The MeerKAT UltraDeep HI Survey

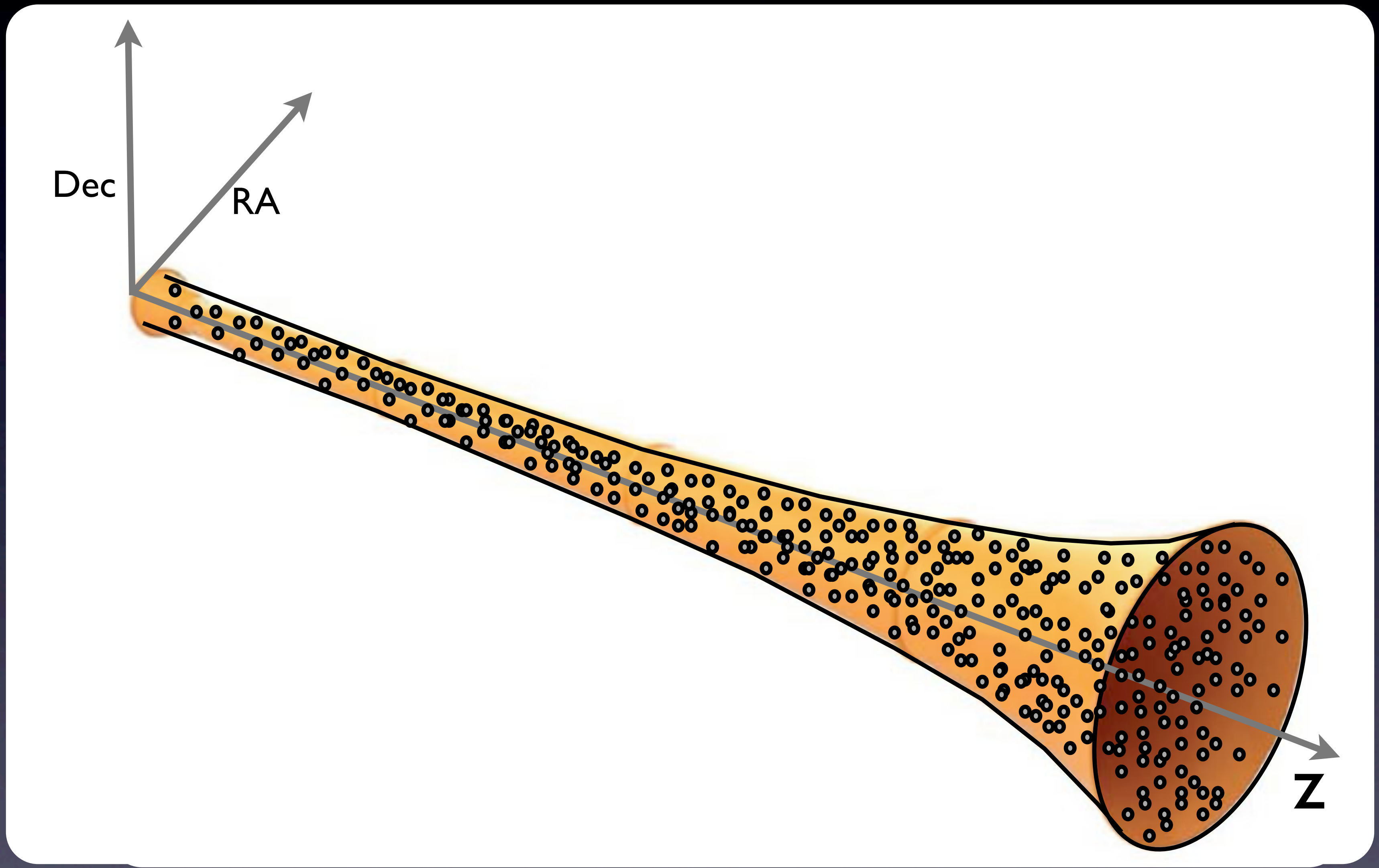
(affectionately: Vuvuzela)

Sarah Blyth & Benne Holwerda

3rd UCT / ICRAR / APERTIF Workshop
3 May 2010

The MeerKAT UltraDeep HI Survey

(affectionately: Vuvuzela)



Sarah Blyth & Benne Holwerda

3rd UCT / ICRAR / APERTIF Workshop
3 May 2010

Team

35 members so far...

S-L Blyth, B.W. Holwerda, B. Basset, A. Bouchard, F.H. Briggs, B. Catinella, L. Chemin, C. Cress, R. Dean, E. de Blok, E. Elson, A. Faltenbacher, B. Frank, T. Henning, M. Jarvis, R. Johnston, H-R. Kloekner, R.C. Kraan-Korteweg, P. Lah, M. Lehnert, G. Meurer, M. Meyer, S-H. Oh, D.J. Pisano, S. Rawlings, A. Schroder, K. Sheth, M. Smith, L. Staveley-Smith, I. Stewart, K.J. van der Heyden, W. van Driel, M. Verheijen, P. Woudt, M. Zwaan

Science Justification I

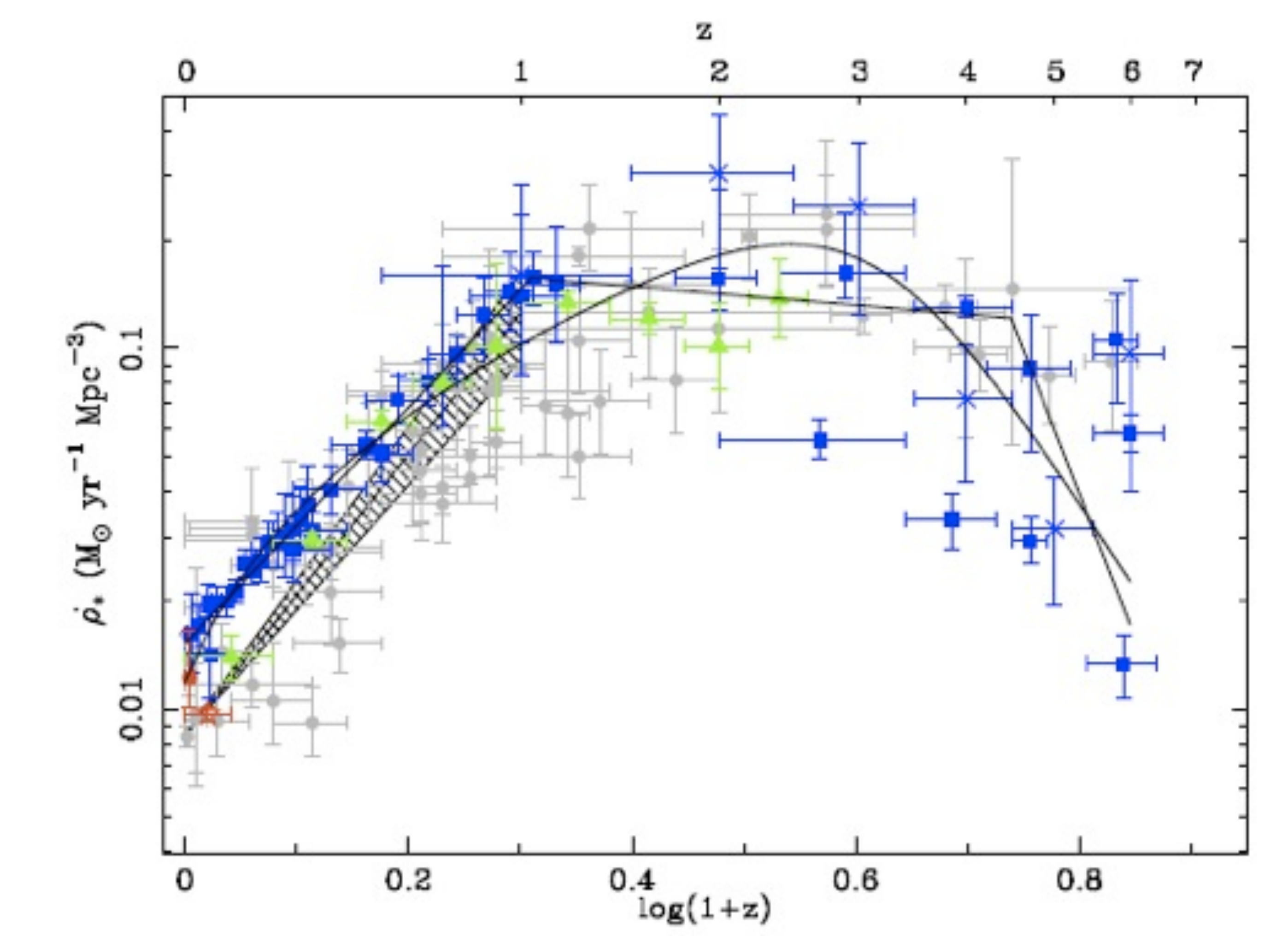
Galaxies show significant evolution since z=1, but what drives this...

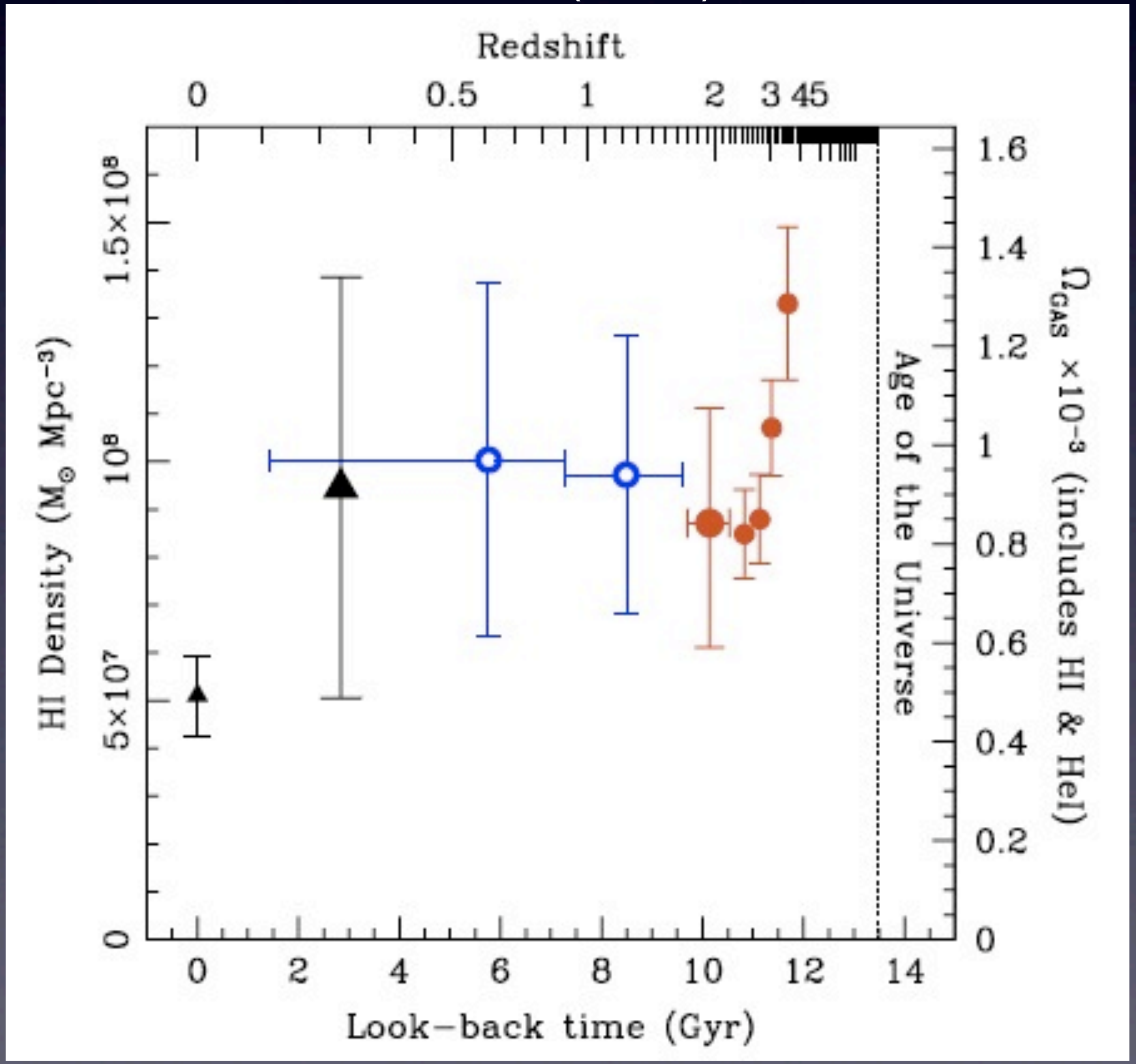
Since z~1:

- number density of blue galaxies ↓, but red galaxies ↑
- SFR has dropped by order of magnitude but Ω_{HI} ~ const?

P. Lah (2010)

Hopkins & Beacom (2005)



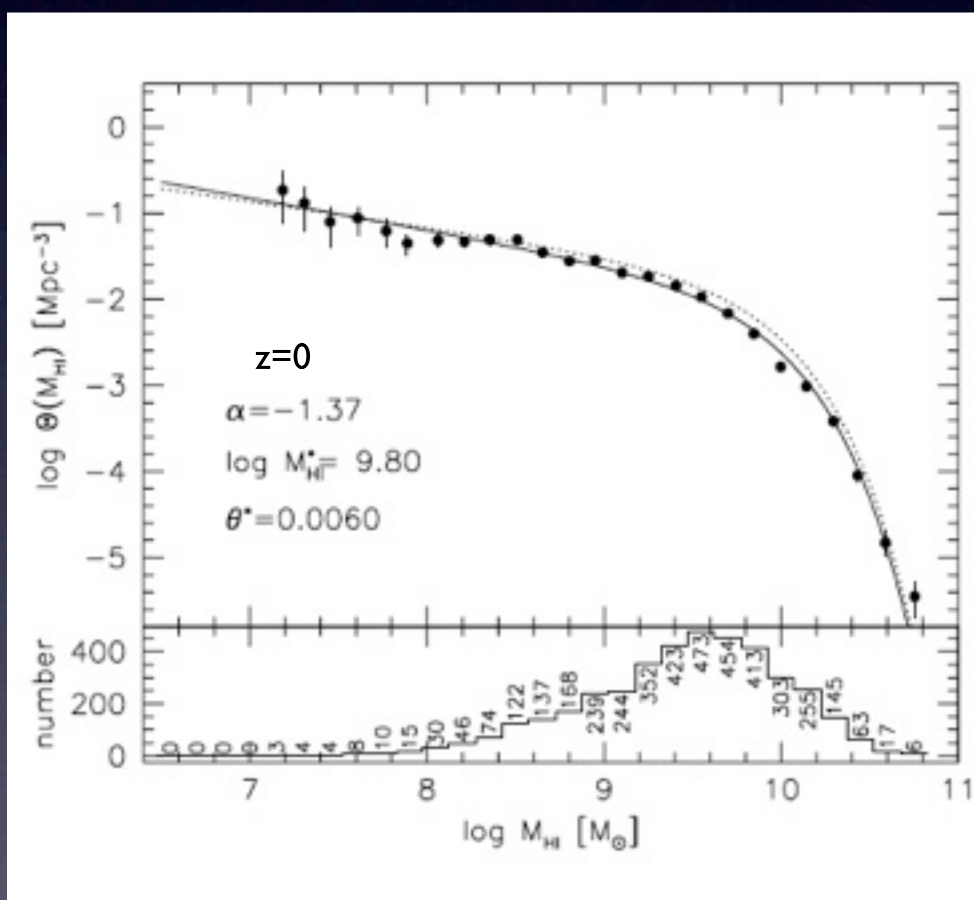


Science Justification II

To study galaxy evolution over cosmic time, we need to understand ***where*** *&* ***how much*** *HI exists...*

HIMF vs. z

Zwaan et al., MNRAS 359 (2005) L30



only measured for z=0!

1) What is the distribution of HI within galaxies?

- How do M^*_{HI}, α & normalisation vary vs. redshift?
- Help to constrain hierarchical galaxy formation models
- Effect of different environments?

Science Justification II

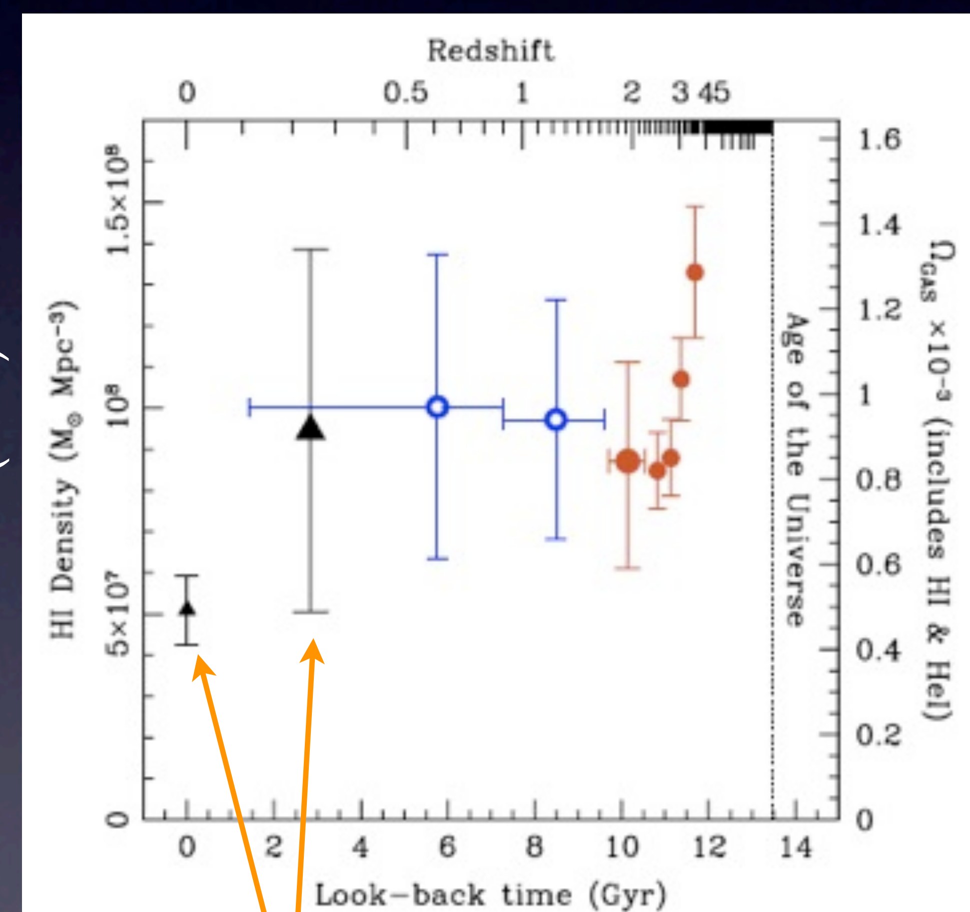
To study galaxy evolution over cosmic time, we need to understand ***where*** *&* ***how much*** *HI exists...*

2) What is the average amount of HI at different z?

- What is the trend for 0.2< z <0.6 where SFR is increasing?
- How will HI measurements compare to Lyα and MgII results at high z?

Ω_{HI} vs. z

P. Lah (2010)



only existing direct HI line detections

Survey Headline Science Goals

Primary aims:

- To measure, for the first time, the evolution of Ω_{HI} using HI emission out to $z \leq 1$
  - requires optical redshifts for stacking of HI spectra at highest z

- To measure the shape of the HIMF in different environments out to $z \leq 0.6$

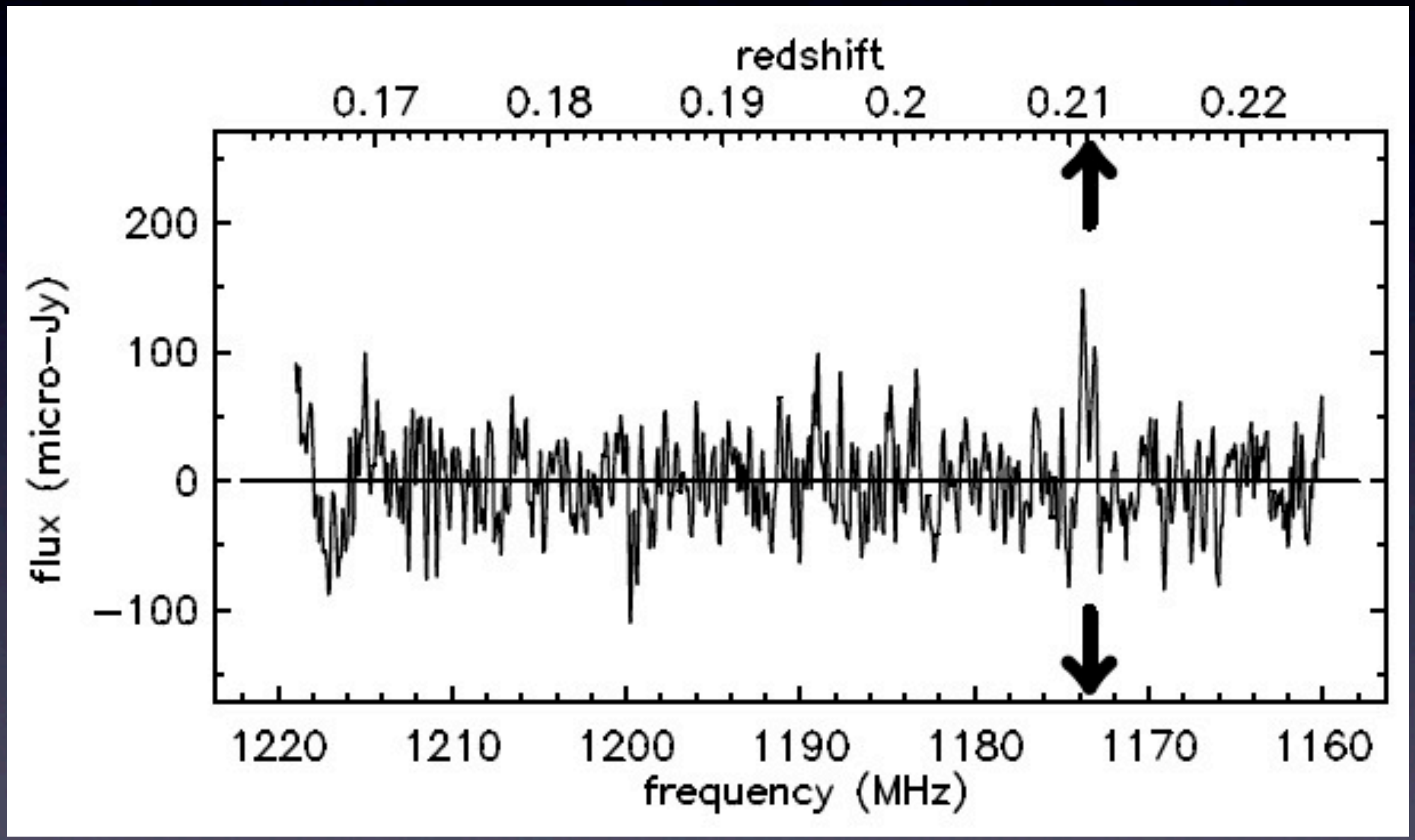
Secondary aims:

- To study evolution of HI properties of galaxies
- To study the star formation law in galaxies vs. z
- To study the evolution of galaxy dynamics (Tully-Fisher relation)

Current surveys

Existing facilities are not optimal to do surveys at these z-depths...

