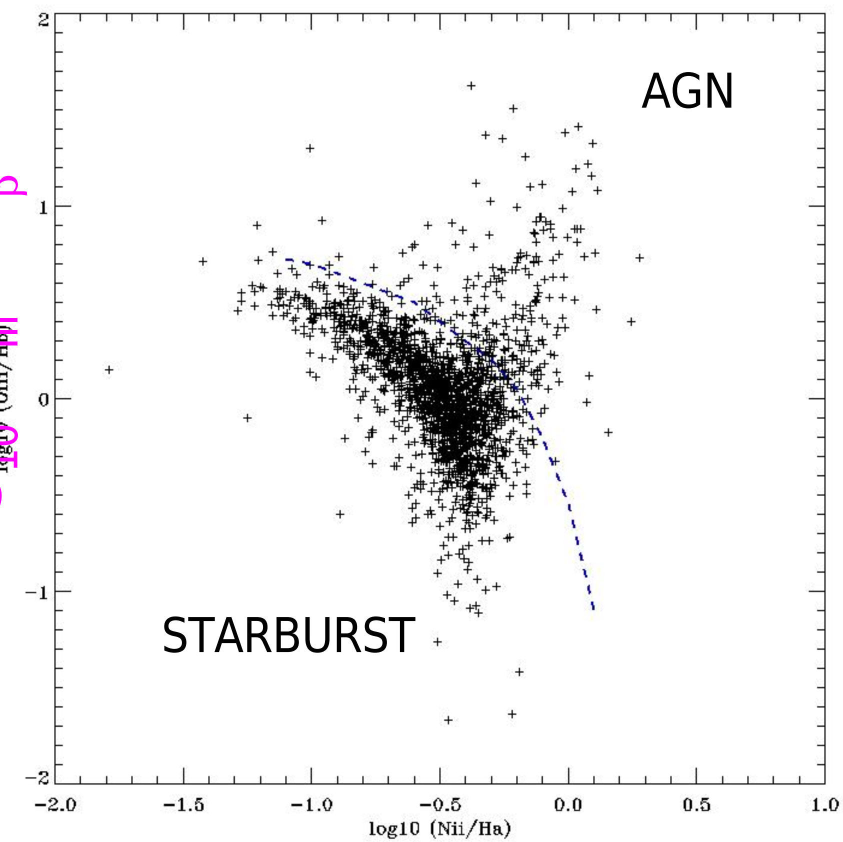
BPT diagrams:

$\log_{10} O_{III} / H_\beta$



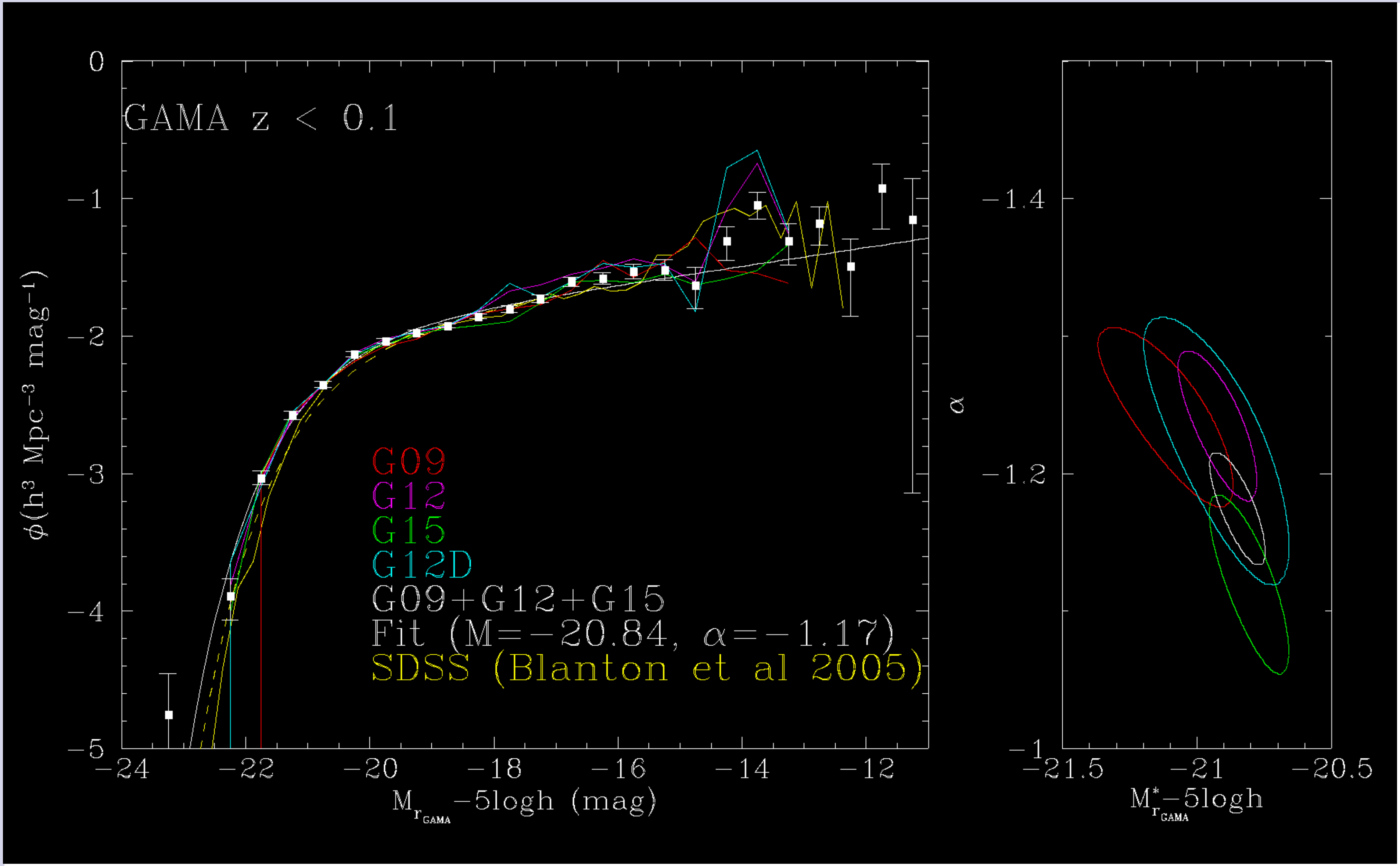
$\log_{10} N_{II} / H_\alpha$

$\log_{10} O_{III} / H_\beta$

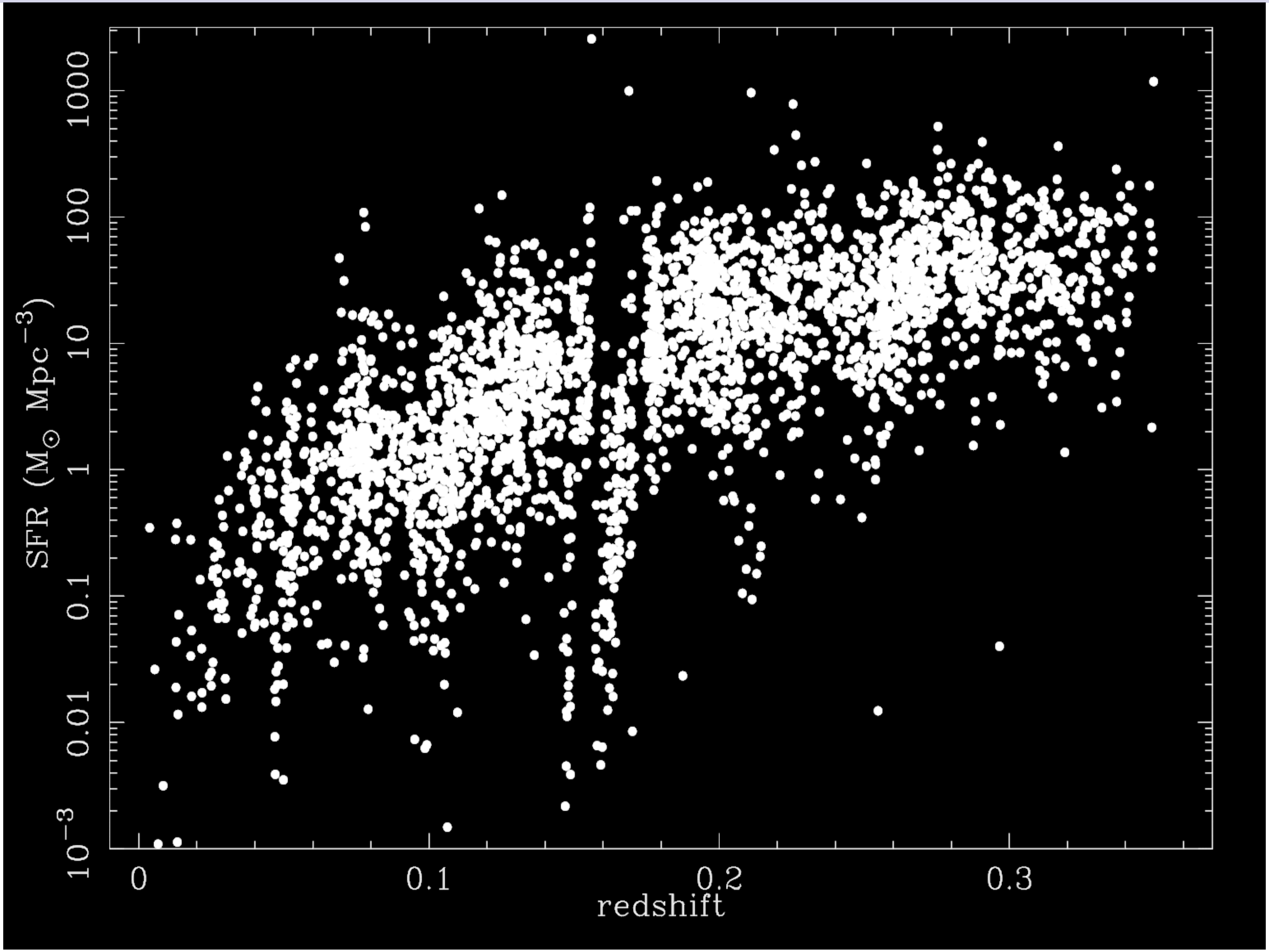


