Cosmological constraints from the galaxy power spectrum of VIPERS
PDR-1 +

Julien Bel
work done by **Stefano Rota,**
Ben Granett, Luigi Guzzo & VIPERS Team

Osservatorio Astronomico di Brera, INAF, Merate/Milano

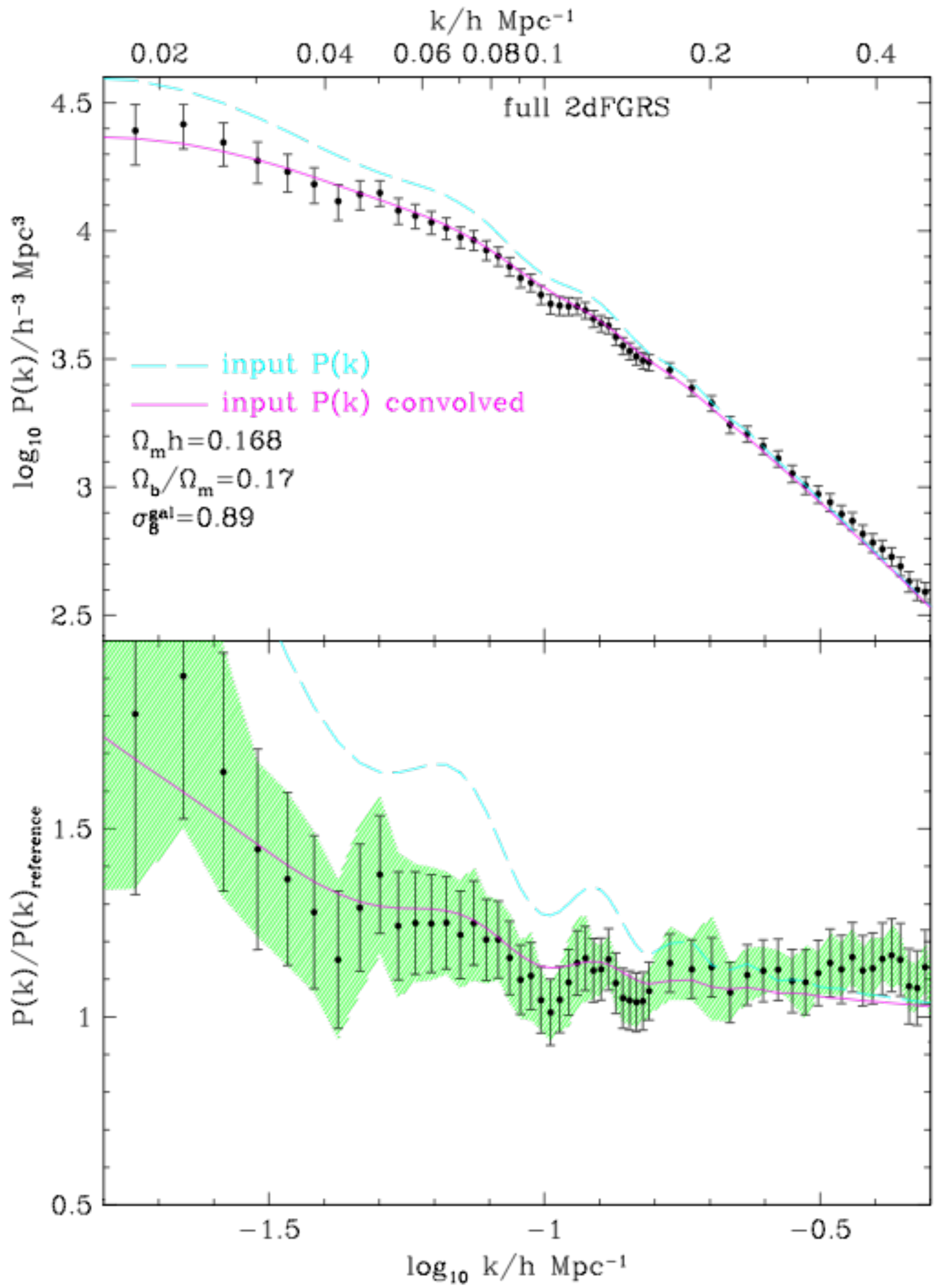
Theoretical and Observational Progress on Large-scale Structure of the Universe
21/07/2015

This project has received funding from the European Union's Seventh Framework Programme for research, technological development and demonstration under grant agreement no 291521

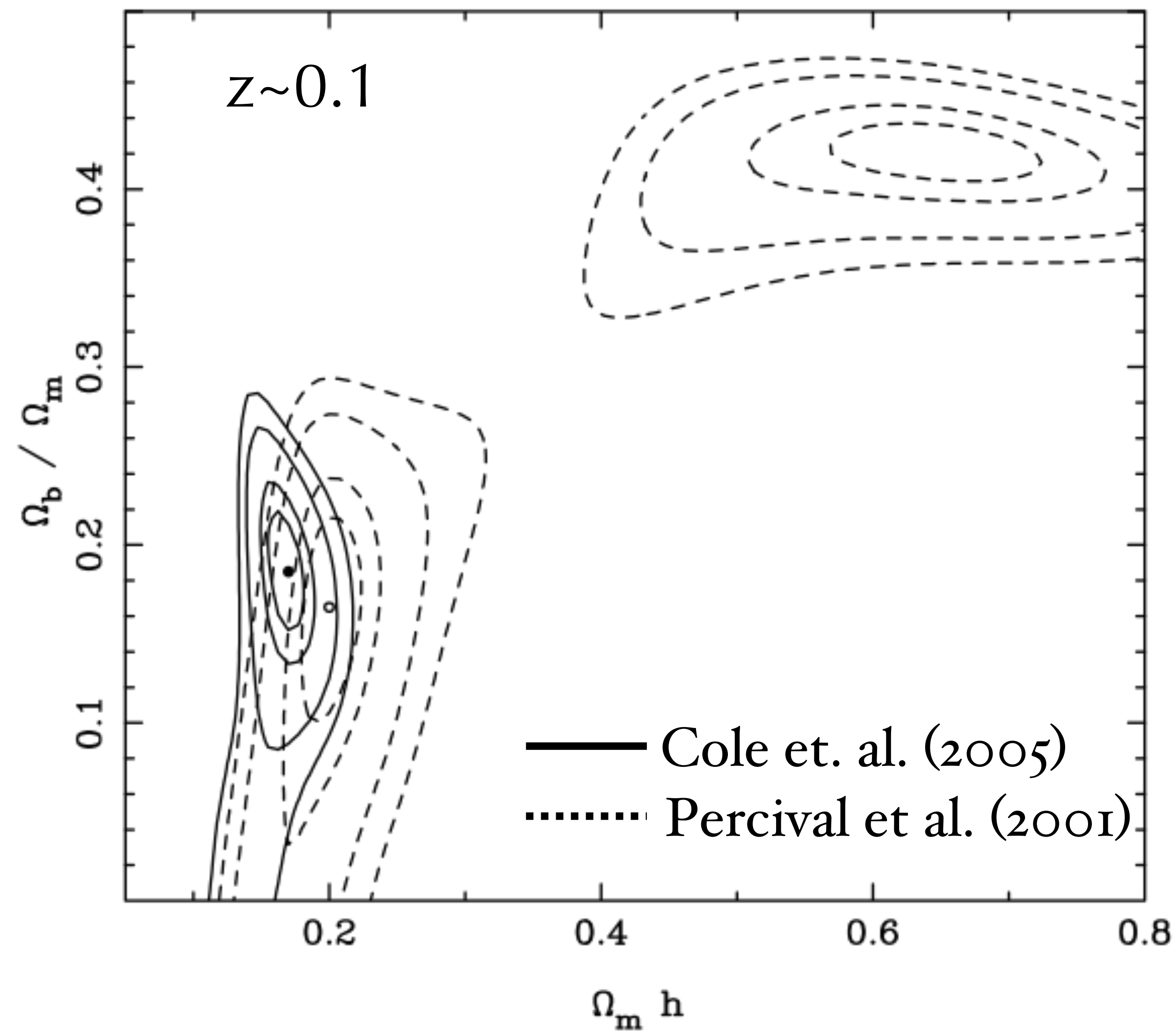
Outline:

1. Model power spectrum
2. Test of systematics
3. VIPERS PDR1 +
4. Comparison with other surveys
5. Conclusions

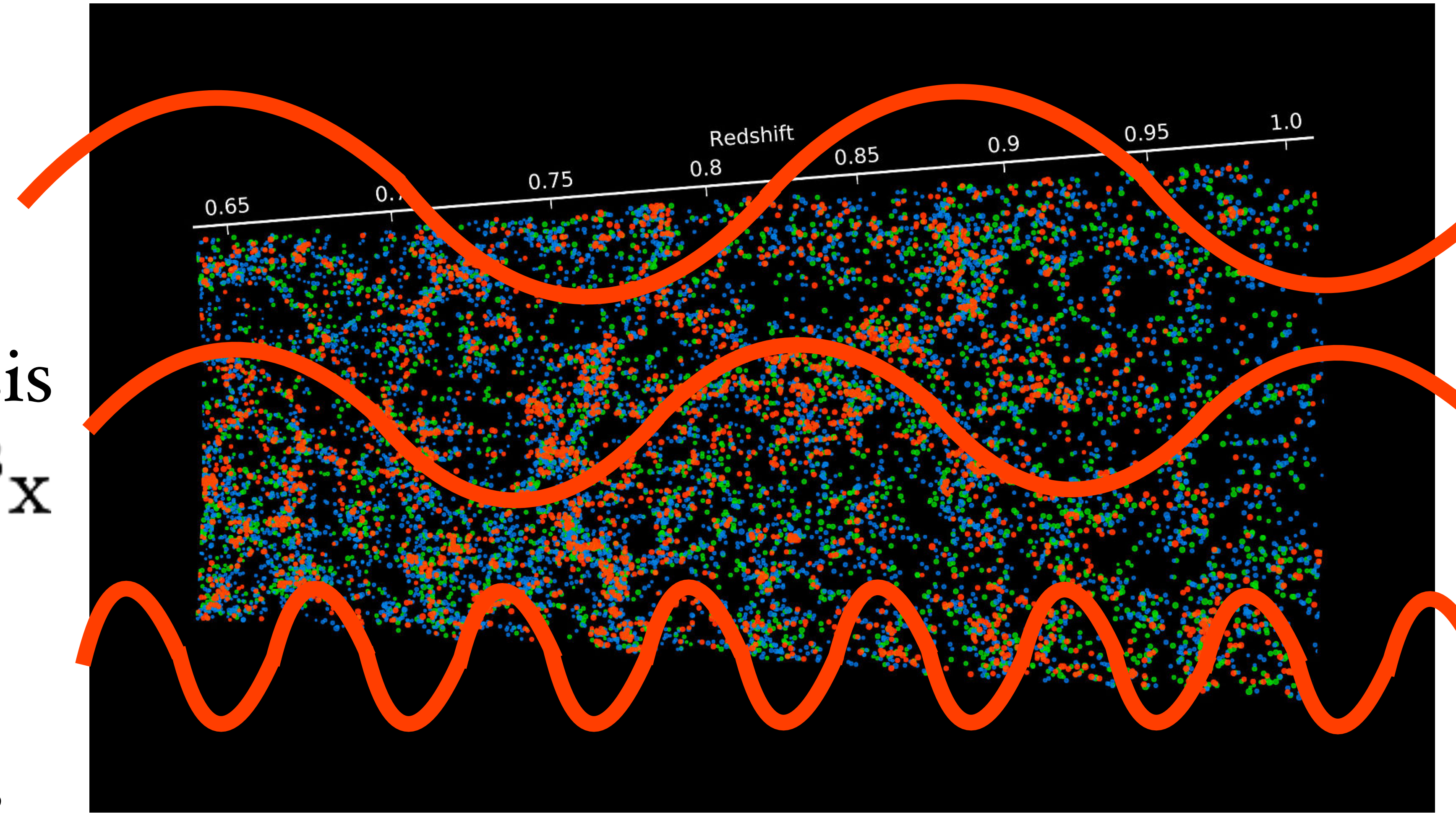
Local Universe, z~0: 2dFGRS



k-range fitted: 0.02 < k < 0.15 h Mpc^{-1}



Measuring the power spectrum



decompose
the density
field on the Fourier basis

$$\delta(\mathbf{x}) = \int \delta(\mathbf{k})\, e^{i\mathbf{k}\cdot\mathbf{x}}\, d^3x$$