Verheijen et al., ApJ 668 (2007) L9

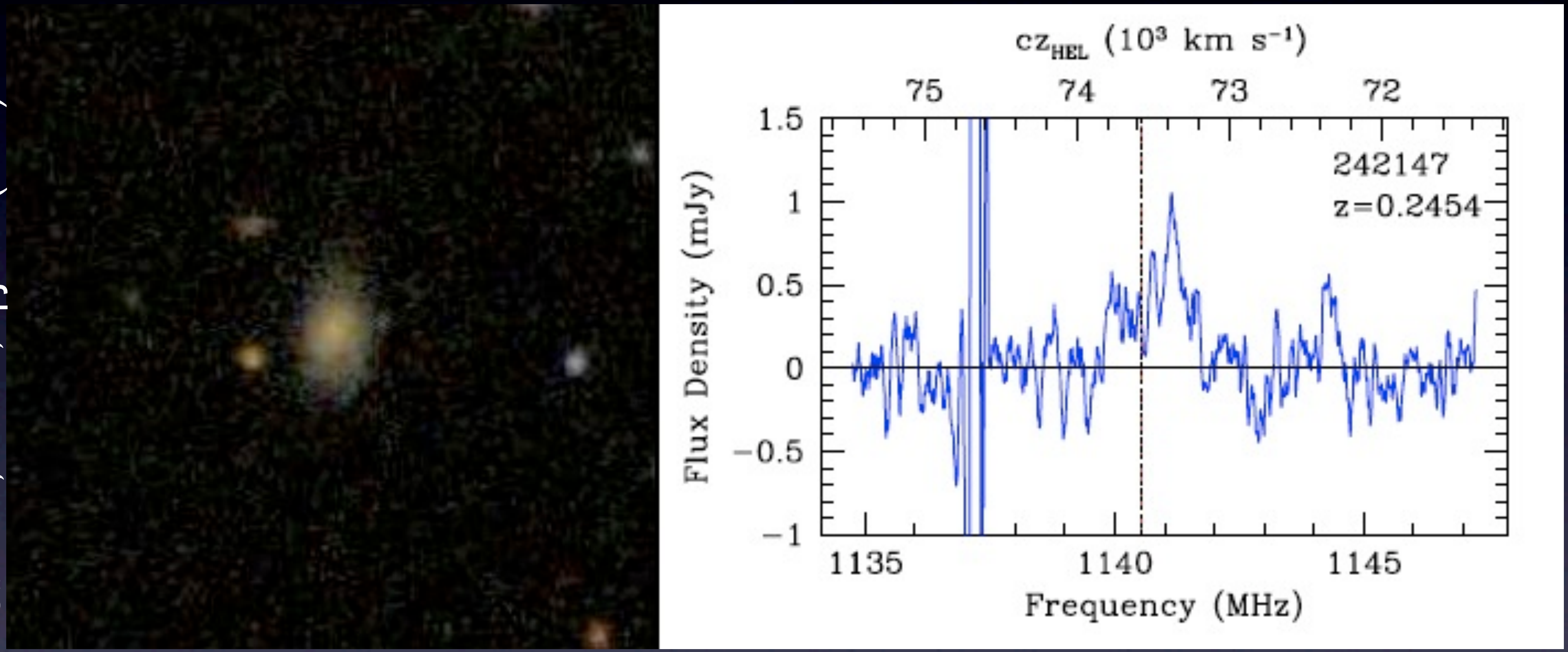


Galaxy in Abell 963, z = 0.21
Observing time: 20x12 hours on WSRT

Current surveys

Existing facilities are not optimal to do surveys at these z-depths...

Catinella, B. et al., ApJ 685 (2008) L13

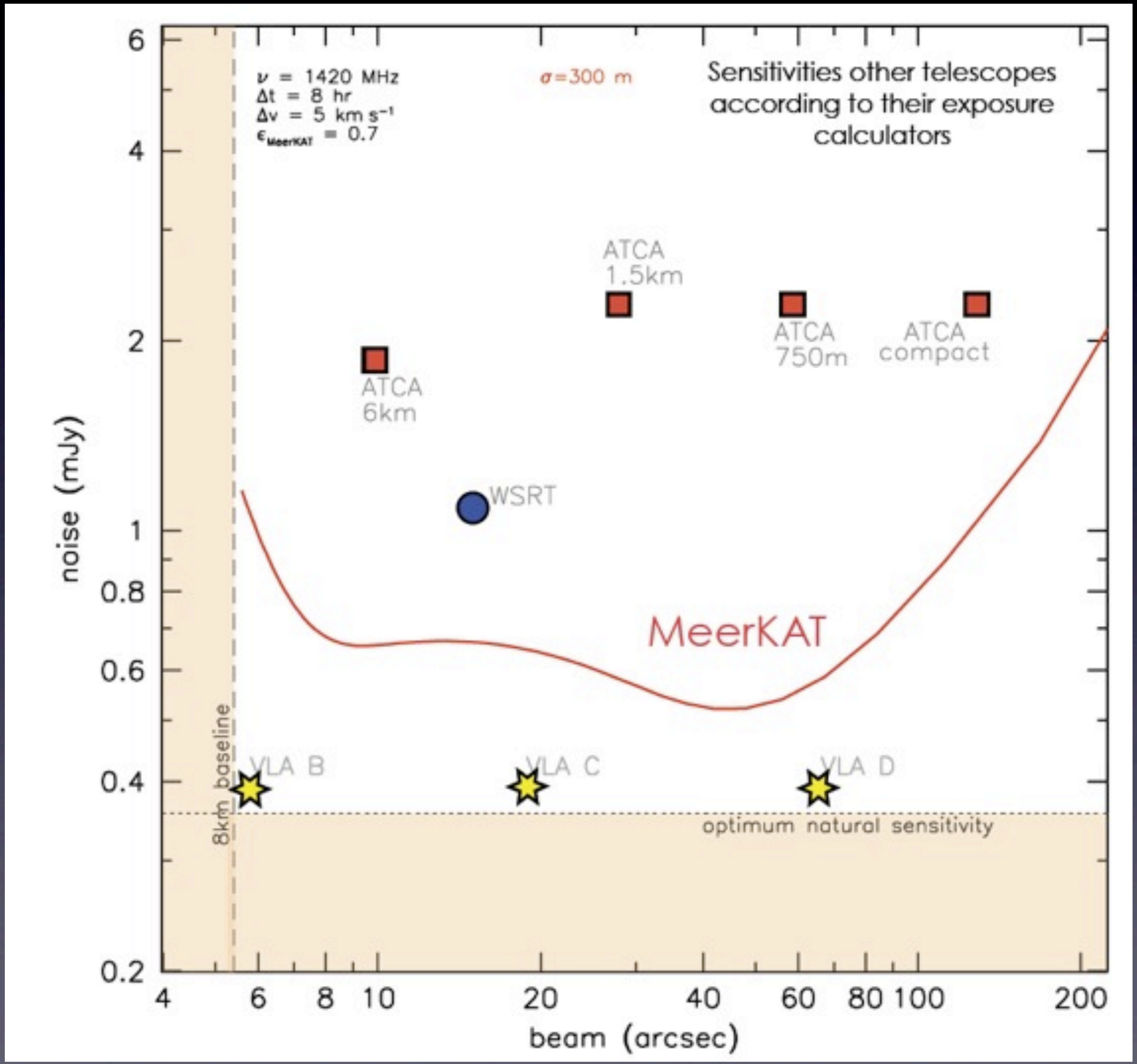


Field galaxy from SDSS (z=0.25)
Observing time: 176 minutes on Arecibo

MeerKAT

MeerKAT: large instantaneous bandwidth + high sensitivity + moderate FoV = ideal instrument!

Point source sensitivity:



(Courtesy E. de Blok)

UCT/ICRAR Workshop, Arniston, May 2-6 2010

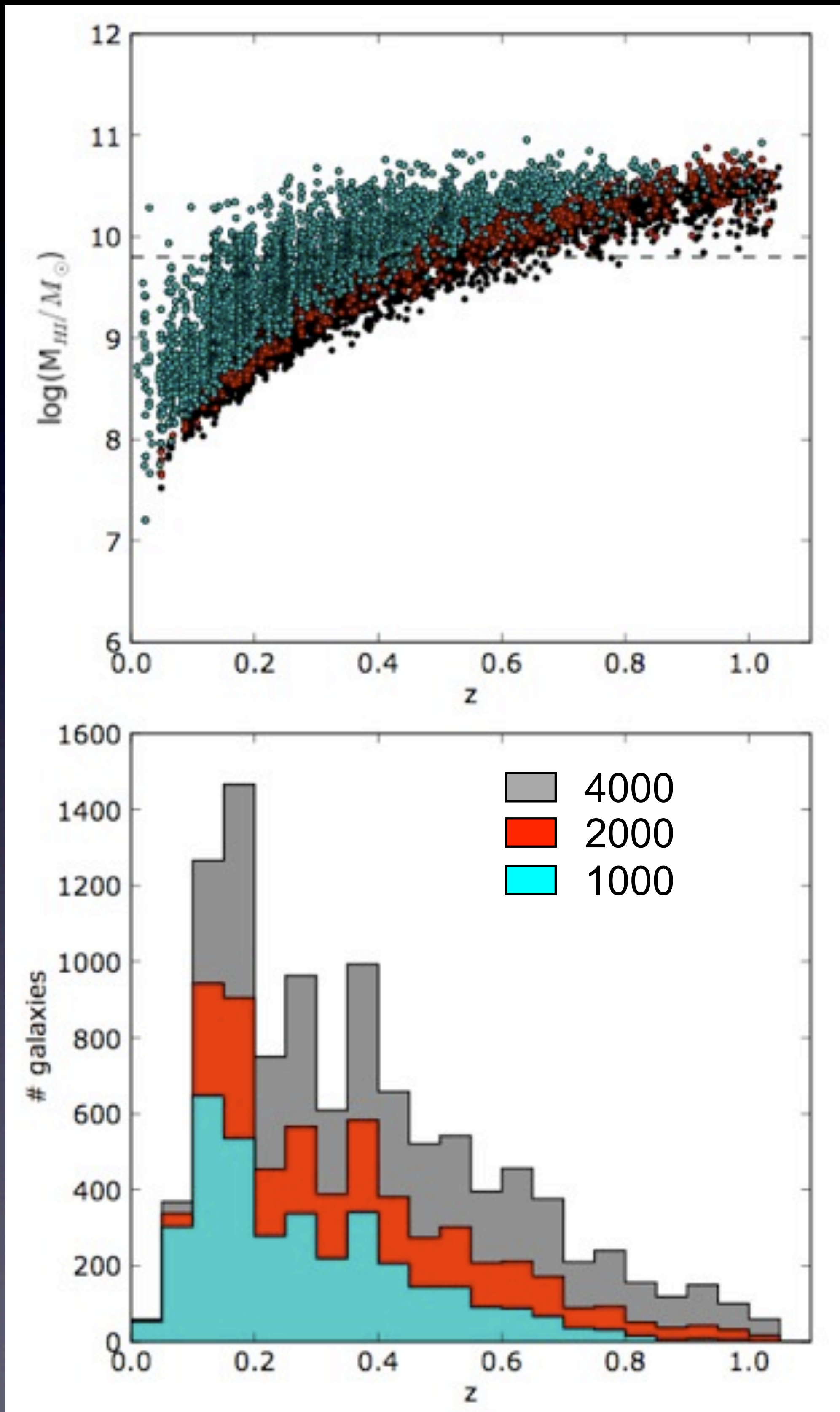
Observing strategy

The observing strategy was driven by the detection constraints of the survey headline goals:

	Phase I (2013-2015)	Phase II (2016 -)
MeerKAT specs:		
Bandwidth (GHz)	0.9 - 1.75	0.58 - 2.5
Redshift range (z)	0.0 - 0.58	0.0 - 1.4
Project goals & milestones:		
Fields	2	1
Observing time (hours)	2×1000h	4000h
Spectroscopic redshifts currently available		
full redshift range	$\sim$10000	$\sim$1000
highest redshift bin	$\sim$1000 (at z=0.6)	$\sim$ 500 (at z=1)
Direct Detection of M^*_{HI}	z=0.4	z=0.6
Ω_{HI} using stacking	z=0.6	z=1.0

- Based on simulations using Oxford S^3-SAX database for direct detections + stacking

Observing strategy: HIMF

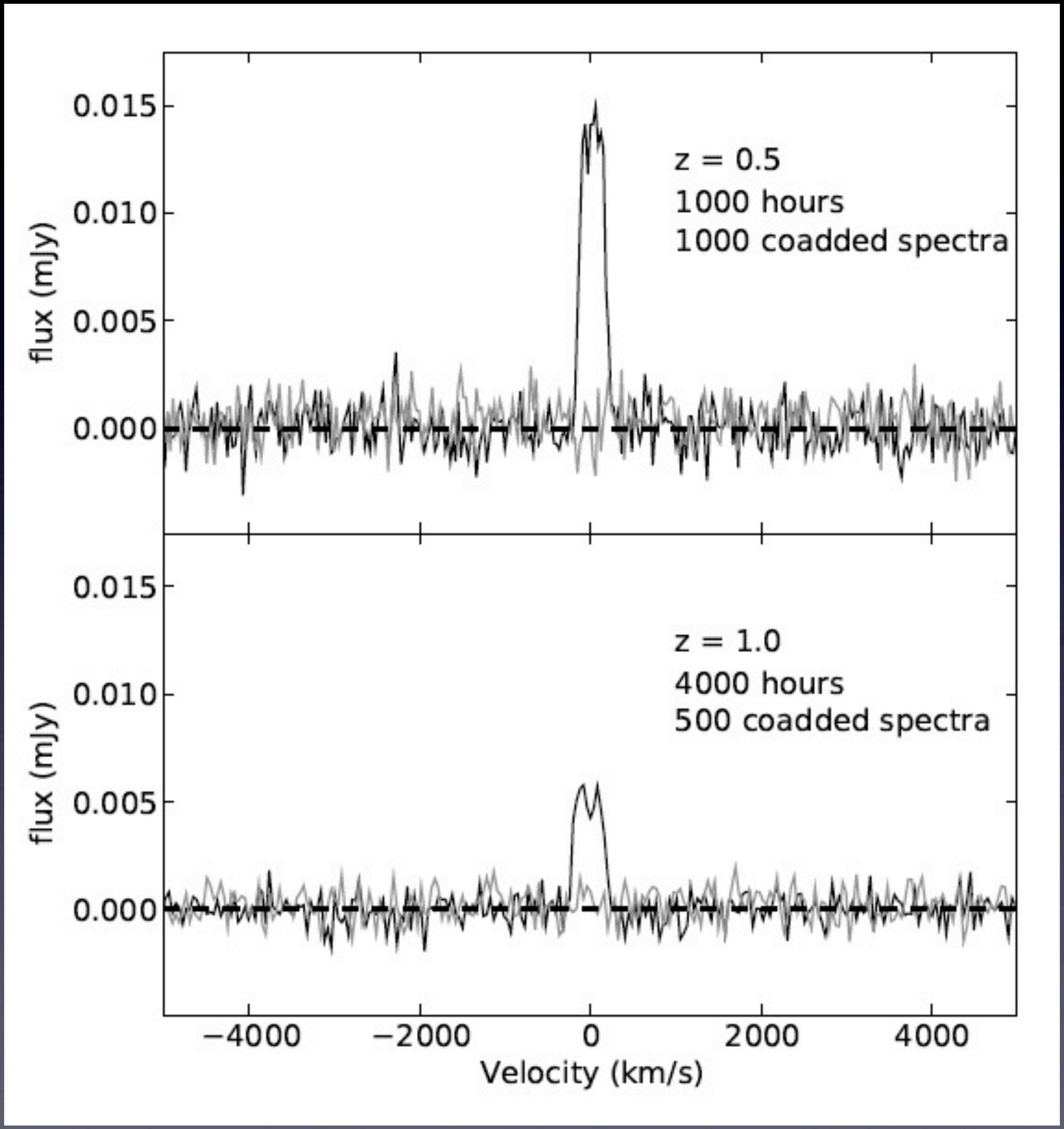


5σ galaxy detections using optimal smoothing on S^3-SAX simulations:

time / z	1000 hours	4000 hours
z<0.4	2712	6474
z<0.6	3297	8591

x 2
(2 fields)

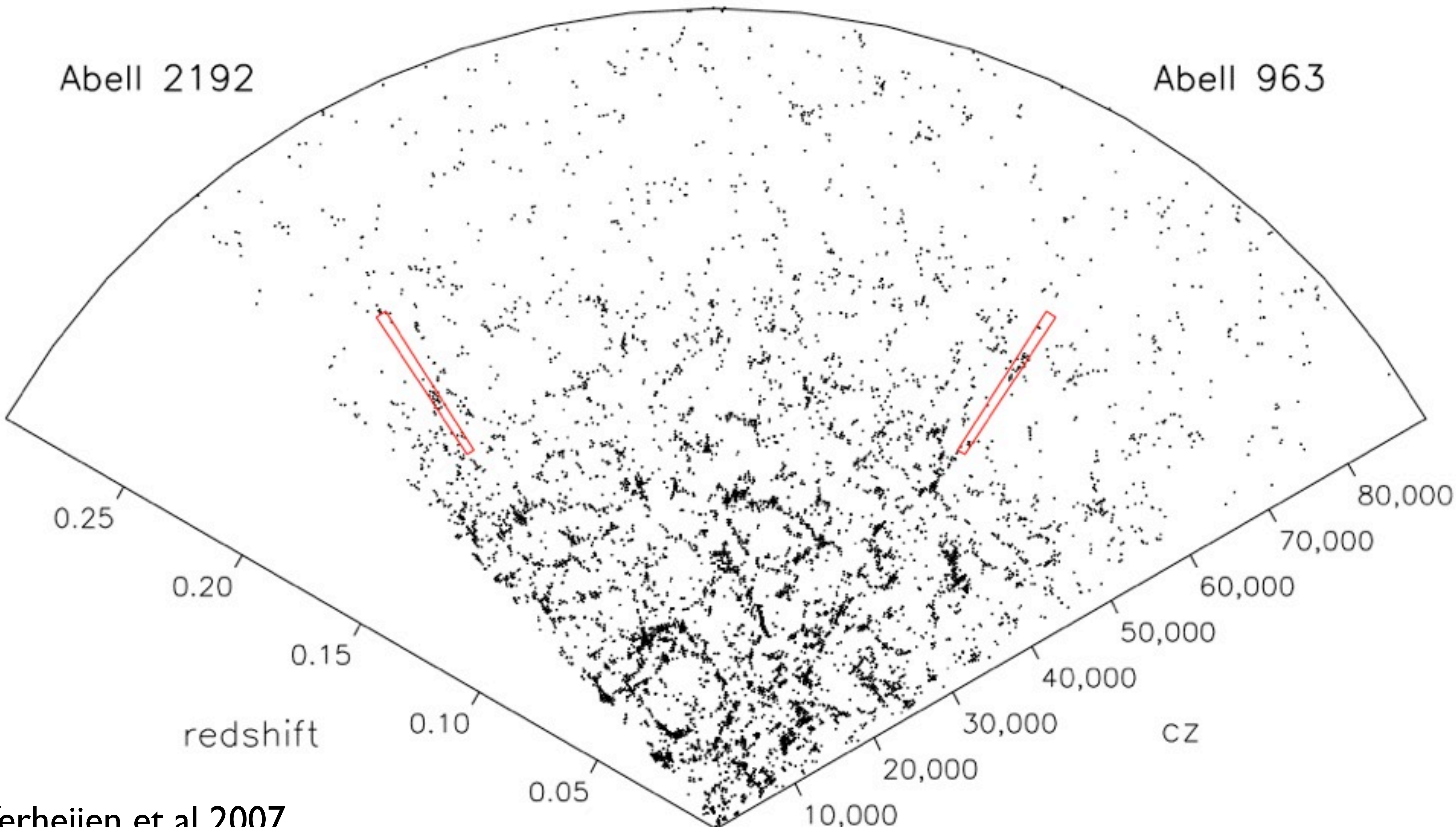
Observing strategy: Ω_{HI}



- Galaxies with m_B<24
- used optical spectra counts from zCOSMOS per z-bin
- even more optical redshifts will be available in few years time...