$\log_{10} N_{II} / H_\alpha$

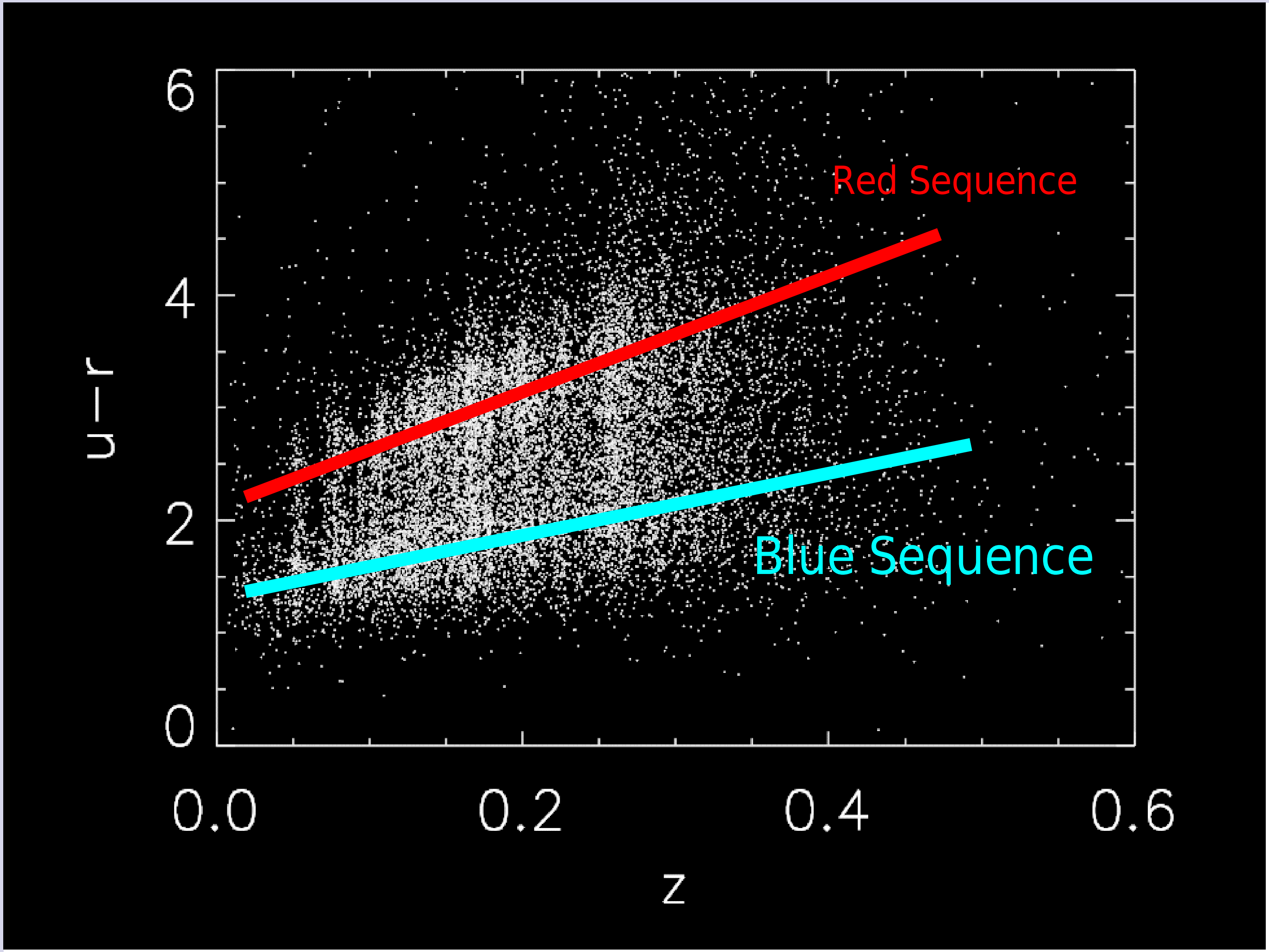
GAMA: Preliminary Results
optical galaxy luminosity function (z<0.1)