the power spectrum is
the amplitude squared
of the coefficients

$$\delta(\mathbf{k}) = \int \delta(\mathbf{x})\, e^{-i\mathbf{k}\cdot\mathbf{x}}\, d^3k$$

FKP, P(k) estimator

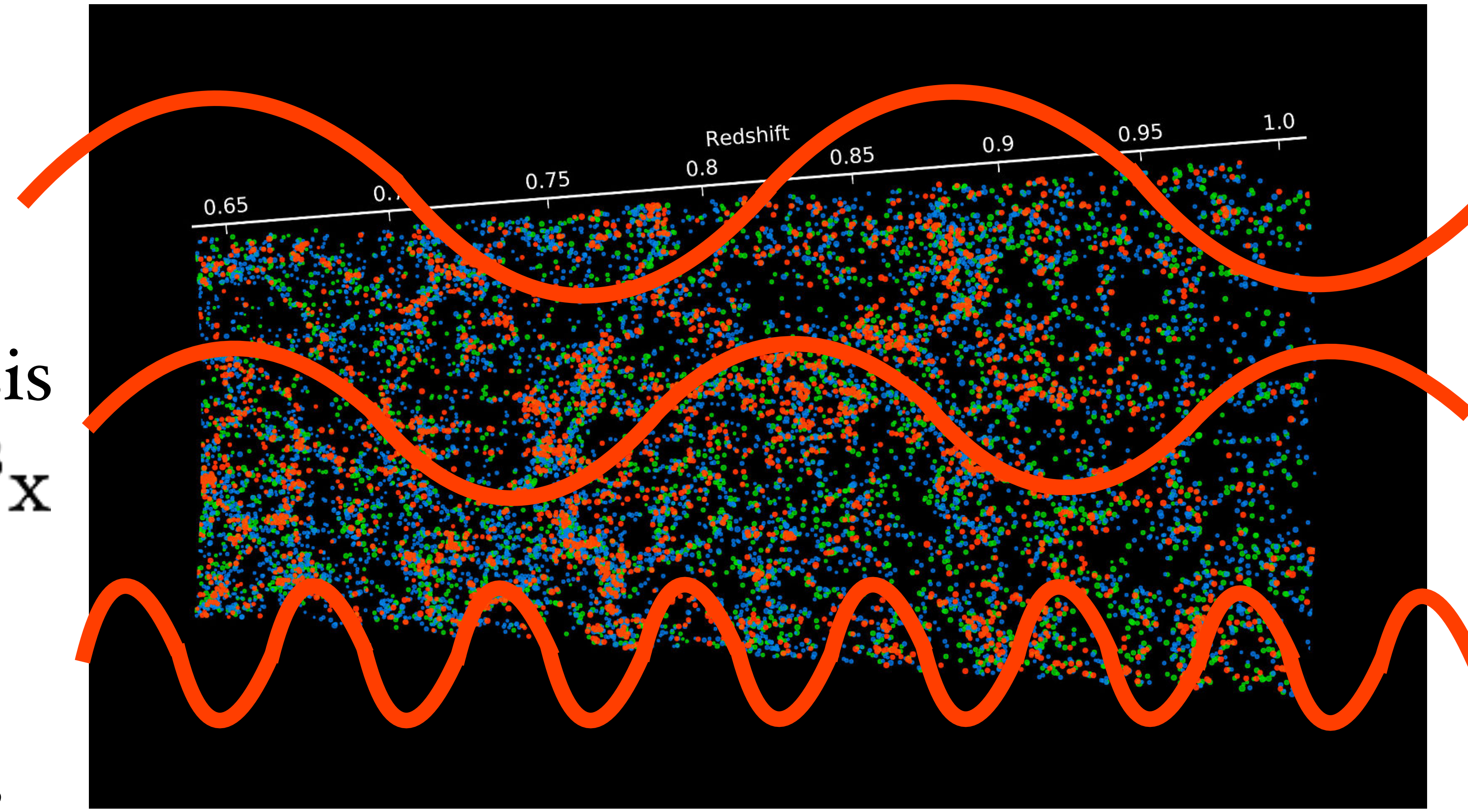
$$\hat{\delta}(\mathbf{x}_P) = w(\mathbf{x}_P)\, \frac{n_G(\mathbf{x}_P) - \alpha\, n_R(\mathbf{x}_P)}{\alpha \sum_R \bar{n}(\mathbf{x}_R)\, w^2(\mathbf{x}_R)}$$

$$\hat{P}(\mathbf{k}) = |\hat{\delta}_{FKP}(\mathbf{k})|^2 - P_{shot}$$

Measuring the power spectrum

decompose
the density
field on the Fourier basis

$$\delta(\mathbf{x}) = \int \delta(\mathbf{k})\, \mathrm{e}^{\mathrm{i}\mathbf{k}\cdot\mathbf{x}}\, \mathrm{d}^3\mathrm{x}$$



the power spectrum is
the amplitude squared
of the coefficients

$$\delta(\mathbf{k}) = \int \delta(\mathbf{x})\, \mathrm{e}^{-\mathrm{i}\mathbf{k}\cdot\mathbf{x}}\, \mathrm{d}^3\mathrm{k}$$

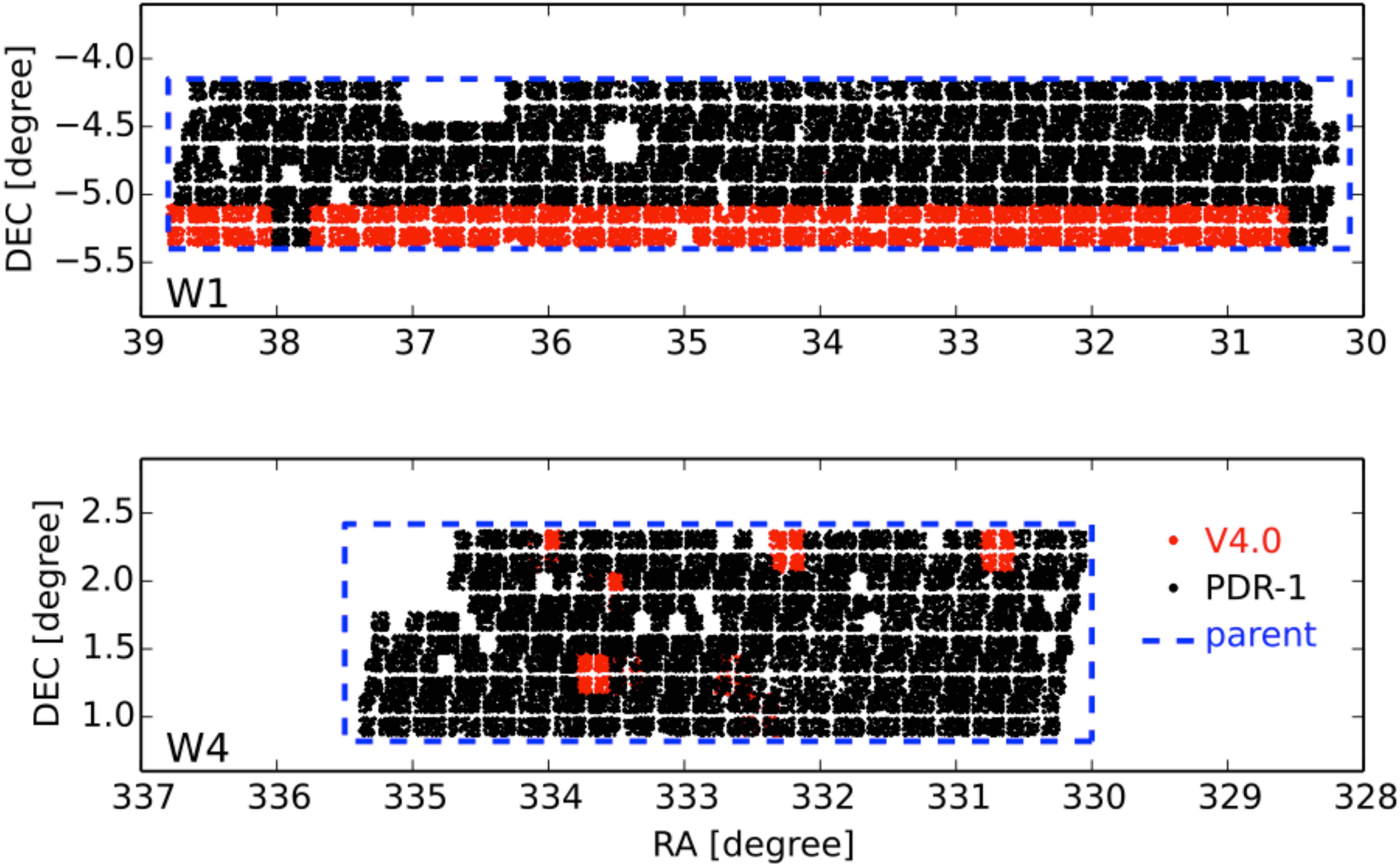
FKP, P(k) estimator

$$\hat{\delta}(\mathbf{x}_\mathrm{P}) = \mathrm{w}(\mathbf{x}_\mathrm{P}) \frac{\mathrm{n}_\mathrm{G}(\mathbf{x}_\mathrm{P}) - \alpha\, \mathrm{n}_\mathrm{R}(\mathbf{x}_\mathrm{P})}{\alpha \sum_\mathrm{R} \bar{\mathrm{n}}(\mathbf{x}_\mathrm{R})\, \mathrm{w}^2(\mathbf{x}_\mathrm{R})}$$