Layer Cake of Surveys

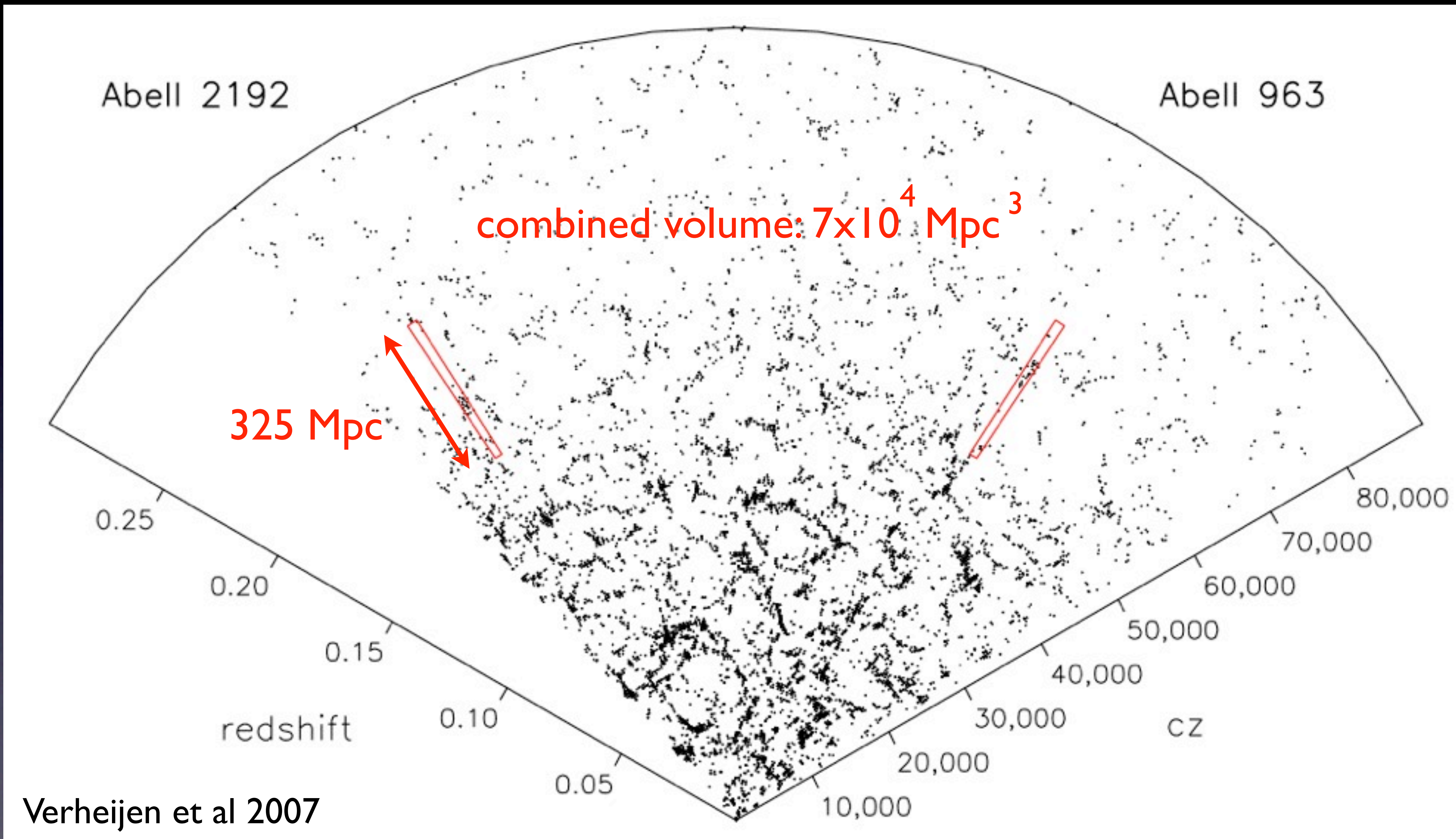
Survey Volume & Large Scale Structure



Verheijen et al 2007

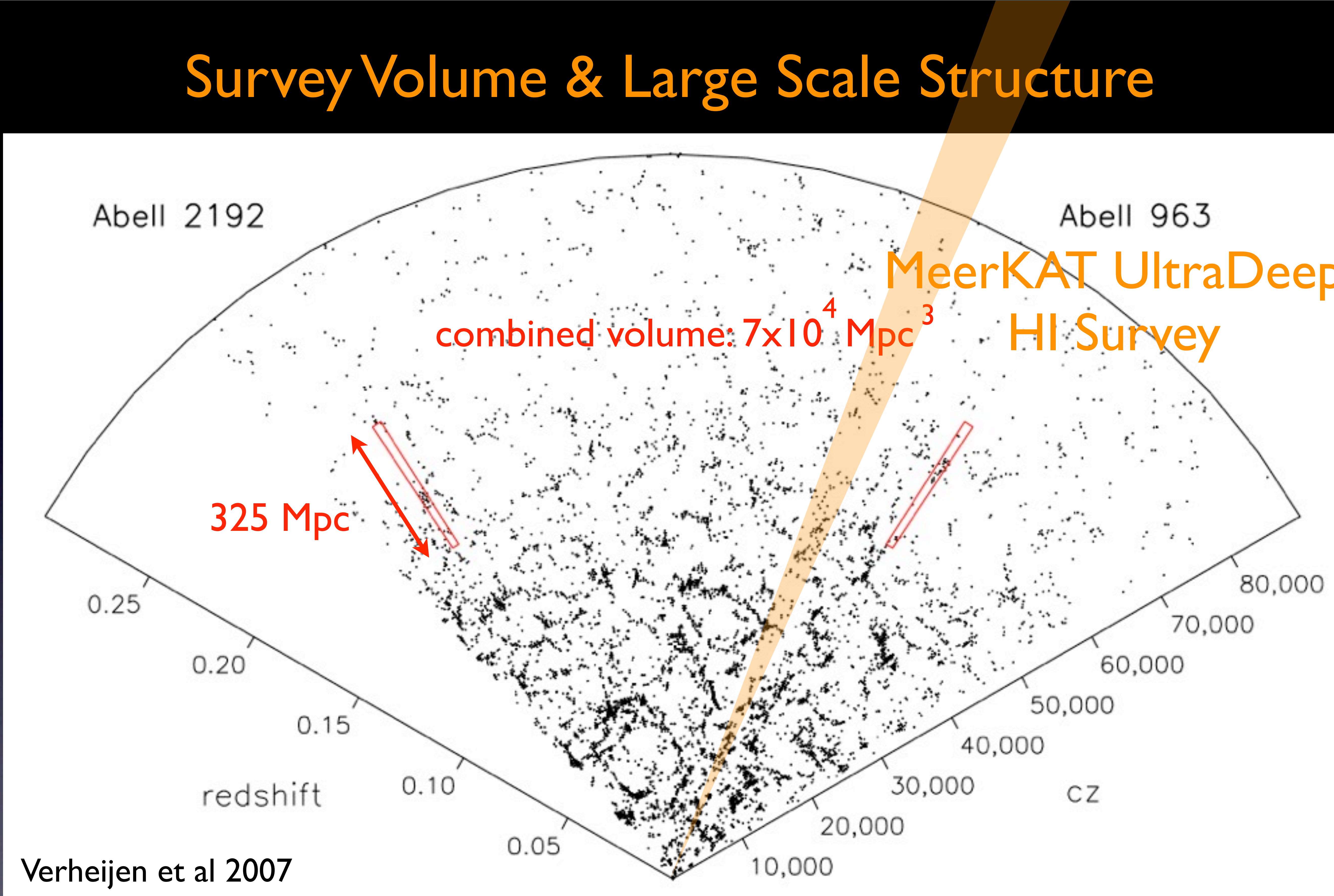
SDSS redshift space

Survey Volume & Large Scale Structure



SDSS redshift space

Survey Volume & Large Scale Structure



SDSS redshift space

Field Requirements

- Easily viewable with MeerKAT.
- A <u>spectroscopic</u> redshift catalogue with excellent spatial and redshift coverage.
- Multi-wavelength complementary data.

Observing Strategy

A two-tier strategy - to make optimal use of MeerKAT's bandwidth at each phase of construction:

	Phase I (2013-2015)	Phase II (2016 -)
MeerKAT specs:		
Bandwidth (GHz)	0.9 - 1.75	0.58 - 2.5
Redshift range (z)	0.0 - 0.58	0.0 - 1.4
Project goals & milestones:		
Fields	2	1
Observing time (hours)	$2\times$1000h	4000h
Spectroscopic redshifts currently available		
full redshift range	$\sim$10000	$\sim$1000
highest redshift bin	$\sim$1000 (at z=0.6)	$\sim$ 500 (at z=1)
Direct Detection of M^*_{HI}	z=0.4	z=0.6
Ω_{HI} using stacking	z=0.6	z=1.0

- Phase-I: Two fields: CDF-S and COSMOS
- Phase II: UltraDeep HI Field
- Final decision UltraDeep HI Field in 2015.

Observing Strategy

A two-tier strategy - to make optimal use of MeerKAT's bandwidth at each phase of construction:

	Phase I (2013-2015)	Phase II (2016 -)
MeerKAT specs:		
Bandwidth (GHz)	0.9 - 1.75	0.58 - 2.5
Redshift range (z)	0.0 - 0.58	0.0 - 1.4
Project goals & milestones:		
Fields	2	1
Observing time (hours)	2×1000h	4000h
Spectroscopic redshifts currently available		
full redshift range	~10000	~1000
highest redshift bin	~1000 (at z=0.6)	~ 500 (at z=1)
Direct Detection of M^*_{HI}	z=0.4	z=0.6
Ω_{HI} using stacking	z=0.6	z=1.0

- Phase-I: Two fields: CDF-S and COSMOS
- Phase II: UltraDeep HI Field
- Final decision UltraDeep HI Field in 2015.

Observing Strategy

A two-tier strategy - to make optimal use of MeerKAT's bandwidth at each phase of construction:

	Phase I (2013-2015)	Phase II (2016 -)
MeerKAT specs:		
Bandwidth (GHz)	0.9 - 1.75	0.58 - 2.5
Redshift range (z)	0.0 - 0.58	0.0 - 1.4
Project goals & milestones:		
Fields	2	1
Observing time (hours)	$2\times$1000h	4000h
Spectroscopic redshifts currently available		
full redshift range	$\sim$10000	$\sim$1000
highest redshift bin	$\sim$1000 (at z=0.6)	$\sim$ 500 (at z=1)
Direct Detection of M^*_{HI}	z=0.4	z=0.6
Ω_{HI} using stacking	z=0.6	z=1.0

- Phase-I: Two fields: CDF-S and COSMOS
- Phase II: UltraDeep HI Field
- Final decision UltraDeep HI Field in 2015.

Observing Strategy

A two-tier strategy - to make optimal use of MeerKAT's bandwidth at each phase of construction:

	Phase I (2013-2015)	Phase II (2016 -)
MeerKAT specs:		
Bandwidth (GHz)	0.9 - 1.75	0.58 - 2.5
Redshift range (z)	0.0 - 0.58	0.0 - 1.4
Project goals & milestones:		
Fields	2	1
Observing time (hours)	2×1000h	4000h
Spectroscopic redshifts currently available		
full redshift range	$\sim$10000	$\sim$1000
highest redshift bin	$\sim$1000 (at z=0.6)	$\sim$ 500 (at z=1)
Direct Detection of M^*_{HI}	z=0.4	z=0.6
Ω_{HI} using stacking	z=0.6	z=1.0

- Phase-I: Two fields: CDF-S and COSMOS
- Phase II: UltraDeep HI Field
- Final decision UltraDeep HI Field in 2015.

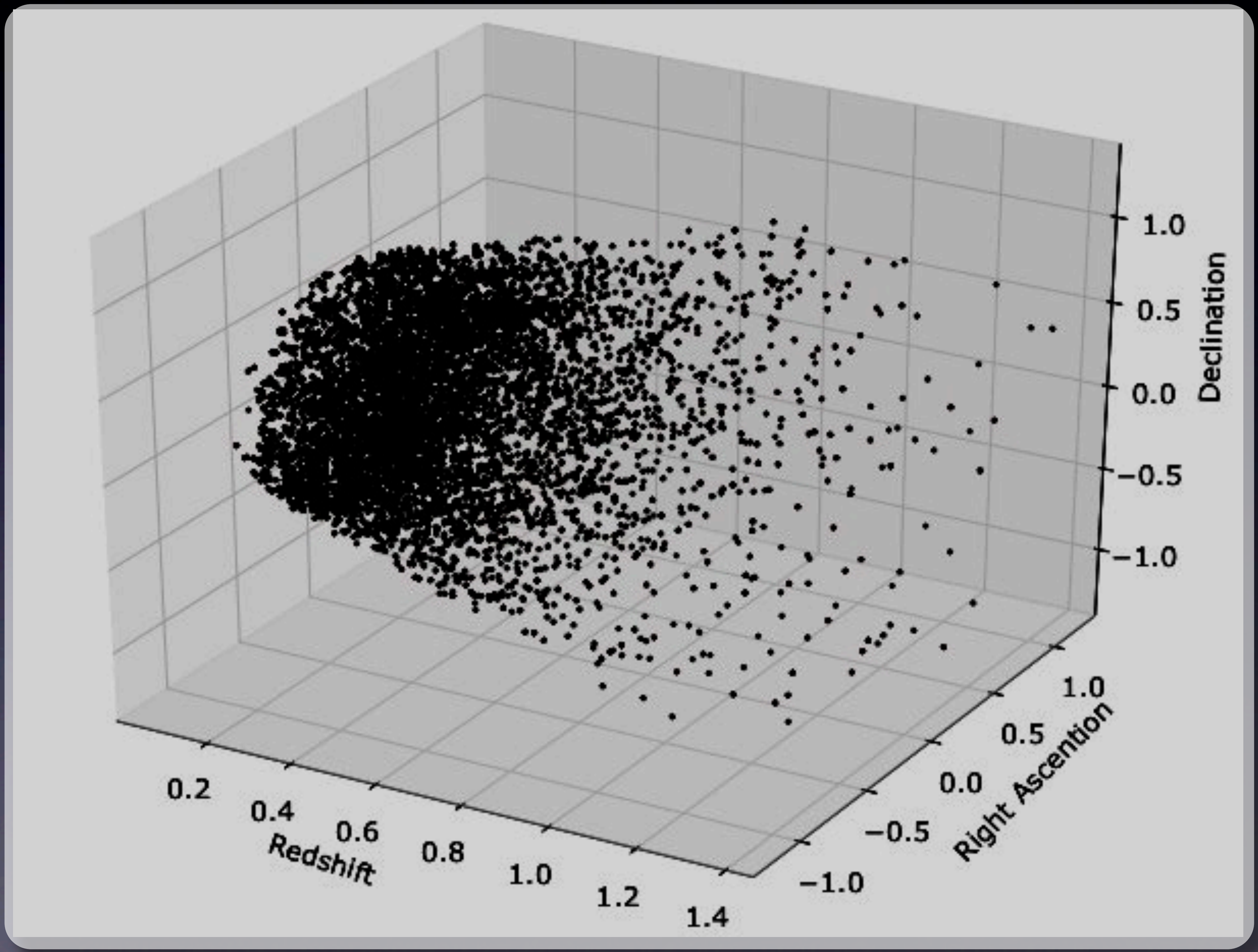
Observing Strategy

A two-tier strategy - to make optimal use of MeerKAT's bandwidth at each phase of construction:

	Phase I (2013-2015)	Phase II (2016 -)
MeerKAT specs:		
Bandwidth (GHz)	0.9 - 1.75	0.58 - 2.5
Redshift range (z)	0.0 - 0.58	0.0 - 1.4
Project goals & milestones:		
Fields	2	1
Observing time (hours)	$2\times$1000h	4000h
Spectroscopic redshifts currently available		
full redshift range	$\sim$10000	$\sim$1000
highest redshift bin	$\sim$1000 (at z=0.6)	$\sim$ 500 (at z=1)
Direct Detection of M^*_{HI}	z=0.4	z=0.6
Ω_{HI} using stacking	z=0.6	z=1.0

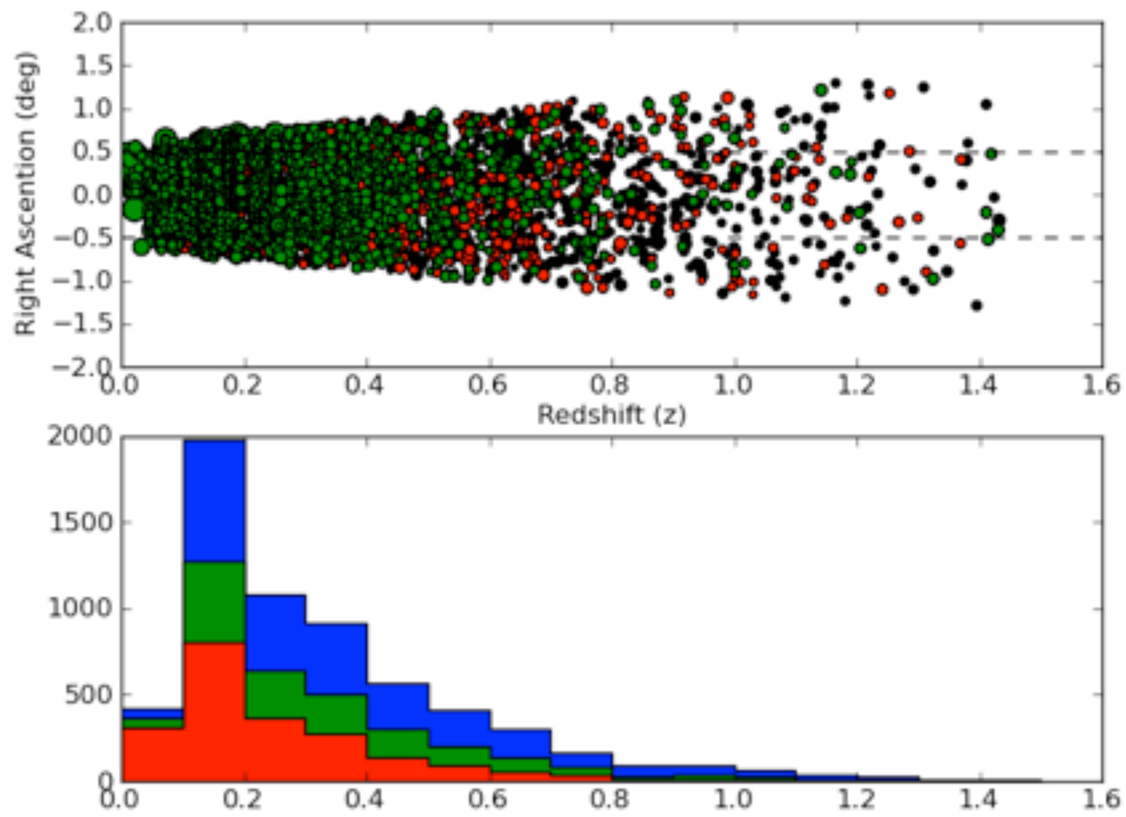
- Phase-I: Two fields: CDF-S and COSMOS
- Phase II: UltraDeep HI Field
- Final decision UltraDeep HI Field in 2015.

The Vuvuzela



Spectroscopic Challenge

- Primary beam of the meerKAT increases with redshift (the vuvuzela)
- Number of detections lowers with z: greater need for stacking.
- Need high-redshift, wide-field spectral redshift surveys.