GAMA: Preliminary Results
galaxy star formation rate vs redshift



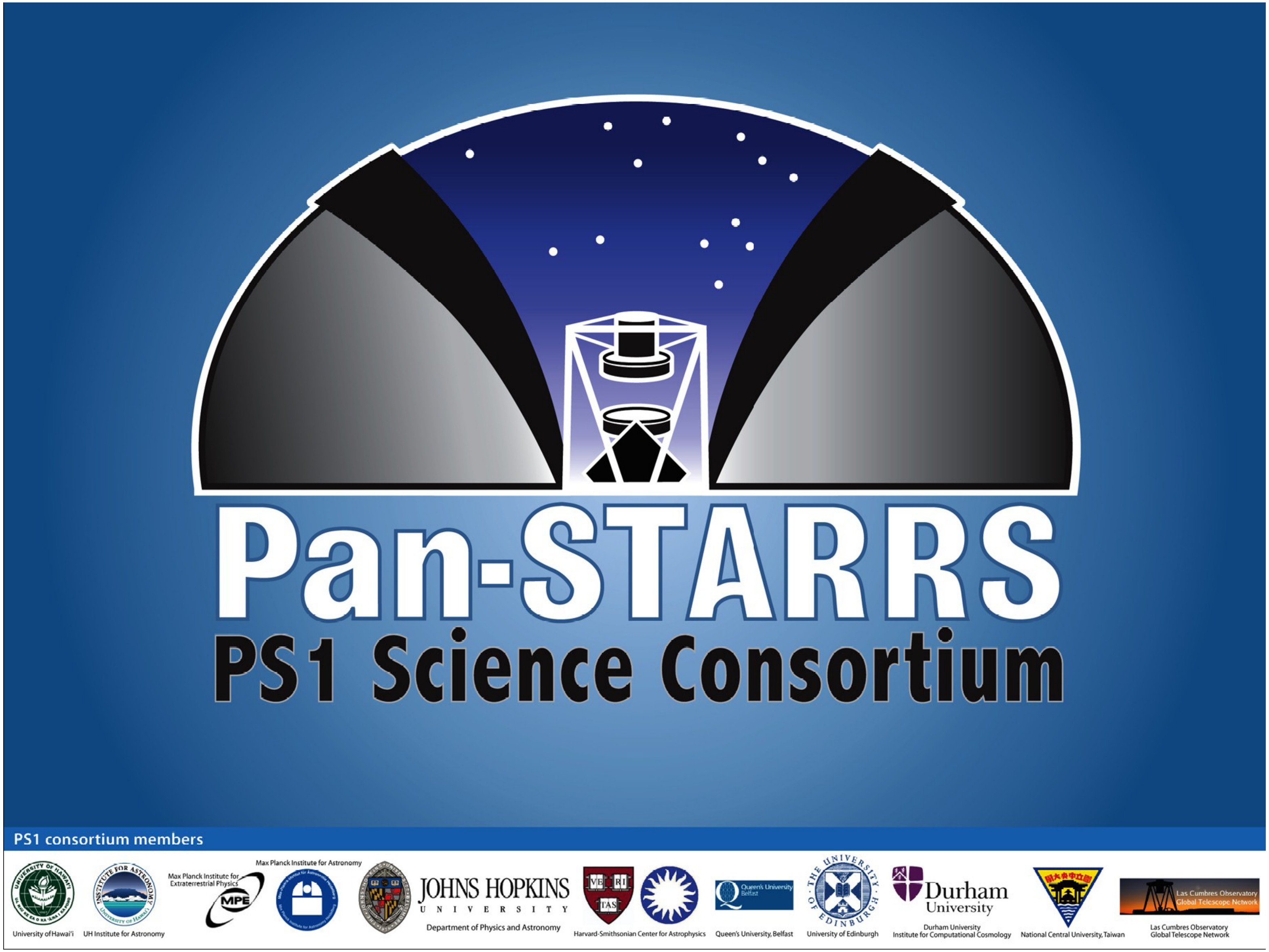
GAMA: Preliminary Results
colour bi-modality vs redshift



