VIPERS

The VIMOS Public Extragalactic Redshift Survey

The VIPERS View of Large-scale Structure at Redshift 1

Ben Granett

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On behalf of the VIPERS collaboration

LSS, Garching, 21 July 2015

erc DARK LIGHT

VIMOS Public Extragalactic Redshift Survey

★ VIPERS aims

  ★ Sample L* galaxies in a representative volume at $0.5 < z < 1.2$

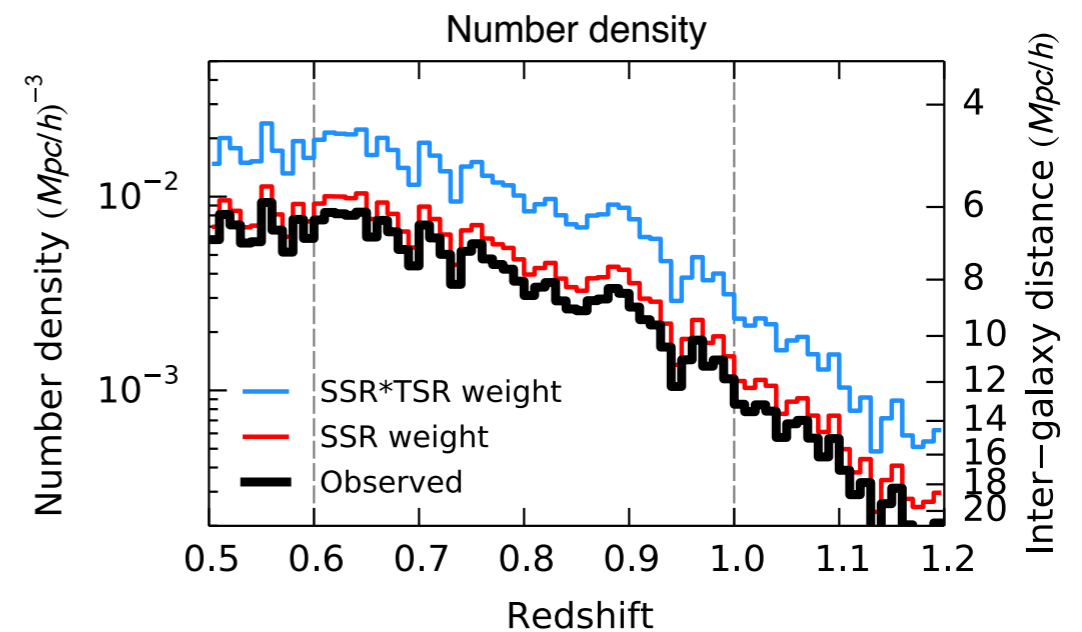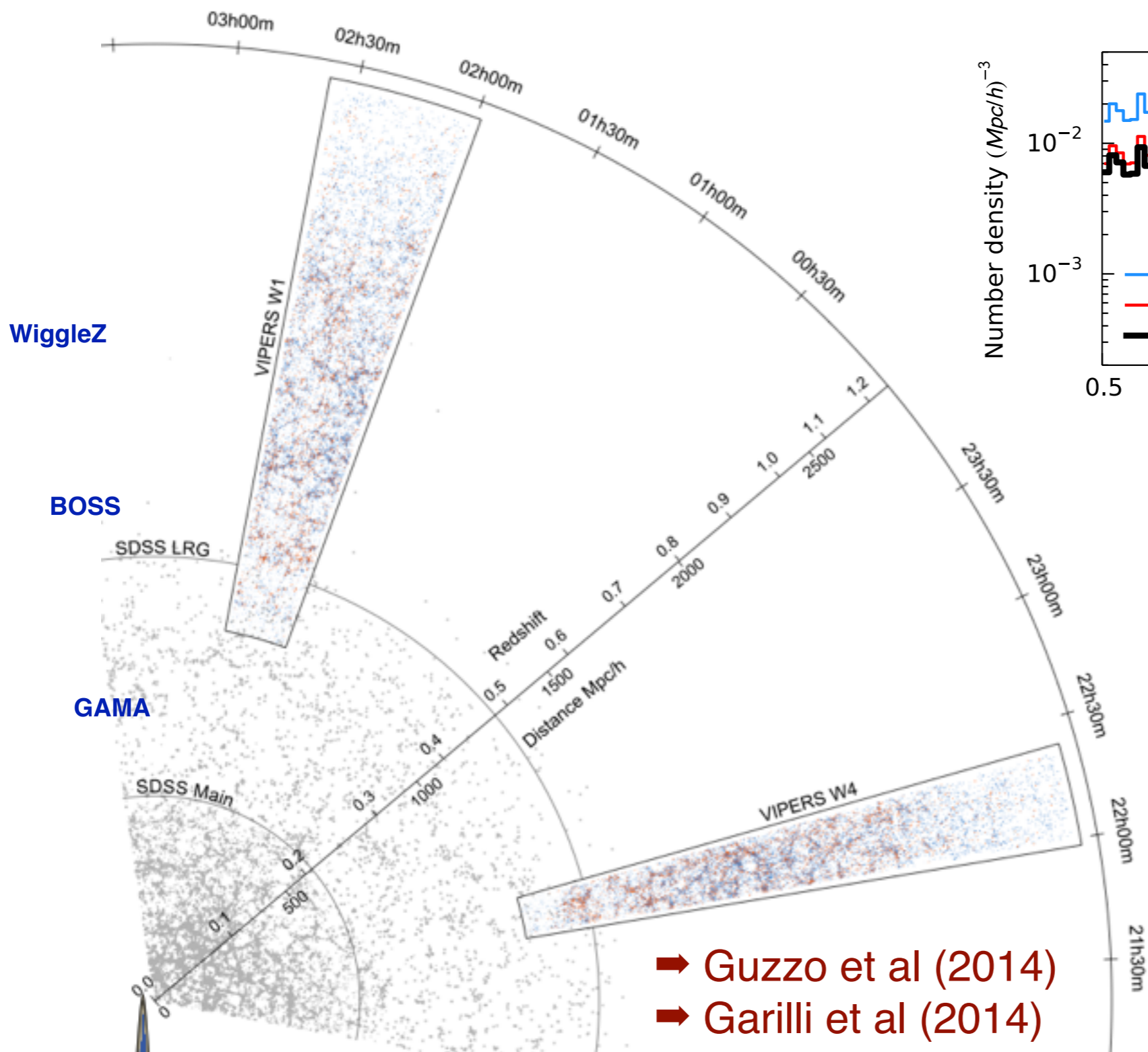| 6dFGS	1 m
SDSS	2 m
2dFGRS	4 m
VIPERS	8 m

z~0.05

to

z~1

➡ Cosmological constraints from galaxy clustering and redshift-space distortions

➡ Evolution of galaxy physical properties as a function of environment

Ideal combination of sampling and volume for LSS morphology

Number density

Number density $(Mpc/h)^{-3}$ — Inter−galaxy distance (Mpc/h)

- SSR*TSR weight
- SSR weight
- Observed

Redshift

WiggleZ

BOSS

SDSS LRG

GAMA

SDSS Main
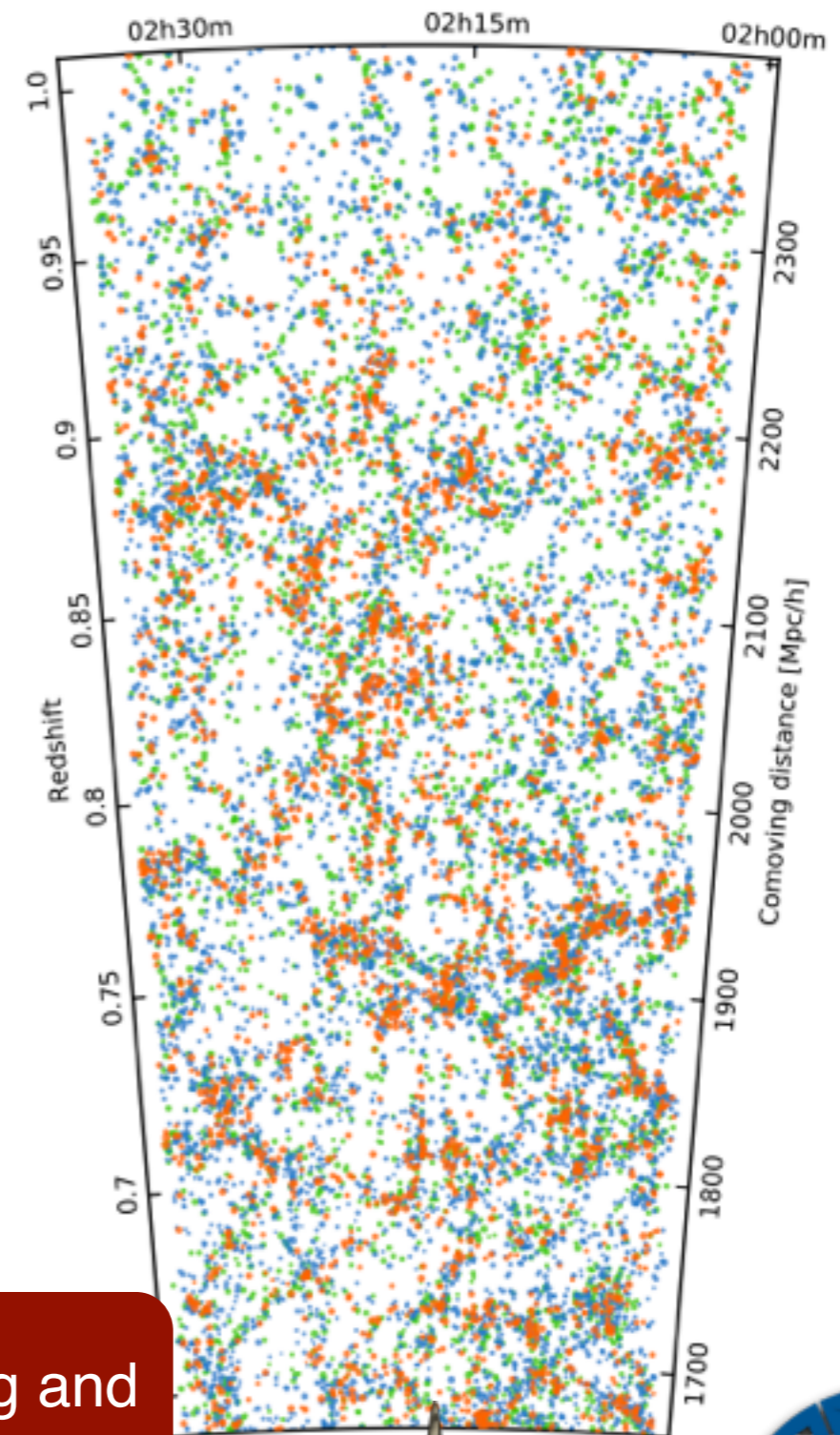
VIPERS W1

VIPERS W4

★ Flux limit $i_{AB} < 22.5$

★ ~90 000 redshifts

★ Area: 24 square degrees

★ Volume: 0.05 $h^{-3}Gpc^3$

★ Density: 8x10^{-3} h^3Mpc^{-3}

➡ Guzzo et al (2014)
➡ Garilli et al (2014)

Team VIPERS

(Here in Garching)

★ **MILANO OAB** (Project Office): **L. Guzzo** (PI),
  B. Granett, J. Bel, A. Iovino, S. Rota, **F. Mohammad, A. Pezzotta, A. Hawken**, U. Abbas (Turin)

★ **MILANO IASF** (Data Reduction Centre): B. Garilli, M. Scodeggio, D. Bottini, A. Fritz,
  A. Marchetti, P. Franzetti, D. Maccagni, L. Paioro, M. Polletta

★ **BOLOGNA**: M. Bolzonella, O. Cucciati, L. Moscardini, A. Cappi, Y. Davidzon,
  C. Di Porto, F. Marulli, M. Moresco, D. Vergani, G. Zamorani, A. Zanichelli, E. Branchini (Rome)

★ **EDINBURGH**: **J. Peacock**, **M. Wilson**, L. Eardley

★ **MARSEILLE**: S. de la Torre, O. Le Fevre, C. Adami, V. Le Brun, L. Tasca, C. Marinoni, E. Jullo,
  C. Schimd

★ **PARIS** (TERAPIX CFHTLS): H. McCracken, Y. Mellier, V. Scottez, J. Coupon (Geneva),
  J. Blaizot (Lyon)

★ **PORTSMOUTH**: W. Percival, R. Tojeiro, A. Burden, R. Nichol

★ **TRIESTE**: G. De Lucia

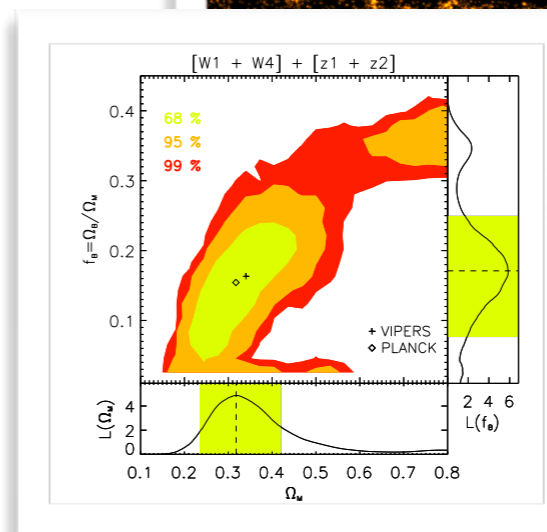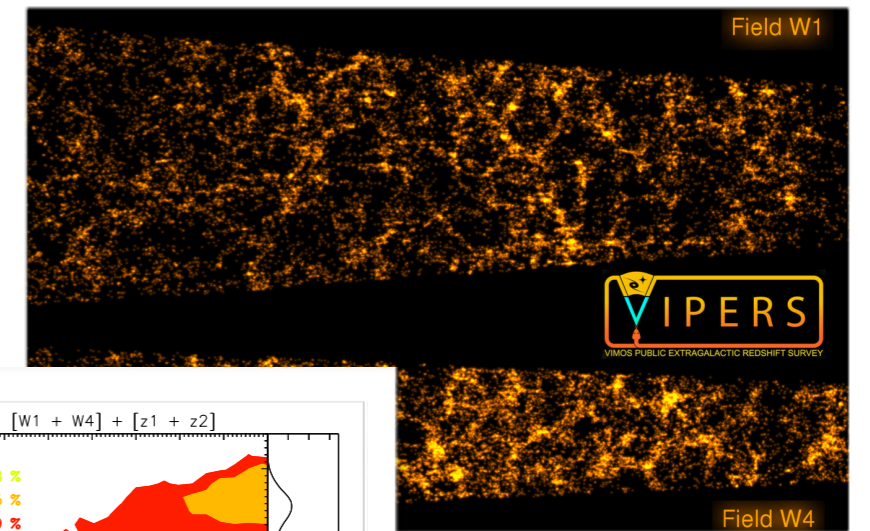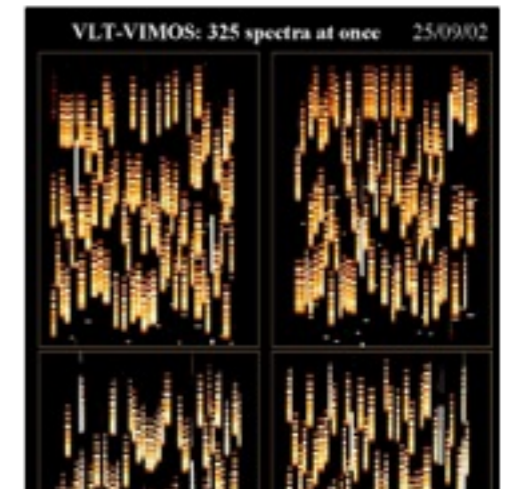★ **WARSAW**: A. Pollo, J. Krywult (Kielce), K. Malek, O. Solarz