Spectroscopic Coverage

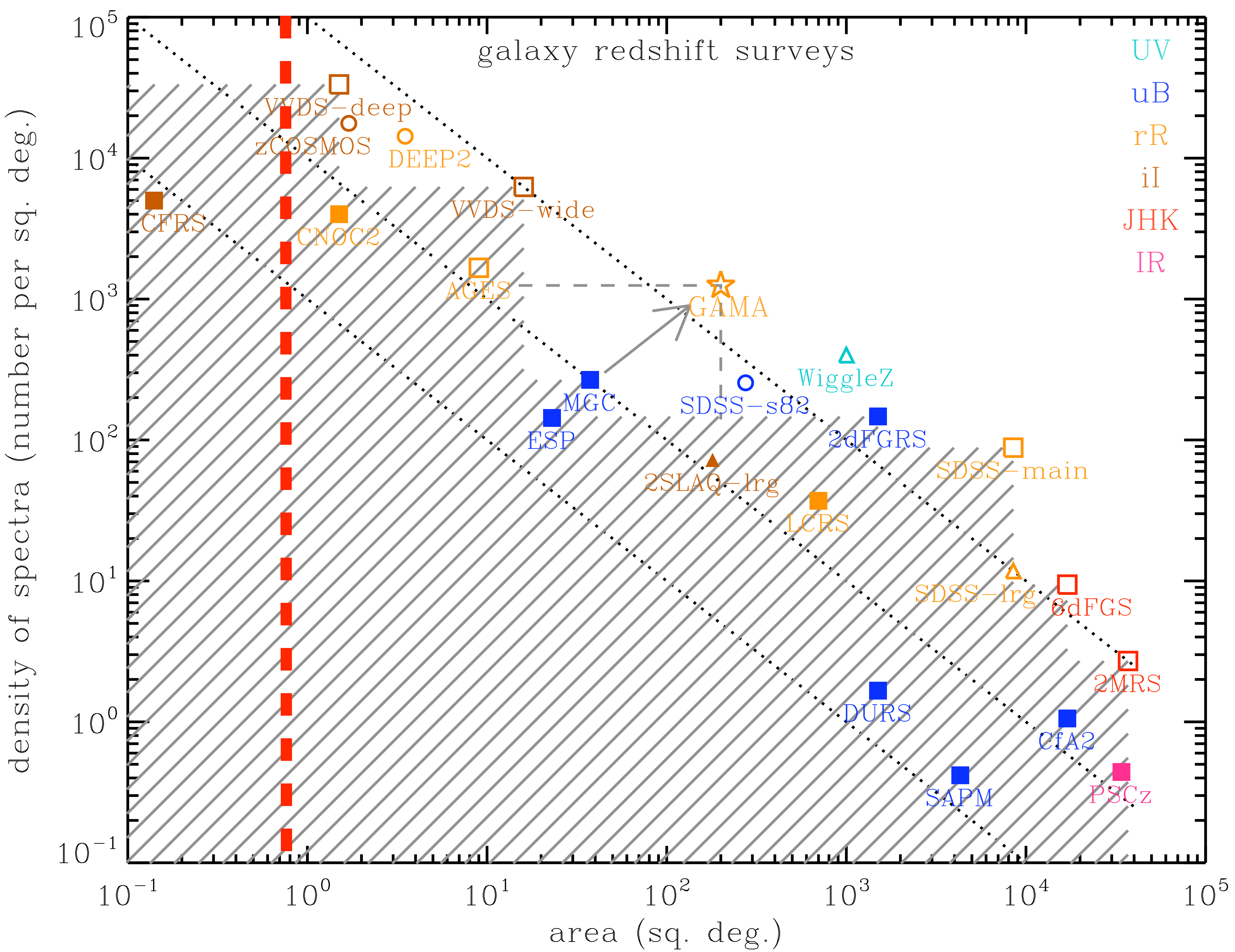


Figure courtesy of I.K. Baldry

Spectroscopic Coverage

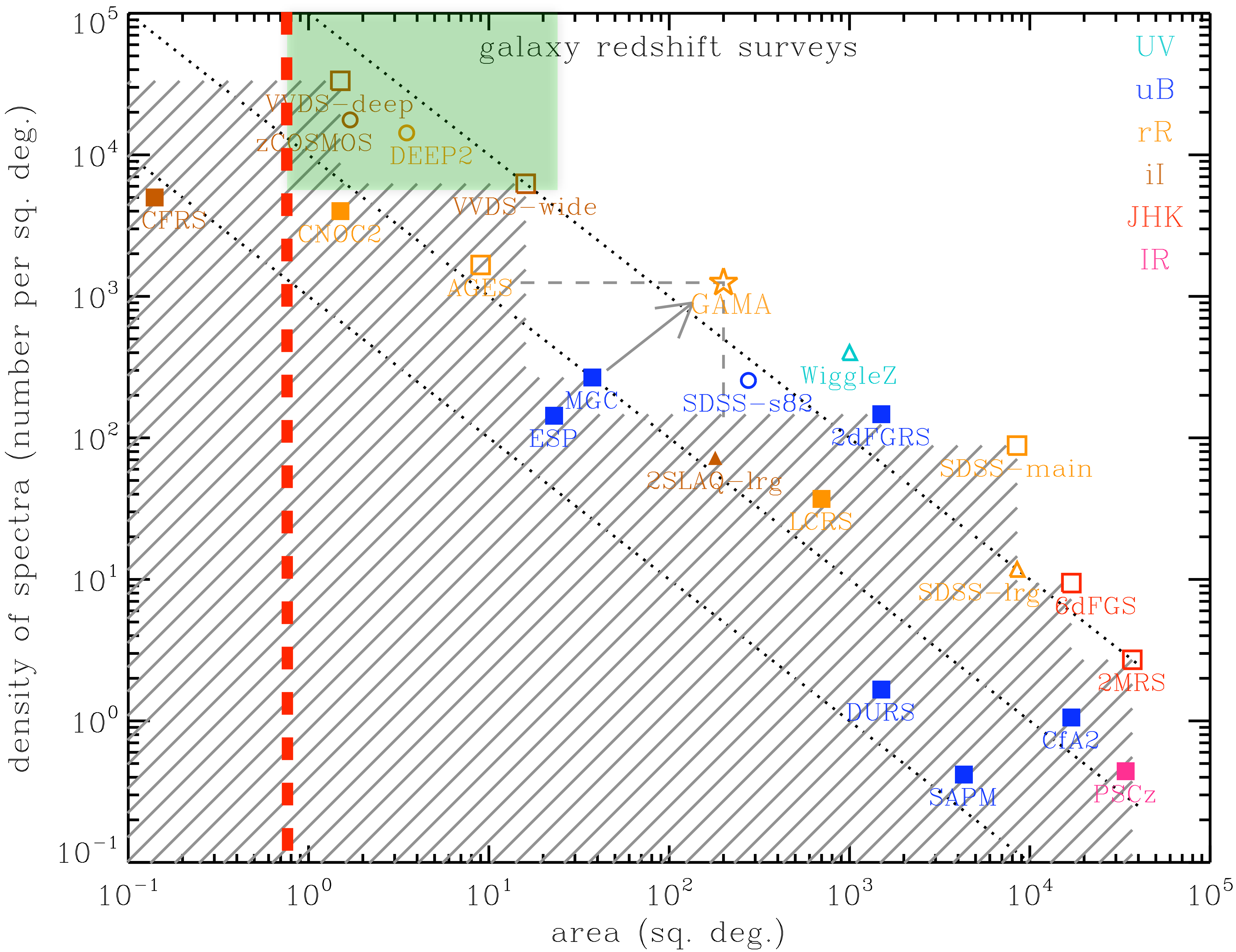


Figure courtesy of I.K. Baldry

Spectroscopic Coverage

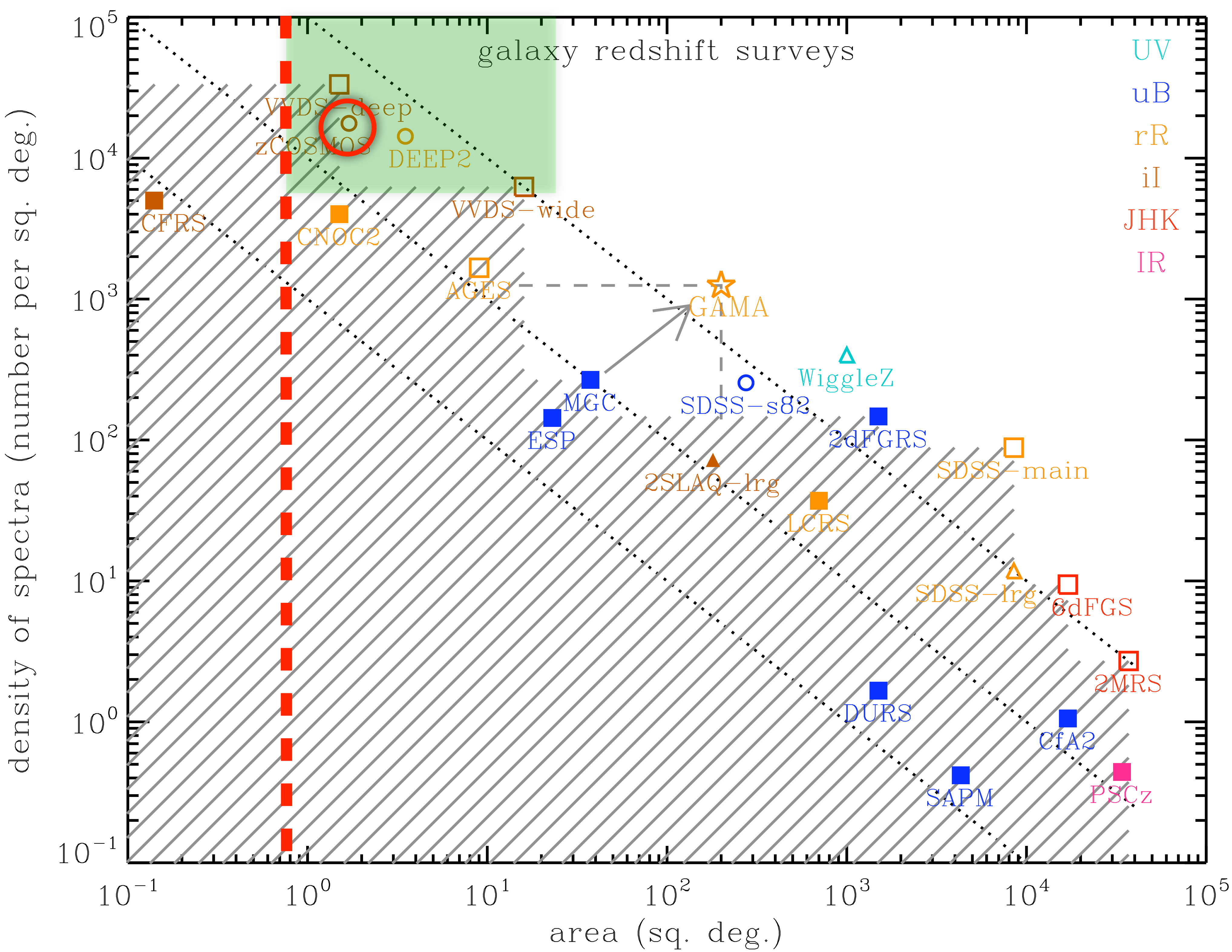


Figure courtesy of I.K. Baldry

COSMOS

Spectroscopic Coverage

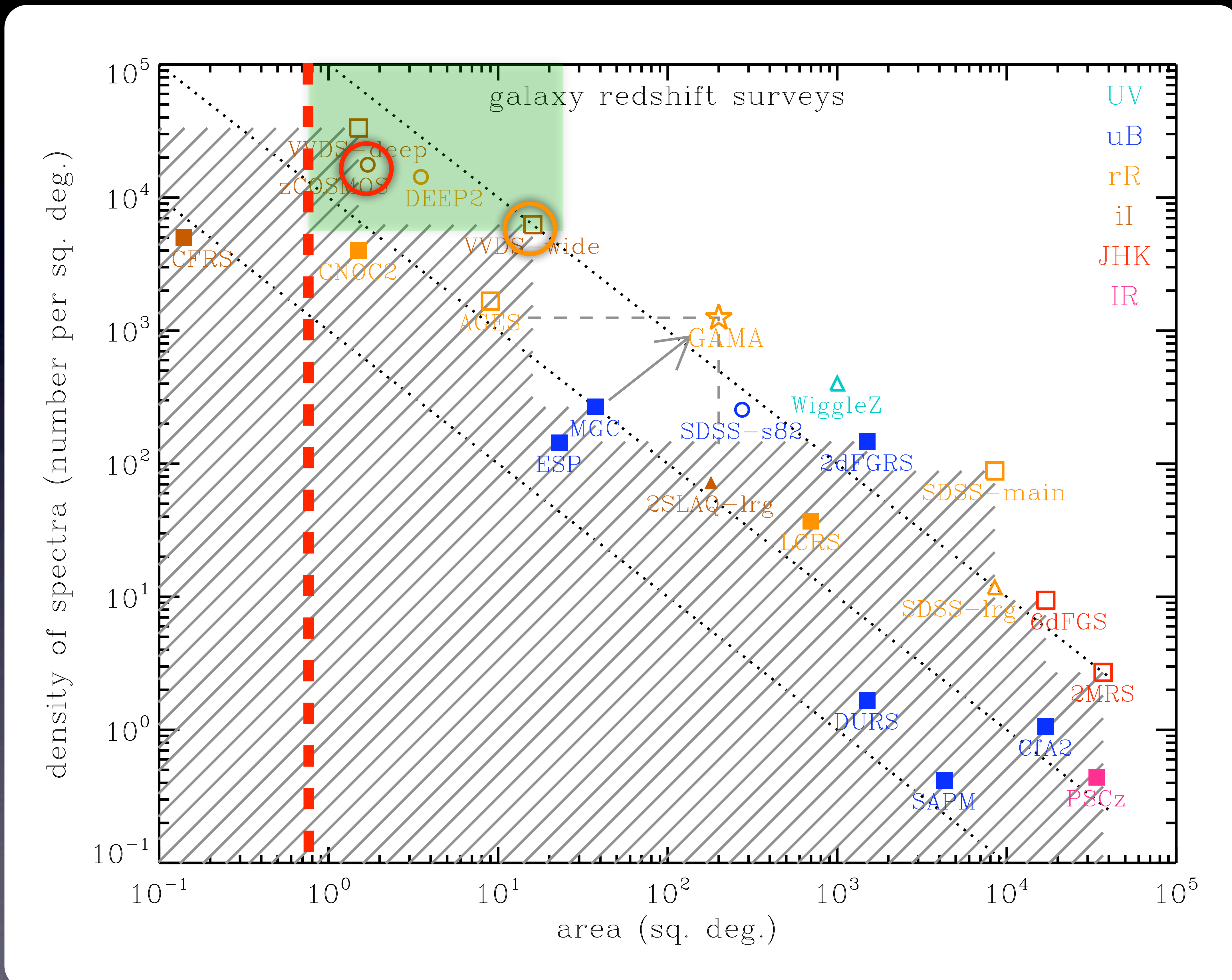


Figure courtesy of I.K. Baldry

COSMOS

CDF-S

Spectroscopic Coverage

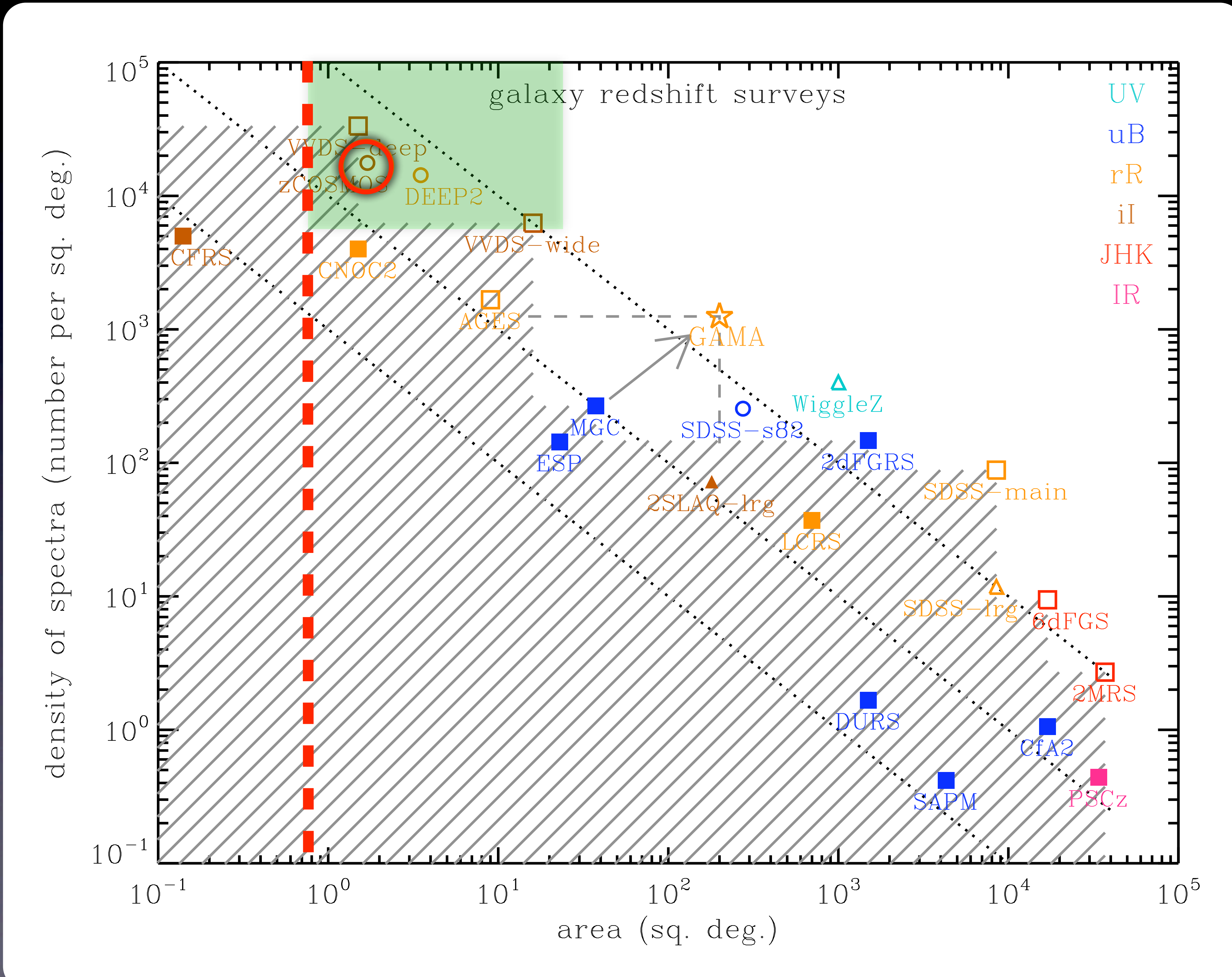


Figure courtesy of I.K. Baldry

COSMOS

CDF-S

Spectroscopic Coverage

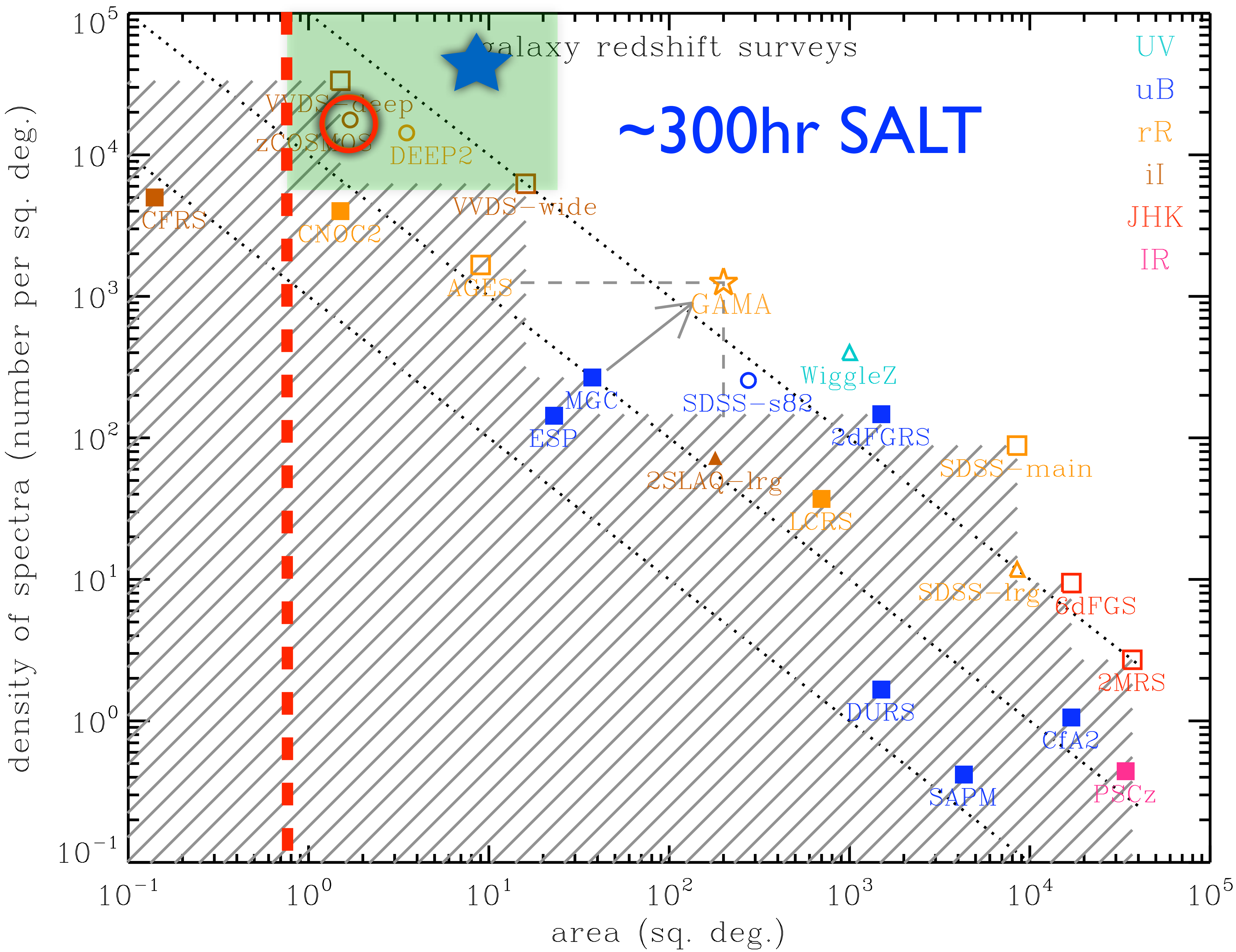


Figure courtesy of I.K. Baldry

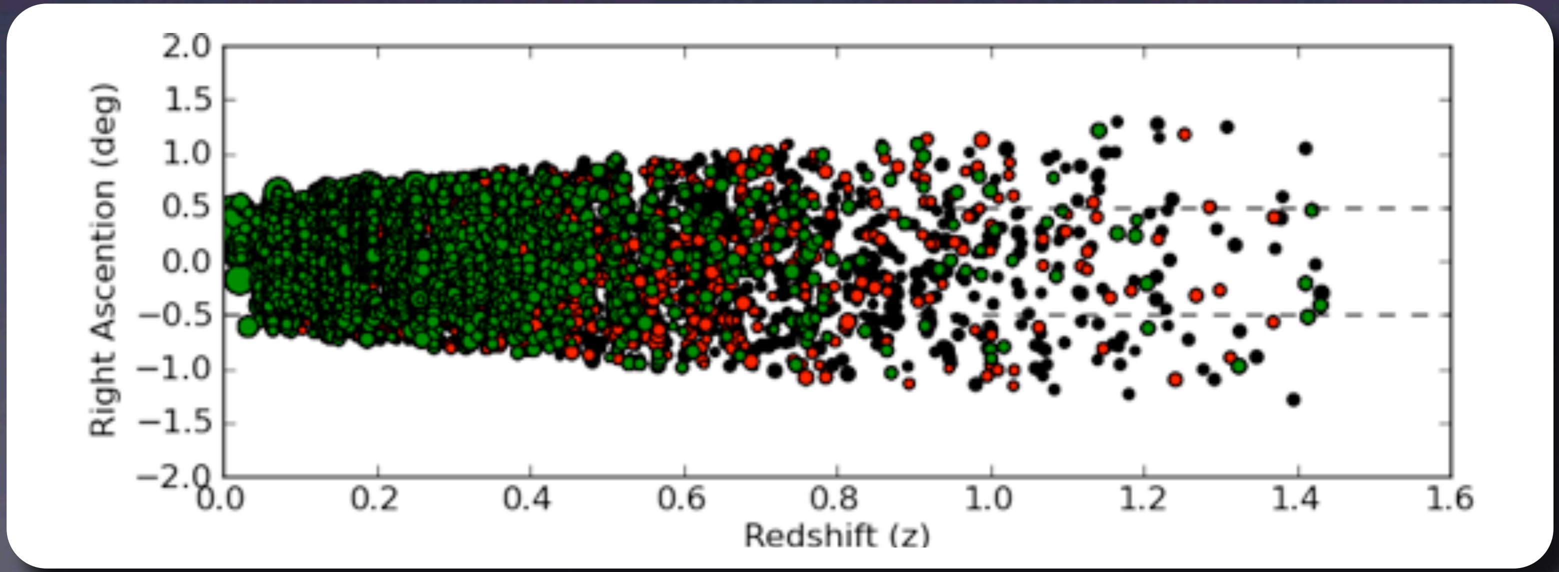
COSMOS

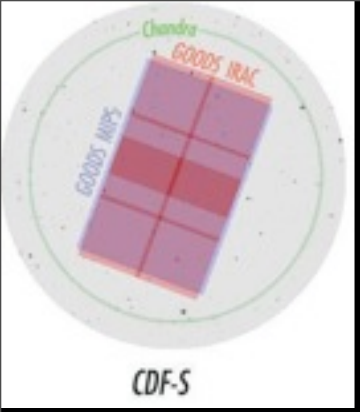
CDF-S

Wednesday, 5 May 2010

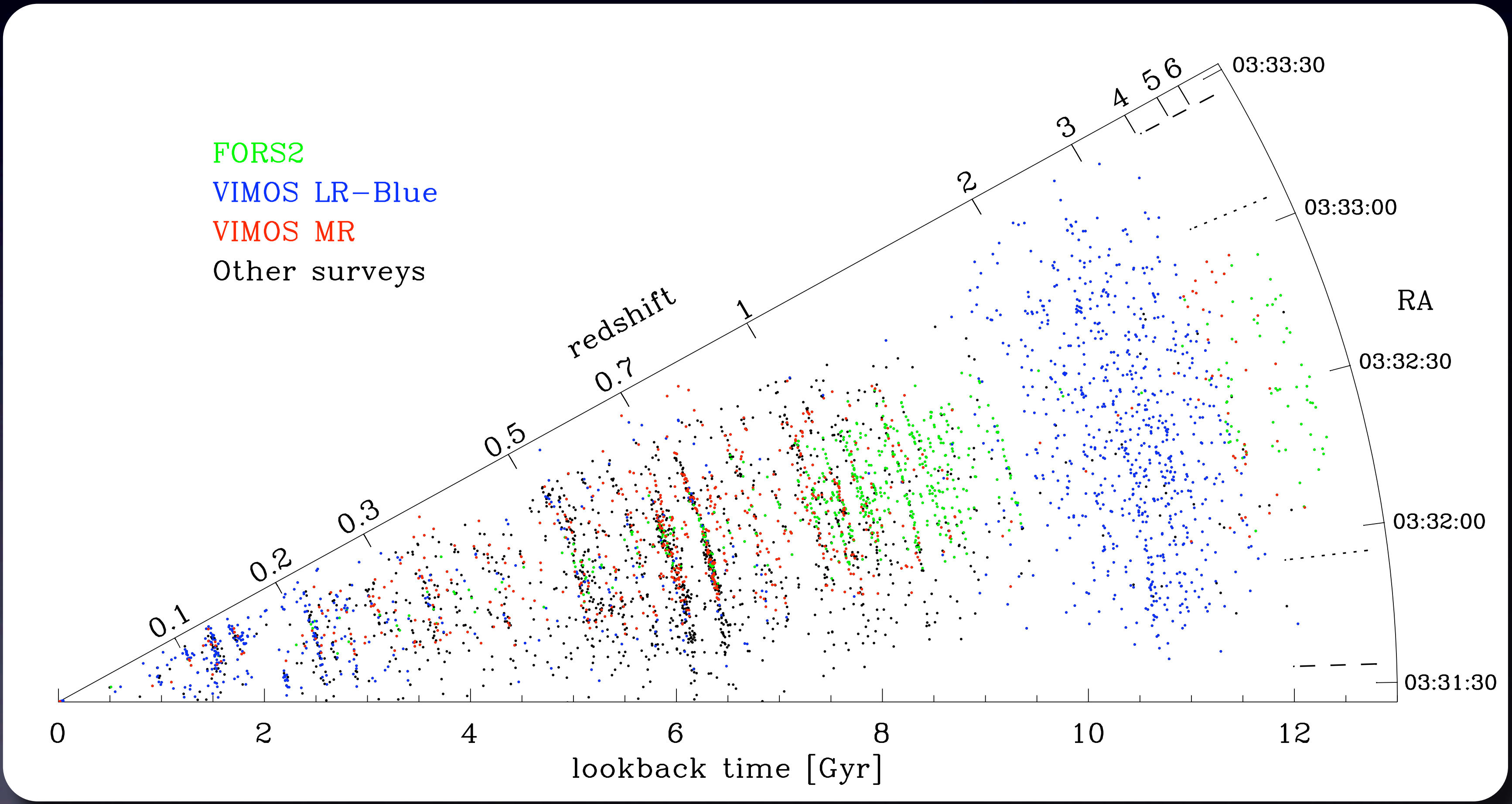
SALT proposal

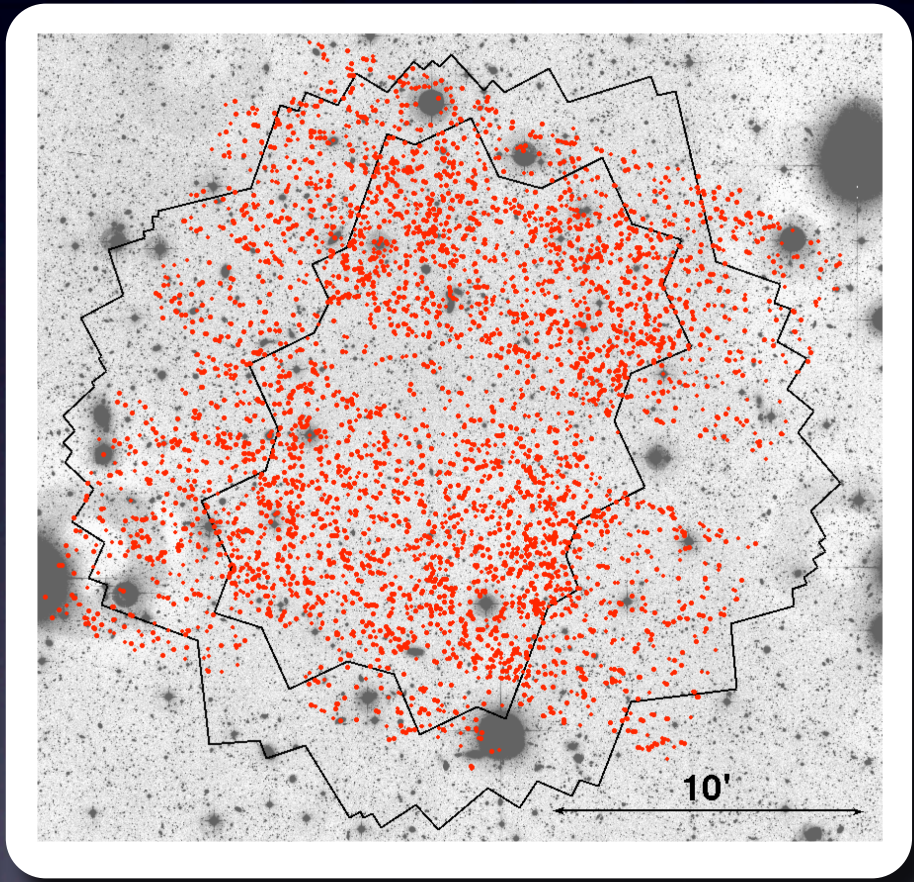
- Proposed for the GOOD-S field where a photometric redshift catalogue already exists but not a complete spectroscopic one.
- Commissioning proposal: 20 hours (8 x 30 min exposures), medium resolution
- Plan to obtain spectra (same as VLT A-sample) to verify spectrograph and MOS mode to plan of large survey