Andrea Pezzotta's poster

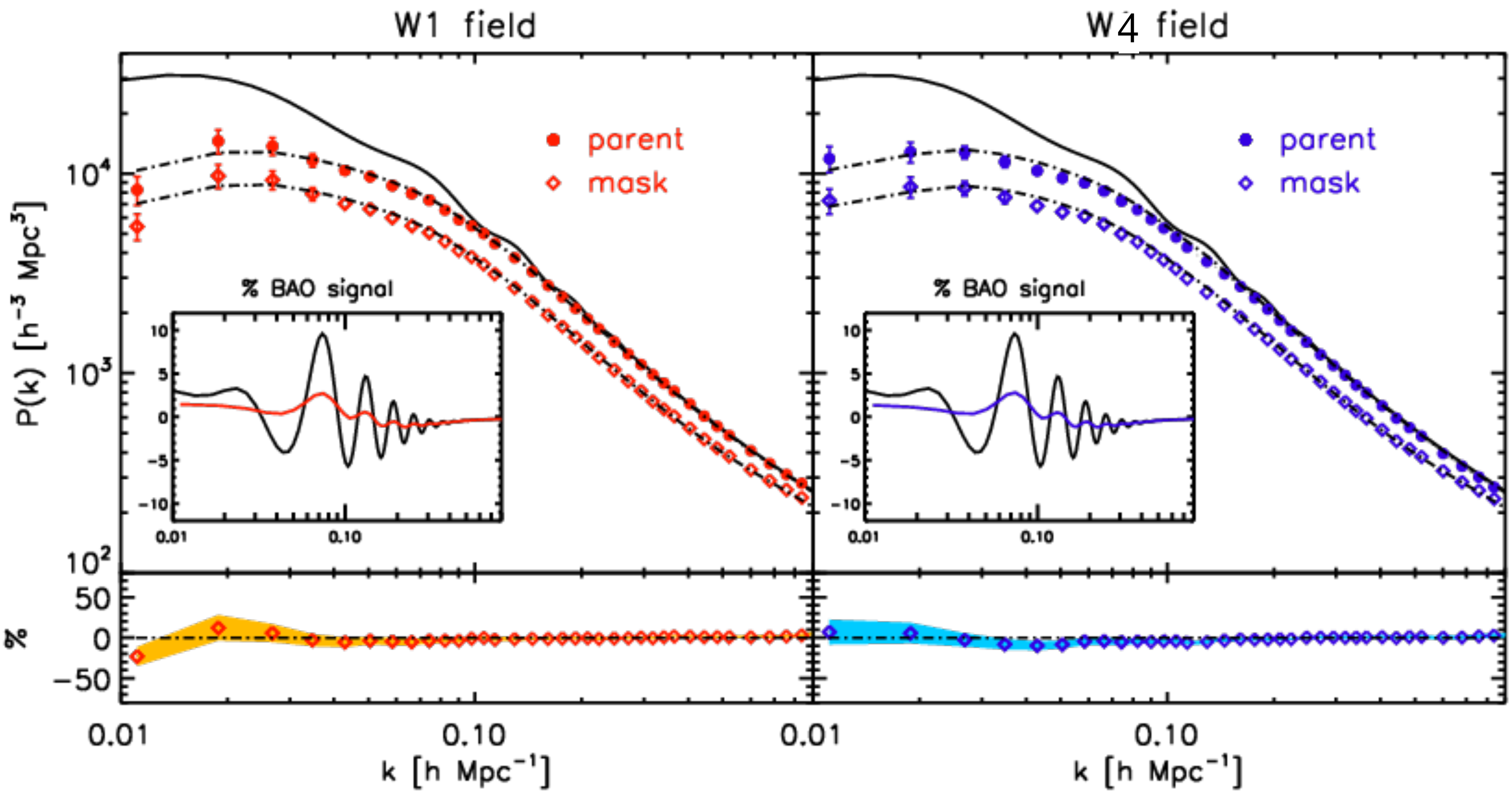
$$\hat{\mathrm{P}}(\mathbf{k}) = |\hat{\delta}_\mathrm{FKP}(\mathbf{k})|^2 - \mathrm{P}_\mathrm{shot}$$

VIPERS window function



VIPERS window function

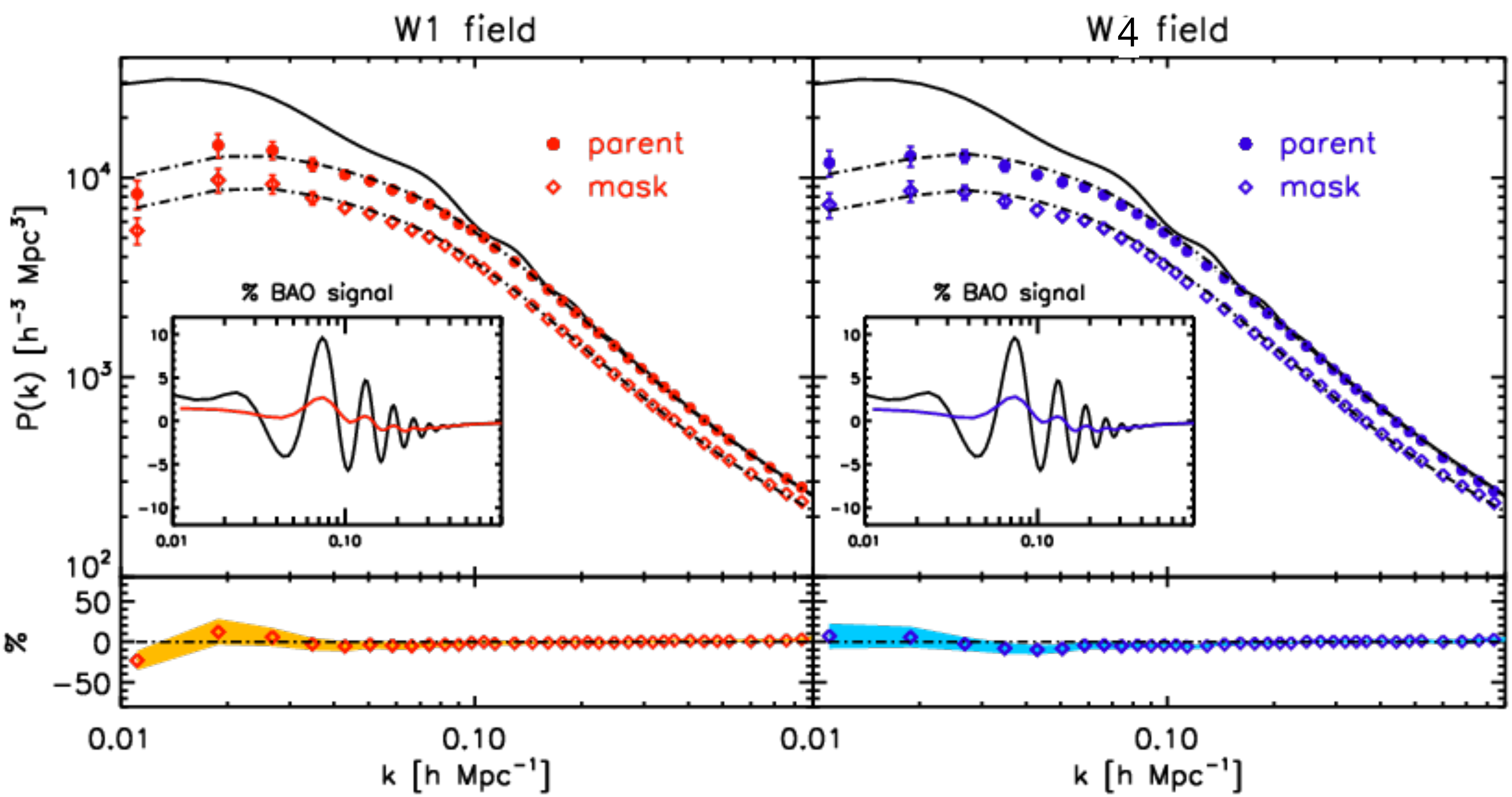
$$\hat{P}_{obs}(\mathbf{k}) = \int P(\mathbf{k}')\,|W(\mathbf{k}-\mathbf{k}')|^2 \frac{d^3\mathbf{k}'}{(2\pi)^3} = P * |W|^2$$



MultiDark (Prada et al. 2012) HOD mock catalogues made by S. de la Torre

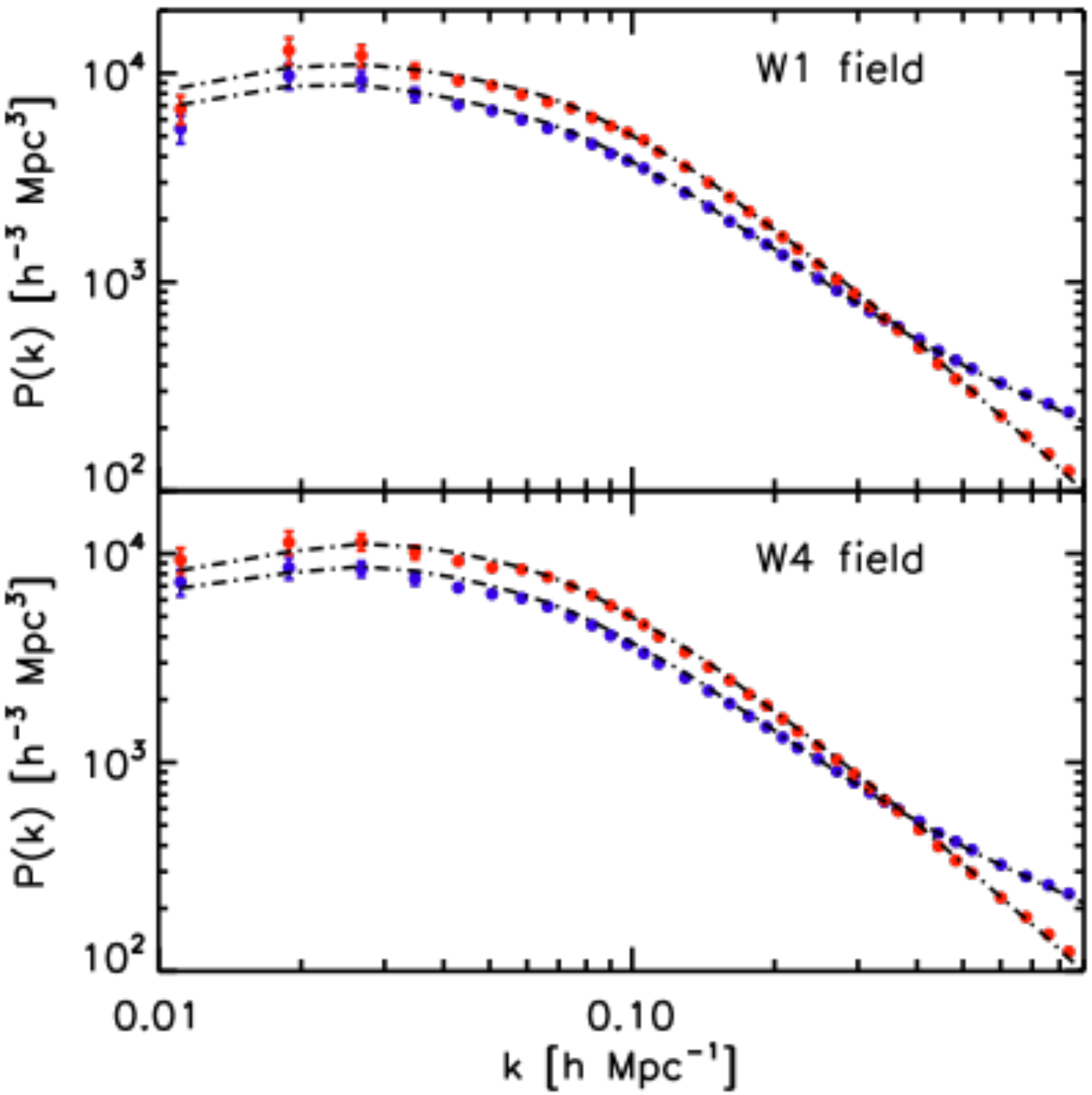
VIPERS window function

$$\hat{P}_{obs}(\mathbf{k}) = \int P(\mathbf{k}') \, |W(\mathbf{k} - \mathbf{k}')|^2 \, \frac{d^3\mathbf{k}'}{(2\pi)^3} = P * |W|^2$$