Team VIPERS

Edinburgh, September 2012

**ben.granett@brera.inaf.it**   *LSS, Garching, 21 July 2015*

A quick review
of VIPERS results

★ Fourier-space analyses
  & cosmological interpretation

★ Growth rate and redshift-space clustering

★ Density field reconstructions

★ Cosmic voids

CFHT Legacy Survey

- Use the full CFHTLS to study VIPERS-*like* galaxies over a large volume

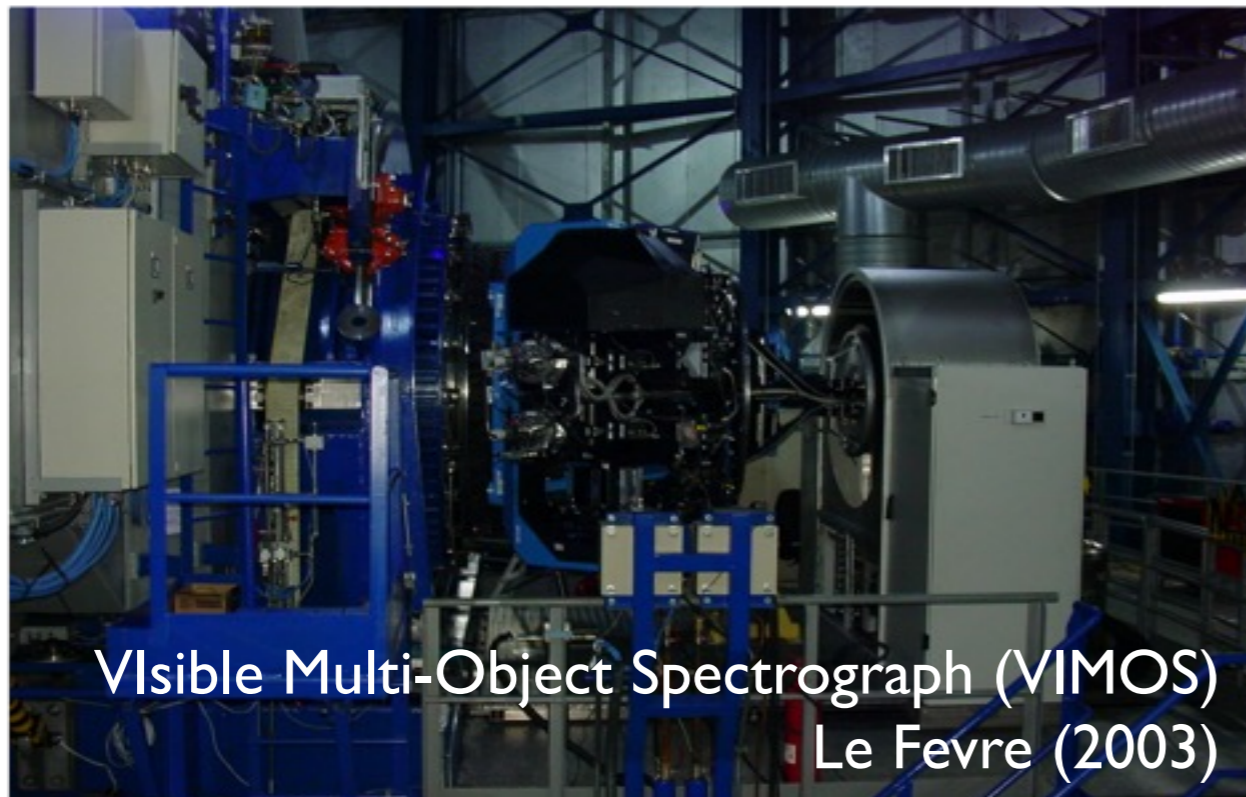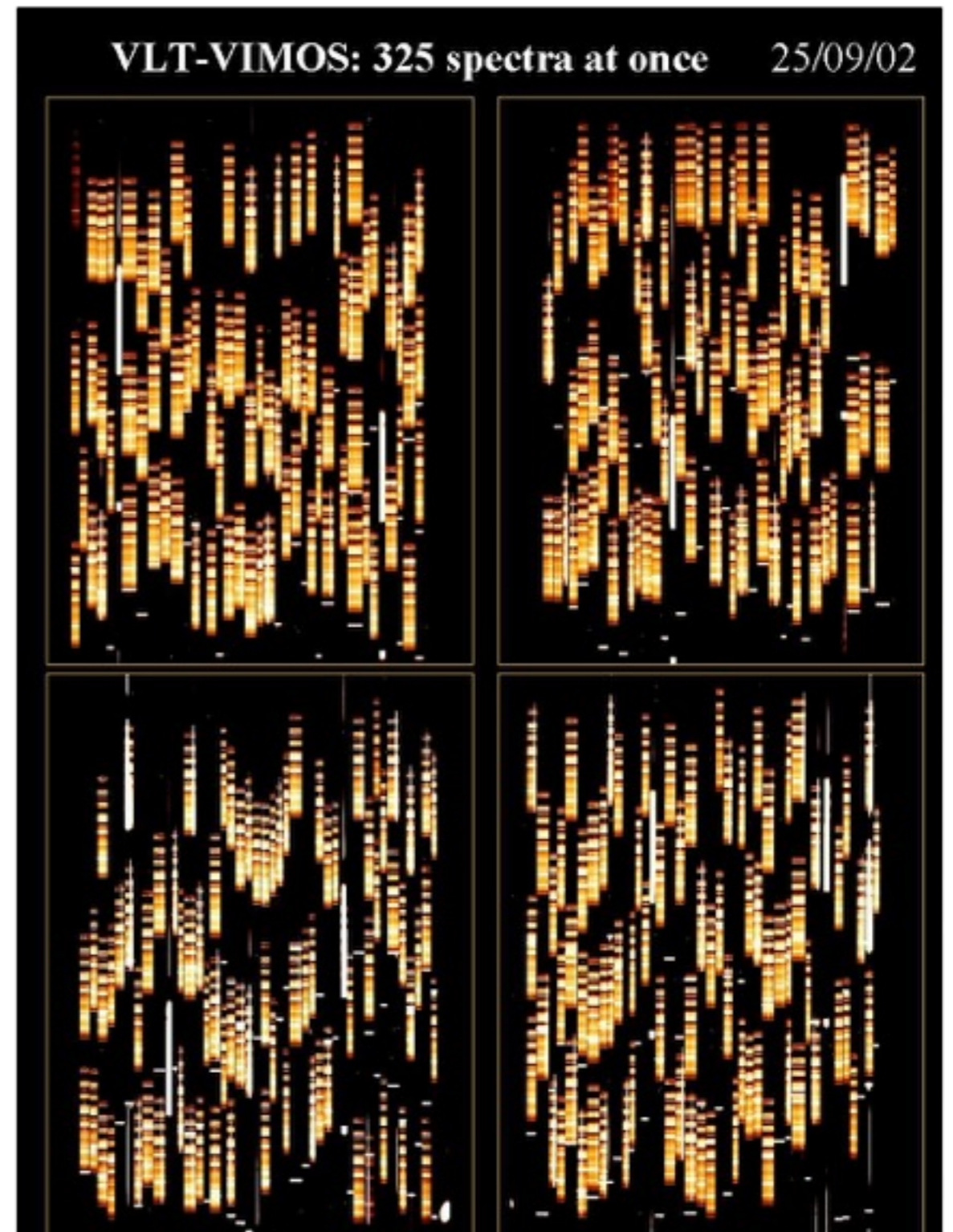- Wide survey: 133 sqr deg; Volume ~ 1/3 SDSS main sample (z<1.2, *iAB*<22.5)
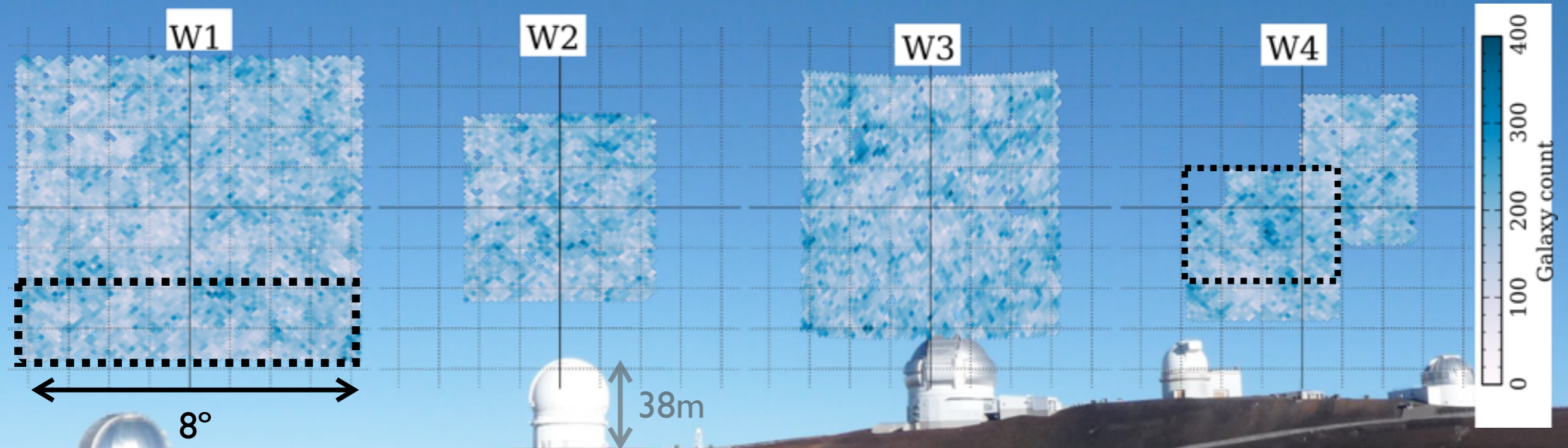
- Angular power spectrum: Granett et al (2012)
- HOD modeling: Coupon et al (2012)
- Higher order statistics: Wolk et al (2013)

# VIMOS at ESO Very Large Telescope


VLT at Paranal

(see http://vipers.inaf.it)

VIsible Multi-Object Spectrograph (VIMOS)
Le Fevre (2003)