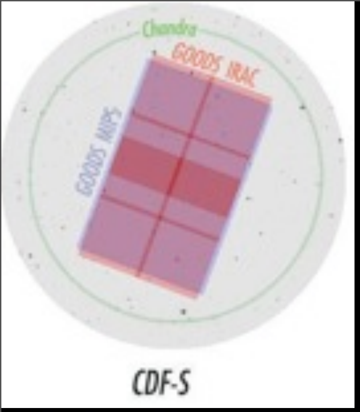


VLT coverage



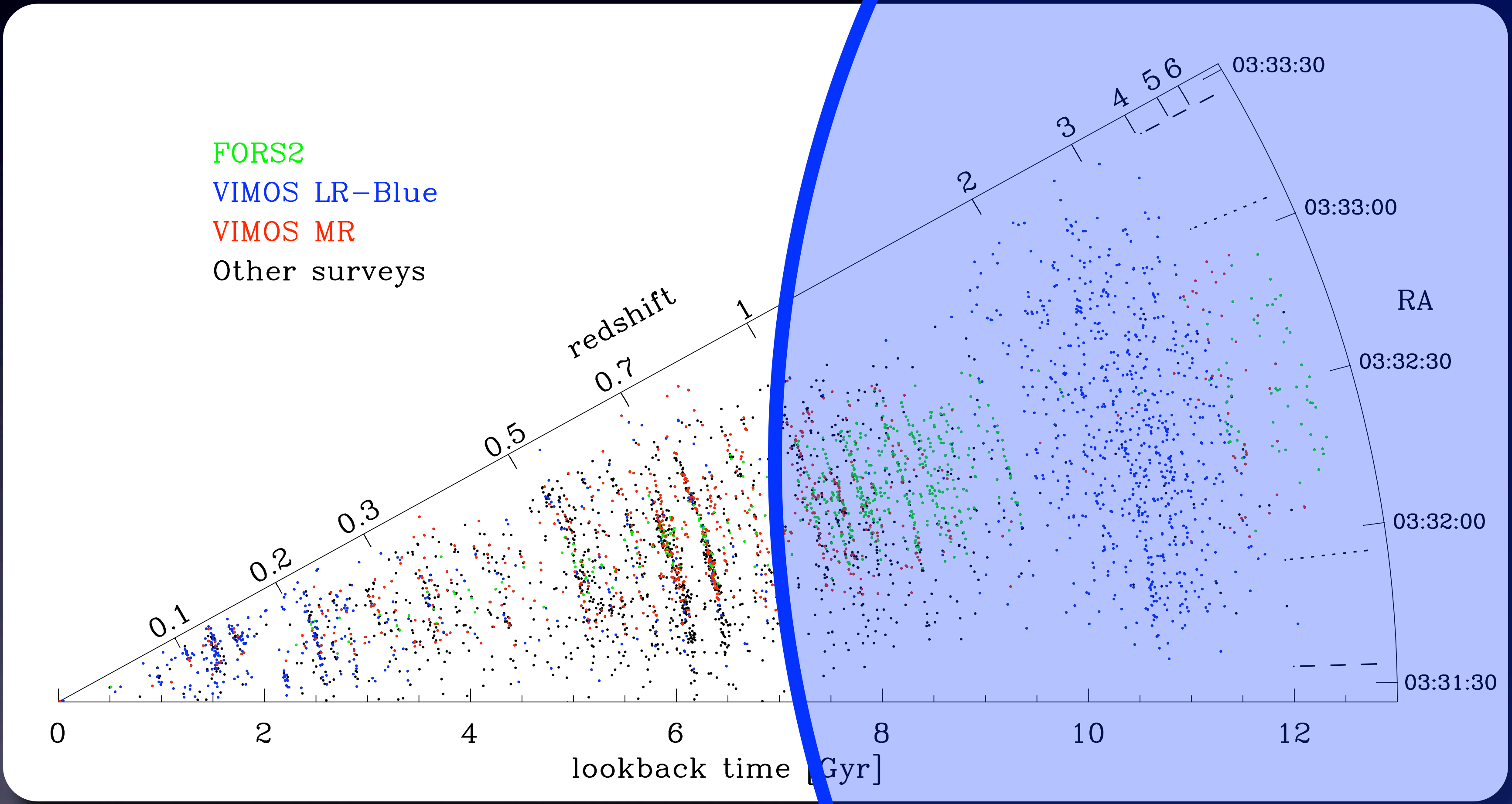


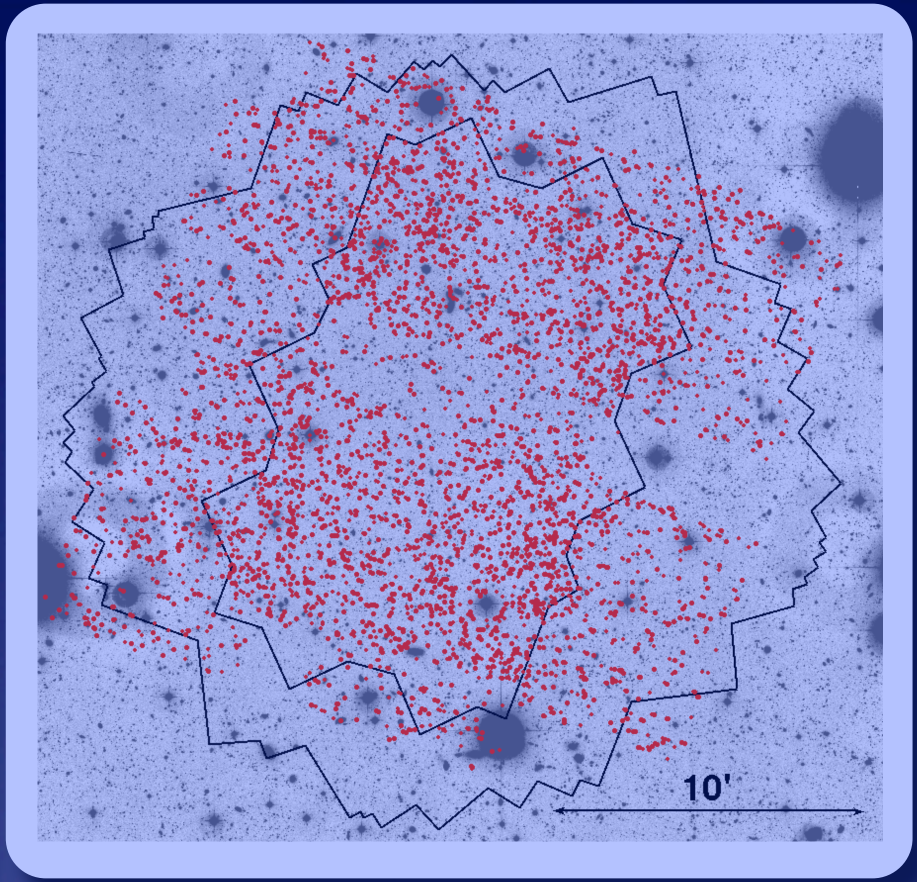
Balestra et al. A&A 512, A12, 2010



VLT coverage

MeerKAT FOV

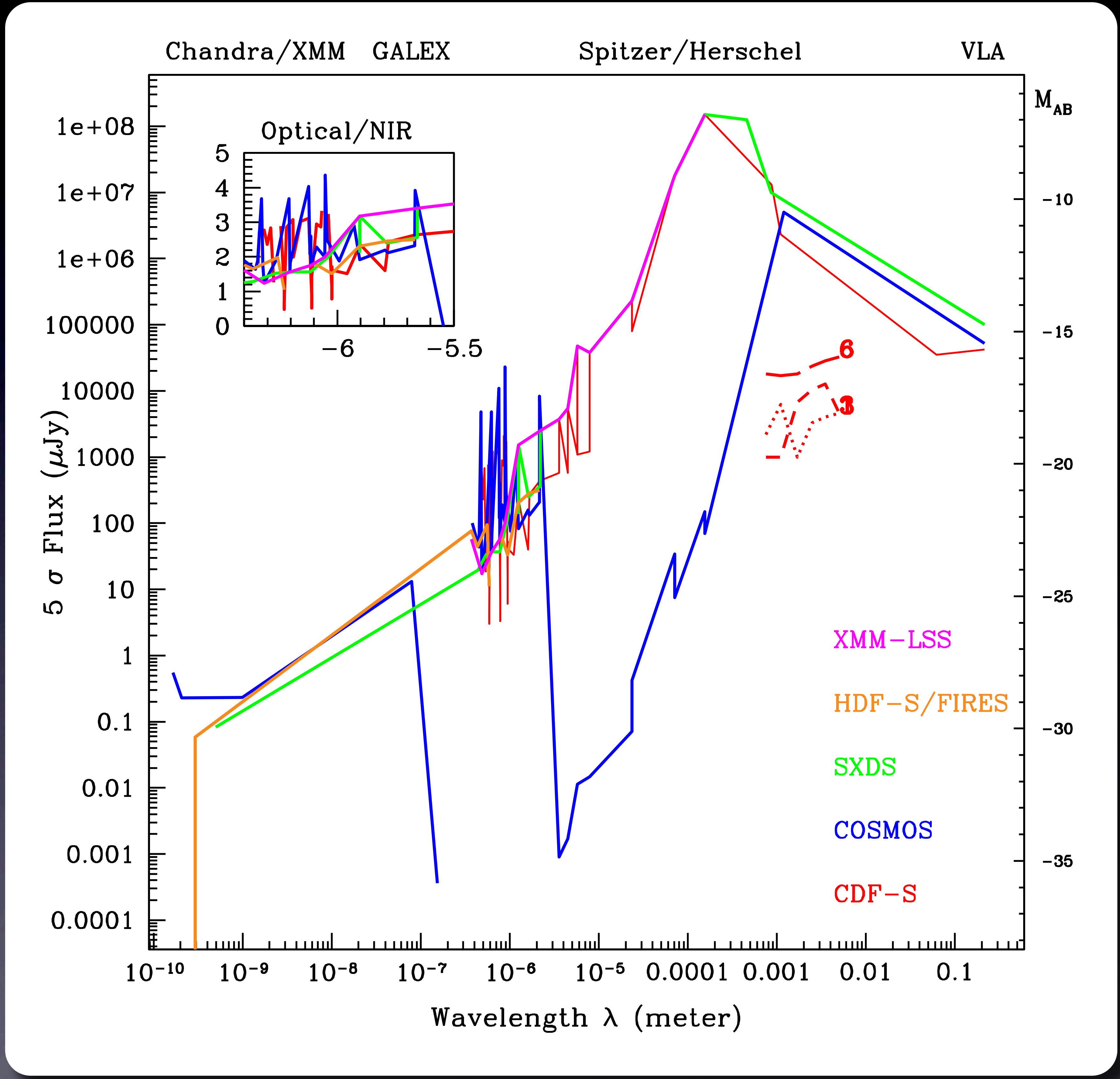




Balestra et al. A&A 512, A12, 2010

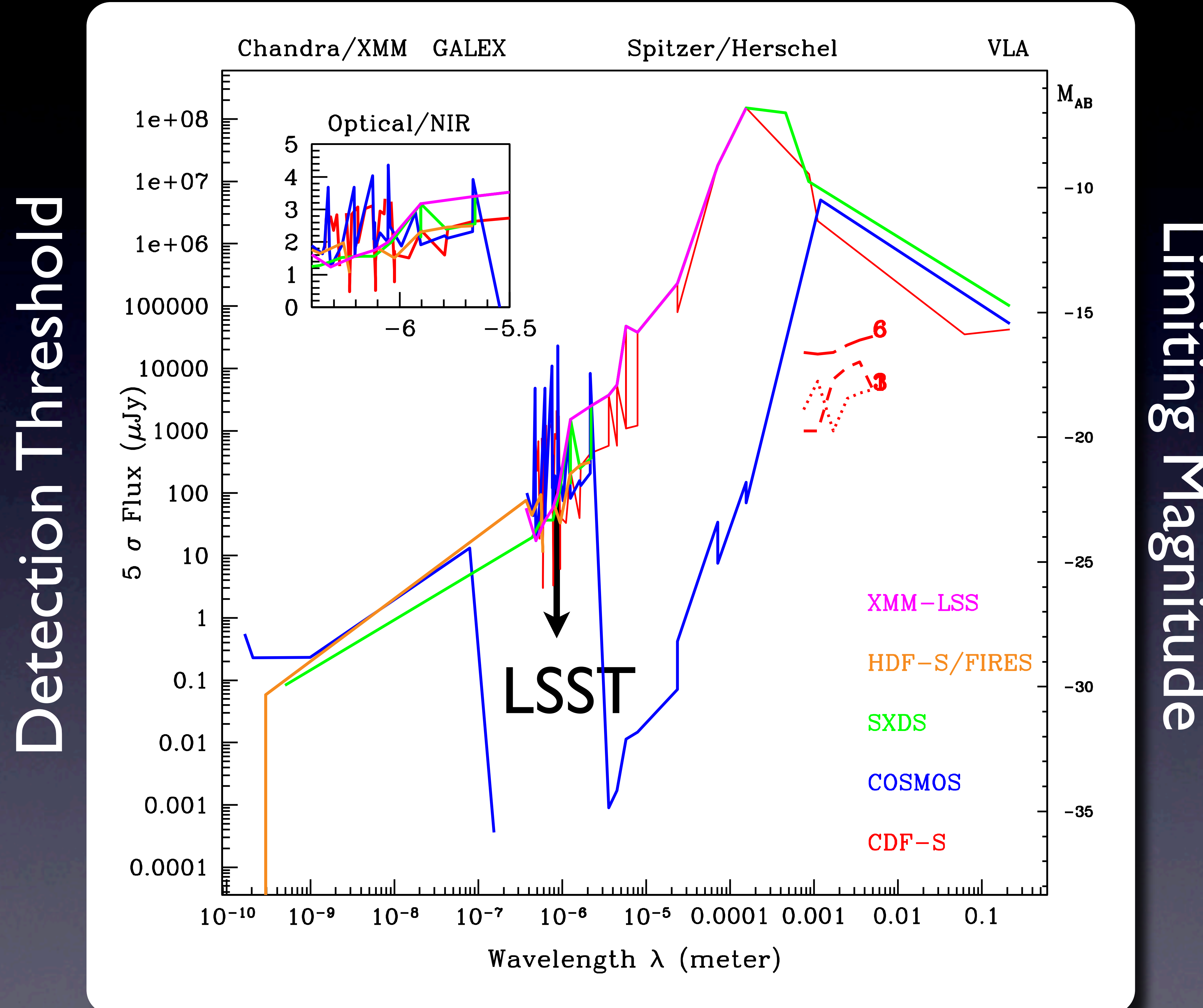
UCT/ICRAR Workshop, Arniston, May 2-6 2010

Multi-wavelength Coverage



UCT/ICRAR Workshop, Arniston, May 2-6 2010

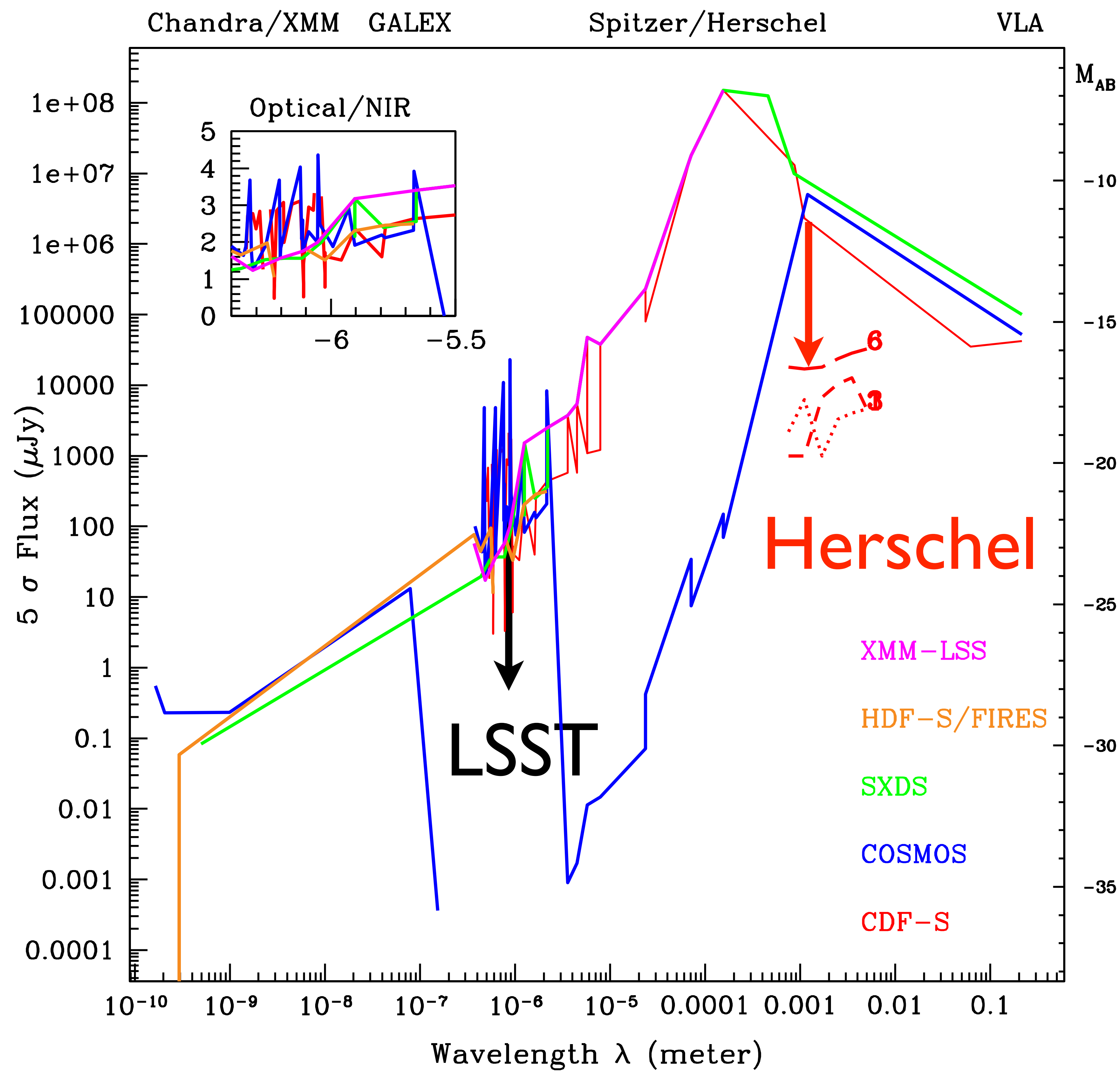
Multi-wavelength Coverage



UCT/ICRAR Workshop, Arniston, May 2-6 2010

Multi-wavelength Coverage

Detection Threshold



Limiting Magnitude

UCT/ICRAR Workshop, Arniston, May 2-6 2010

Galaxy Evolution

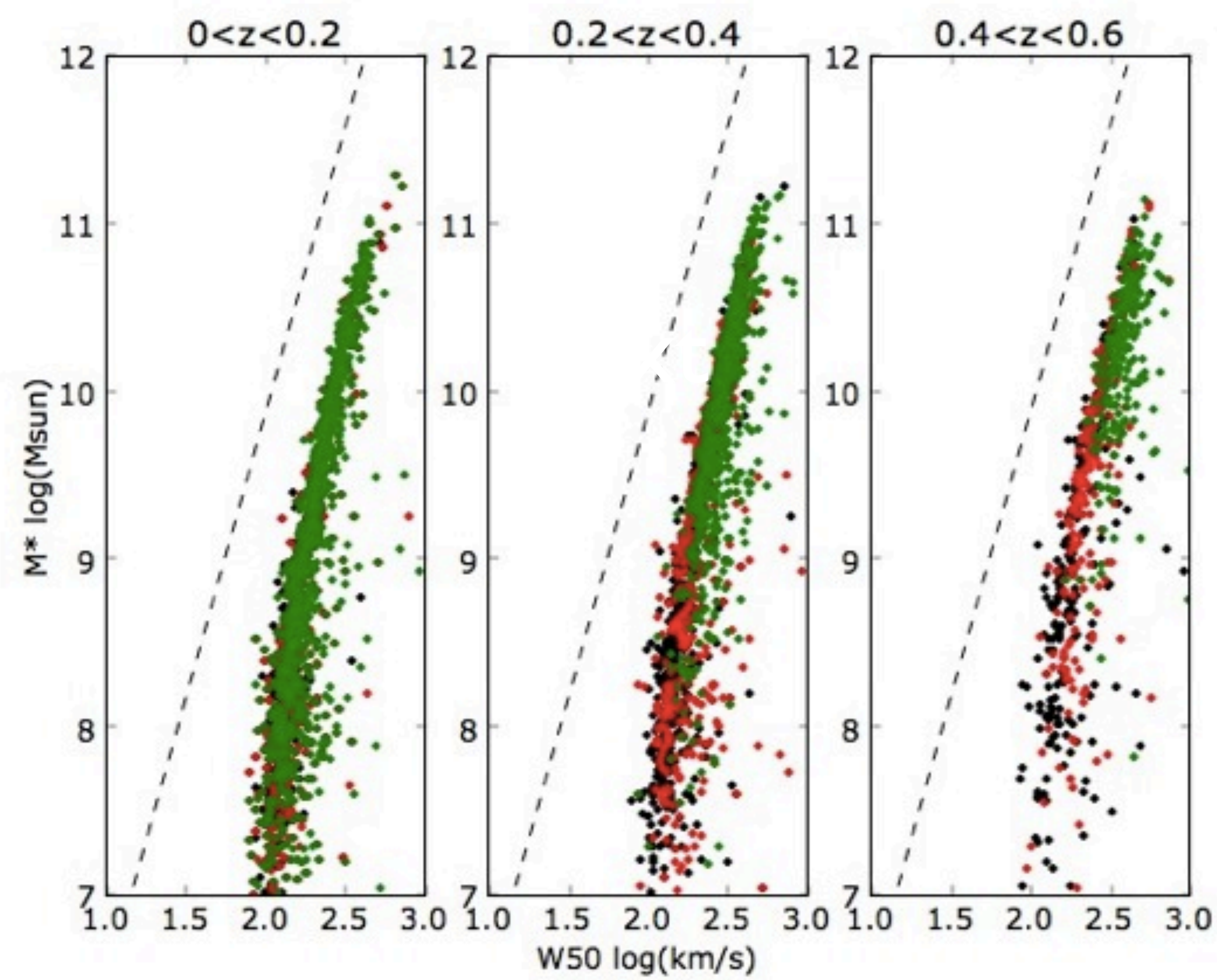
- Tully-Fisher relation (direct detections)
- Star-formation efficiency (detections and stacking)
- Hubble Sequence or Luminosity classes (direct detections and stacking).