Possible BAO reconstruction ? (Angela Burden and Will Percival)

Redshift-space distortions



measured P(k) in redshift space

convolved P(k) model in real space

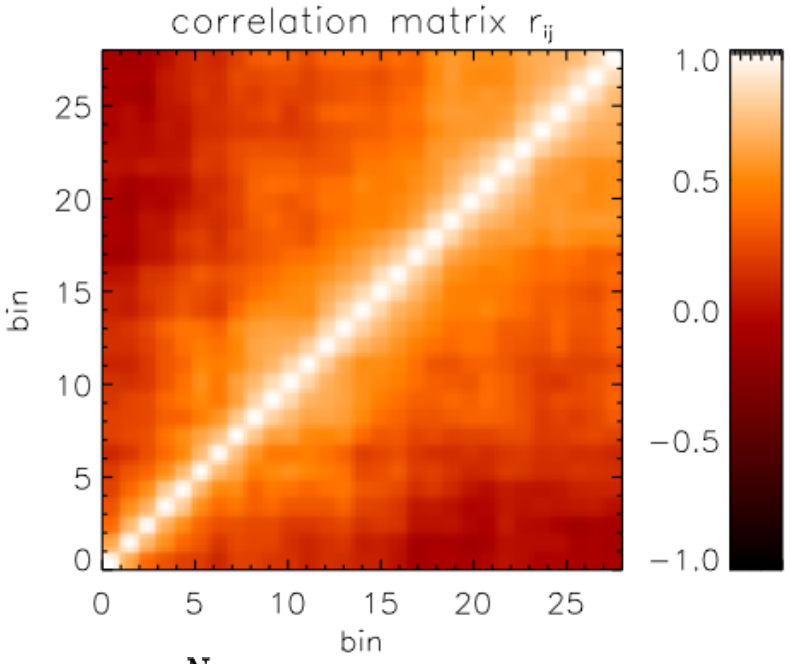
measured P(k) in real space

convolved P(k) model in redshift space

$$P_s(\mathbf{k}) = P_r(\mathbf{k})(1+\beta\mu_{\mathbf{k}}^2)^2\, e^{-[\mu_{\mathbf{k}}\, k\, \sigma_v]^2}$$

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

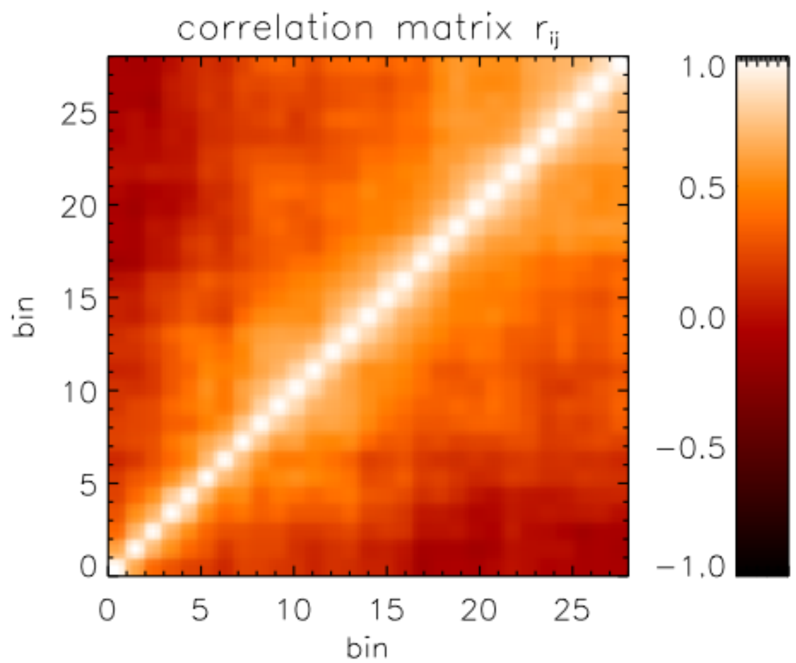
Test of systematics



$$C_{ij} = \frac{1}{N_R - 1} \sum_{m}^{N_R} \left[P_m(k_i) - \bar{P}(k_i)\right] \left[P_m(k_j) - \bar{P}(k_j)\right]$$

Obtained from 200
Pinocchio mock catalogues
(Monaco et al. 2002)

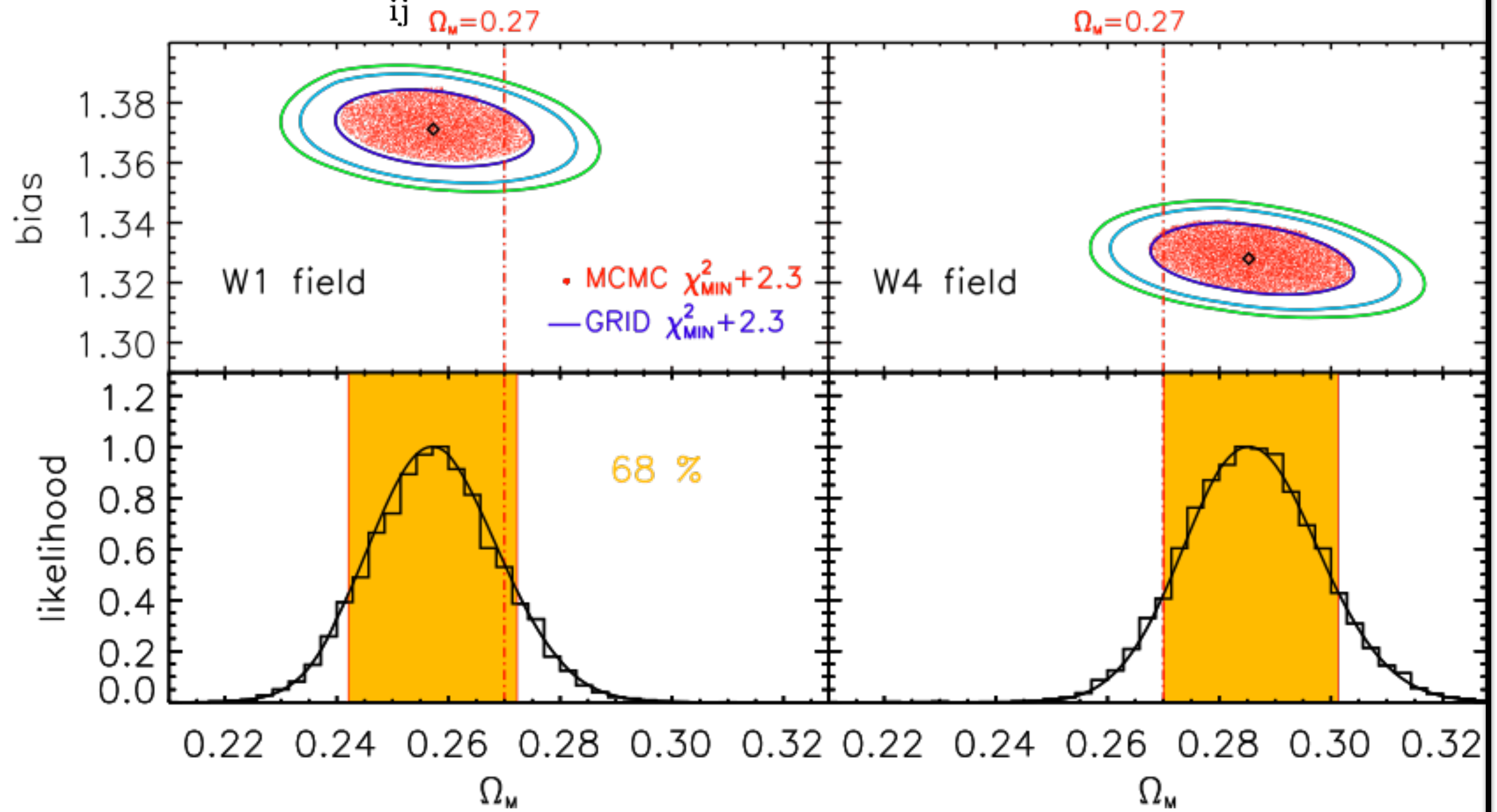
Test of systematics



$$C_{ij} = \frac{1}{N_R - 1} \sum_{m}^{N_R} \left[P_m(k_i) - \bar{P}(k_i)\right] \left[P_m(k_j) - \bar{P}(k_j)\right]$$