VLT-VIMOS: 325 spectra at once   25/09/02

VIPERS colour pre-selection

★ Color selection removes low redshift galaxies

★ Reaches ~100% complete flux-limited sample at z > 0.6

★ Boosts sampling rate 0.5 < z < 1.2

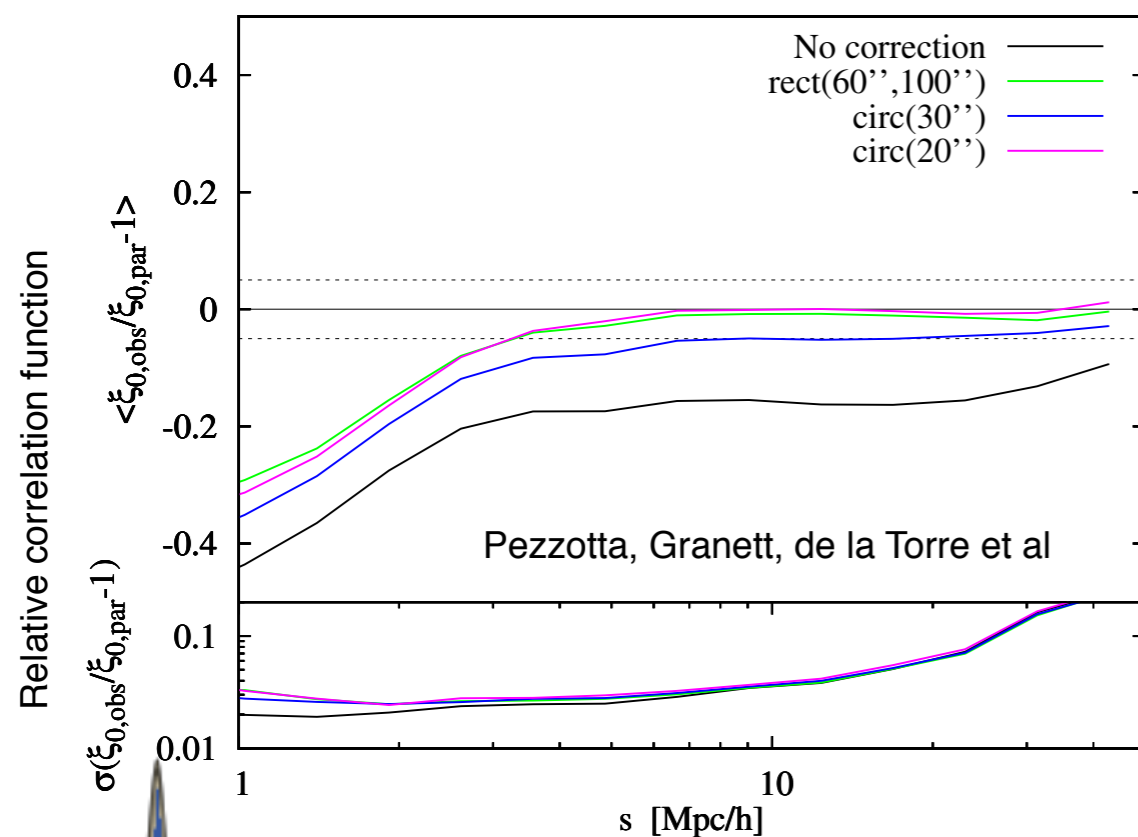★ Additional AGN selection criteria

Field W1

Field W4

100 Mpc/h

VIPERS
VIMOS PUBLIC EXTRAGALACTIC REDSHIFT SURVEY

z=0.9
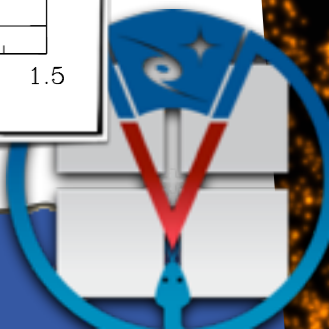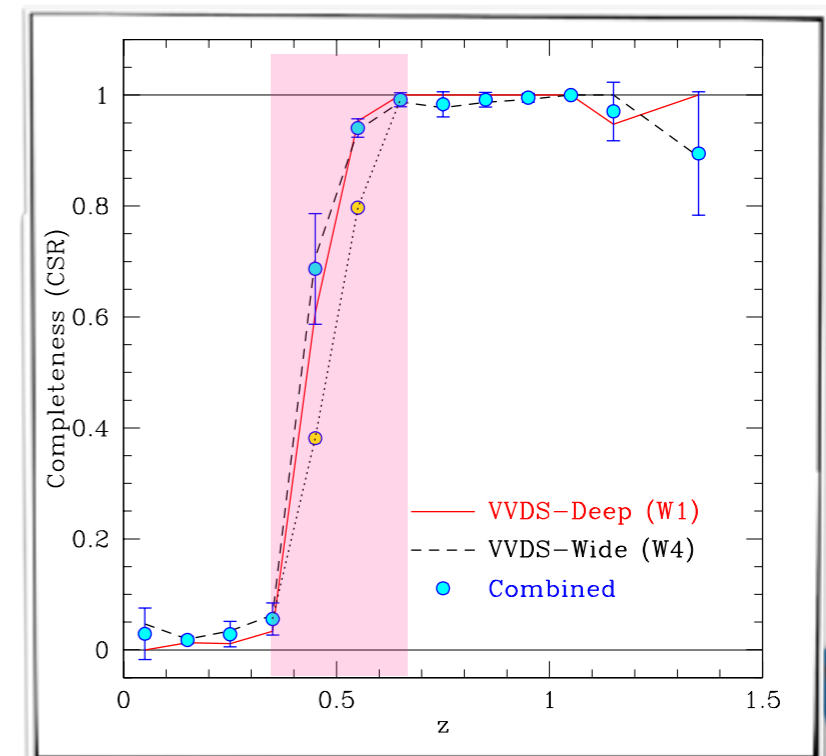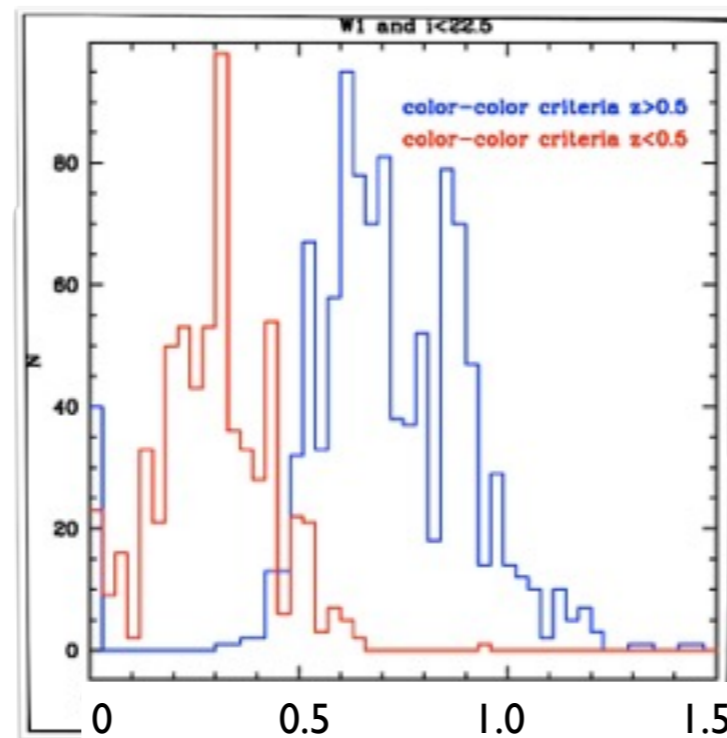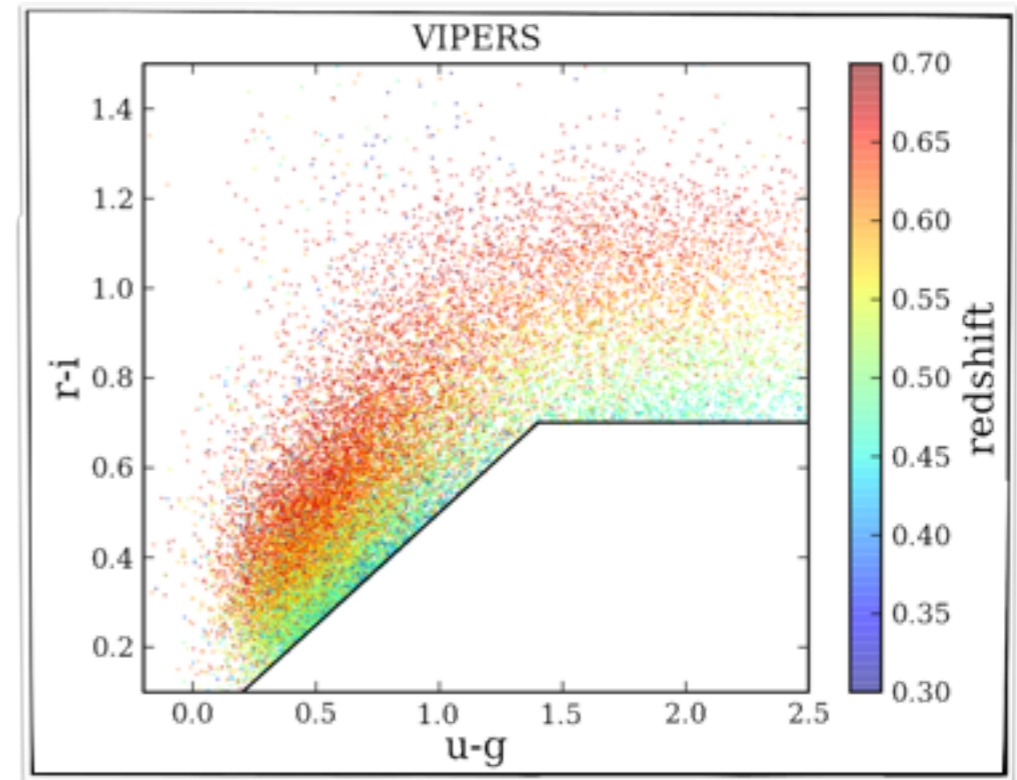
z=0.5

A. Iovino

Slit exclusion effects

★ **Single-pass observations**

★ **Spectra cannot overlap on the focal plane**

★ **Suppression of the correlation function on all scales**

Pezzotta, Granett, de la Torre et al

Legend: No correction; rect(60'',100''); circ(30''); circ(20'')

Relative correlation function $\langle \xi_{0,obs}/\xi_{0,par}-1 \rangle$

$\sigma(\xi_{0,obs}/\xi_{0,par}-1)$

s [Mpc/h]

Target sampling rate

★ The sampling rate depends on local density

  ★ undersample high density regions

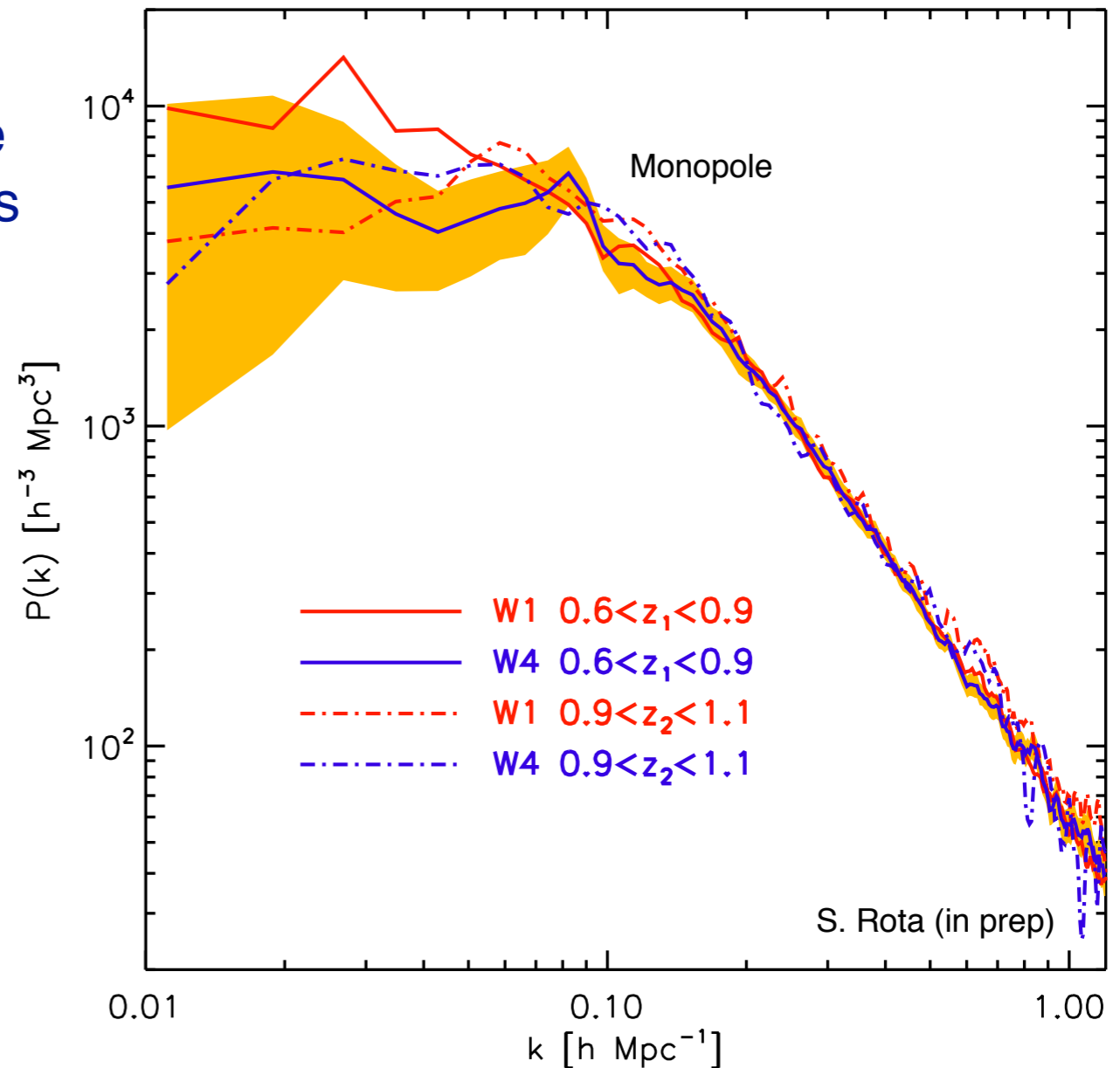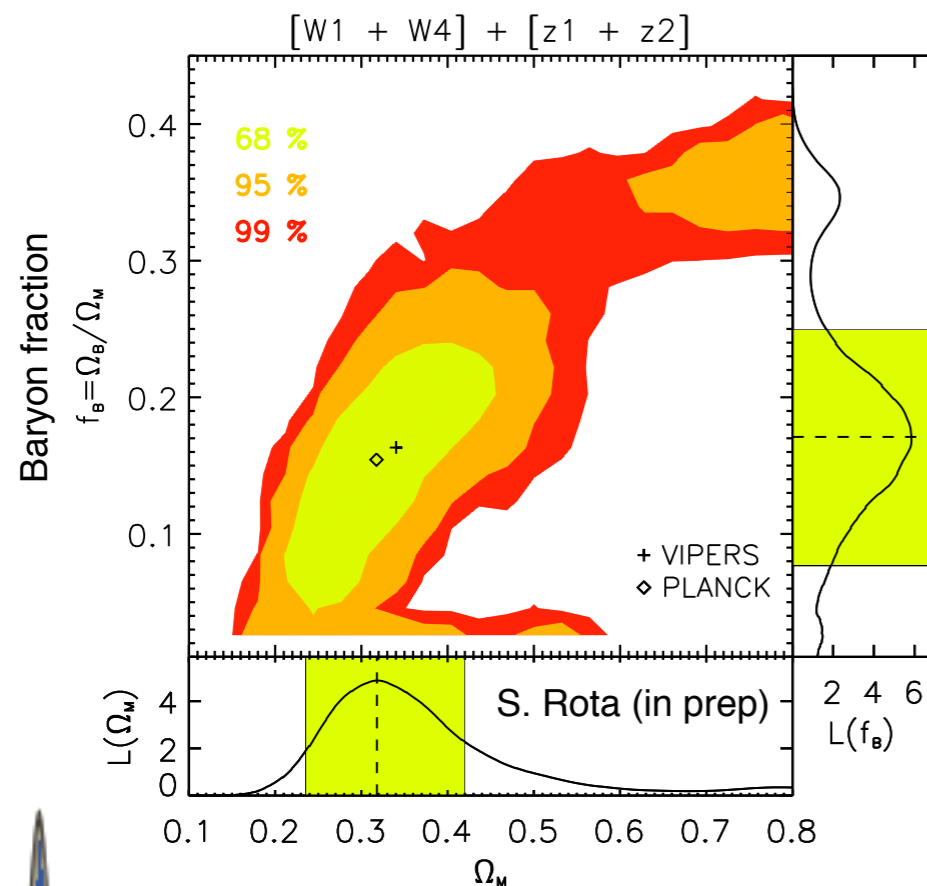 ★ like a thresholding of the density field

★ Mean sampling rate is 40%

(not the full sample)

ben.granett@brera.inaf.it *LSS, Garching, 21 July 2015*
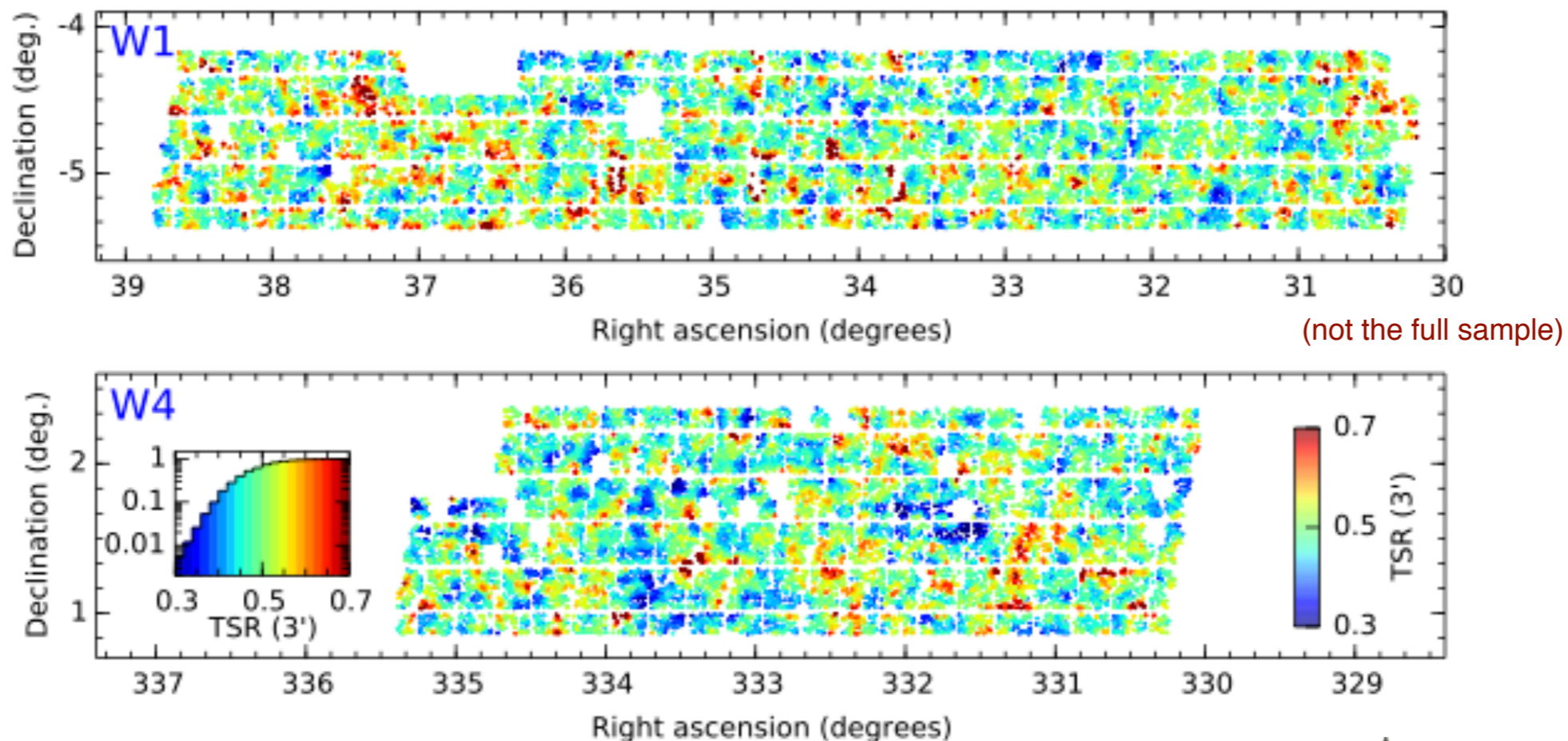
Mock samples

★ Many realisations of mock surveys are essential

   ★ Investigate systematics

   ★ Estimate sample covariance

★ VIPERS suite of mocks built with:

   ★ Pinocchio (Monaco)

   ★ Multidark (Prada et al)

★ Galaxies added with HOD technique with luminosity and colour (de la Torre et al 2013)