- Other topics: “dark galaxies”, the cosmic web, OH maser counts.

Tully-Fisher

- Need high s/n individual detections. No stacking.
- Evolution is expected and seen by some authors based on small samples (~100 galaxies) with optical rotation curves.
- MUDHI will provide thousands of HI linewidths: probe virial radius and proper statistics.
- Direct view of Galaxy Assembly: zeropoint, slope and scatter of complete TF samples.

Tully-Fisher

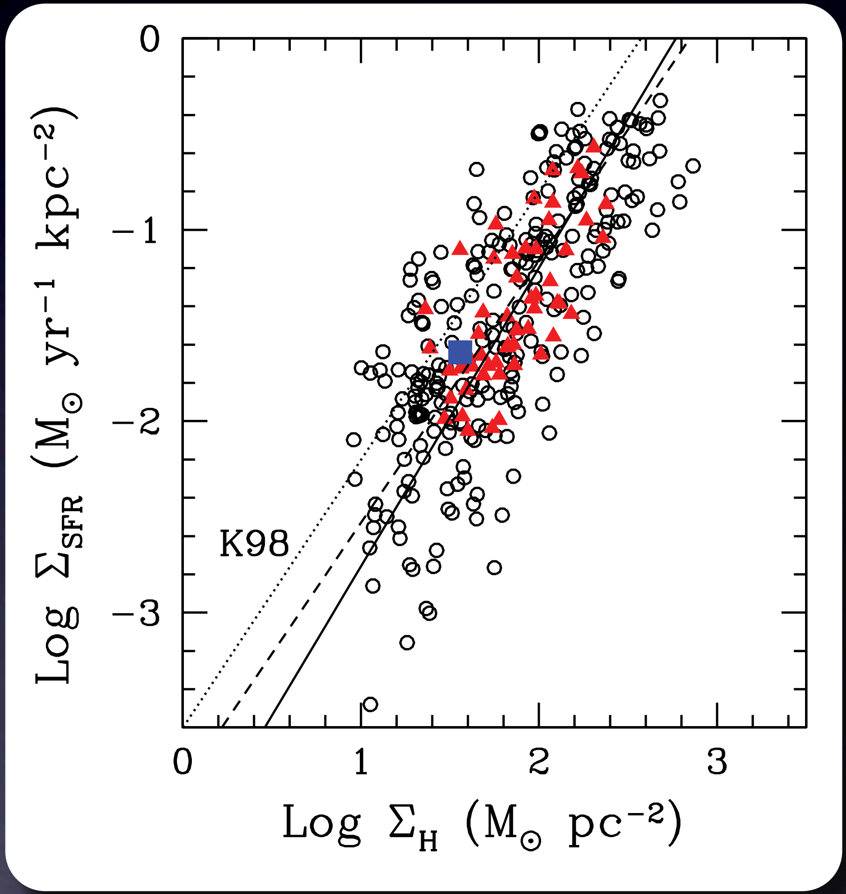


UCT/ICRAR Workshop, Arniston, May 2-6 2010

SKADS

Star Formation Law

- Schmidt-Kennicutt law for whole disk and HI surface density.
- Missing Molecular (H_2) component.
- Follow-up with ALMA for the direct detections.



Kennicutt et al. 2007

HI in Galaxy Populations

- Subdivide the galaxy population based on e.g., Hubble type or other property from multi-wavelength data
- Stack sub-populations.
- Characterise HI gas content vs B/D, Lum class, Type, SF etc. etc.

Strange new galaxies

- At higher redshift there are examples of many new types of galaxies. The HI perspective will help understand them, e.g.:
- ULIRGS at higher redshifts; stage of interaction? Dynamics?
- Chain galaxies: are they rotating or not?

Elmegreen et al. 2006

Conclusions

- MeerKAT is ideally suited to detect HI at high redshift.
- Bandwidth drives two-tiered strategy.
- HIMF and Ω_{HI} headline science.
- Challenge to optical spectroscopy.
- Galaxy Evolution from multi-wavelength.

Back-up slides

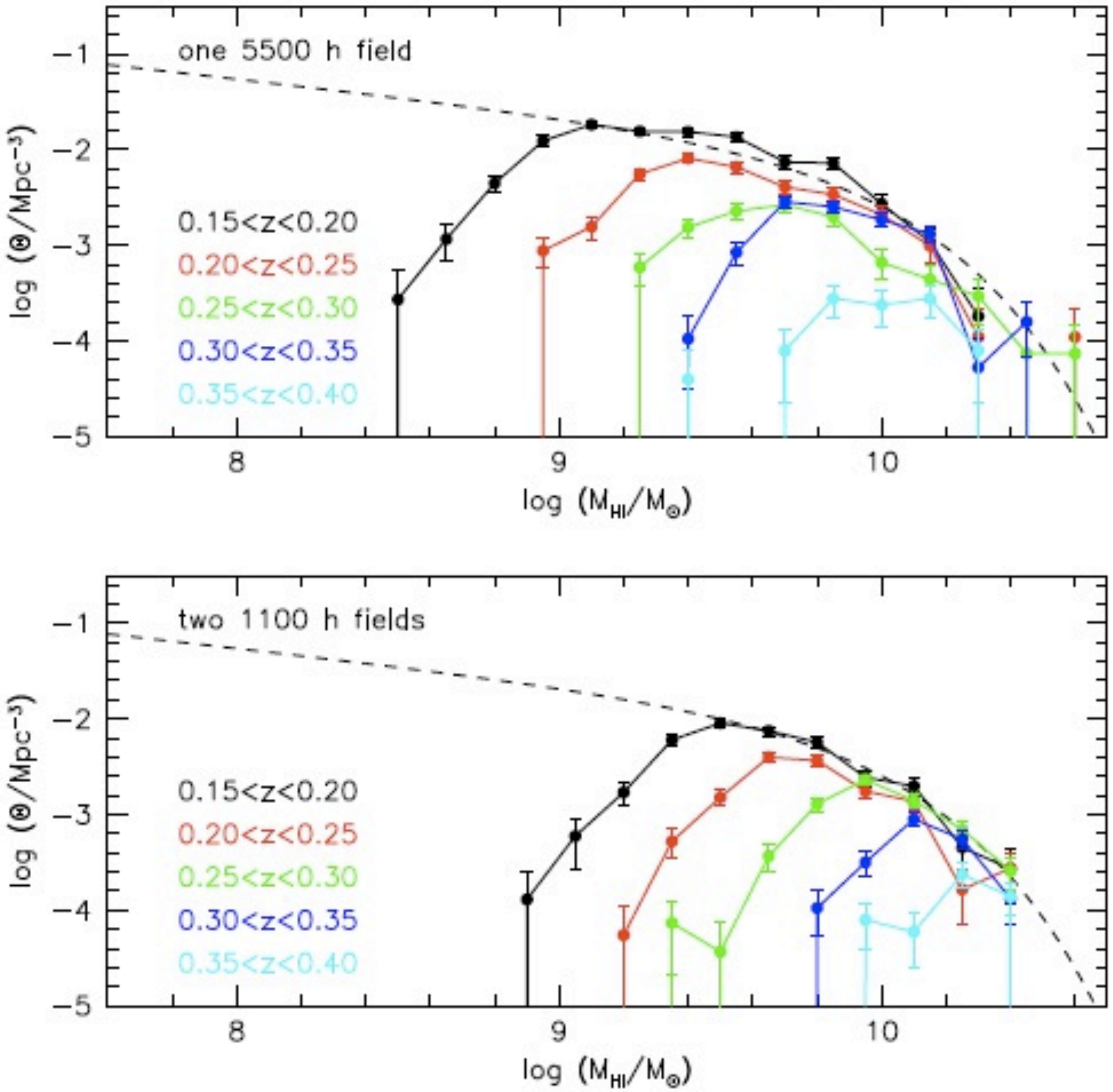
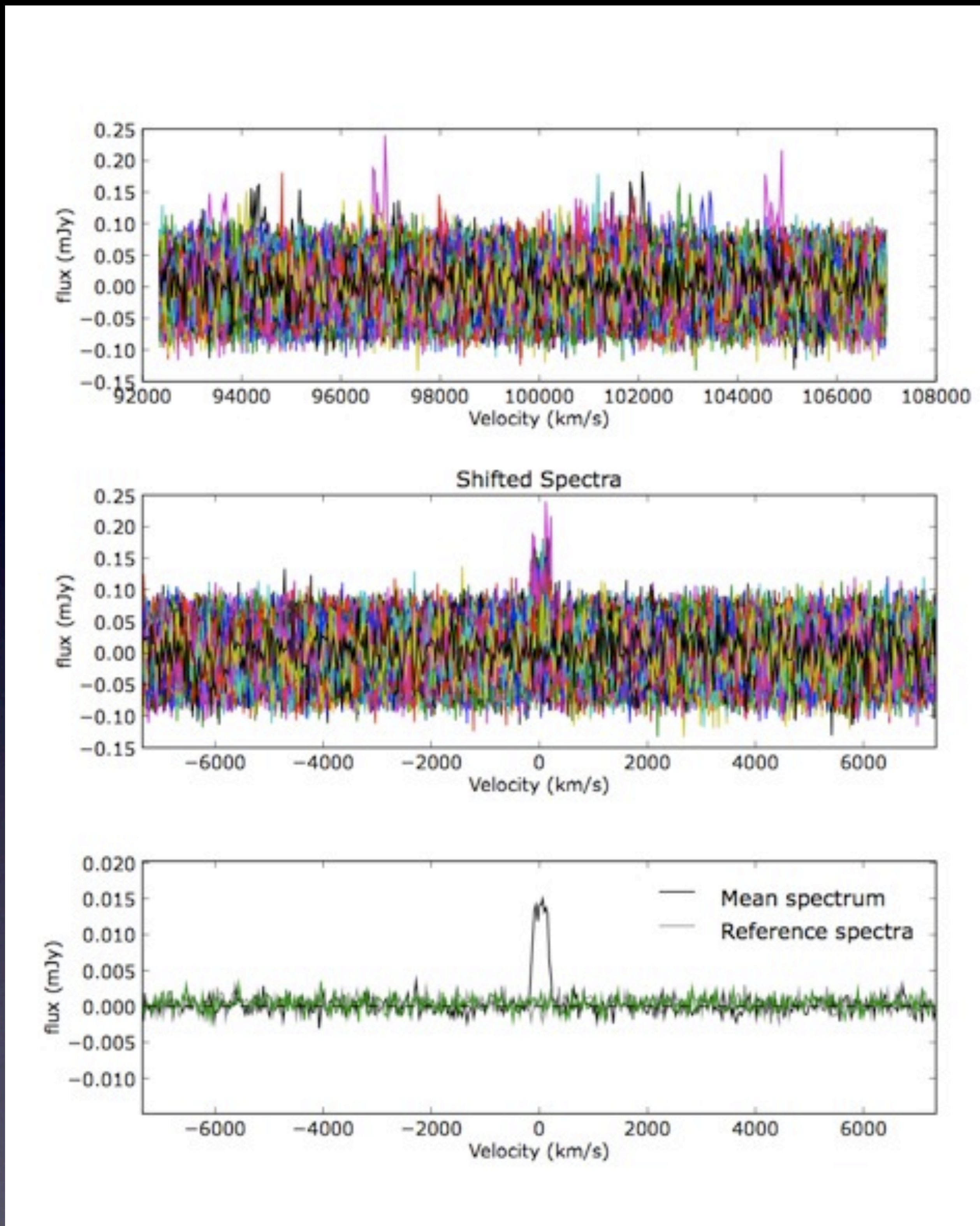


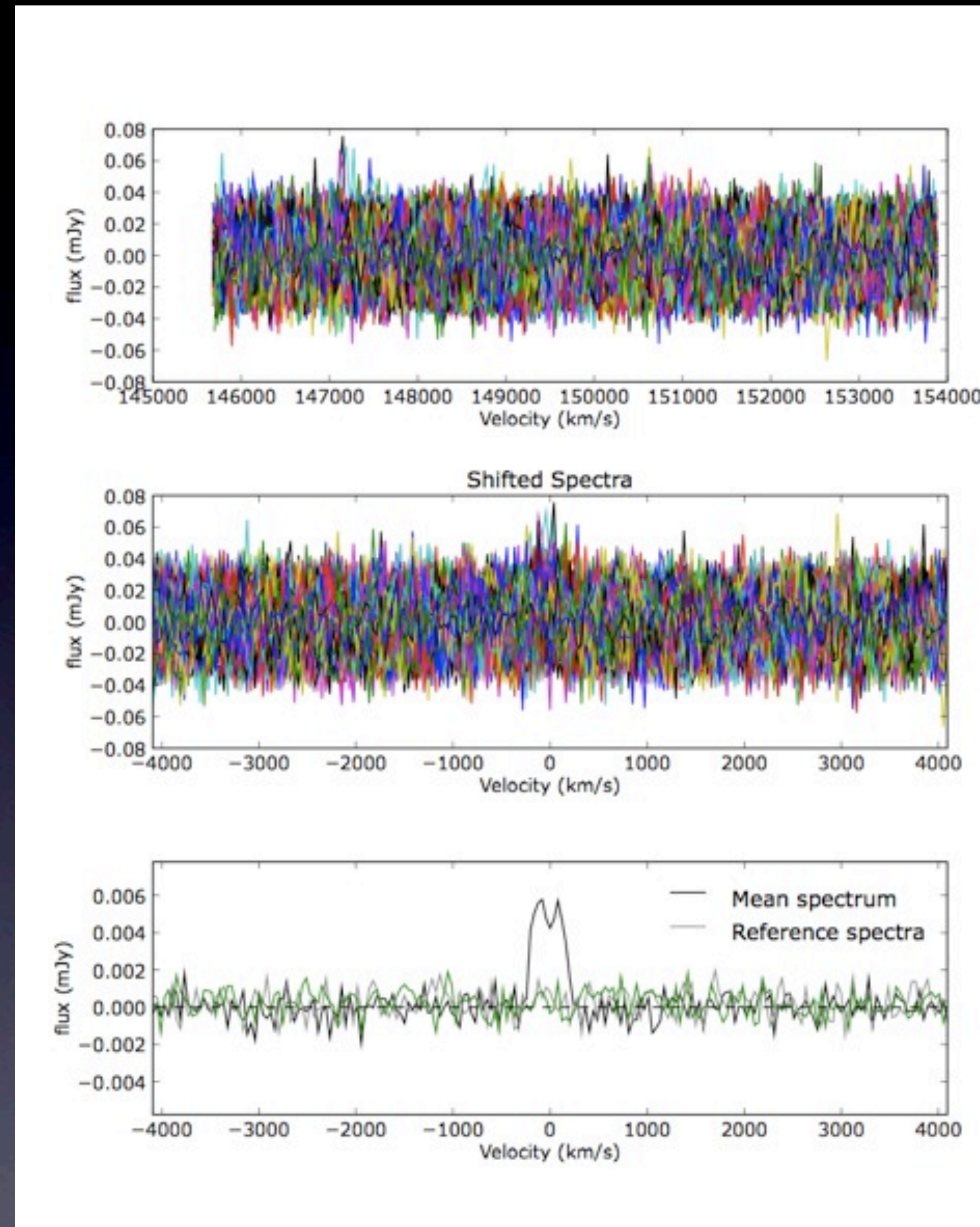
Figure 1: The HI Mass Functions based on mock catalogues by M. Zwaan. Galaxies are detected using optimal smoothing and we use a HIPASS-like correlation statistics between HI mass and velocity width and other parameters. No evolution in the HIMF is assumed. Image courtesy of M. Zwaan

z=0.5 (1000 galaxies)



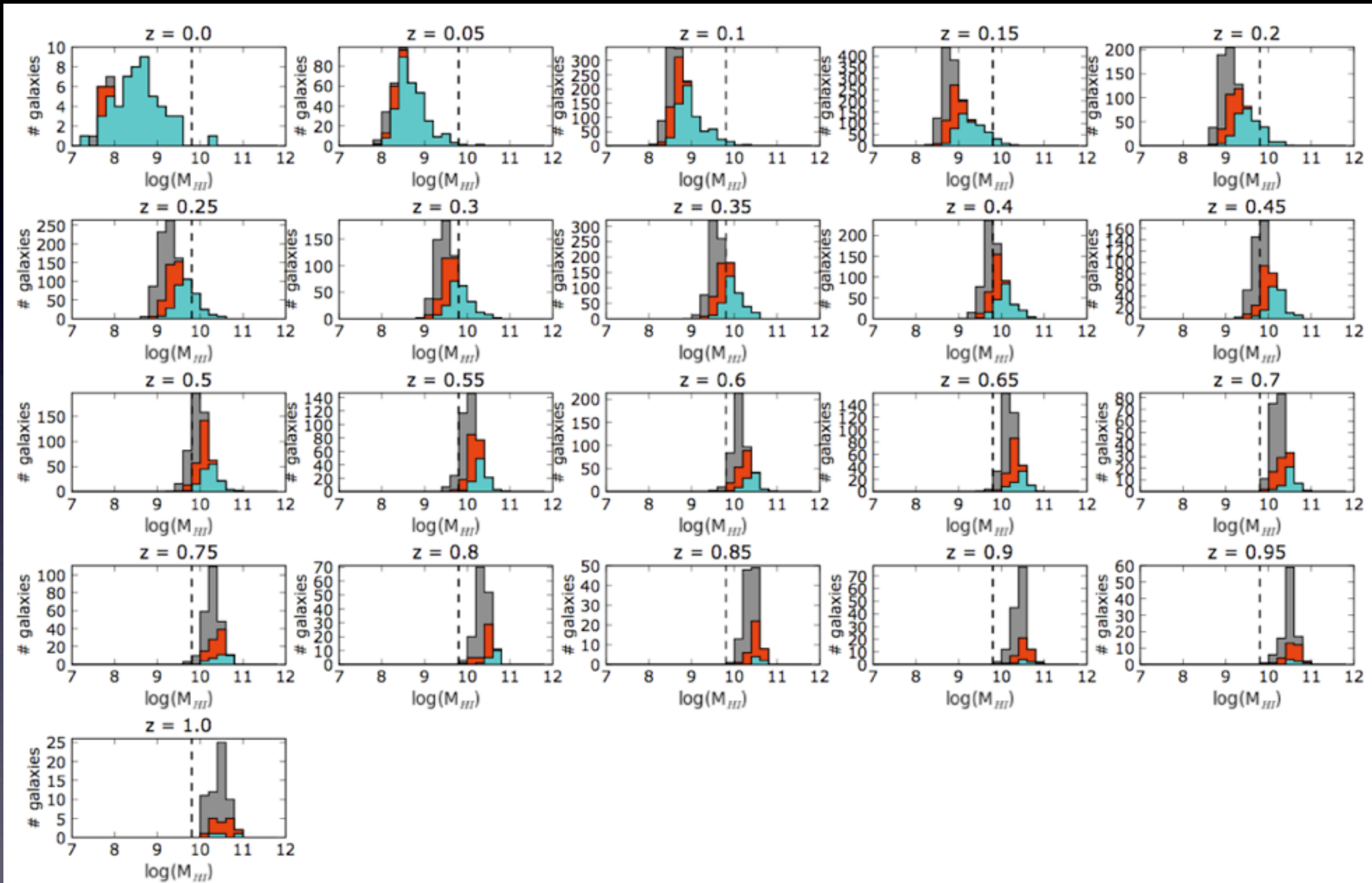
Survey 1: 1000 hour observations,
noise = 0.0286 mJy
Δv = 30 km/s

z=1.0 (500 galaxies)



Survey 3: 4000 hour observations,
noise = 0.0143 mJy
Δv = 40 km/s

Observing strategy: HIMF



5σ detections using optimal smoothing

For survey S3, detections:

z= 0.0	59
z= 0.05	368
z= 0.1	1266
z= 0.15	1466
z= 0.2	750
z= 0.25	963
z= 0.3	609
z= 0.35	993
z= 0.4	658
z= 0.45	521
z= 0.5	542
z= 0.55	396
z= 0.6	456
z= 0.65	376
z= 0.7	210
z= 0.75	240
z= 0.8	156
z= 0.85	119
z= 0.9	150
z= 0.95	101
z= 1.0	60

total galaxies detected: 10459

For survey S2, detections:

z= 0.0	57
z= 0.05	338
z= 0.1	943
z= 0.15	905
z= 0.2	454
z= 0.25	566
z= 0.3	388
z= 0.35	583
z= 0.4	381
z= 0.45	274
z= 0.5	302
z= 0.55	208
z= 0.6	211
z= 0.65	172
z= 0.7	89
z= 0.75	93
z= 0.8	51
z= 0.85	37
z= 0.9	43
z= 0.95	32
z= 1.0	17

total galaxies detected: 6144

For survey S1, detections:

z= 0.0	53
z= 0.05	302
z= 0.1	647
z= 0.15	535
z= 0.2	278
z= 0.25	337
z= 0.3	219
z= 0.35	341
z= 0.4	206
z= 0.45	144
z= 0.5	144
z= 0.55	91
z= 0.6	88
z= 0.65	67
z= 0.7	36
z= 0.75	32
z= 0.8	16
z= 0.85	6
z= 0.9	8
z= 0.95	6
z= 1.0	3

total galaxies detected: 3559

OH Maser Counts

- Galaxy-Galaxy merger is ideal setting for OH megamasers:
    - high molecular density.
    - an IR pump (star-formation) to invert the OH molecule population.
    - a background of 1.6 GHz seed photons to be amplified.
- Redshifted OH maser lines can be identified by known redshifts from spectroscopy or photo-z's.