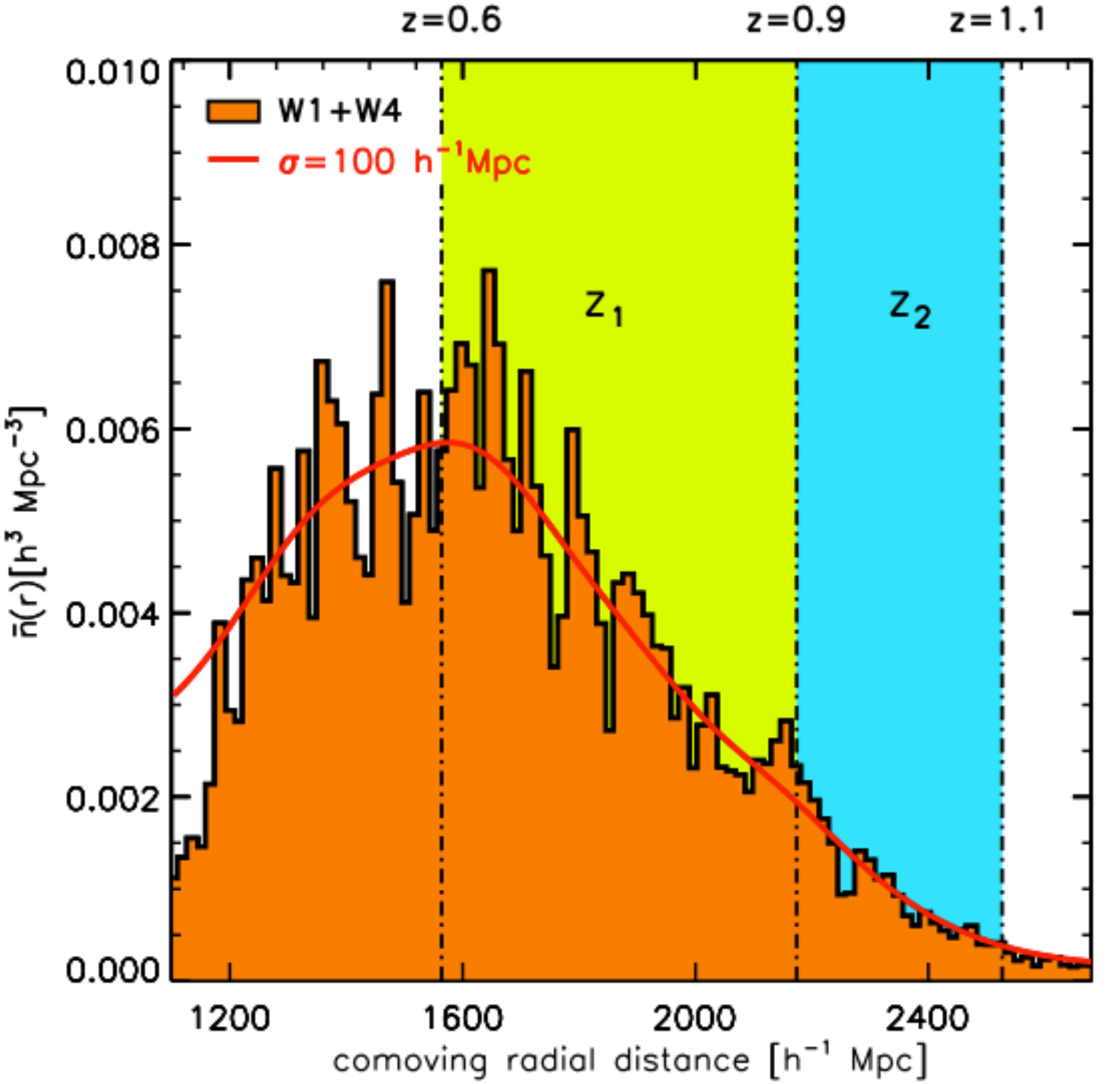
Obtained from 200 Pinocchio mock catalogues (Monaco et al. 2002)

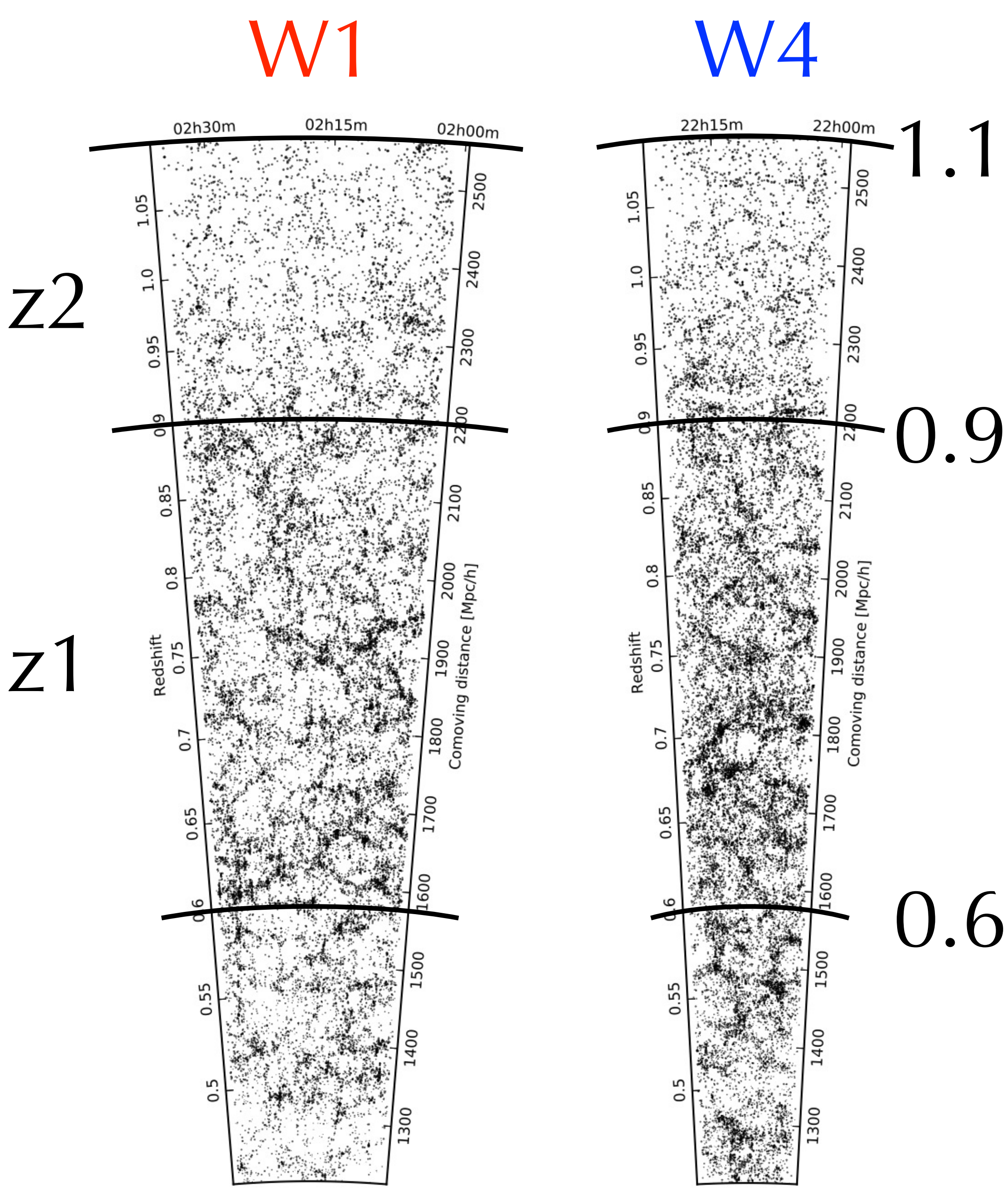
$$\chi^2(\mathbf{p}) = \sum_{ij} \left[P_{obs}(k_i) - P_M(k_i;\mathbf{p})\right] C_{ij}^{-1} \left[P_{obs}(k_j) - P_M(k_j;\mathbf{p})\right]$$



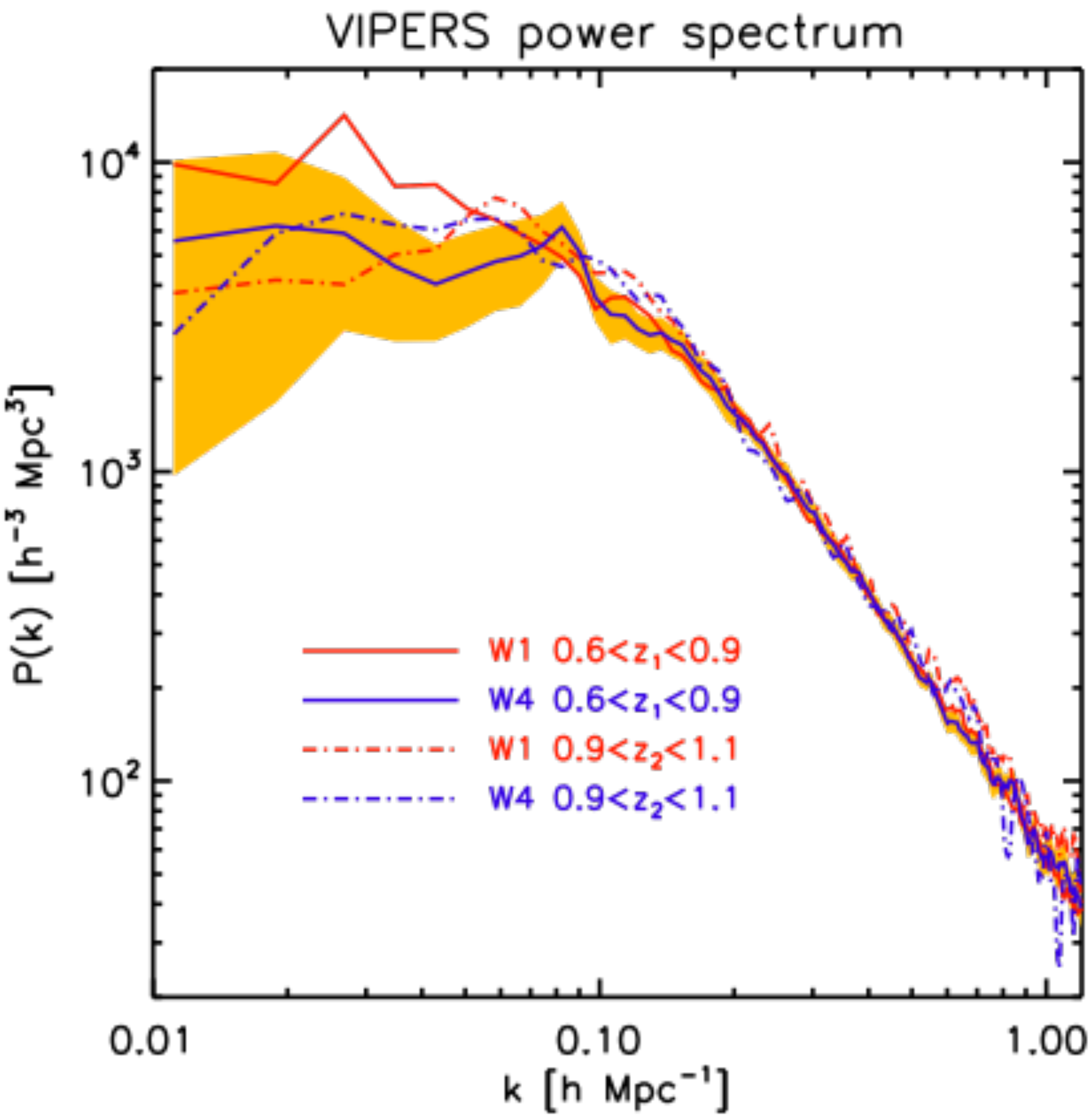
Error on the average of 26 (W1) and 31 (W4) N-body based mock catalogues (S. de la Torre)