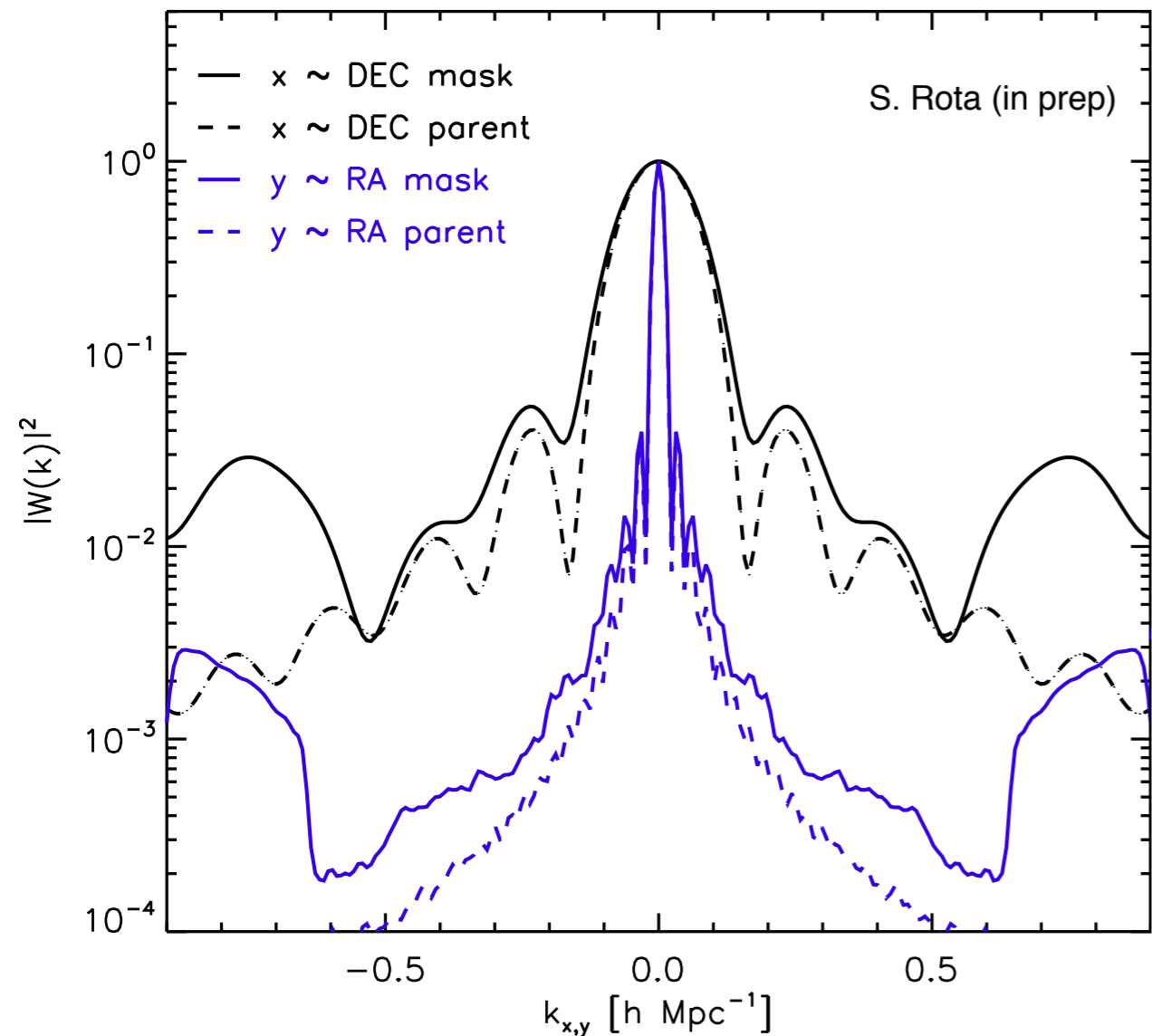★ Halos are added below the mass limit (de la Torre & Peacock 2012)

Original $m<10^{11.5}$ h^{-1} $M_\odot$

Reconstructed $m<10^{11.5}$ h^{-1} $M_\odot$ w/ G=2.5 h^{-1} Mpc
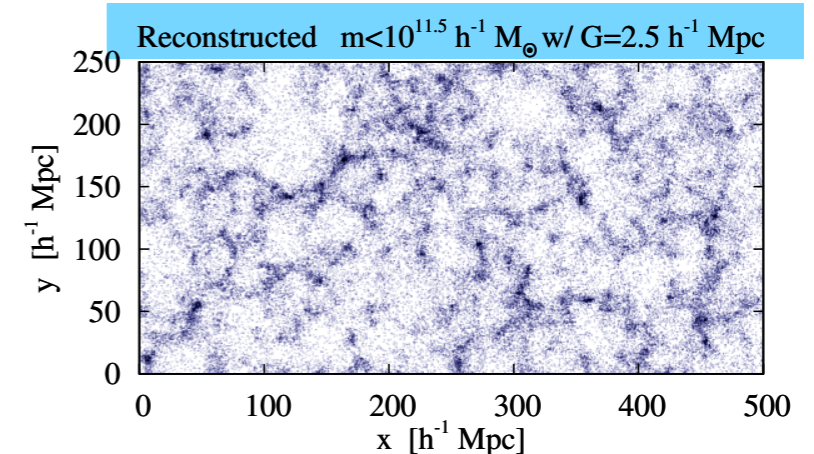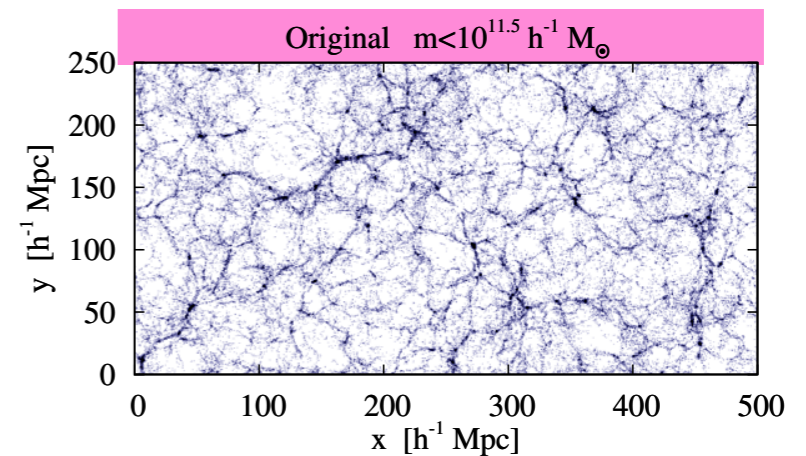
Fourier-space analysis

★ Stefano Rota+ (in prep) measures the galaxy power spectrum in redshift bins

★ Cosmological interpretation of the monopole

★ Julien Bel's talk (afternoon)

[W1 + W4] + [z1 + z2]

68 %
95 %
99 %

Baryon fraction
$f_B = \Omega_B / \Omega_M$

+ VIPERS
◇ PLANCK

$L(\Omega_M)$

S. Rota (in prep)

$L(f_B)$

Ω_M

Monopole

$P(k)$ $[h^{-3}$ $Mpc^3]$

W1 $0.6 < z_1 < 0.9$
W4 $0.6 < z_1 < 0.9$
W1 $0.9 < z_2 < 1.1$
W4 $0.9 < z_2 < 1.1$

S. Rota (in prep)

k $[h$ $Mpc^{-1}]$

(Not the full sample)

Anisotropic survey window function

W1

S. Rota (in prep)

Legend:
- — x ~ DEC mask
- – – x ~ DEC parent
- — y ~ RA mask
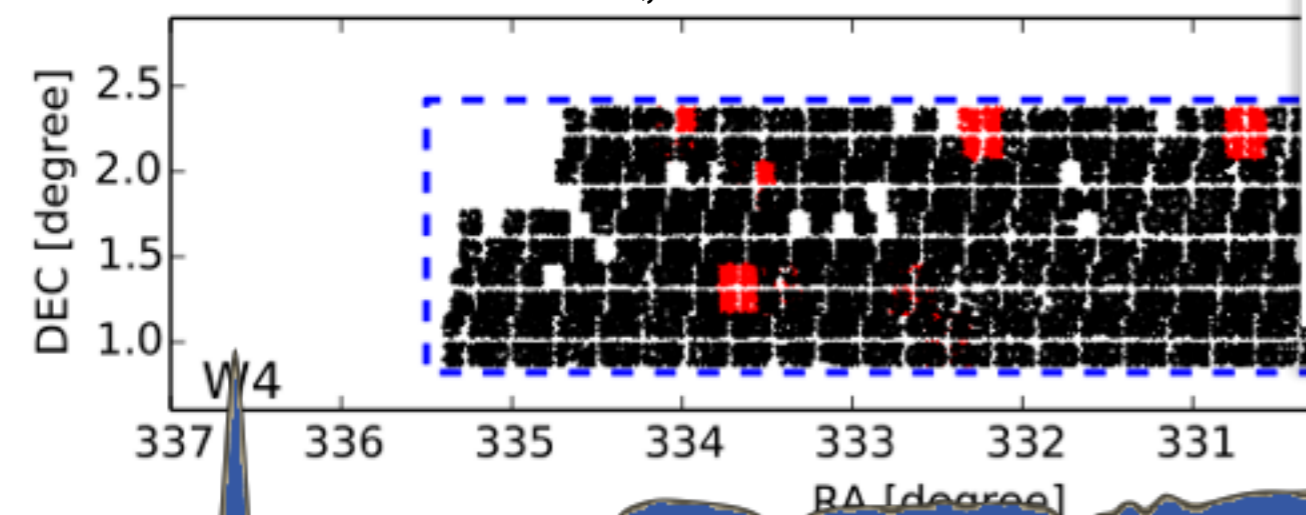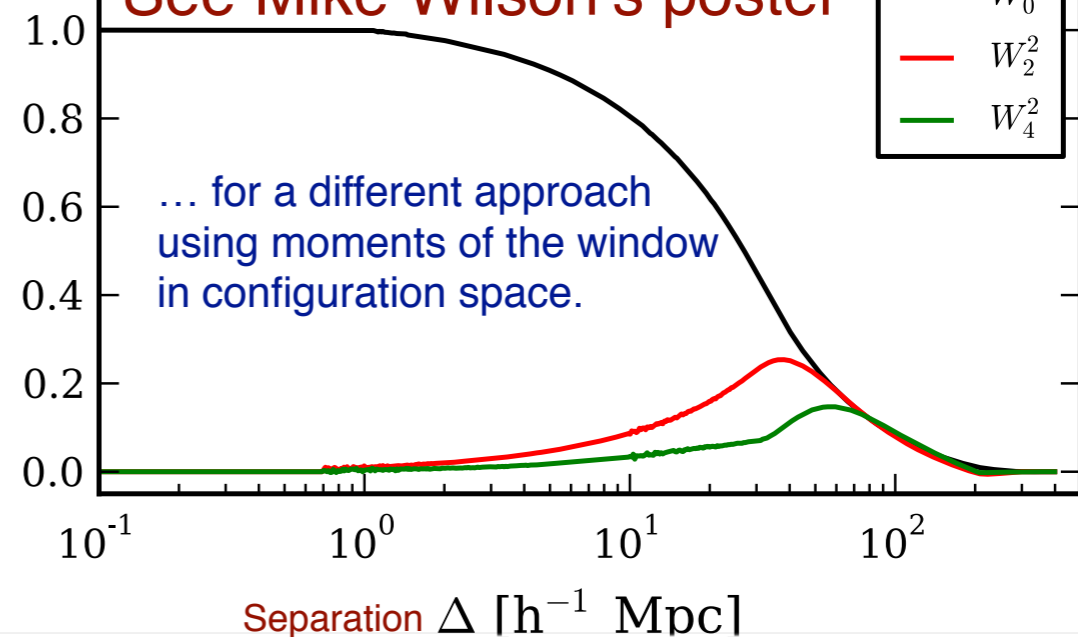- – – y ~ RA parent

$|W(k)|^2$ vs $k_{x,y}$ [h Mpc^{-1}]

★ Window function structure corresponds to scale of pointings

★ Anisotropic in the RA, Dec and line-of-sight

$$P_{CONV}(\mathbf{k}) = \int P_s(\mathbf{k}') \, |W(\mathbf{k} - \mathbf{k}')|^2 \, \frac{d^3 k'}{(2\pi)^3}.$$

See Mike Wilson's poster

… for a different approach using moments of the window in configuration space.

Legend:
- — W_0^2
- — W_2^2
- — W_4^2

Separation Δ [h^{-1} Mpc]

W4

DEC [degree] vs RA [degree]

Redshift-space distortions

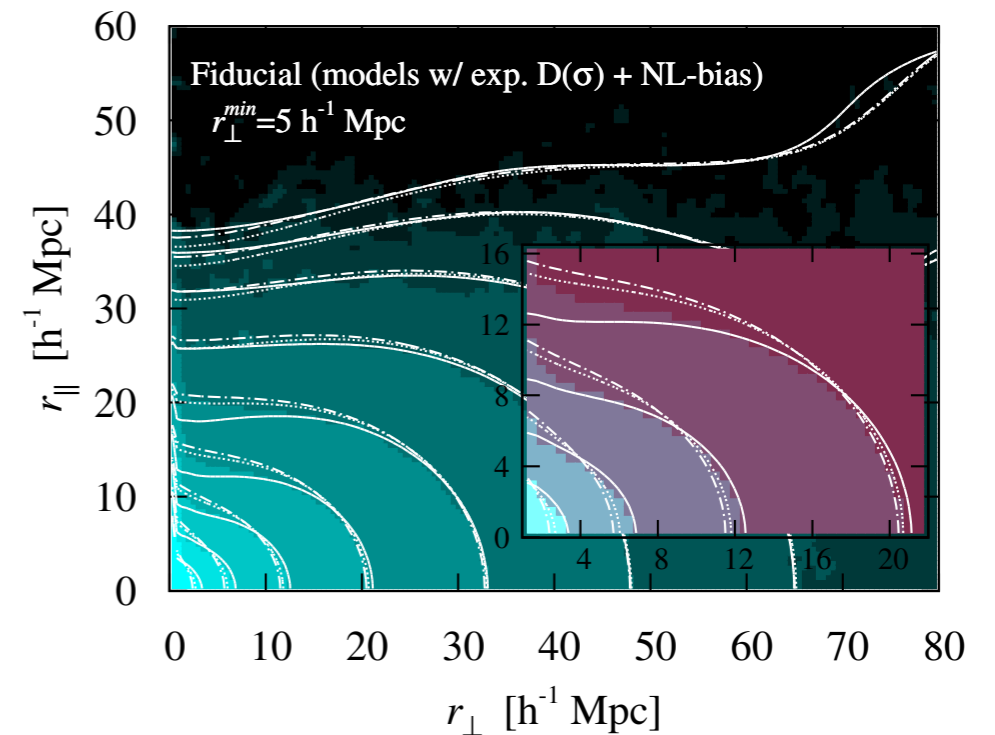Distance in redshift-space: $s = r + \dfrac{v_{los}}{aH}$

Redshift-space power spectrum (Kaiser formula):

$$P^s(\vec{k}) = (b + f\mu^2)^2 P(\vec{k})$$

Linear growth factor: $f \equiv \dfrac{d\ln D}{d\ln a} \approx \Omega_m(z)^\gamma$
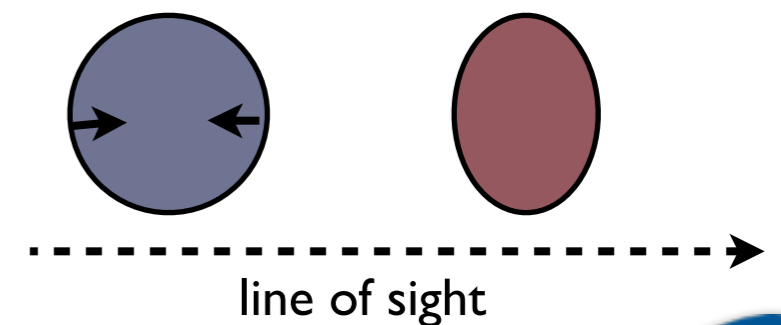
Transform to the correlation function:

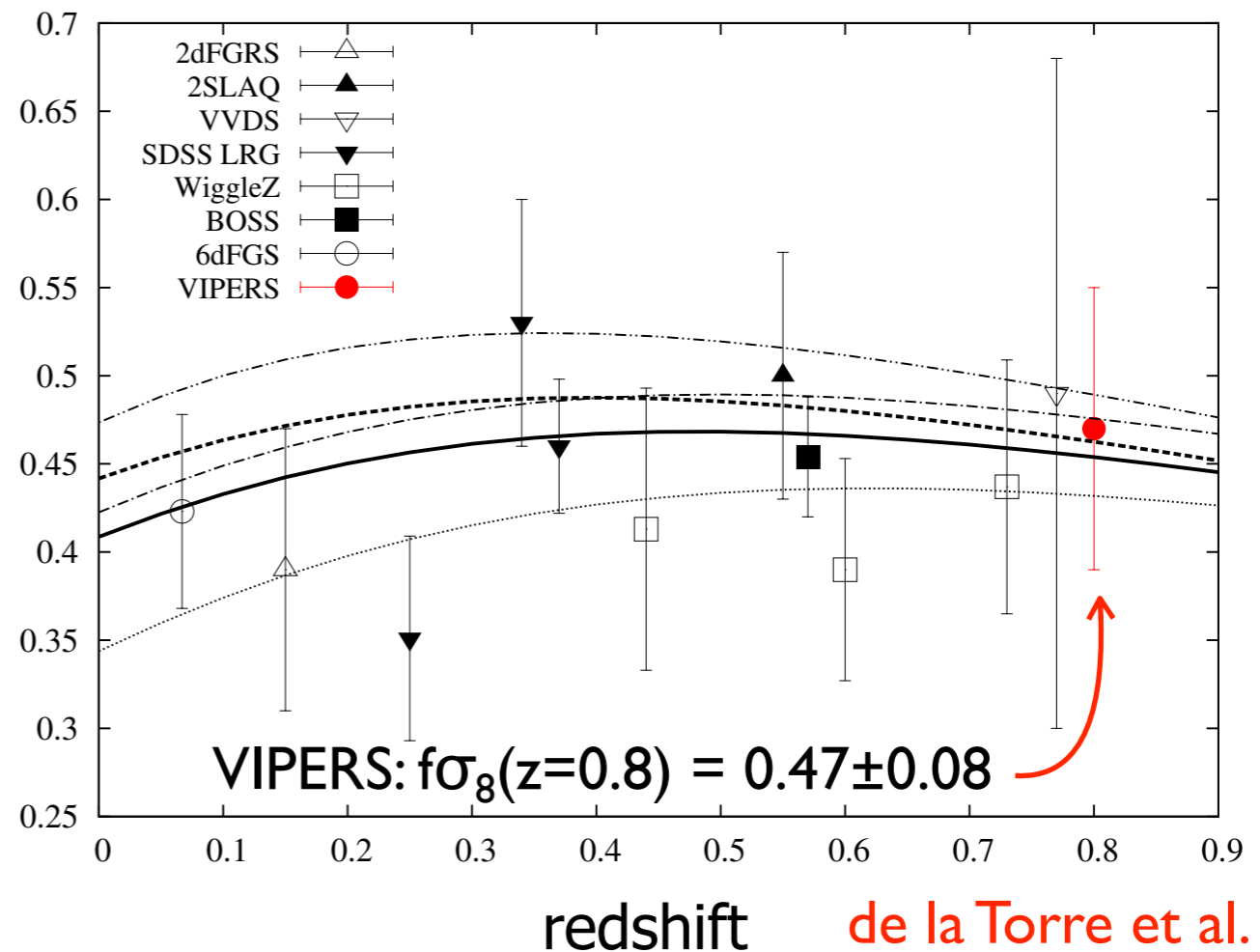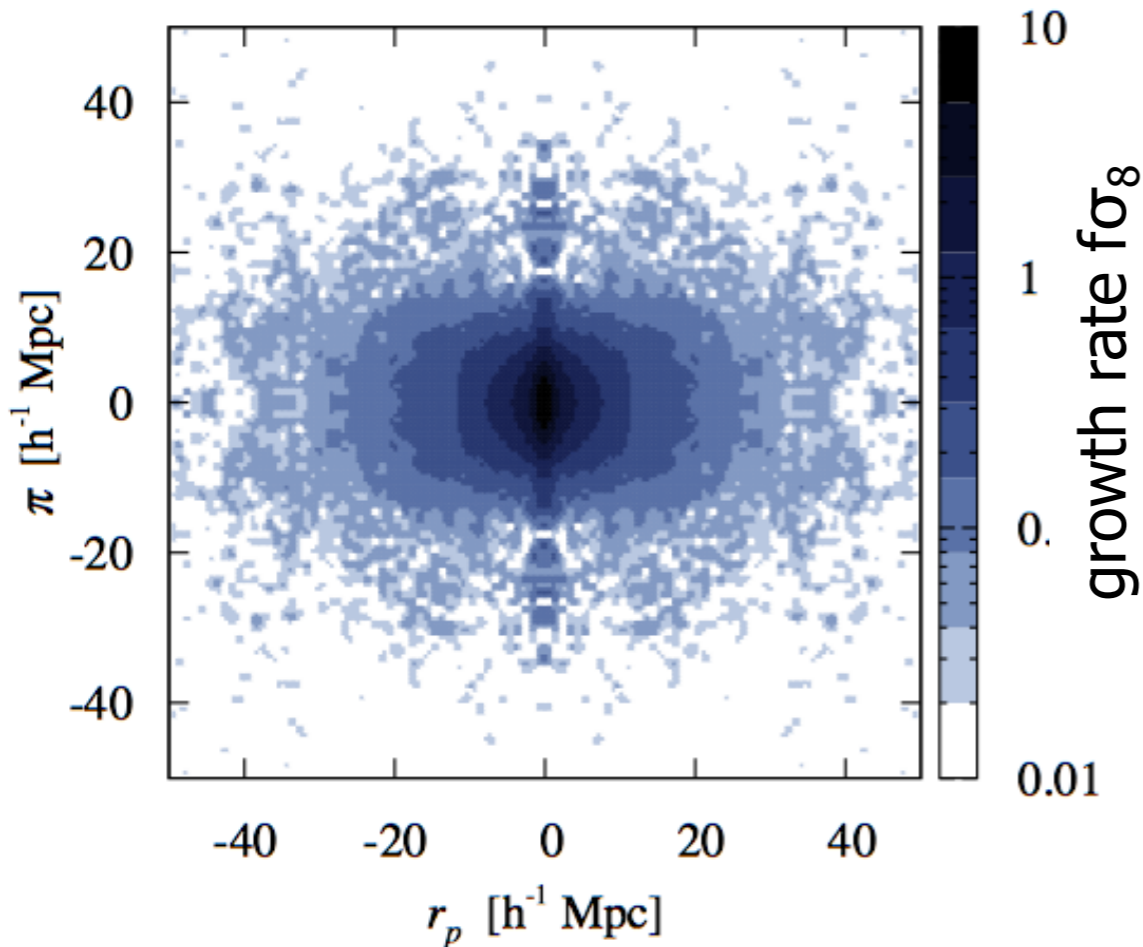$$\xi^s(\vec{r}) = \int \frac{d^3k}{(2\pi)^3} e^{i\vec{k}\cdot\vec{s}} P^s(k,\mu)$$

Fiducial (models w/ exp. D(σ) + NL-bias)

$r_\perp^{min}$=5 h^{-1} Mpc

$r_\parallel$ [h^{-1} Mpc]

$r_\perp$ [h^{-1} Mpc]

de la Torre & Guzzo 20

real-space   redshift-space

line of sight

Growth of structure with RSD

★ Analysis of full sample underway

VIPERS: $f\sigma_8(z=0.8) = 0.47\pm0.08$

redshift

de la Torre et al. 2013

★ **Addressing non-linearities in the data**

   ★ Multiple tracers by **Faizan Mohammad** (talk this afternoon)

   ★ Fourier analysis and clipped power spectrum by **Mike Wilson** (poster)
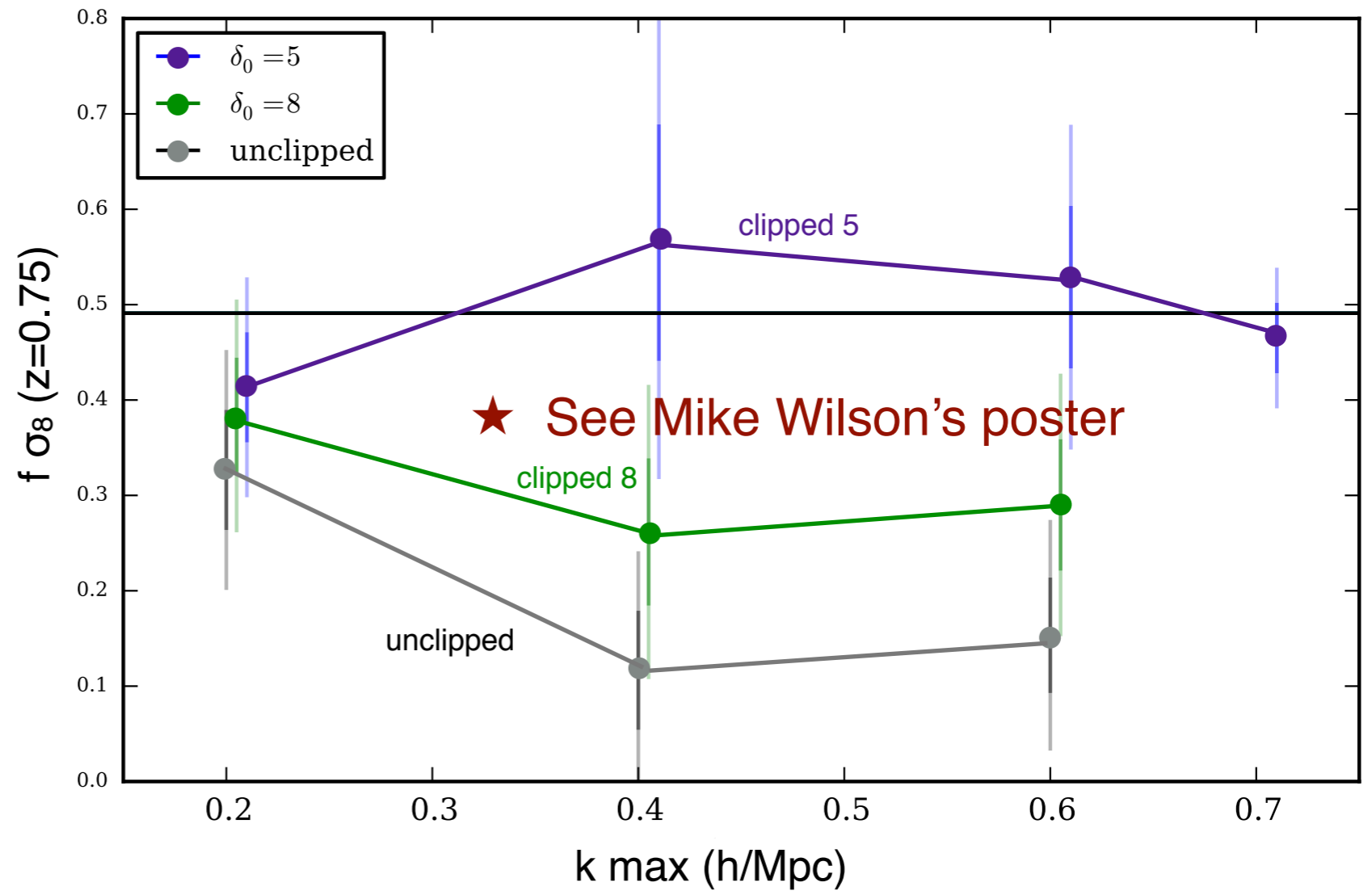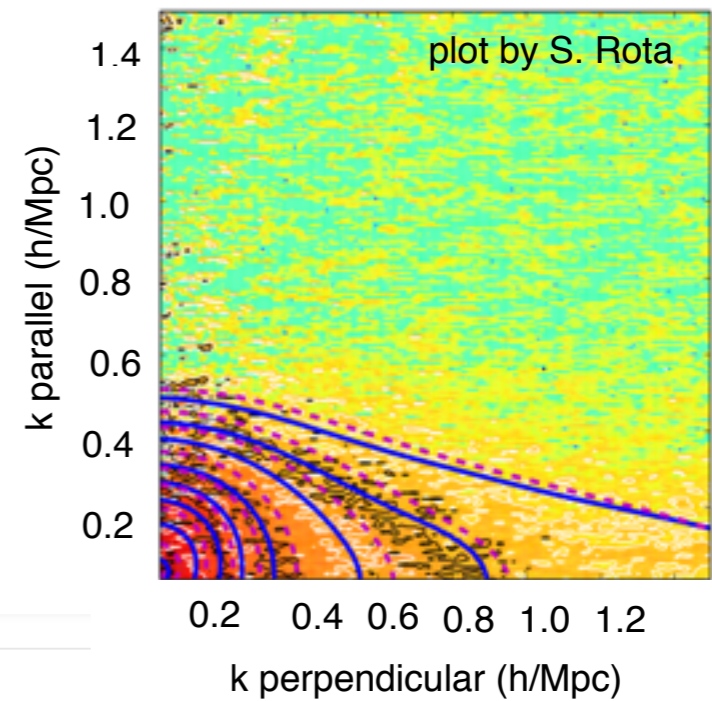
   ★ Wiener filtered field (**BRG**+2015)

See also

   ★ Full sample and modelling by **Andrea Pezzotta** (poster)

➡ Modelling side: Bianchi, Chiesa, Guzzo 2014
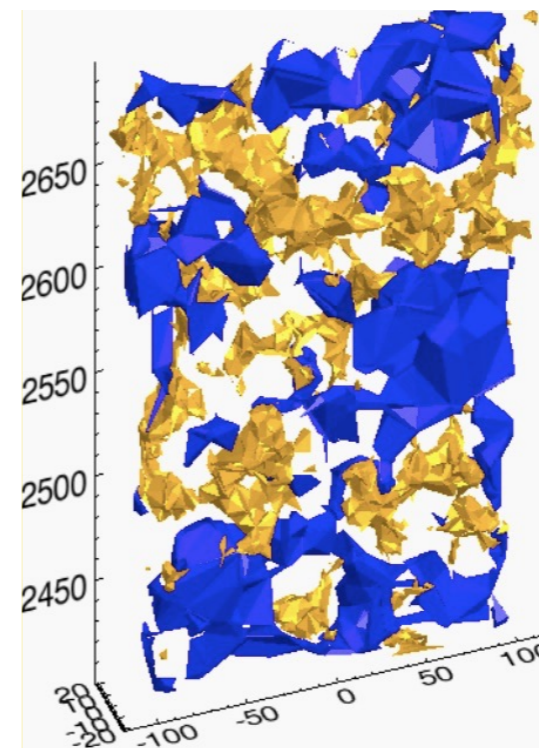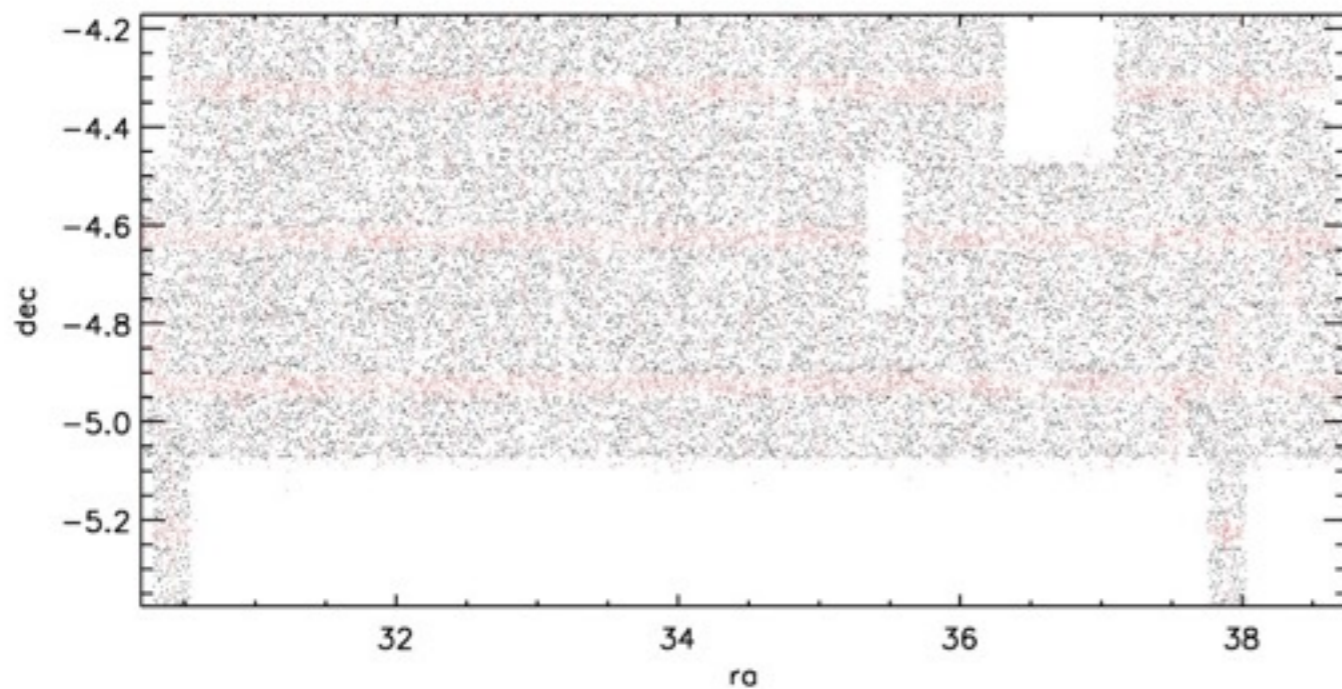
Mocks
Likelihood data