Second Tier Sanity Checks

- Verify the stacked results from phase-1 (z=0-0.6) at z~0.5 with direct detections in phase II.
- For example, stacked results for faint HIMF, SFR, gas fractions for different galaxy types can all be verified in phase-II (z=0-1.42

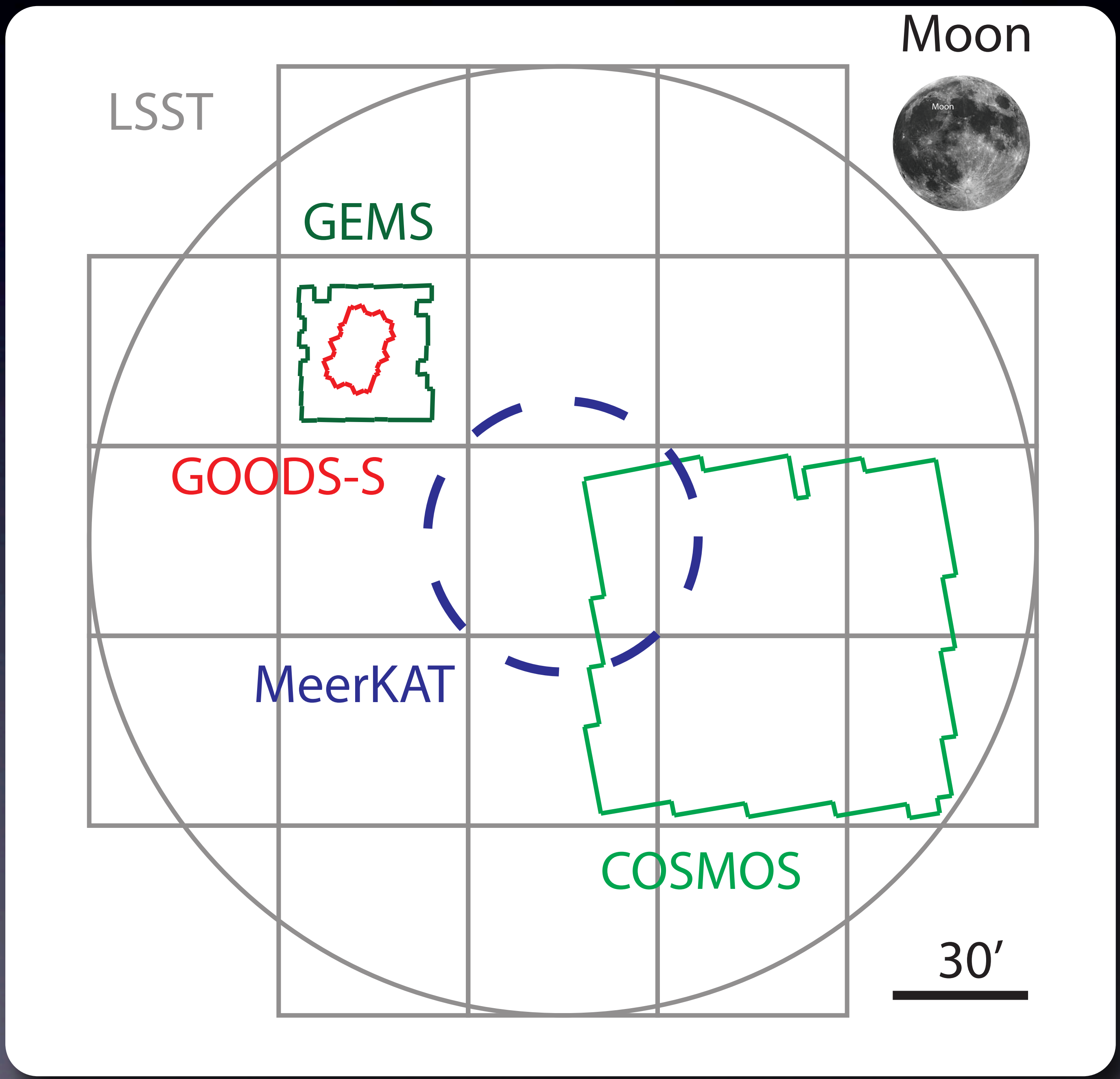
Data Releases

- Initial data releases for team consumption only: pipeline verification only.
- First big data-release after 1000 hr on one field completed. Early science, stacking results etc.

Data Releases

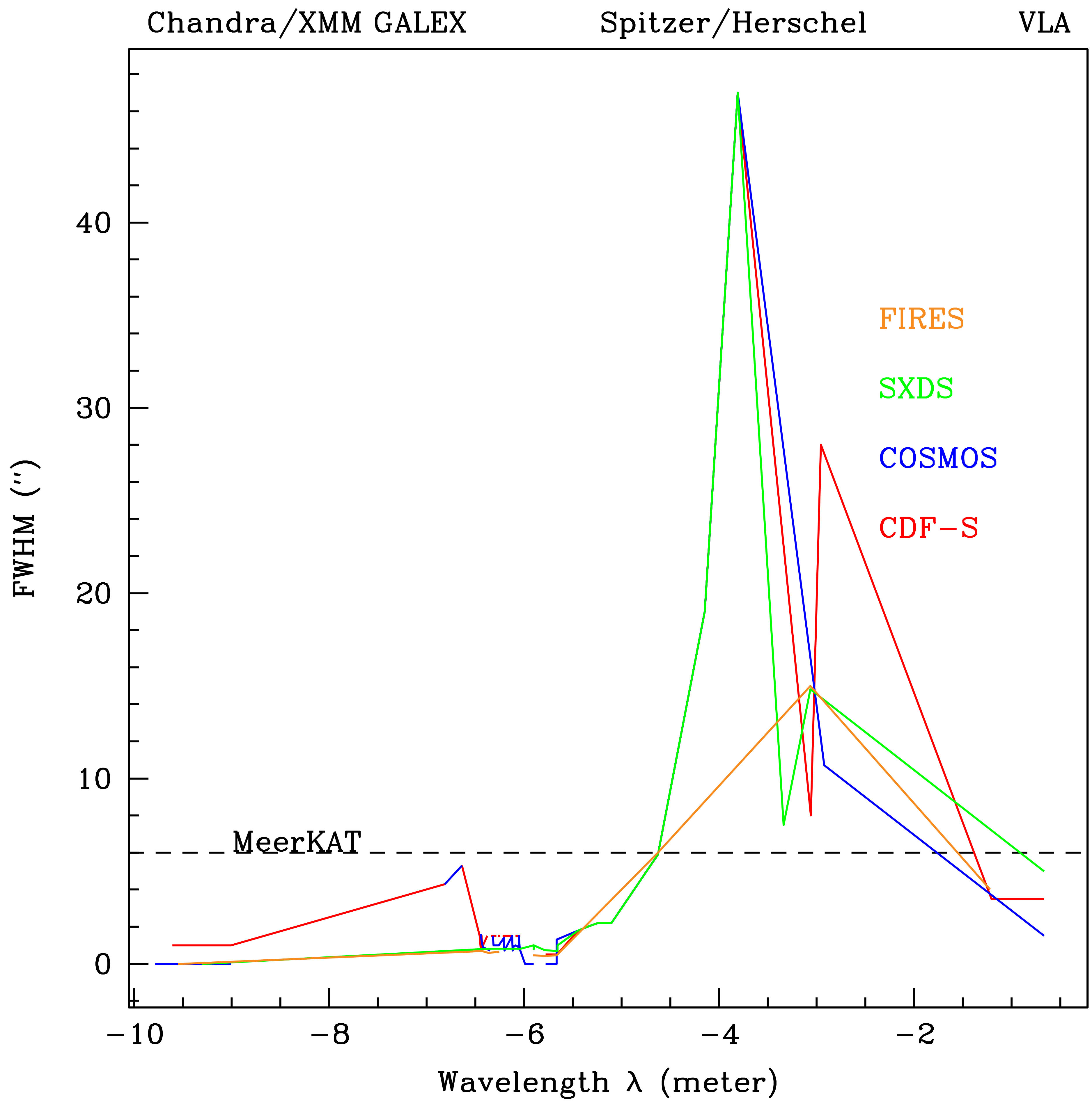
Phase	Data release	Description
Phase I		
	0.1-0.9	1 field, tens to hundreds of hours
		internal "releases" to check s/n improvement and source counts
	Release 1	Field 1, 1 month of integration
	Release 2	Field 2, 1 month of integration
	Release 3	Field 1, full integration (1000 hours)
	Release 4	Field 2, full integration (1000 hours)
Phase II		
	Release 5	3 months integration
	Release 6	6 months integration
	Release 7	full integration (4000 hours)

CDF-S vs COSMOS

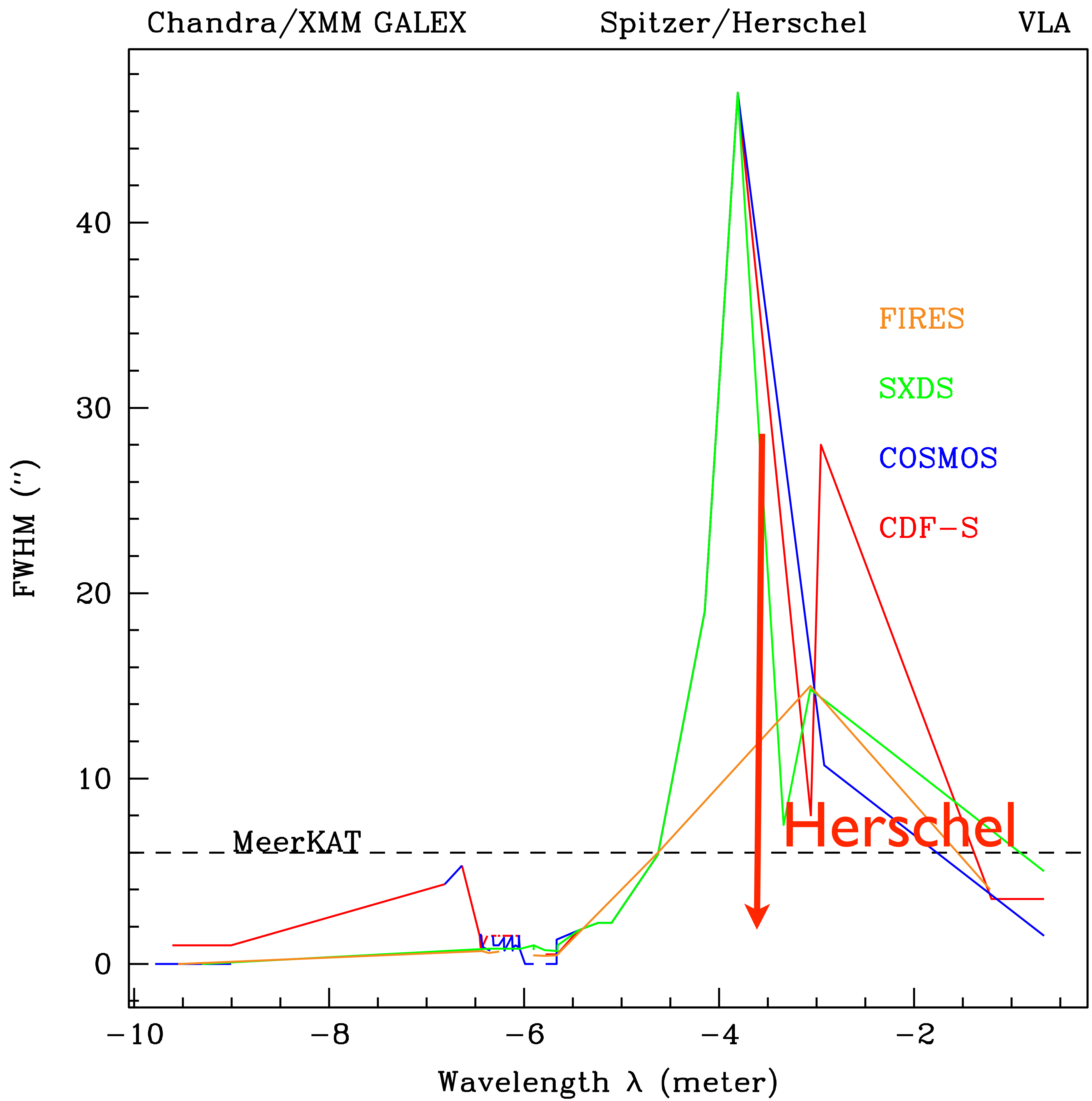


- HST coverage:
- CDFS by HUDF, GOODS-S, GEMS
- COSMOS

Spatial Resolution



Spatial Resolution



Complentarity

- MHONGOOSE/DINGO: use the higher frequency part of the datacubes as cosmic variance checks.
- MIGHTEE: highest tier observations, commensal with ours.
- THUNDERKAT: parallel analysis of the same data (piggybacking pipeline).

CDFS vs COSMOS

Category	Chandra Deep Field	COSMOS
Position	RA=03:32:28 DEC=-27:48:30	RA=10:00:43 DEC=02:10:23
Spectral coverage	30% in the medium deep field VVDS	70% zCOSMOS
Spectral Resolution (R)	R=230, R better for some	R=600
Deep	18k redshifts over ~1 sq. deg., $I_{AB} < 24.0$. (1 of 2 fields) 2500 in central 30'x30' available	10-12k redshifts over 1.0 sq. deg., $I_{AB} < 24.0$
Hubble Space Telescope	V and I (GEMS), B,V,I,Z (GOODS-South) B,V,I,Z (UDF)	F814W (I) only
GALEX	deepest available	< 26 M_{AB}
Spitzer	very deep IRAC & MIPS SWIRE fields	sCOSMOS, uniform coverage
Herschel	deepest available,SERVS	HERSCHEL-HERMES field
X-ray	second deepest anywhere on sky with Chandra, deepest in southern hemisphere (940 ks)	XMM - 1.4 megaseconds Chandra - 200 ksec, mosaiced
Radio	Some continuum with ATCA, 20 cm with VLA	Continuum with VLA, some line observations with GMRT
Optical	SWIRE CTIO mosaic data r,i to 24.2,23.2 (AB) over most of field. SpARCS z-band to 24.2 (AB)	Subaru B (27.4), V (27.2), r+ (26.9), i+ (26.9), z+ (25.6) CFHT-LS u*,g*,r*,i*,z*
NIR	VIDEO Z,Y,J,H,K to 25.7,24.6,24.5,24.0,23.5 (AB) JHK (ISAAC & SOFI)	JH (CFHT-LS)
Lensing cluster?	Small group at z=0.1, definitely. no lensing	Small cluster at z=0.2, no reported lensing.

CDFS vs COSMOS

Category	Chandra Deep Field	COSMOS
Position	RA=03:32:28 DEC=-27:48:30	RA=10:00:43 DEC=02:10:23
Spectral coverage	30% in the medium deep field VVDS	70% zCOSMOS
Spectral Resolution (R)	R=230, R better for some	R=600
Deep	18k redshifts over ~1 sq. deg., $I_{AB} < 24.0$. (1 of 2 fields) 2500 in central 30'x30' available	10-12k redshifts over 1.0 sq. deg., $I_{AB} < 24.0$
Hubble Space Telescope	V and I (GEMS), B,V,I,Z (GOODS-South) B,V,I,Z (UDF)	F814W (I) only
GALEX	deepest available	$< 26\ M_{AB}$
Spitzer	very deep IRAC & MIPS SWIRE fields	sCOSMOS, uniform coverage
Herschel	deepest available,SERVS	HERSCHEL-HERMES field
X-ray	second deepest anywhere on sky with Chandra, deepest in southern hemisphere (940 ks)	XMM - 1.4 megaseconds Chandra - 200 ksec, mosaiced
Radio	Some continuum with ATCA, 20 cm with VLA	Continuum with VLA, some line observations with GMRT
Optical	SWIRE CTIO mosaic data r,i to 24.2,23.2 (AB) over most of field. SpARCS z-band to 24.2 (AB)	Subaru B (27.4), V (27.2), r+ (26.9), i+ (26.9), z+ (25.6) CFHT-LS u*,g*,r*,i*,z*
NIR	VIDEO Z,Y,J,H,K to 25.7,24.6,24.5,24.0,23.5 (AB) JHK (ISAAC & SOFI)	JH (CFHT-LS)
Lensing cluster?	Small group at z=0.1, definitely. no lensing	Small cluster at z=0.2, no reported lensing.

CDFS vs COSMOS

Category	Chandra Deep Field	COSMOS
Position	RA=03:32:28 DEC=-27:48:30	RA=10:00:43 DEC=02:10:23
Spectral coverage	30% in the medium deep field VVDS	70% zCOSMOS
Spectral Resolution (R)	R=230, R better for some	R=600
Deep	18k redshifts over ~1 sq. deg., $I_{AB} < 24.0$. (1 of 2 fields) 2500 in central 30'x30' available	10-12k redshifts over 1.0 sq. deg., $I_{AB} < 24.0$
Hubble Space Telescope	V and I (GEMS), B,V,I,Z (GOODS-South) B,V,I,Z (UDF)	F814W (I) only
GALEX	deepest available	$< 26\ M_{AB}$
Spitzer	very deep IRAC & MIPS SWIRE fields	sCOSMOS, uniform coverage
Herschel	deepest available,SERVS	HERSCHEL-HERMES field
X-ray	second deepest anywhere on sky with Chandra, deepest in southern hemisphere (940 ks)	XMM - 1.4 megaseconds Chandra - 200 ksec, mosaiced
Radio	Some continuum with ATCA, 20 cm with VLA	Continuum with VLA, some line observations with GMRT
Optical	SWIRE CTIO mosaic data r,i to 24.2,23.2 (AB) over most of field. SpARCS z-band to 24.2 (AB)	Subaru B (27.4), V (27.2), r+ (26.9), i+ (26.9), z+ (25.6) CFHT-LS u*,g*,r*,i*,z*
NIR	VIDEO Z,Y,J,H,K to 25.7,24.6,24.5,24.0,23.5 (AB) JHK (ISAAC & SOFI)	JH (CFHT-LS)
Lensing cluster?	Small group at z=0.1, definitely. no lensing	Small cluster at z=0.2, no reported lensing.

CDFS vs COSMOS

Category	Chandra Deep Field	COSMOS
Position	RA=03:32:28 DEC=-27:48:30 ✔	RA=10:00:43 DEC=02:10:23 ✔
Spectral coverage	30% in the medium deep field VVDS	70% zCOSMOS
Spectral Resolution (R)	R=230, R better for some	R=600 ✔
Deep	18k redshifts over ~1 sq. deg., $I_{AB} < 24.0$. (1 of 2 fields) 2500 in central 30'x30' available	10-12k redshifts over 1.0 sq. deg., $I_{AB} < 24.0$
Hubble Space Telescope	V and I (GEMS), B,V,I,Z (GOODS-South) B,V,I,Z (UDF)	F814W (I) only
GALEX	deepest available	$< 26\ M_{AB}$
Spitzer	very deep IRAC & MIPS SWIRE fields	sCOSMOS, uniform coverage
Herschel	deepest available,SERVS	HERSCHEL-HERMES field
X-ray	second deepest anywhere on sky with Chandra, deepest in southern hemisphere (940 ks)	XMM - 1.4 megaseconds Chandra - 200 ksec, mosaiced
Radio	Some continuum with ATCA, 20 cm with VLA	Continuum with VLA, some line observations with GMRT
Optical	SWIRE CTIO mosaic data r,i to 24.2,23.2 (AB) over most of field. SpARCS z-band to 24.2 (AB)	Subaru B (27.4), V (27.2), r+ (26.9), i+ (26.9), z+ (25.6) CFHT-LS u*,g*,r*,i*,z*
NIR	VIDEO Z,Y,J,H,K to 25.7,24.6,24.5,24.0,23.5 (AB) JHK (ISAAC & SOFI)	JH (CFHT-LS)
Lensing cluster?	Small group at z=0.1, definitely. no lensing	Small cluster at z=0.2, no reported lensing.

CDFS vs COSMOS

Category	Chandra Deep Field	COSMOS
Position	RA=03:32:28 DEC=-27:48:30	RA=10:00:43 DEC=02:10:23
Spectral coverage	30% in the medium deep field VVDS	70% zCOSMOS
Spectral Resolution (R)	R=230, R better for some	R=600
Deep	18k redshifts over ~1 sq. deg., $I_{AB} < 24.0$. (1 of 2 fields) 2500 in central 30'x30' available	10-12k redshifts over 1.0 sq. deg., $I_{AB} < 24.0$
Hubble Space Telescope	V and I (GEMS), B,V,I,Z (GOODS-South) B,V,I,Z (UDF)	F814W (I) only
GALEX	deepest available	$< 26\ M_{AB}$
Spitzer	very deep IRAC & MIPS SWIRE fields	sCOSMOS, uniform coverage
Herschel	deepest available,SERVS	HERSCHEL-HERMES field
X-ray	second deepest anywhere on sky with Chandra, deepest in southern hemisphere (940 ks)	XMM - 1.4 megaseconds Chandra - 200 ksec, mosaiced
Radio	Some continuum with ATCA, 20 cm with VLA	Continuum with VLA, some line observations with GMRT
Optical	SWIRE CTIO mosaic data r,i to 24.2,23.2 (AB) over most of field. SpARCS z-band to 24.2 (AB)	Subaru B (27.4), V (27.2), r+ (26.9), i+ (26.9), z+ (25.6) CFHT-LS u*,g*,r*,i*,z*
NIR	VIDEO Z,Y,J,H,K to 25.7,24.6,24.5,24.0,23.5 (AB) JHK (ISAAC & SOFI)	JH (CFHT-LS)
Lensing cluster?	Small group at z=0.1, definitely. no lensing	Small cluster at z=0.2, no reported lensing.

CDFS vs COSMOS

Category	Chandra Deep Field	COSMOS
Position	RA=03:32:28 DEC=-27:48:30	RA=10:00:43 DEC=02:10:23
Spectral coverage	30% in the medium deep field VVDS	70% zCOSMOS
Spectral Resolution (R)	R=230, R better for some	R=600
Deep	18k redshifts over ~1 sq. deg., $I_{AB} < 24.0$. (1 of 2 fields) 2500 in central 30'x30' available	10-12k redshifts over 1.0 sq. deg., $I_{AB} < 24.0$
Hubble Space Telescope	V and I (GEMS), B,V,I,Z (GOODS-South) B,V,I,Z (UDF)	F814W (I) only
GALEX	deepest available	< 26 M_{AB}
Spitzer	very deep IRAC & MIPS SWIRE fields	sCOSMOS, uniform coverage
Herschel	deepest available,SERVS	HERSCHEL-HERMES field
X-ray	second deepest anywhere on sky with Chandra, deepest in southern hemisphere (940 ks)	XMM - 1.4 megaseconds Chandra - 200 ksec, mosaiced
Radio	Some continuum with ATCA, 20 cm with VLA	Continuum with VLA, some line observations with GMRT
Optical	SWIRE CTIO mosaic data r,i to 24.2,23.2 (AB) over most of field. SpARCS z-band to 24.2 (AB)	Subaru B (27.4), V (27.2), r+ (26.9), i+ (26.9), z+ (25.6) CFHT-LS u*,g*,r*,i*,z*
NIR	VIDEO Z,Y,J,H,K to 25.7,24.6,24.5,24.0,23.5 (AB) JHK (ISAAC & SOFI)	JH (CFHT-LS)
Lensing cluster?	Small group at z=0.1, definitely. no lensing	Small cluster at z=0.2, no reported lensing.