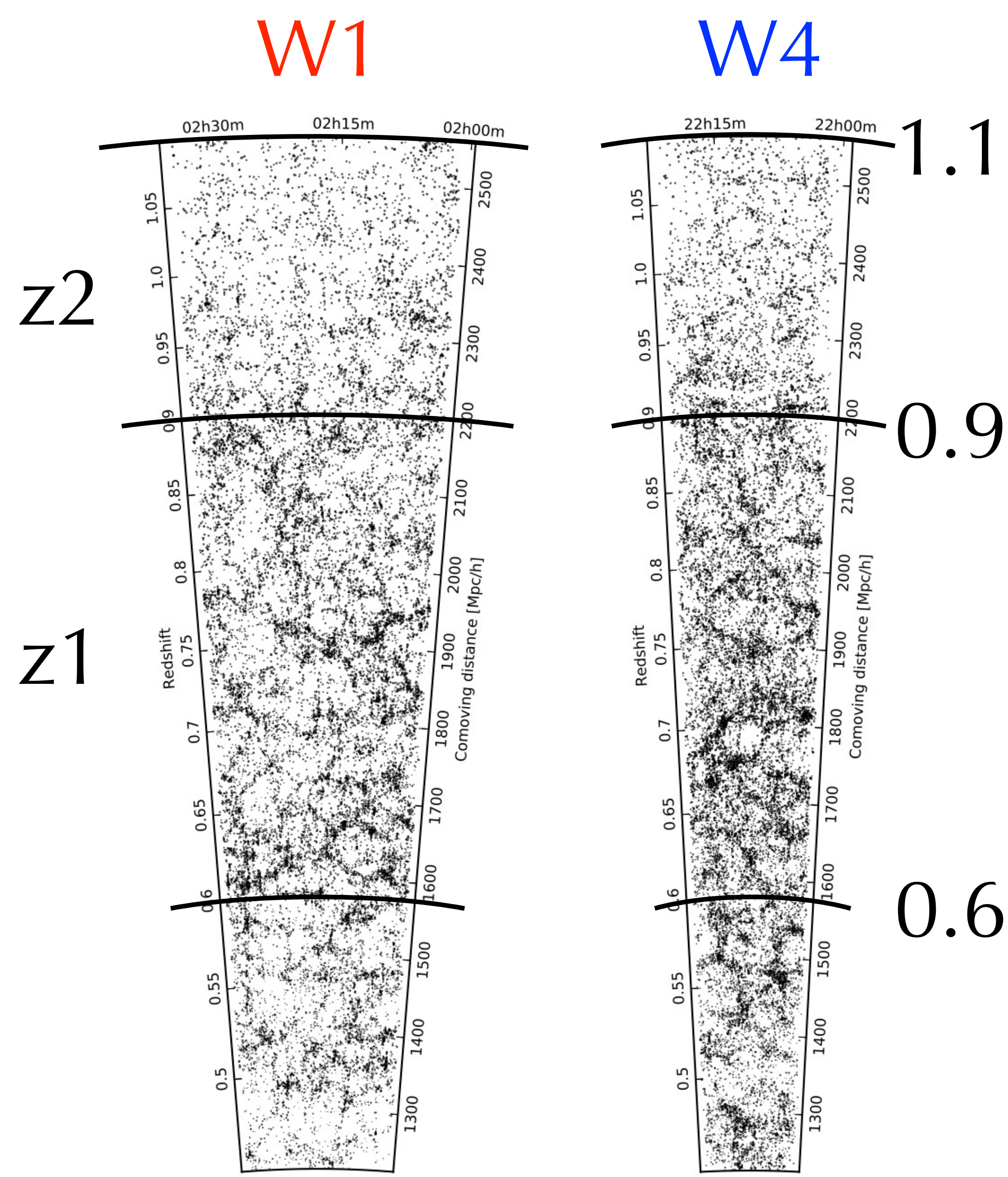
P(k) from the VIPERS PDR-1





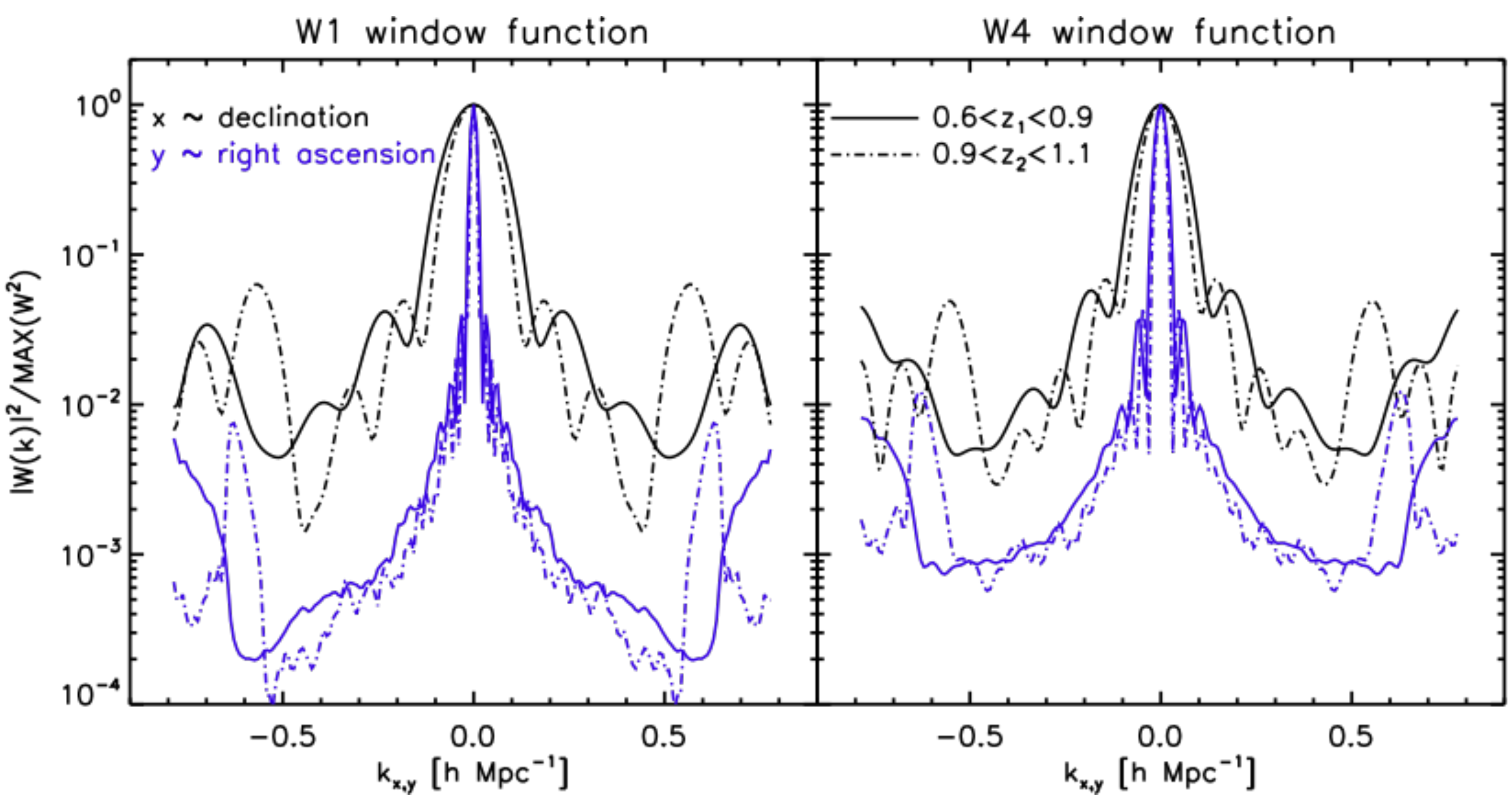
P(k) from the VIPERS PDR-1



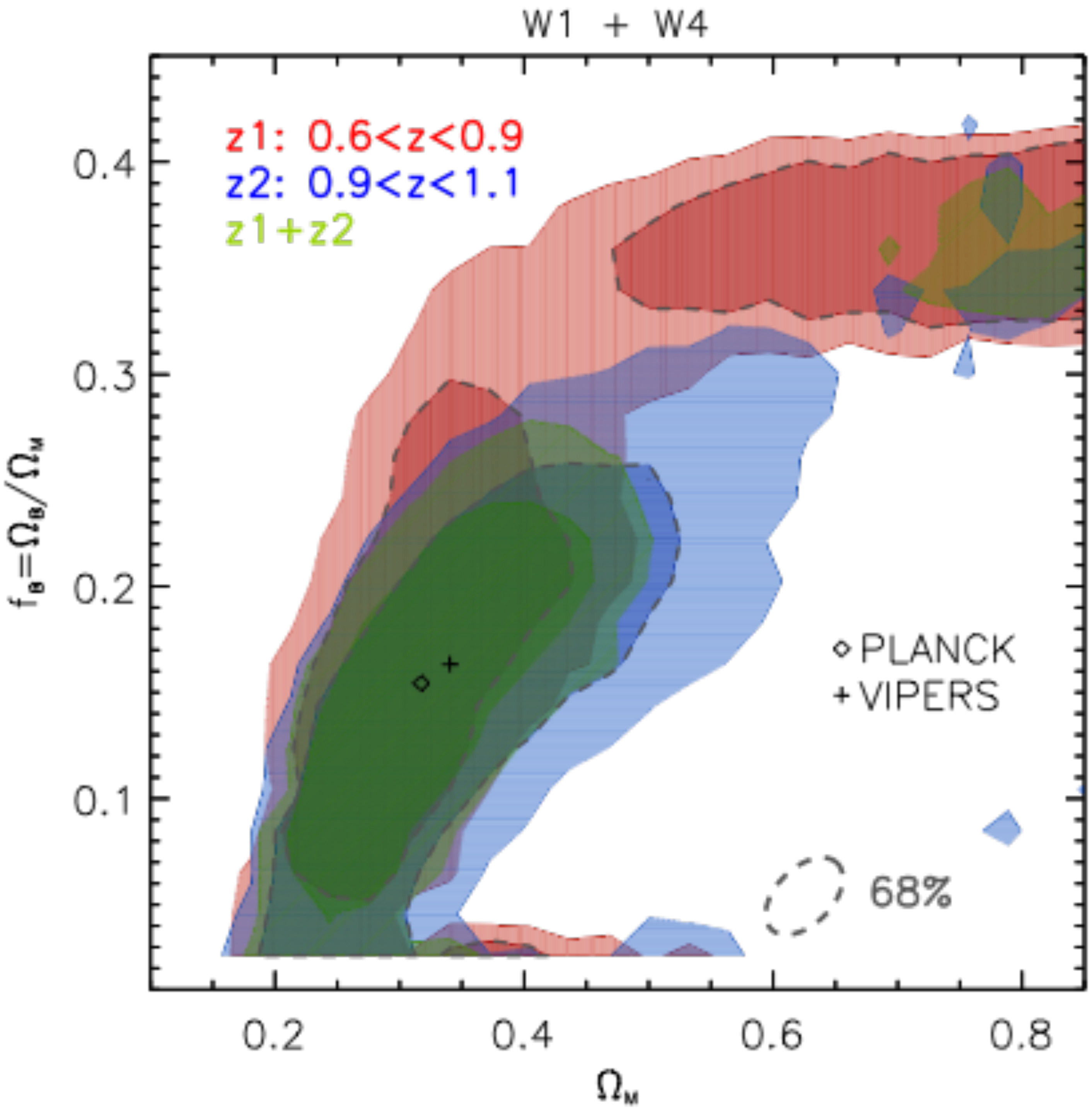


Cosmology

- CAMB (Ω_M,f_B) + HALOFIT non-linearities
- linear and scale-independent bias (b)
- redshift-space distortions: KAISER + DISPERSION MODEL (σ_v)
- window function