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

- What is GAMA?
  - New generation SDSS scale survey: 250 sq deg, 2mag deeper than SDSS
  - Multi-wavelength: AAT, VST, VISTA, HERSCHEL (XMM, SCUBA II, ASKAP)
  - Comprehensive study of matter and energy on Mpc to kpc scales $z < 0.4$
- Overlap with ASKAP/DEEP?
  - Superb overlap with ASKAP field-of-view
  - Comparable n(z) distributions
  - Will spectroscopically resolve ASKAPs 10’’ beam
  - Will provide: optical, near-IR, far-IR, & spectra for galaxies in ASKAP/DEEP
- GAMA update:
  - GAMA started March 1st 2008
  - >50k spectra measured in 3 weeks with AAT/AAΩ: >95% target completeness
  - Preliminary science: LF, colour bi-modality, BPT, SFR, photo-z calibration, ...
- How you can get involved:
  - Annual data release (December 2008...)
  - Website: http://www.eso.org/~jliske/gama/
  - Contact: Simon Driver spd3@st-andrews.ac.uk .

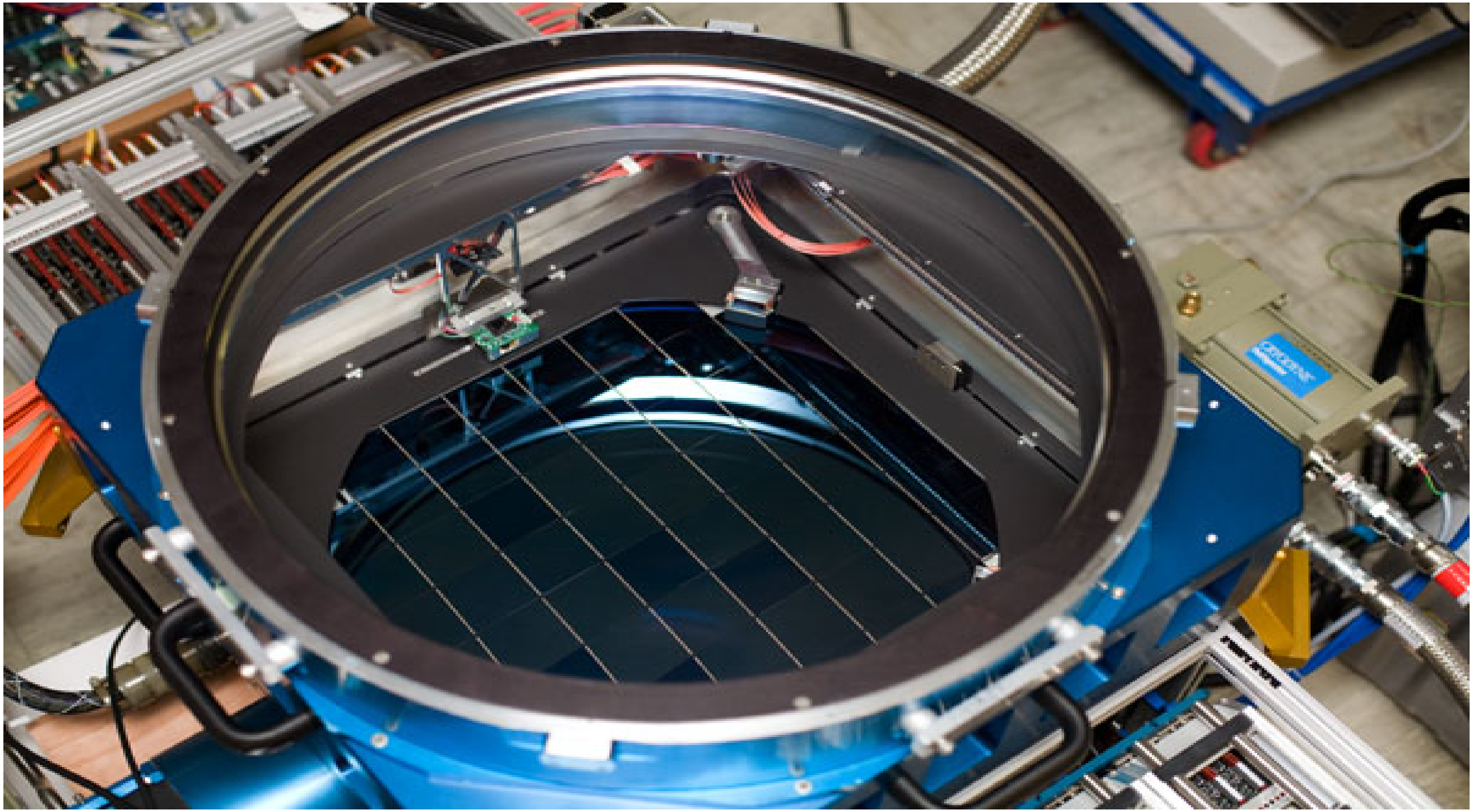
Pan-STARRS PS1: Consortium Composition



Pan-STARRS PS1: 3π & MD surveys
the key to a vital Dark Energy constraint?

- 1.8m on Haleakala (Maui, Hawaii)
- Test technology needed for PS4
  (telescope design, cameras & data reduction software)
- Pan-STARRS PS1 surveys:
  - 3π & Medium Deep survey (LSS)
  - Solar System Sweet Spot Survey
  - Stellar Transit Survey
  - Deep Survey of M31
- Camera consists of an array of 64x64 CCDs (600x600 pixels): 1.4 Gpixels spread over 40 cm x 40 cm!
- Orthogonal transfer allows for a shift of the image during the observation -> tip-tilt correction on the chip
- Expected data flow: ~50 Tb / month