RSD with clipped field

★ Clipping is a non-linear transform of the density field that thresholds peaks (F. Simpson, M. Wilson)

★ Reduce systematics from fingers-of-god

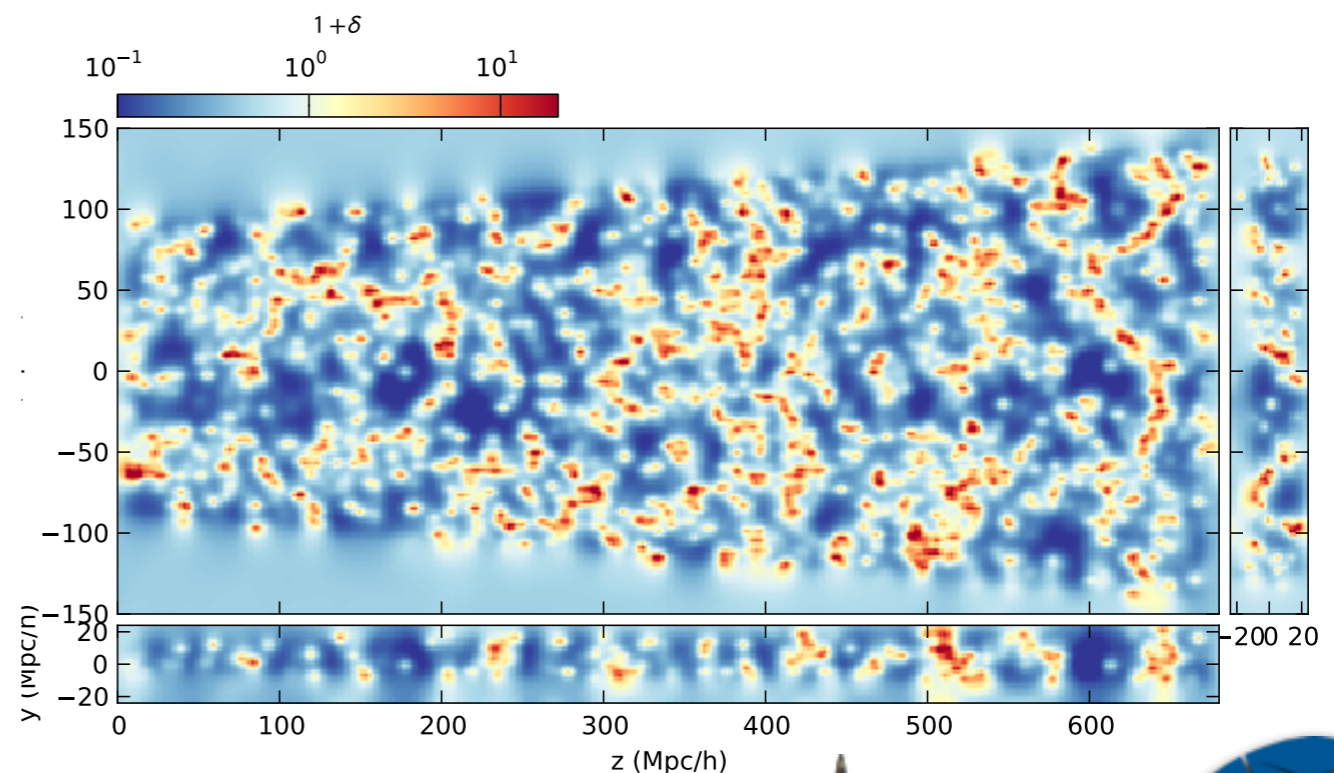Comparison of best-fit growth rate as a function of maximum wavenumber.

★ See Mike Wilson's poster

M. Wilson

Density field - mind the gaps

Use photometric sample to *Fill in the gaps*
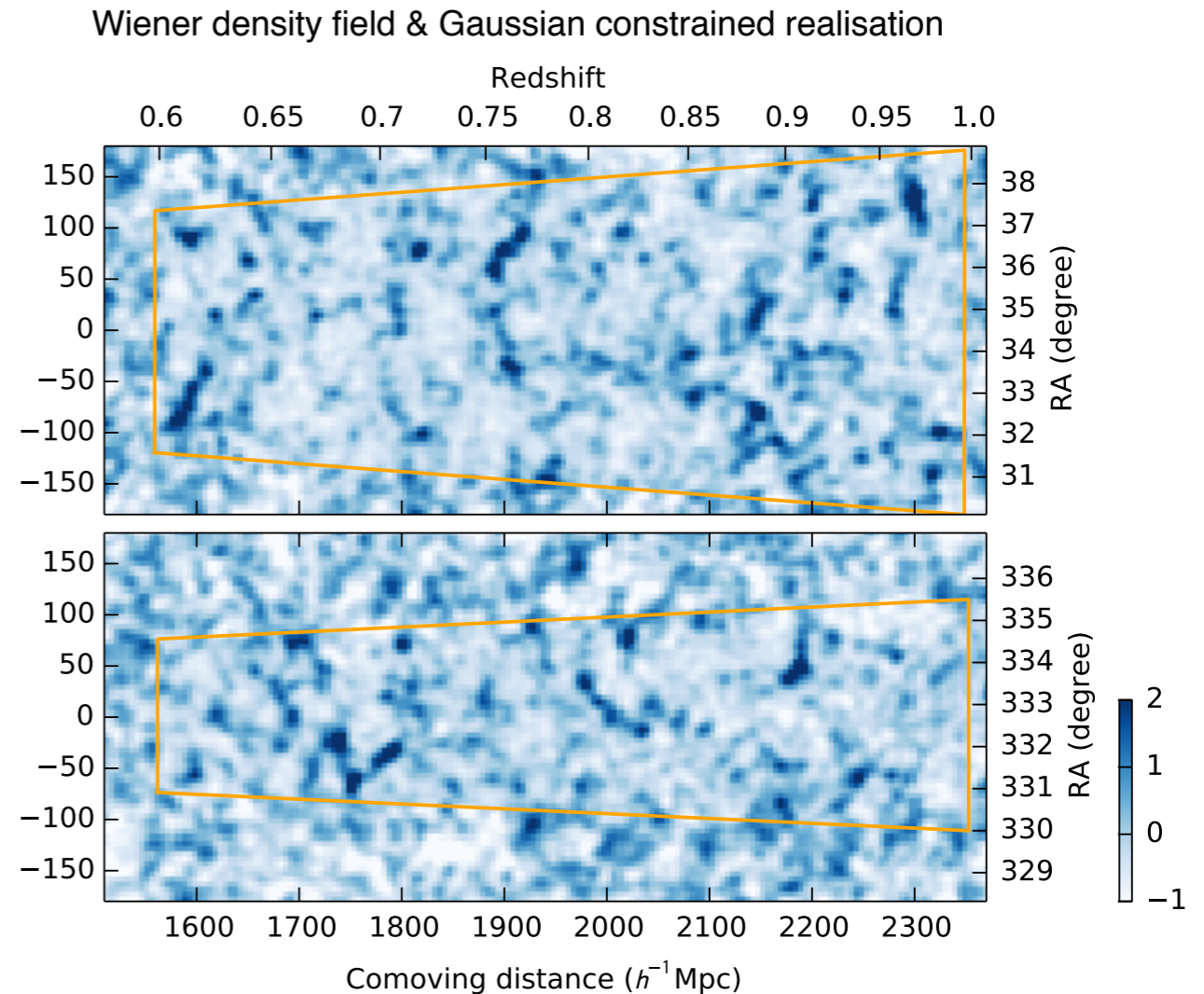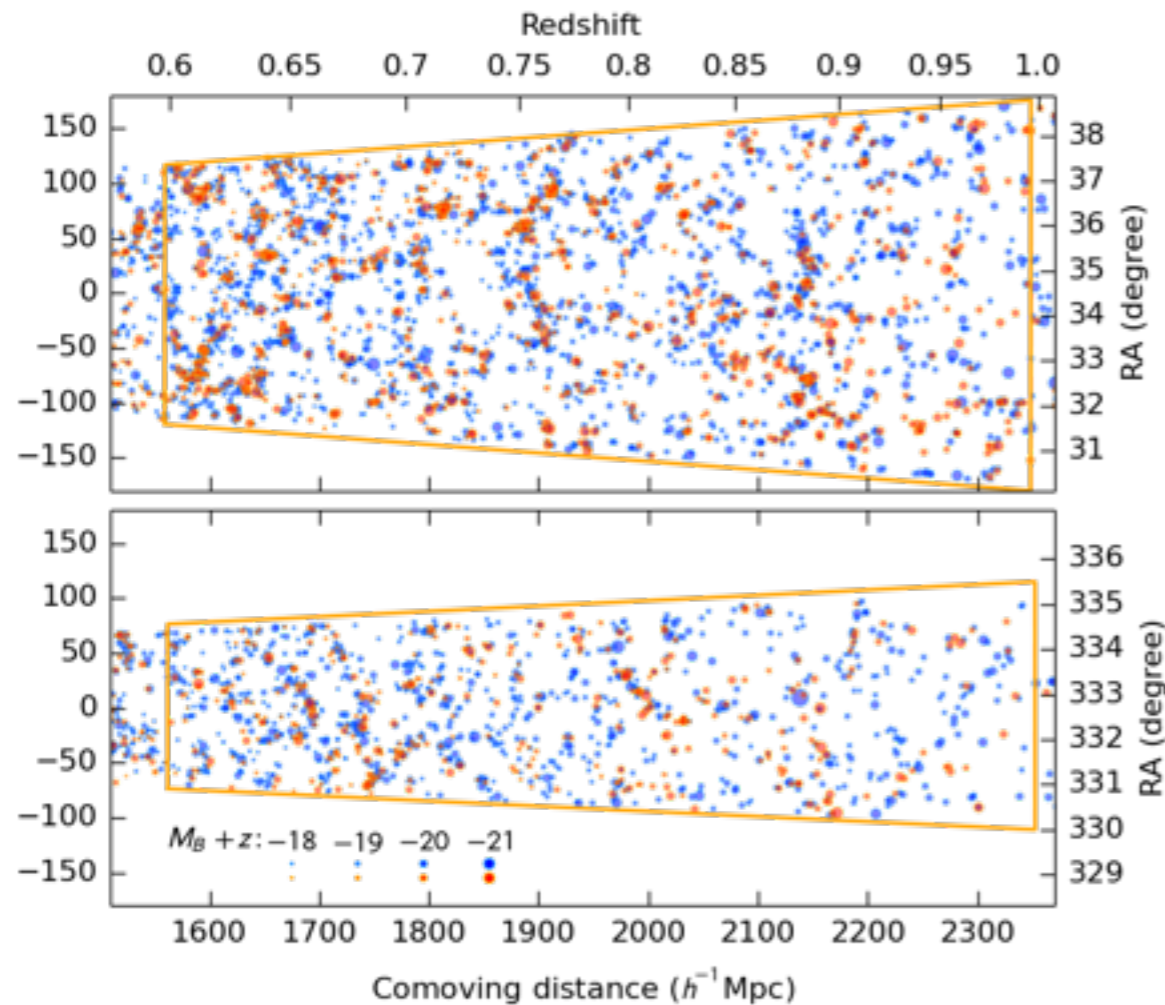Cloning, ZADE photo-z attractor, Cucciati+2014

Bayesian density field estimation
Wiener filtering, Lognormal poisson prior
Cucciati+2014, Granett+2015

Joint reconstruction
δ, P(k,μ), b$_g$, n(L)/dL

Wiener density field & Gaussian constrained realisation

★ Use of Gibbs sampler to jointly estimate density field, power spectrum, galaxy biases and luminosity function.
Granett+2015