Cosmological results: Ω_M and Ω_B/Ω_M



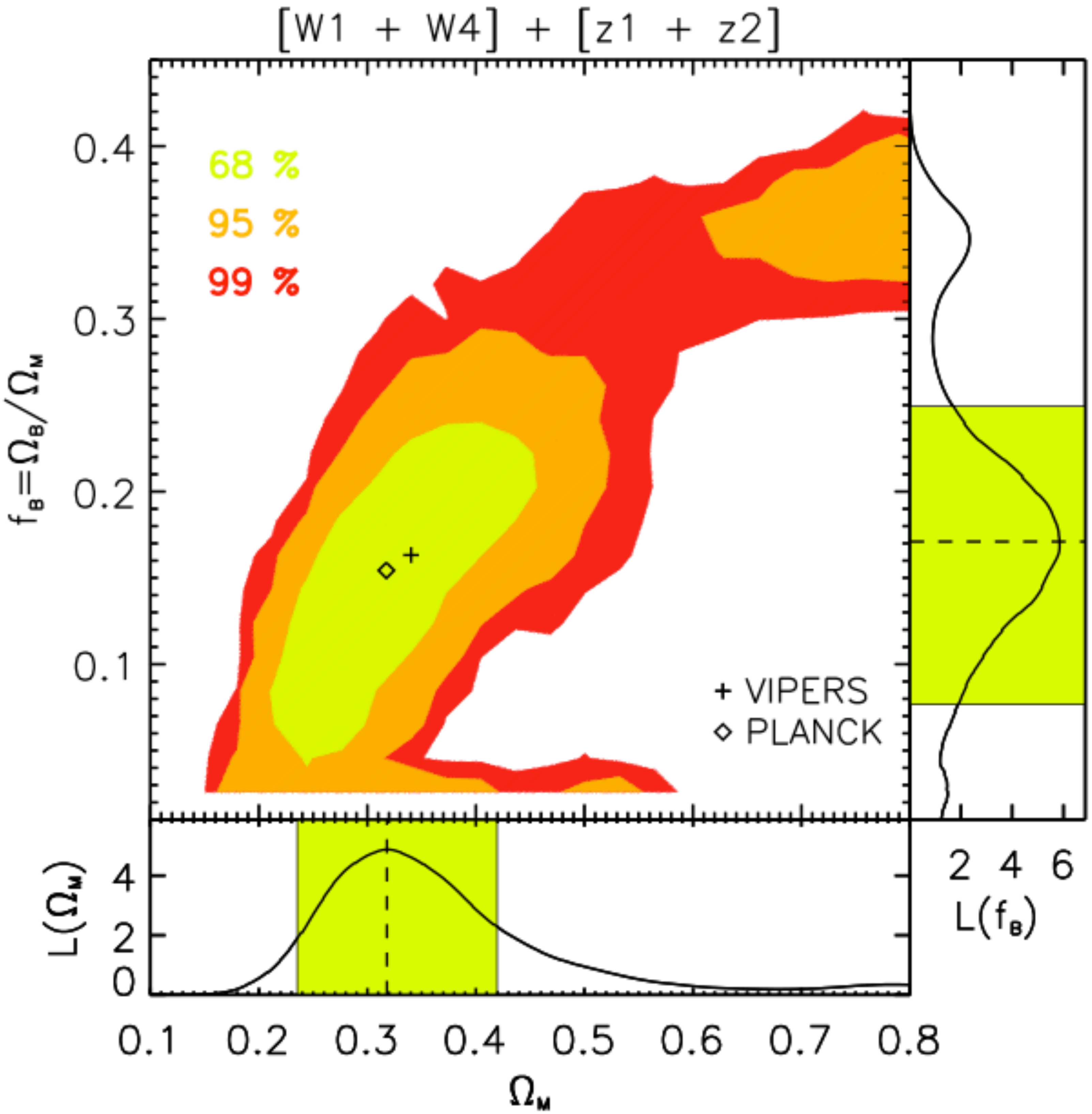
ASSUMPTIONS:
flat ΛCDM Universe

COSMOLOGICAL PARAMETERS FIXED TO PLANCK:
h, Hubble constant
n_s, spectral index
A_s, primordial amplitude

FREE PARAMETERS:
σ_v, velocity dispersion
b, linear bias
$f_b=\Omega_B/\Omega_M$,baryonic fraction
Ω_M, matter density

FIT:
$0.01 < k < 0.3$ h Mpc^{-1}
($500 \lesssim \lambda \lesssim 20$ h^{-1} Mpc)

Cosmological results: Ω_M and Ω_B/Ω_M



ASSUMPTIONS:
flat ΛCDM Universe

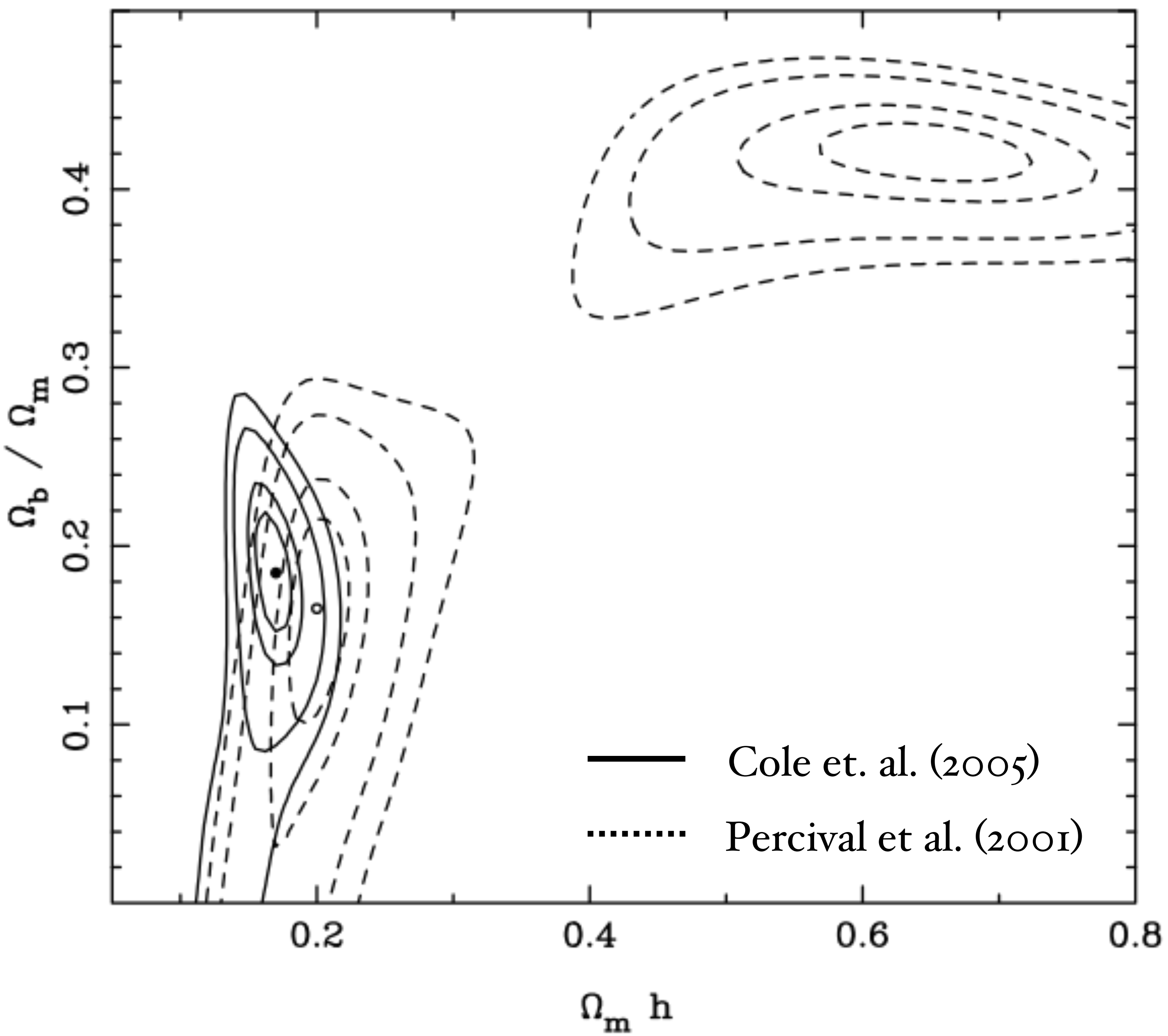
COSMOLOGICAL PARAMETERS FIXED TO PLANCK:
h, Hubble constant
n_s, spectral index
A_s, primordial amplitude

FREE PARAMETERS:
σ_v, velocity dispersion
b, linear bias
Ω_B/Ω_M ,baryonic fraction
Ω_M, matter density

FIT:
$0.01 < k < 0.3$ h Mpc^{-1}
($500 \lesssim \lambda \lesssim 20$ h^{-1} Mpc)