Pan-STARRS PS1:
1.4 Gigapixel camera with 7 sq.deg FoV

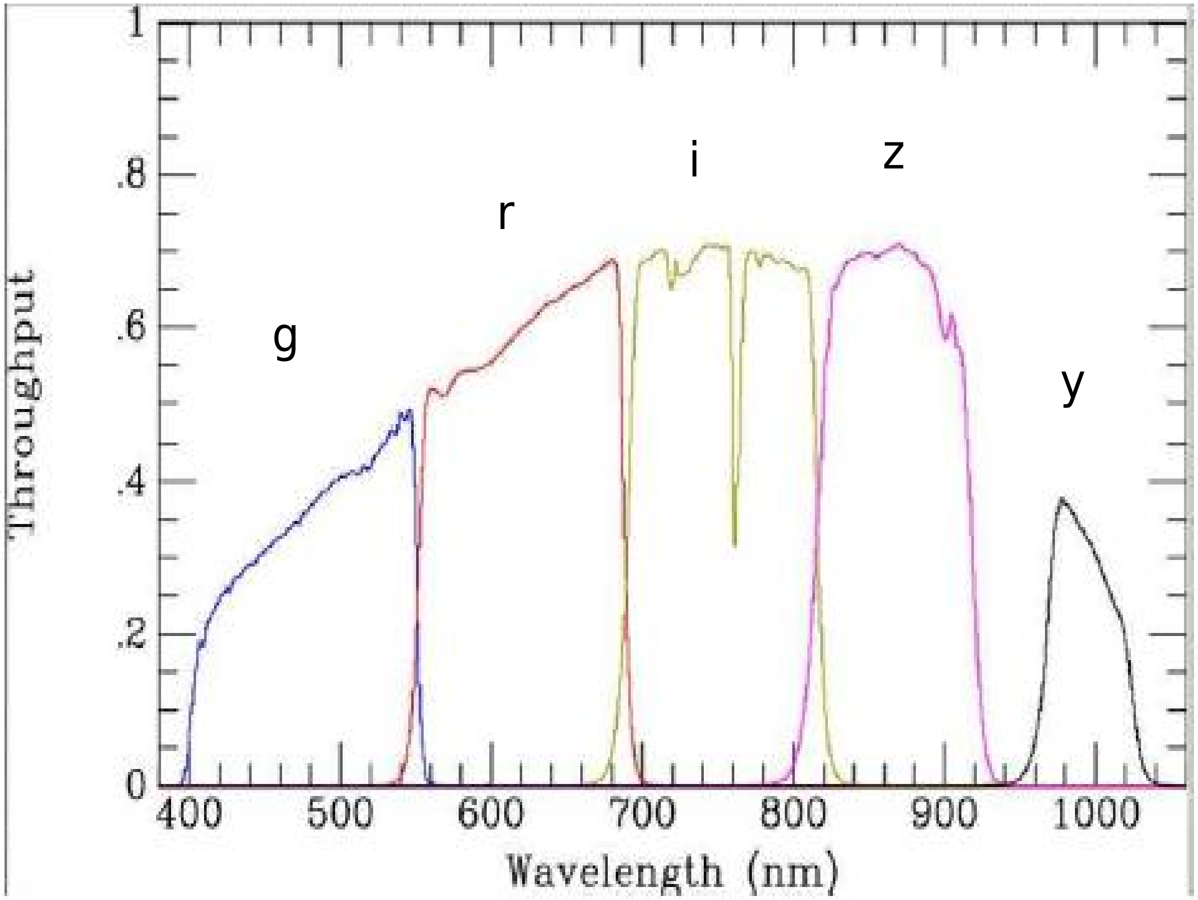


Pan-STARRS PS1: a small shutter...

The “Bonn - Shutter”:

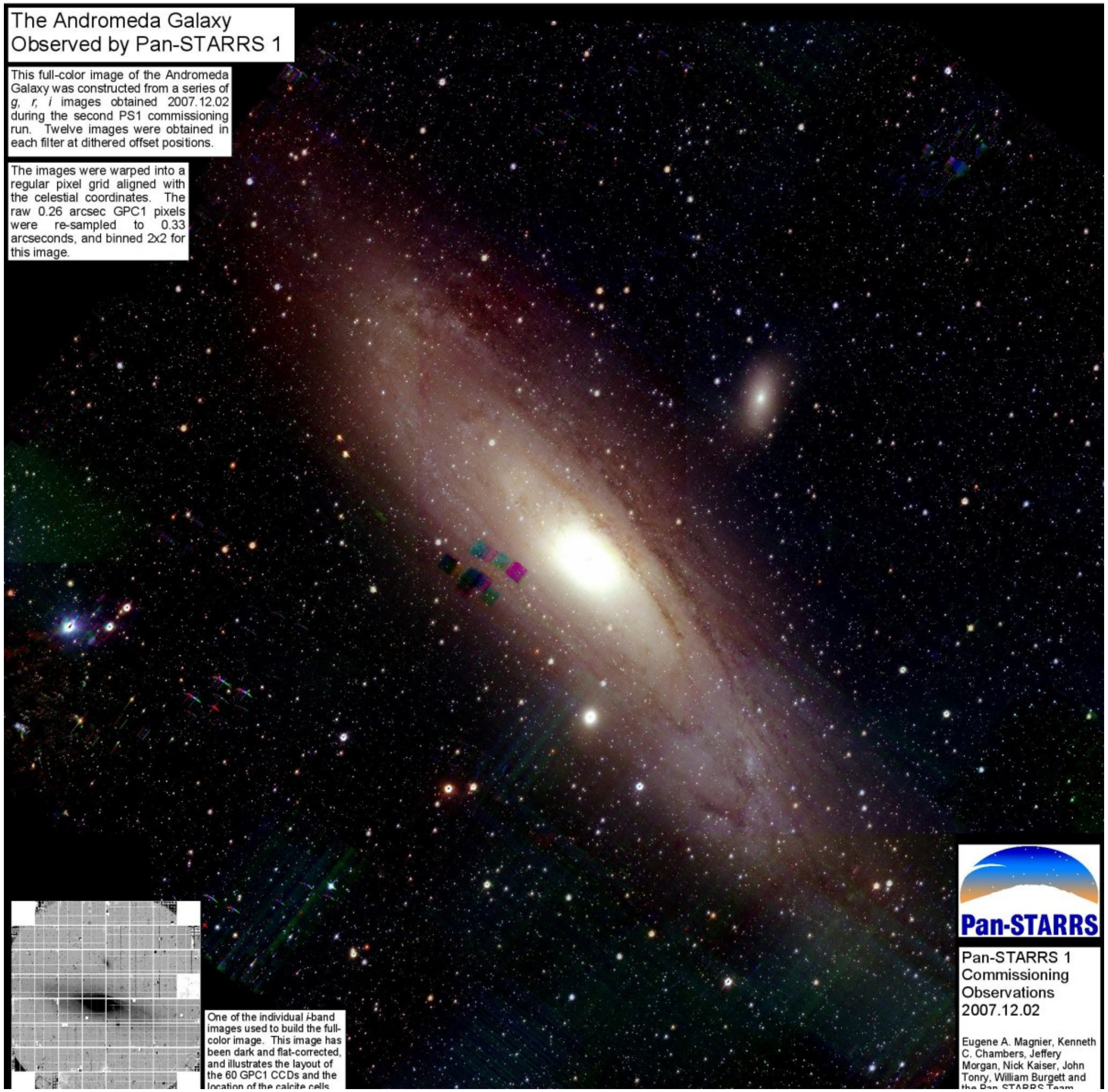
- Length: 1.664 m
- Width: 63.2 cm
- Depth: 5 cm
- Shutter aperture: 48 x 48 cm
- Mass: 30 kg
- Uniform exposure
- Has to open and close up to a million times!
- Shortest possible exposure: 300μs
- Homogeneity of exposure: 0.3% at 0.2s