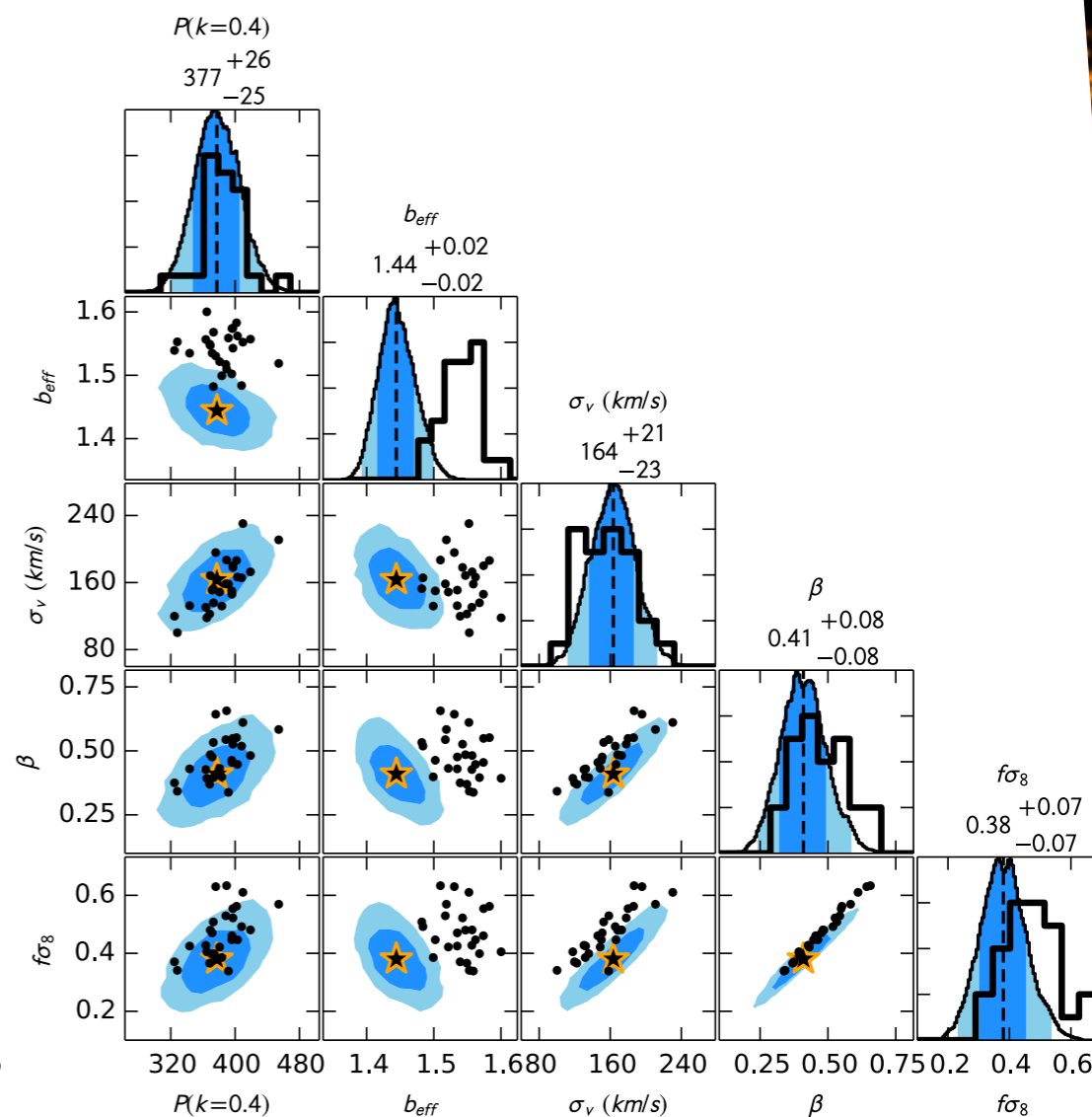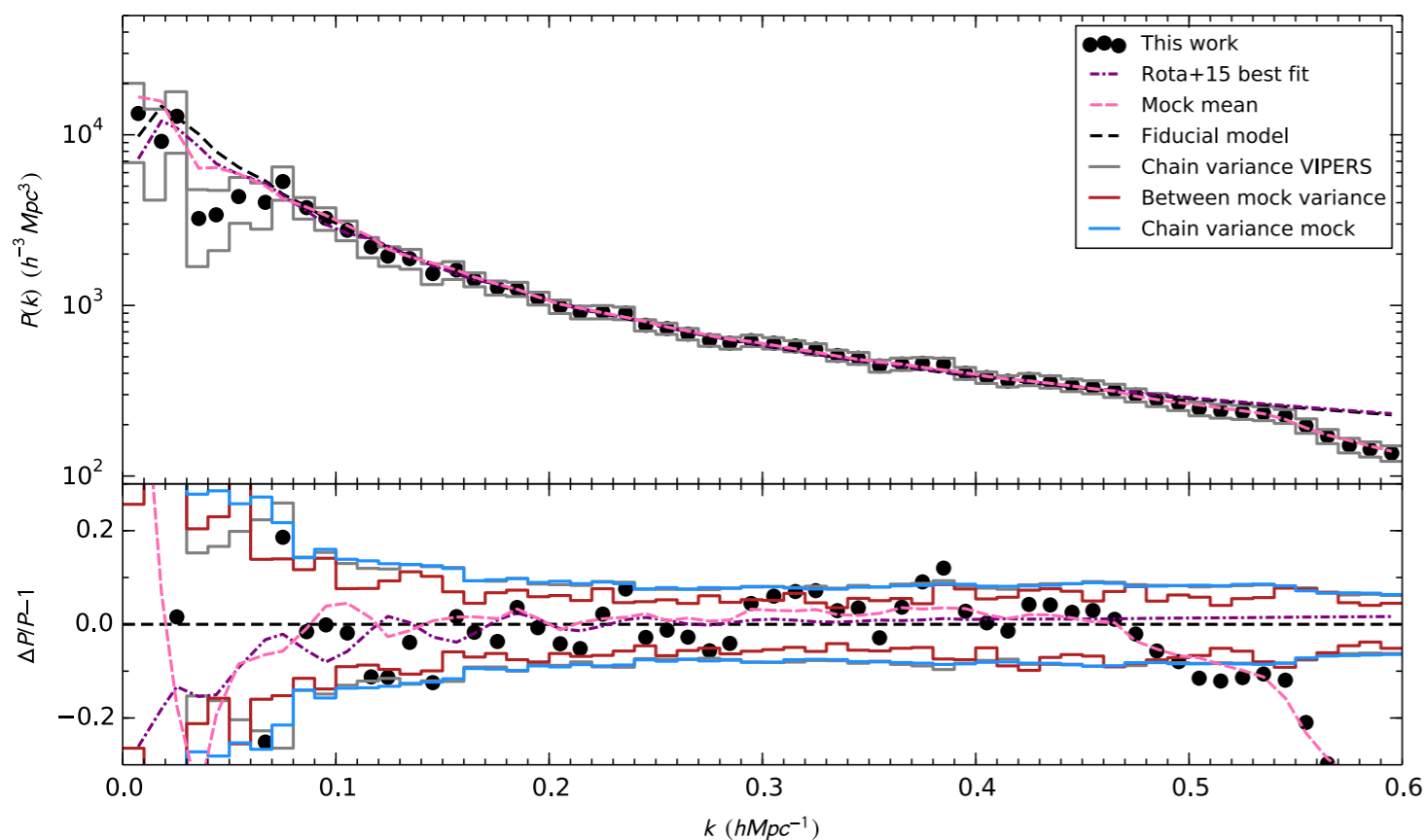**ben.granett@brera.inaf.it**   *LSS, Garching, 21 July 2015*

Joint reconstruction
δ, P(k,µ), b$_g$, n(L)/dL

$$S(k,\mu;\beta,\sigma_v,\sigma_{obs}) = A\frac{\left(1+\beta\mu^2\right)^2}{1+k_{los}^2\sigma_v^2}e^{-\frac{k_{los}^2\sigma_{obs}^2}{2}}\mathcal{B}^2(k_x,k_y,k_z)P(k),$$
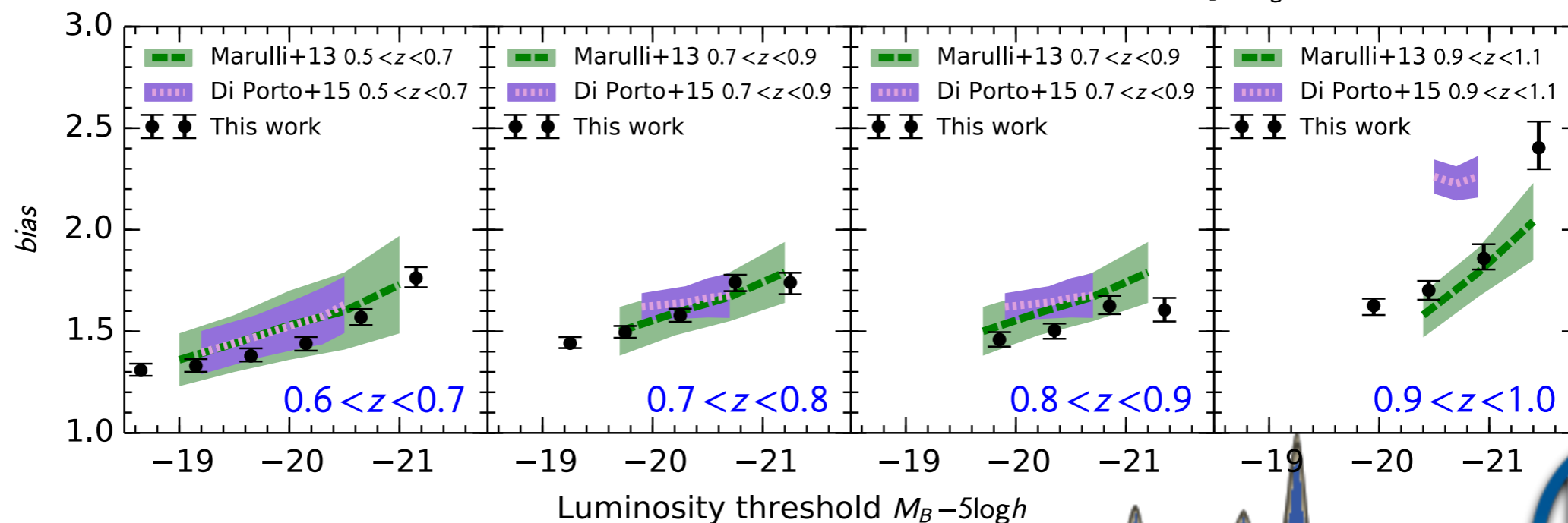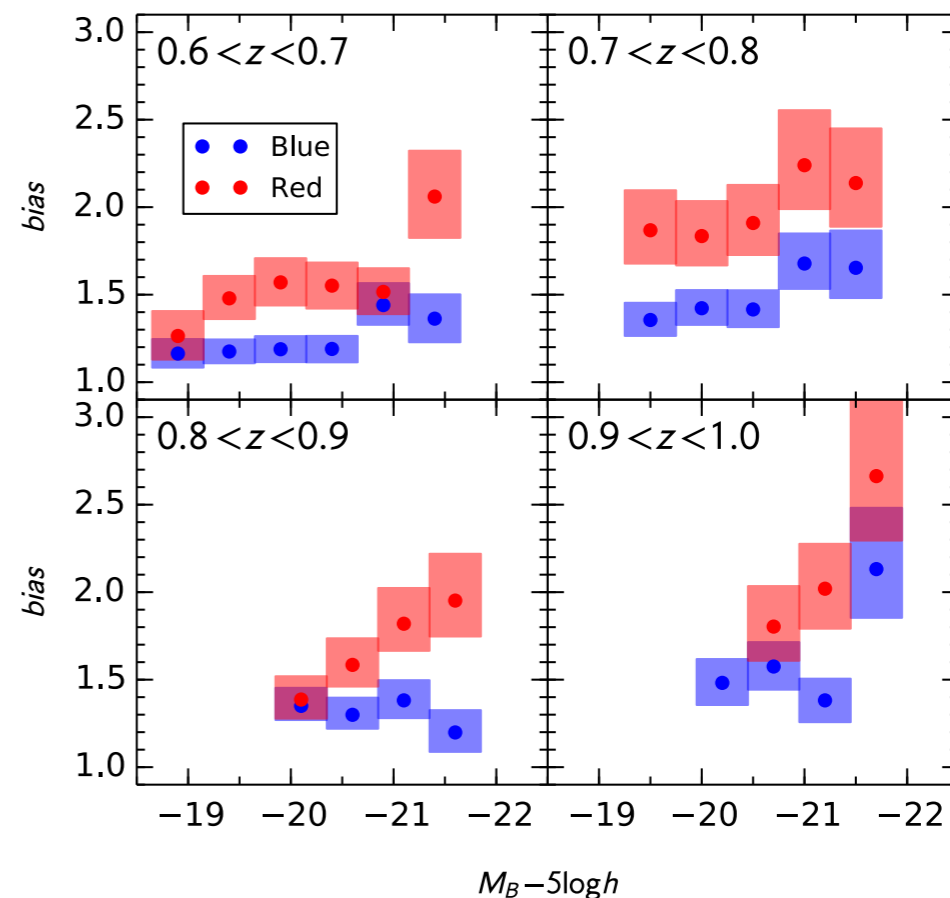
Joint reconstruction
δ, P(k,μ), b_g, n(L)/dL

★ Color dependence shows red/blue bimodality

★ Luminosity dependence in agreement with previous VIPERS analyses.

➡ Projected correlation function (**Marulli+13**)
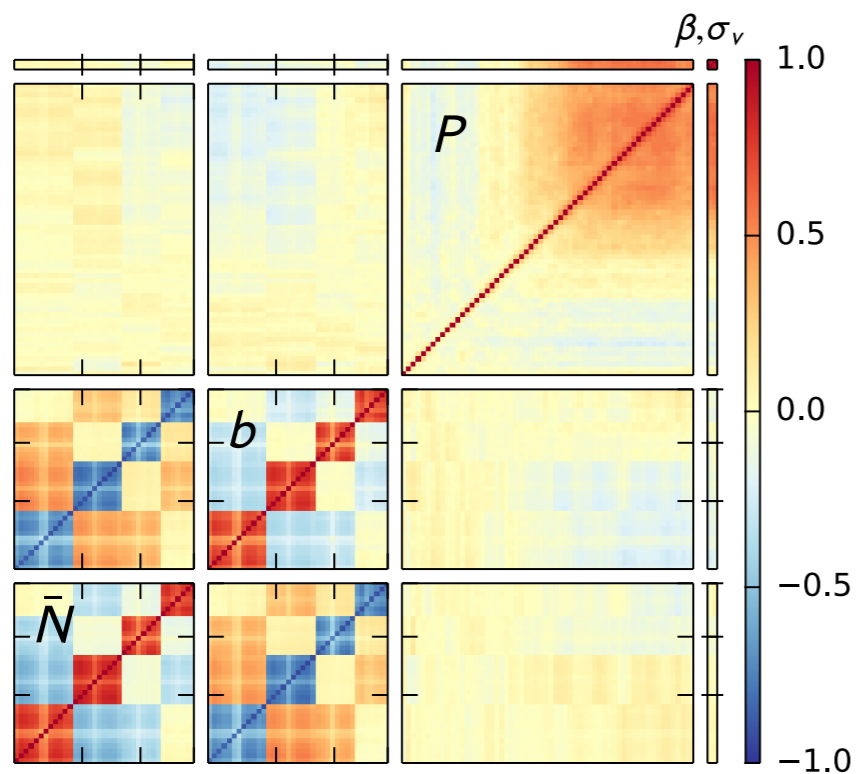➡ Counts-in-cells PDF (**Di Porto+15, Cappi+15**)