CDFS vs COSMOS

Category	Chandra Deep Field	COSMOS
Position	RA=03:32:28 DEC=-27:48:30	RA=10:00:43 DEC=02:10:23
Spectral coverage	30% in the medium deep field VVDS	70% zCOSMOS
Spectral Resolution (R)	R=230, R better for some	R=600
Deep	18k redshifts over ~1 sq. deg., $I_{AB} < 24.0$. (1 of 2 fields) 2500 in central 30'x30' available	10-12k redshifts over 1.0 sq. deg., $I_{AB} < 24.0$
Hubble Space Telescope	V and I (GEMS), B,V,I,Z (GOODS-South) B,V,I,Z (UDF)	F814W (I) only
GALEX	deepest available	< 26 M_{AB}
Spitzer	very deep IRAC & MIPS SWIRE fields	sCOSMOS, uniform coverage
Herschel	deepest available,SERVS	HERSCHEL-HERMES field
X-ray	second deepest anywhere on sky with Chandra, deepest in southern hemisphere (940 ks)	XMM - 1.4 megaseconds Chandra - 200 ksec, mosaiced
Radio	Some continuum with ATCA, 20 cm with VLA	Continuum with VLA, some line observations with GMRT
Optical	SWIRE CTIO mosaic data r,i to 24.2,23.2 (AB) over most of field. SpARCS z-band to 24.2 (AB)	Subaru B (27.4), V (27.2), r+ (26.9), i+ (26.9), z+ (25.6) CFHT-LS u*,g*,r*,i*,z*
NIR	VIDEO Z,Y,J,H,K to 25.7,24.6,24.5,24.0,23.5 (AB) JHK (ISAAC & SOFI)	JH (CFHT-LS)
Lensing cluster?	Small group at z=0.1, definitely. no lensing	Small cluster at z=0.2, no reported lensing.

CDFS vs COSMOS

Category	Chandra Deep Field	COSMOS
Position	RA=03:32:28 DEC=-27:48:30	RA=10:00:43 DEC=02:10:23
Spectral coverage	30% in the medium deep field VVDS	70% zCOSMOS
Spectral Resolution (R)	R=230, R better for some	R=600
Deep	18k redshifts over ~1 sq. deg., $I_{AB} < 24.0$. (1 of 2 fields) 2500 in central 30'x30' available	10-12k redshifts over 1.0 sq. deg., $I_{AB} < 24.0$
Hubble Space Telescope	V and I (GEMS), B,V,I,Z (GOODS-South) B,V,I,Z (UDF)	F814W (I) only
GALEX	deepest available	< 26 M_{AB}
Spitzer	very deep IRAC & MIPS SWIRE fields	sCOSMOS, uniform coverage
Herschel	deepest available,SERVS	HERSCHEL-HERMES field
X-ray	second deepest anywhere on sky with Chandra, deepest in southern hemisphere (940 ks)	XMM - 1.4 megaseconds Chandra - 200 ksec, mosaiced
Radio	Some continuum with ATCA, 20 cm with VLA	Continuum with VLA, some line observations with GMRT
Optical	SWIRE CTIO mosaic data r,i to 24.2,23.2 (AB) over most of field. SpARCS z-band to 24.2 (AB)	Subaru B (27.4), V (27.2), r+ (26.9), i+ (26.9), z+ (25.6) CFHT-LS u*,g*,r*,i*,z*
NIR	VIDEO Z,Y,J,H,K to 25.7,24.6,24.5,24.0,23.5 (AB) JHK (ISAAC & SOFI)	JH (CFHT-LS)
Lensing cluster?	Small group at z=0.1, definitely. no lensing	Small cluster at z=0.2, no reported lensing.

CDFS vs COSMOS

Category	Chandra Deep Field	COSMOS
Position	RA=03:32:28 DEC=-27:48:30	RA=10:00:43 DEC=02:10:23
Spectral coverage	30% in the medium deep field VVDS	70% zCOSMOS
Spectral Resolution (R)	R=230, R better for some	R=600
Deep	18k redshifts over ~1 sq. deg., $I_{AB} < 24.0$. (1 of 2 fields) 2500 in central 30'x30' available	10-12k redshifts over 1.0 sq. deg., $I_{AB} < 24.0$
Hubble Space Telescope	V and I (GEMS), B,V,I,Z (GOODS-South) B,V,I,Z (UDF)	F814W (I) only
GALEX	deepest available	< 26 M_{AB}
Spitzer	very deep IRAC & MIPS SWIRE fields	sCOSMOS, uniform coverage
Herschel	deepest available,SERVS	HERSCHEL-HERMES field
X-ray	second deepest anywhere on sky with Chandra, deepest in southern hemisphere (940 ks)	XMM - 1.4 megaseconds Chandra - 200 ksec, mosaiced
Radio	Some continuum with ATCA, 20 cm with VLA	Continuum with VLA, some line observations with GMRT
Optical	SWIRE CTIO mosaic data r,i to 24.2,23.2 (AB) over most of field. SpARCS z-band to 24.2 (AB)	Subaru B (27.4), V (27.2), r+ (26.9), i+ (26.9), z+ (25.6) CFHT-LS u*,g*,r*,i*,z*
NIR	VIDEO Z,Y,J,H,K to 25.7,24.6,24.5,24.0,23.5 (AB) JHK (ISAAC & SOFI)	JH (CFHT-LS)
Lensing cluster?	Small group at z=0.1, definitely. no lensing	Small cluster at z=0.2, no reported lensing.

CDFS vs COSMOS

Category	Chandra Deep Field	COSMOS
Position	RA=03:32:28 DEC=-27:48:30	RA=10:00:43 DEC=02:10:23
Spectral coverage	30% in the medium deep field VVDS	70% zCOSMOS
Spectral Resolution (R)	R=230, R better for some	R=600
Deep	18k redshifts over ~1 sq. deg., $I_{AB} < 24.0$. (1 of 2 fields) 2500 in central 30'x30' available	10-12k redshifts over 1.0 sq. deg., $I_{AB} < 24.0$
Hubble Space Telescope	V and I (GEMS), B,V,I,Z (GOODS-South) B,V,I,Z (UDF)	F814W (I) only
GALEX	deepest available	< 26 M_{AB}
Spitzer	very deep IRAC & MIPS SWIRE fields	sCOSMOS, uniform coverage
Herschel	deepest available,SERVS	HERSCHEL-HERMES field
X-ray	second deepest anywhere on sky with Chandra, deepest in southern hemisphere (940 ks)	XMM - 1.4 megaseconds Chandra - 200 ksec, mosaiced
Radio	Some continuum with ATCA, 20 cm with VLA	Continuum with VLA, some line observations with GMRT
Optical	SWIRE CTIO mosaic data r,i to 24.2,23.2 (AB) over most of field. SpARCS z-band to 24.2 (AB)	Subaru B (27.4), V (27.2), r+ (26.9), i+ (26.9), z+ (25.6) CFHT-LS u*,g*,r*,i*,z*
NIR	VIDEO Z,Y,J,H,K to 25.7,24.6,24.5,24.0,23.5 (AB) JHK (ISAAC & SOFI)	JH (CFHT-LS)
Lensing cluster?	Small group at z=0.1, definitely. no lensing	Small cluster at z=0.2, no reported lensing.

CDFS vs COSMOS

Category	Chandra Deep Field	COSMOS
Position	RA=03:32:28 DEC=-27:48:30	RA=10:00:43 DEC=02:10:23
Spectral coverage	30% in the medium deep field VVDS	70% zCOSMOS
Spectral Resolution (R)	R=230, R better for some	R=600
Deep	18k redshifts over ~1 sq. deg., $I_{AB} < 24.0$. (1 of 2 fields) 2500 in central 30'x30' available	10-12k redshifts over 1.0 sq. deg., $I_{AB} < 24.0$
Hubble Space Telescope	V and I (GEMS), B,V,I,Z (GOODS-South) B,V,I,Z (UDF)	F814W (I) only
GALEX	deepest available	$< 26\ M_{AB}$
Spitzer	very deep IRAC & MIPS SWIRE fields	sCOSMOS, uniform coverage
Herschel	deepest available,SERVS	HERSCHEL-HERMES field
X-ray	second deepest anywhere on sky with Chandra, deepest in southern hemisphere (940 ks)	XMM - 1.4 megaseconds Chandra - 200 ksec, mosaiced
Radio	Some continuum with ATCA, 20 cm with VLA	? Continuum with VLA, some line observations with GMRT
Optical	SWIRE CTIO mosaic data r,i to 24.2,23.2 (AB) over most of field. SpARCS z-band to 24.2 (AB)	Subaru B (27.4), V (27.2), r+ (26.9), i+ (26.9), z+ (25.6) CFHT-LS u*,g*,r*,i*,z*
NIR	VIDEO Z,Y,J,H,K to 25.7,24.6,24.5,24.0,23.5 (AB) JHK (ISAAC & SOFI)	JH (CFHT-LS)
Lensing cluster?	Small group at z=0.1, definitely. no lensing	Small cluster at z=0.2, no reported lensing.

CDFS vs COSMOS

Category	Chandra Deep Field	COSMOS
Position	RA=03:32:28 DEC=-27:48:30	RA=10:00:43 DEC=02:10:23
Spectral coverage	30% in the medium deep field VVDS	70% zCOSMOS
Spectral Resolution (R)	R=230, R better for some	R=600
Deep	18k redshifts over ~1 sq. deg., $I_{AB} < 24.0$. (1 of 2 fields) 2500 in central 30'x30' available	10-12k redshifts over 1.0 sq. deg., $I_{AB} < 24.0$
Hubble Space Telescope	V and I (GEMS), B,V,I,Z (GOODS-South) B,V,I,Z (UDF)	F814W (I) only
GALEX	deepest available	$< 26\ M_{AB}$
Spitzer	very deep IRAC & MIPS SWIRE fields	sCOSMOS, uniform coverage
Herschel	deepest available,SERVS	HERSCHEL-HERMES field
X-ray	second deepest anywhere on sky with Chandra, deepest in southern hemisphere (940 ks)	XMM - 1.4 megaseconds Chandra - 200 ksec, mosaiced
Radio	Some continuum with ATCA, 20 cm with VLA	Continuum with VLA, some line observations with GMRT
Optical	SWIRE CTIO mosaic data r,i to 24.2,23.2 (AB) over most of field. SpARCS z-band to 24.2 (AB)	Subaru B (27.4), V (27.2), r+ (26.9), i+ (26.9), z+ (25.6) CFHT-LS u*,g*,r*,i*,z*
NIR	VIDEO Z,Y,J,H,K to 25.7,24.6,24.5,24.0,23.5 (AB) JHK (ISAAC & SOFI)	JH (CFHT-LS)
Lensing cluster?	Small group at z=0.1, definitely. no lensing	Small cluster at z=0.2, no reported lensing.

CDFS vs COSMOS

Category	Chandra Deep Field	COSMOS
Position	RA=03:32:28 DEC=-27:48:30	RA=10:00:43 DEC=02:10:23
Spectral coverage	30% in the medium deep field VVDS	70% zCOSMOS
Spectral Resolution (R)	R=230, R better for some	R=600
Deep	18k redshifts over ~1 sq. deg., $I_{AB} < 24.0$. (1 of 2 fields) 2500 in central 30'x30' available	10-12k redshifts over 1.0 sq. deg., $I_{AB} < 24.0$
Hubble Space Telescope	V and I (GEMS), B,V,I,Z (GOODS-South) B,V,I,Z (UDF)	F814W (I) only
GALEX	deepest available	$< 26\ M_{AB}$
Spitzer	very deep IRAC & MIPS SWIRE fields	sCOSMOS, uniform coverage
Herschel	deepest available,SERVS	HERSCHEL-HERMES field
X-ray	second deepest anywhere on sky with Chandra, deepest in southern hemisphere (940 ks)	XMM - 1.4 megaseconds Chandra - 200 ksec, mosaiced
Radio	Some continuum with ATCA, 20 cm with VLA	? Continuum with VLA, some line observations with GMRT
Optical	SWIRE CTIO mosaic data r,i to 24.2,23.2 (AB) over most of field. SpARCS z-band to 24.2 (AB) but LSST will make it moot	? Subaru B (27.4), V (27.2), r+ (26.9), i+ (26.9), z+ (25.6) CFHT-LS u*,g*,r*,i*,z*
NIR	VIDEO Z,Y,J,H,K to 25.7,24.6,24.5,24.0,23.5 (AB) JHK (ISAAC & SOFI)	JH (CFHT-LS)
Lensing cluster?	Small group at z=0.1, definitely. no lensing	Small cluster at z=0.2, no reported lensing.

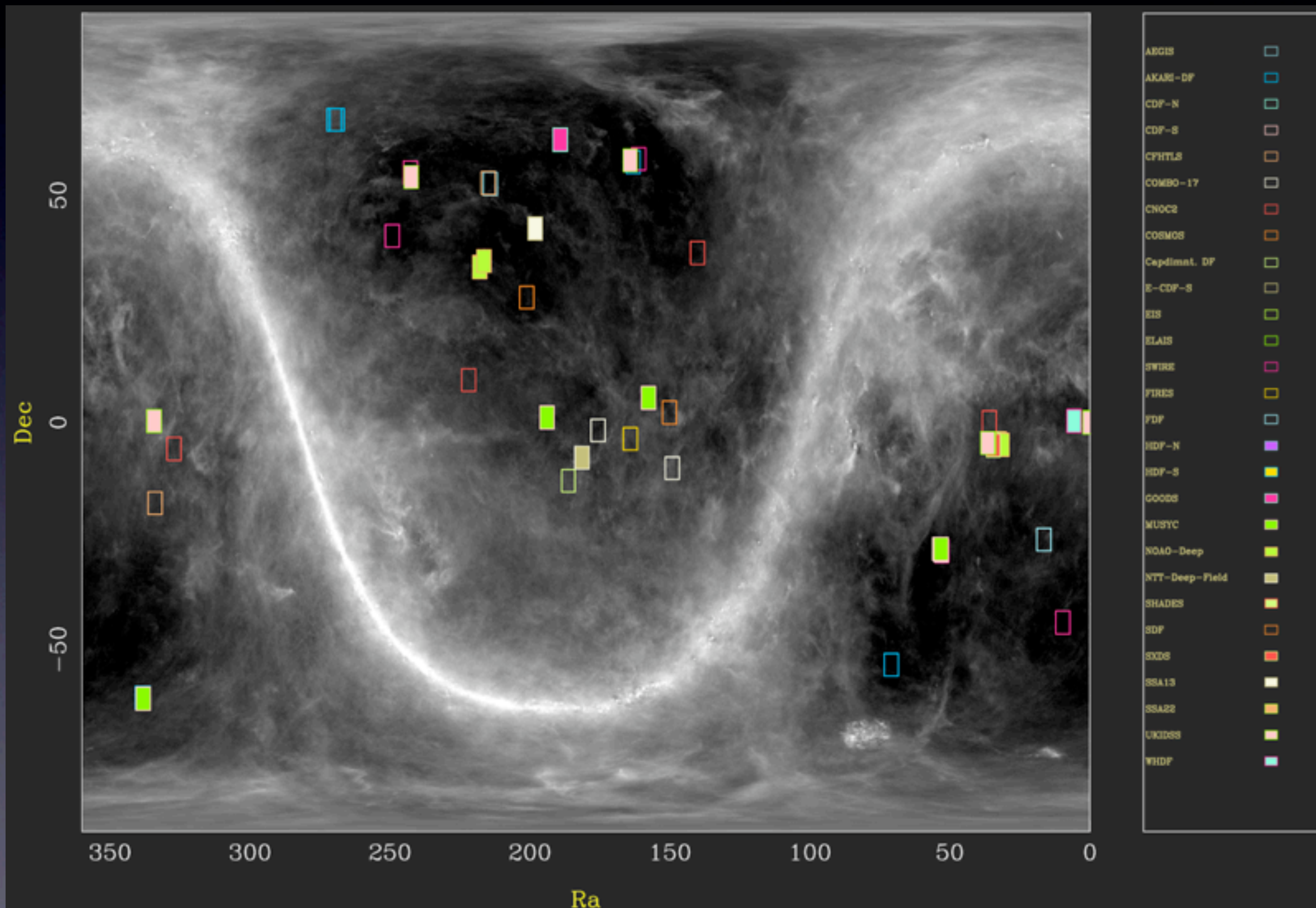
CDFS vs COSMOS

Category	Chandra Deep Field	COSMOS
Position	RA=03:32:28 DEC=-27:48:30	RA=10:00:43 DEC=02:10:23
Spectral coverage	30% in the medium deep field VVDS	70% zCOSMOS
Spectral Resolution (R)	R=230, R better for some	R=600
Deep	18k redshifts over ~1 sq. deg., $I_{AB} < 24.0$. (1 of 2 fields) 2500 in central 30'x30' available	10-12k redshifts over 1.0 sq. deg., $I_{AB} < 24.0$
Hubble Space Telescope	V and I (GEMS), B,V,I,Z (GOODS-South) B,V,I,Z (UDF)	F814W (I) only
GALEX	deepest available	$< 26\ M_{AB}$
Spitzer	very deep IRAC & MIPS SWIRE fields	sCOSMOS, uniform coverage
Herschel	deepest available,SERVS	HERSCHEL-HERMES field
X-ray	second deepest anywhere on sky with Chandra, deepest in southern hemisphere (940 ks)	XMM - 1.4 megaseconds Chandra - 200 ksec, mosaiced
Radio	Some continuum with ATCA, 20 cm with VLA	? Continuum with VLA, some line observations with GMRT
Optical	SWIRE CTIO mosaic data r,i to 24.2,23.2 (AB) over most of field. SpARCS z-band to 24.2 (AB) but LSST will make it moot	? Subaru B (27.4), V (27.2), r+ (26.9), i+ (26.9), z+ (25.6) CFHT-LS u*,g*,r*,i*,z*
NIR	VIDEO Z,Y,J,H,K to 25.7,24.6,24.5,24.0,23.5 (AB) JHK (ISAAC & SOFI)	JH (CFHT-LS)
Lensing cluster?	Small group at z=0.1, definitely. no lensing	Small cluster at z=0.2, no reported lensing.

CDFS vs COSMOS

Category	Chandra Deep Field	COSMOS
Position	RA=03:32:28 DEC=-27:48:30	RA=10:00:43 DEC=02:10:23
Spectral coverage	30% in the medium deep field VVDS	70% zCOSMOS
Spectral Resolution (R)	R=230, R better for some	R=600
Deep	18k redshifts over ~1 sq. deg., $I_{AB} < 24.0$. (1 of 2 fields) 2500 in central 30'x30' available	10-12k redshifts over 1.0 sq. deg., $I_{AB} < 24.0$
Hubble Space Telescope	V and I (GEMS), B,V,I,Z (GOODS-South) B,V,I,Z (UDF)	F814W (I) only
GALEX	deepest available	$< 26\ M_{AB}$
Spitzer	very deep IRAC & MIPS SWIRE fields	sCOSMOS, uniform coverage
Herschel	deepest available,SERVS	HERSCHEL-HERMES field
X-ray	second deepest anywhere on sky with Chandra, deepest in southern hemisphere (940 ks)	XMM - 1.4 megaseconds Chandra - 200 ksec, mosaiced
Radio	Some continuum with ATCA, 20 cm with VLA	? Continuum with VLA, some line observations with GMRT
Optical	SWIRE CTIO mosaic data r,i to 24.2,23.2 (AB) over most of field. SpARCS z-band to 24.2 (AB) but LSST will make it moot	? Subaru B (27.4), V (27.2), r+ (26.9), i+ (26.9), z+ (25.6) CFHT-LS u*,g*,r*,i*,z*
NIR	VIDEO Z,Y,J,H,K to 25.7,24.6,24.5,24.0,23.5 (AB) JHK (ISAAC & SOFI)	JH (CFHT-LS)
Lensing cluster?	Small group at z=0.1, definitely. no lensing	? Small cluster at z=0.2, no reported lensing.

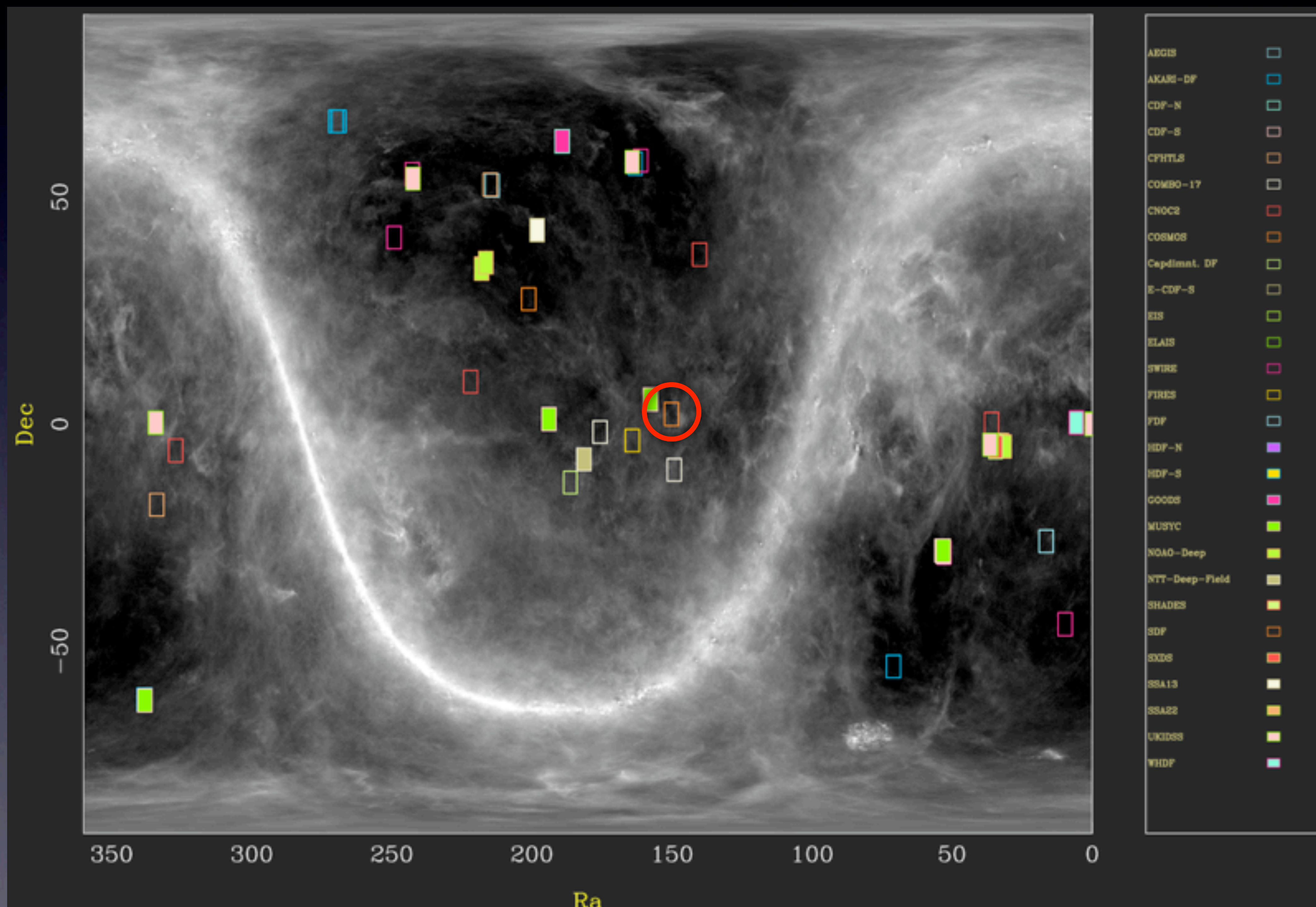
Deep Fields



Dec
50
0
−50
350
300
250
200
150
100
50
0
Ra
AEGIS
AKARI-DF
CDF-N
CDF-S
CFHTLS
COMBO-17
CNOC2
COSMOS
Capdimnt. DF
E-CDF-S
EIS
ELAIS
SWIRE
FIRES
FDF
HDF-N
HDF-S
GOODS
MUSYC
NOAO-Deep
NTT-Deep-Field
SHADES
SDF
SXDS
SSA13
SSA22
UKIDSS
WHDF

Deep Fields

COSMOS



Wide-field HI and Optical Surveys Workshop, Bunker Bay, Nov 17 2009

Deep Fields

COSMOS

CDF-S