Pan-STARRS PS1:
filter selection



- Expected good photo-z for red galaxies; more work for blue galaxies...
- Galaxy property studies: will benefit to be combined with other surveys (photometric & spectroscopic)

Pan-STARRS PS1:
one shot at M31



Pan-STARRS PS1: 3π & Medium Deep surveys

- Pan-STARRS 3π survey (3.5 yrs):
  - 56% of total observing time
  - Each field visited 4 times in each band pass
  - Depth: r_{AB} ~ 24.1 , y_{AB} ~ 21.5
- Pan-STARRS Medium Deep survey (3.5 yrs):
  - 25% of total observing time
  - 10 footprints distributed uniformly across the sky (nightly depth optimized for SN Ia studies at z~0.5)
  - 84 square degrees
  - L* galaxies at z=1.8 -> Depth: r_{AB} ~ 27.0 , y_{AB} ~ 24.8
- Expect ~10^7 LRGs to z~1, with $\sigma_z/(1+z) < 3\%$
- Main cosmology aim: measure w to 3% accuracy

Pan-STARRS PS1:
3π & Medium Deep survey depths

Table 11. Estimated Sensitivities for the 3π Survey. The tabulated numbers use the above equations and assume 75 micron chips, aluminum coating, effective loss of 0.35 area from secondary mirror blockage and diffraction from baffles and secondary mirror support structure. The average sky brightness μ at Haleakala assumes the Wainscoat light pollution factor in g and r band, and an average air mass of 1.4 is assumed. The FWHM is taken to be 0.78 arcsec, or three pixels assuming OTA improvement. A read noise of 5 electrons rms is assumed, and an optimistic zero contribution from RFI.

Filter	Bandpass (nm)	m_1 AB mag	μ AB mag/asec^2	exposure time/visit sec	5σ trailed NEO/visit	5σ pt. source per visit	visits in one night	visits per year	visits per 3 yrs	5σ pt. source in 3 yrs
g	405–550	24.90	21.90	60	23.08	23.24	2	4	12	24.66
r	552–689	25.15	20.86	38	22.63	22.71	2	4	12	24.11
i	691–815	25.00	20.15	60	22.47	22.63	2	4	12	23.96
z	815–915	24.63	19.26	30	21.53	21.59	2	4	12	22.98
y	967-1024	23.03	17.98	30	20.08	20.13	2	4	12	21.52

Table 13. Estimated PS1 Sensitivities for the Medium Deep Survey. The tabulated numbers use the same assumptions as those listed for the 3pi Survey.

Filter	Bandpass (nm)	m_1 AB mag	μ AB mag/asec^2	exp time sec	5σ point source in 4 nts	5σ point source in 1 yr	5σ point source in 3 yrs
g	405–550	24.90	21.90	3×240	24.80	26.72	27.32
r	552–689	25.15	20.85	3×240	24.44	26.36	26.96
i	691–815	25.00	20.15	6×240	24.38	26.31	26.91
z	815–915	24.63	19.26	6×240	23.77	25.69	26.29
y	967-1024	23.03	17.98	6×240	22.32	24.24	24.84