Joint reconstruction
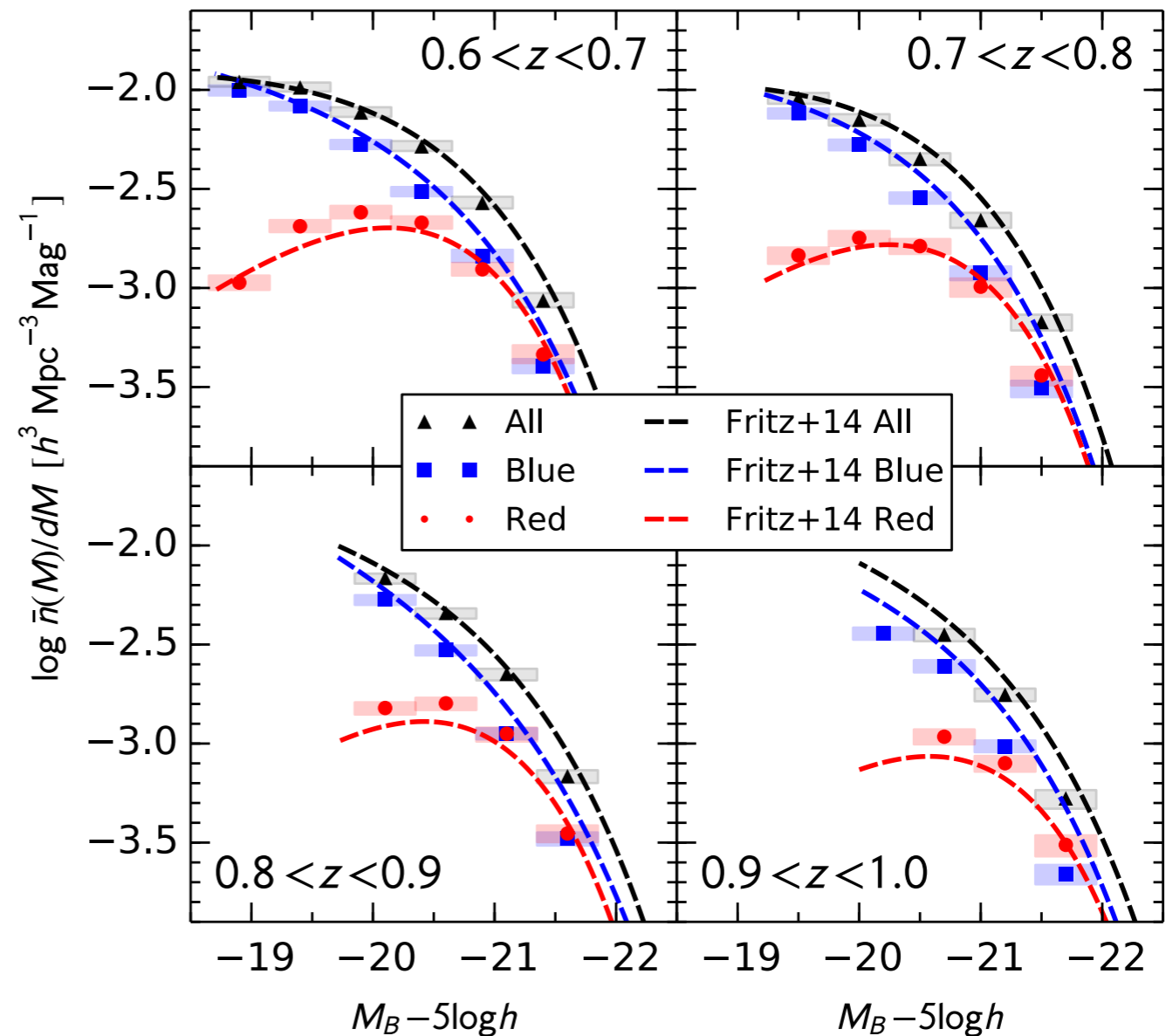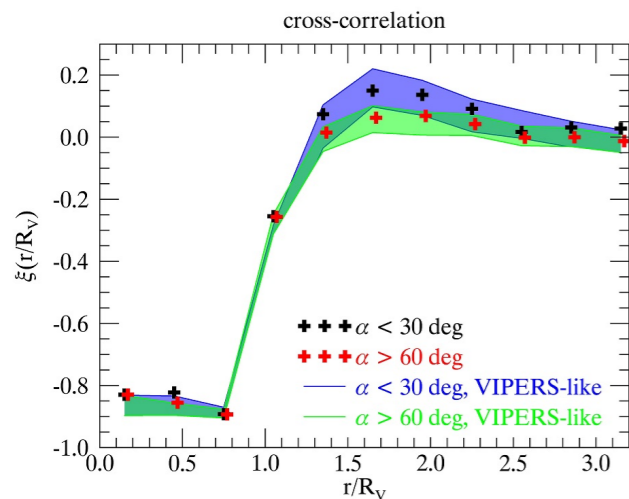# $\delta, P(k,\mu), b_g, n(L)/dL$
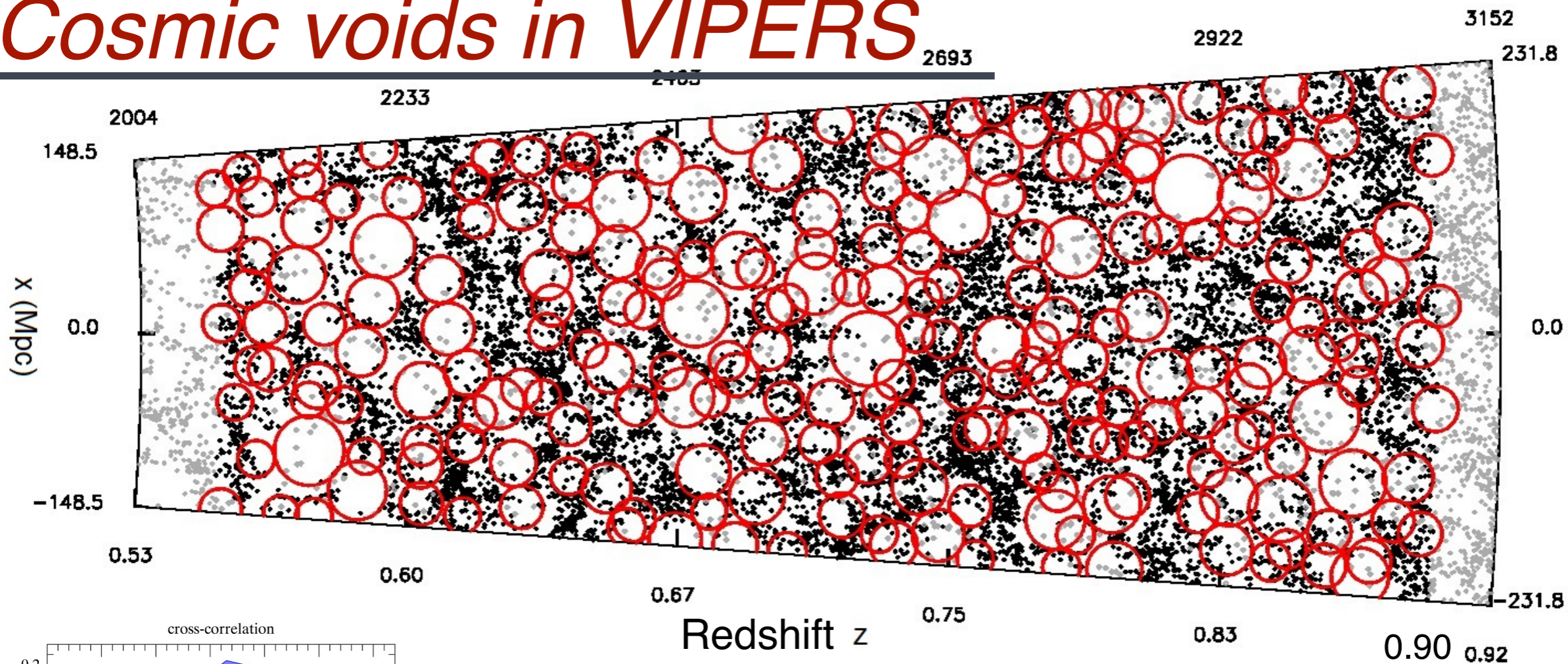
★ Comparison of n(z,L) with Fritz et al

★ Bayesian estimator accounts for correlations between galaxy bias and luminosity
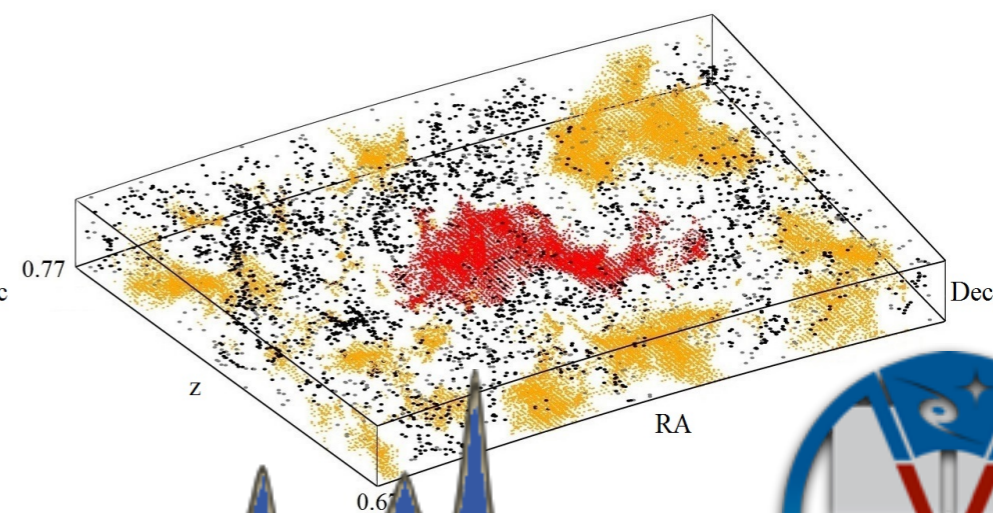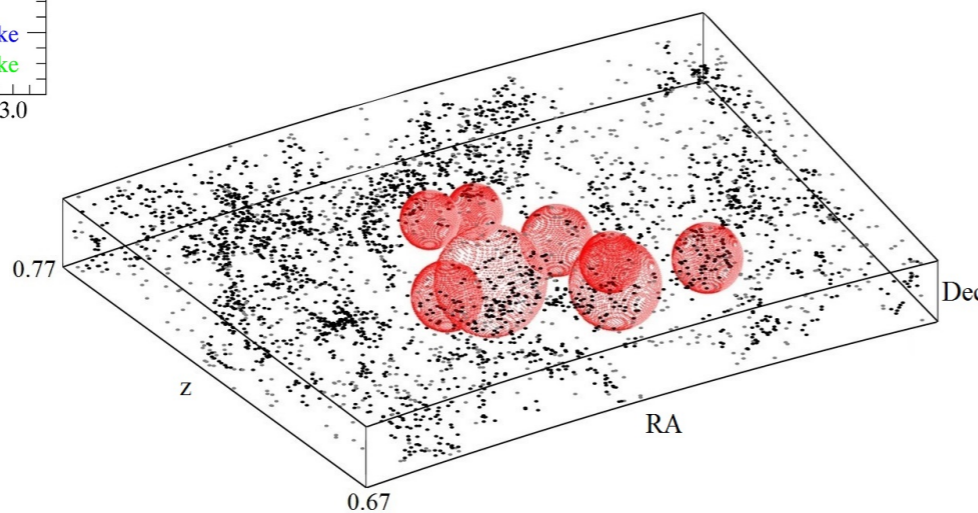(a difference with STY estimator)

Covariance of measurements

Cosmic voids in VIPERS
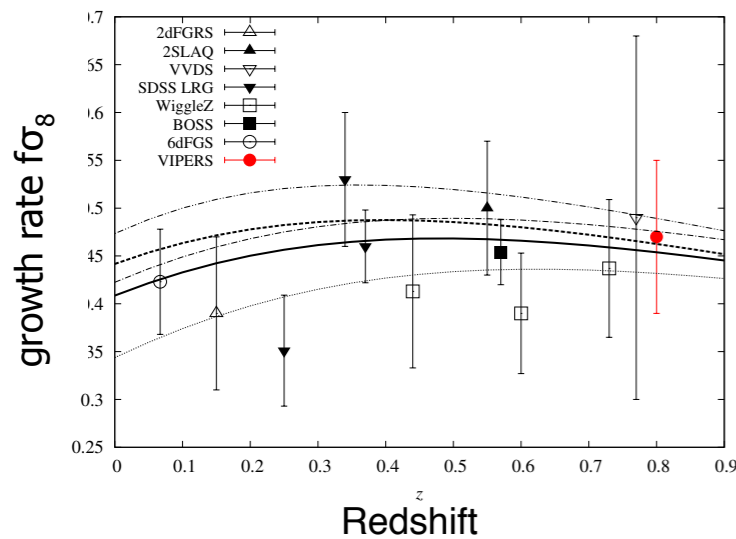

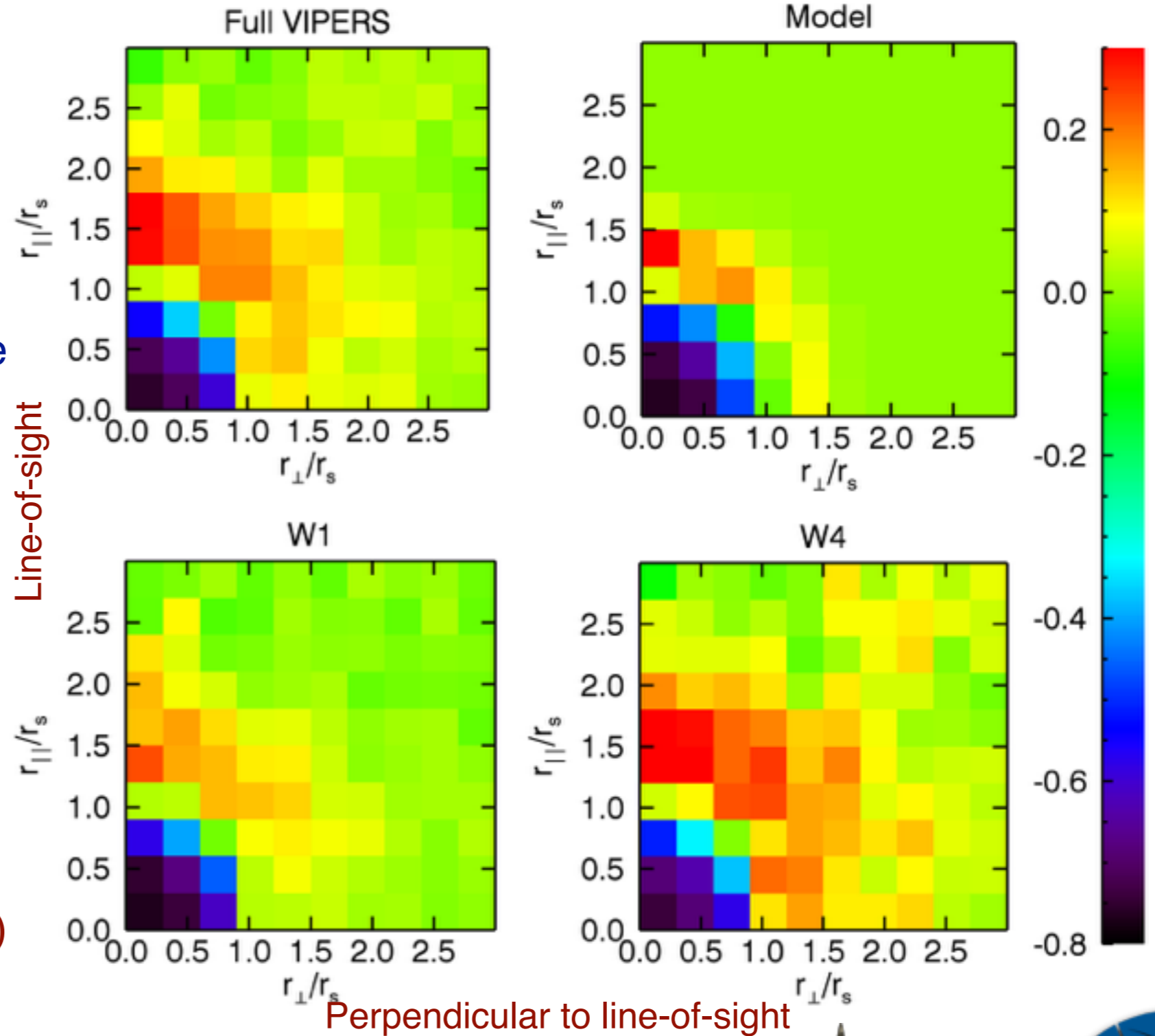★ Void finding algorithm based upon empty spheres
Micheletti,Iovino+(2014)

New test of growth of structure

★ Anisotropic void profiles normalised to void radius

★ Constraints on growth rate

See Adam Hawken (poster)

Full VIPERS

Model

Line-of-sight

W1

W4

Perpendicular to line-of-sight

ben.granett@brera.inaf.it   *LSS, Garching, 21 July 2015*

Summary

★ VIPERS exploits VIMOS capabilities for LSS study, unique at z~1: volume 6 x 10^7 h^{-3} Mpc^3, sampling ~ 40%

★ Volume smaller than BAO surveys (BOSS, Wigglez), but high sampling will allow defining sub-populations and optimize tracers for clustering studies

★ In parallel, powerful probe for galaxy evolution studies over 8 billion years

★ Efficient survey pipeline: automatic data calibration, redshift measurement and database archiving: as of today ~89,000 secure spectra already available

★ Large set of ancillary data already available (GALEX, WIRCAM, VISTA, XMM)

★ Early science release happened March 2013

★ Survey is now complete and final analyses in preparation

    ★ Fourier analysis and cosmological parameters

    ★ Redshift-space clustering and growth rate

    ★ Cosmic voids

    ★ Galaxy environment, bias

★ Final public data release to be in 2016

Thank you

Field W1

VIPERS
VIMOS PUBLIC EXTRAGALACTIC REDSHIFT SURVEY

Field W4

http://vipers.inaf.it

A. Iovino