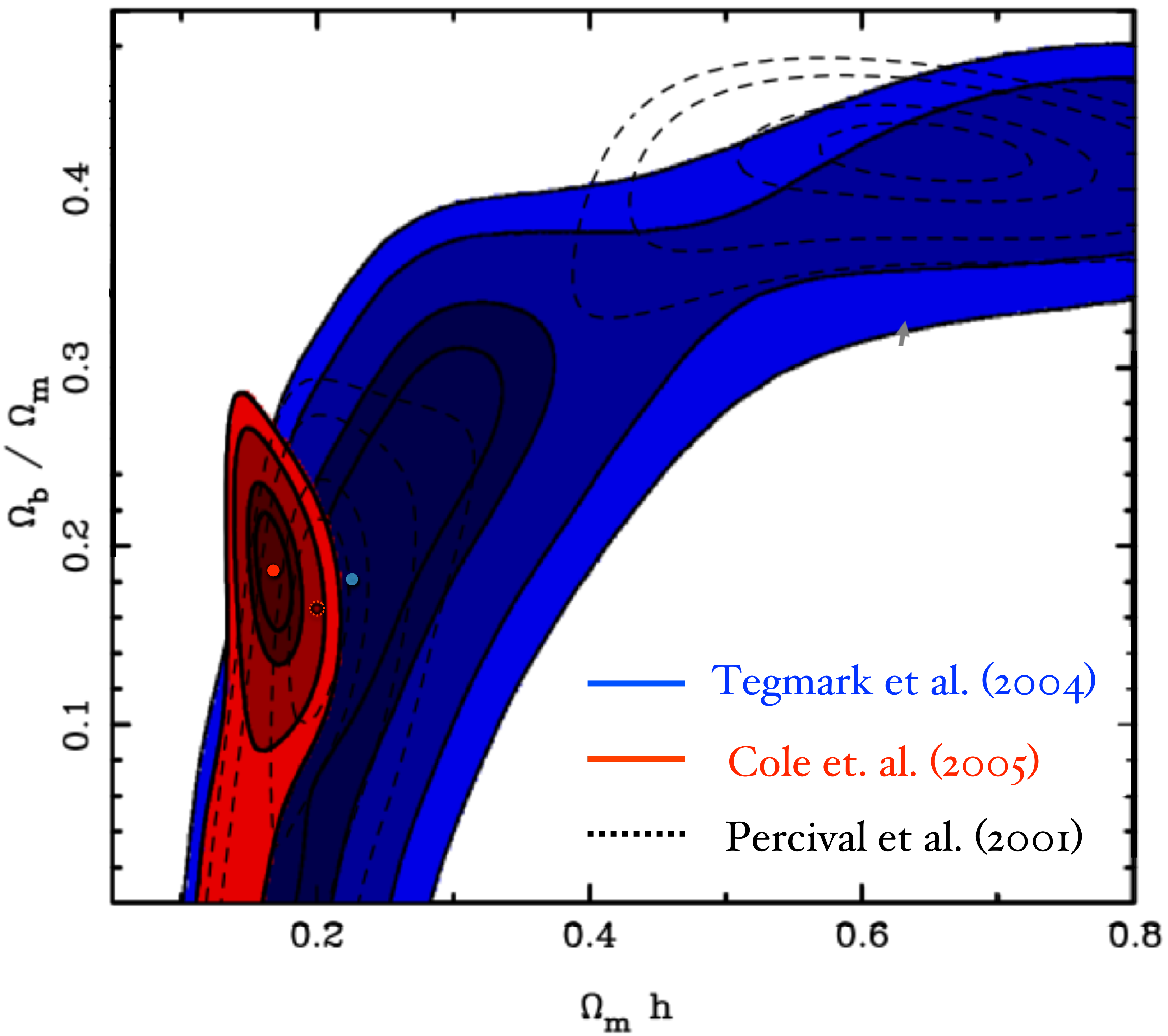
Comparison with z~0, 2dFGRS

h=0.72



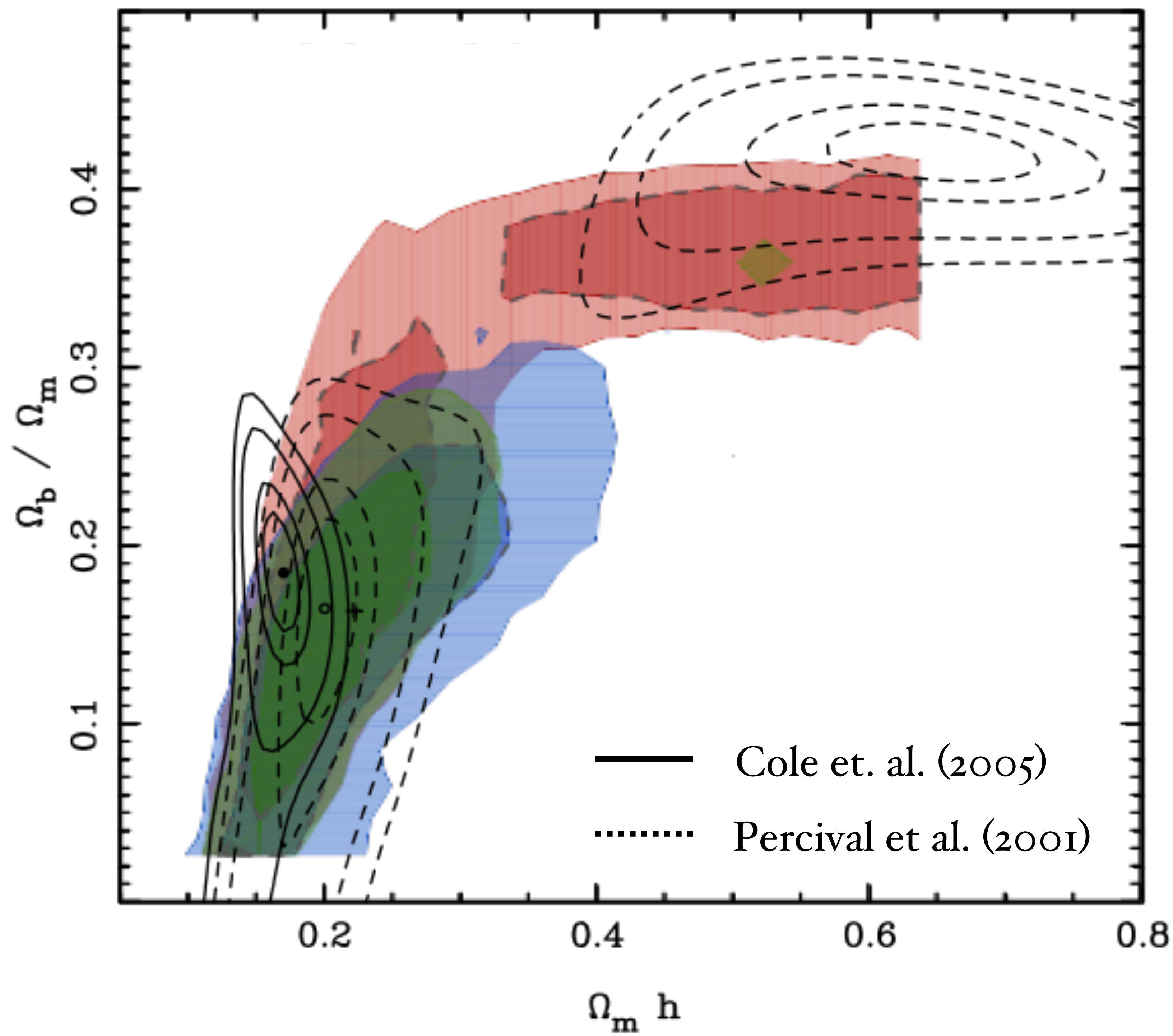
Comparison with z~0, 2dFGRS vs SDSS

h=0.72

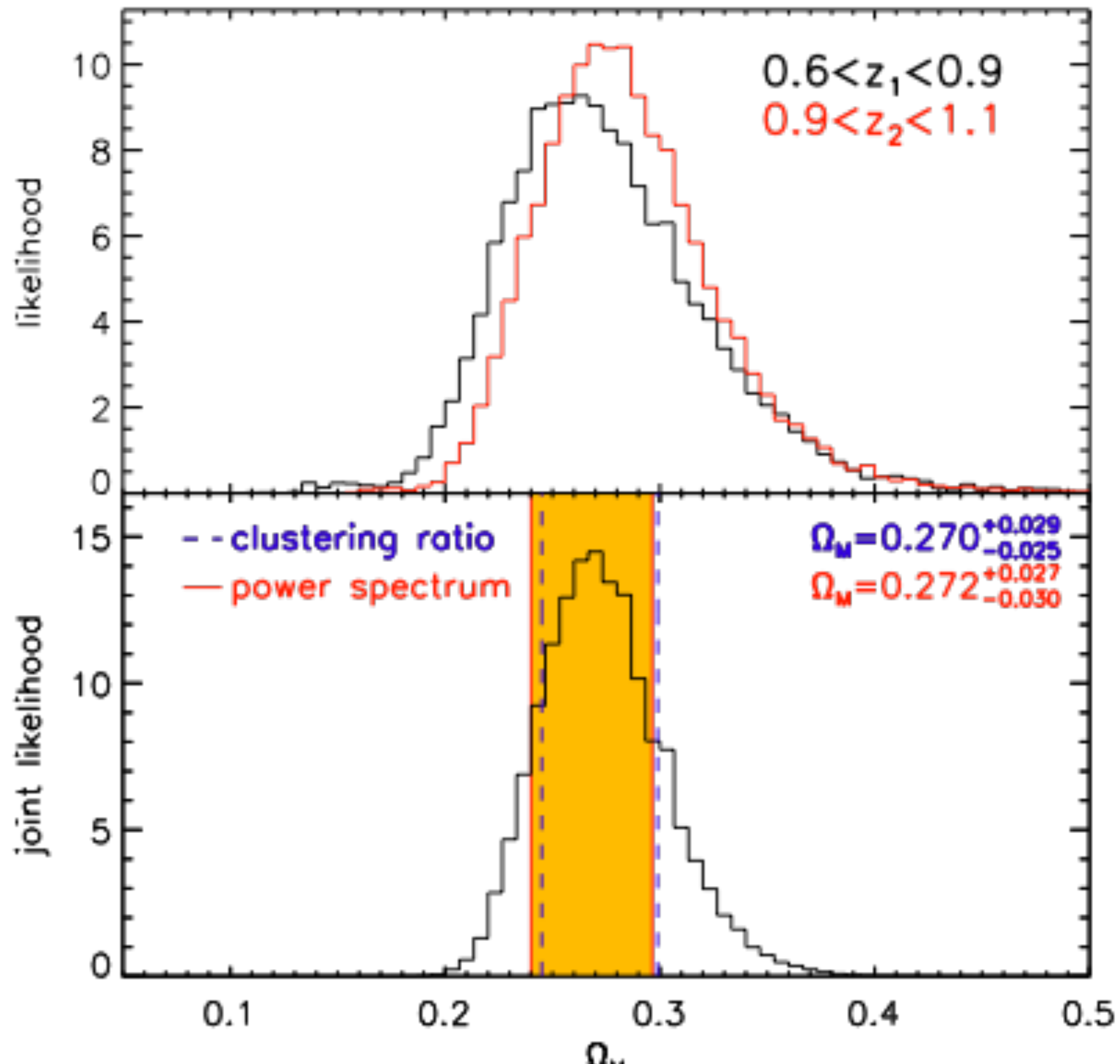


Comparison with z~0, VIPERS vs 2dFGRS

h=0.72



Internal consistency check: Ω_M



Clustering ratio:

$$\eta_{g,R}(r) \equiv \frac{\xi_{g,R}(r)}{\sigma^2_{g,R}}$$

Bel et al. (VIPERS Team) 2013

GAUSSIAN PRIOR ON:

h=0.738 (HST prior)
$\Omega_B h^2$ (BBN prior)
n_s,A_s (Planck prior)

	Ω_M	$\Omega_b h^2$	h	n_s	$ln(10^{10} A_s)$	σ_{TOT} $[km\, s^{-1}]$	$b(z_1 / z_2)$
prior	$0.1 - 0.9$	0.0213 ± 0.0010	0.738 ± 0.024	0.9616 ± 0.0094	3.103 ± 0.072	514 ± 24	$0 - 2$
best fit	$0.272^{+0.027}_{-0.031}$	$0.0211^{+0.0010}_{-0.0004}$	$0.735^{+0.018}_{-0.016}$	$0.9630^{+0.0054}_{-0.0088}$	$3.096^{+0.046}_{-0.057}$	522^{+16}_{-18}	$1.13^{+0.21}_{-0.18}$ / $1.25^{+0.20}_{-0.15}$

Conclusions

- Measure of the VIPERS galaxy power spectrum including all the selection effects of the survey

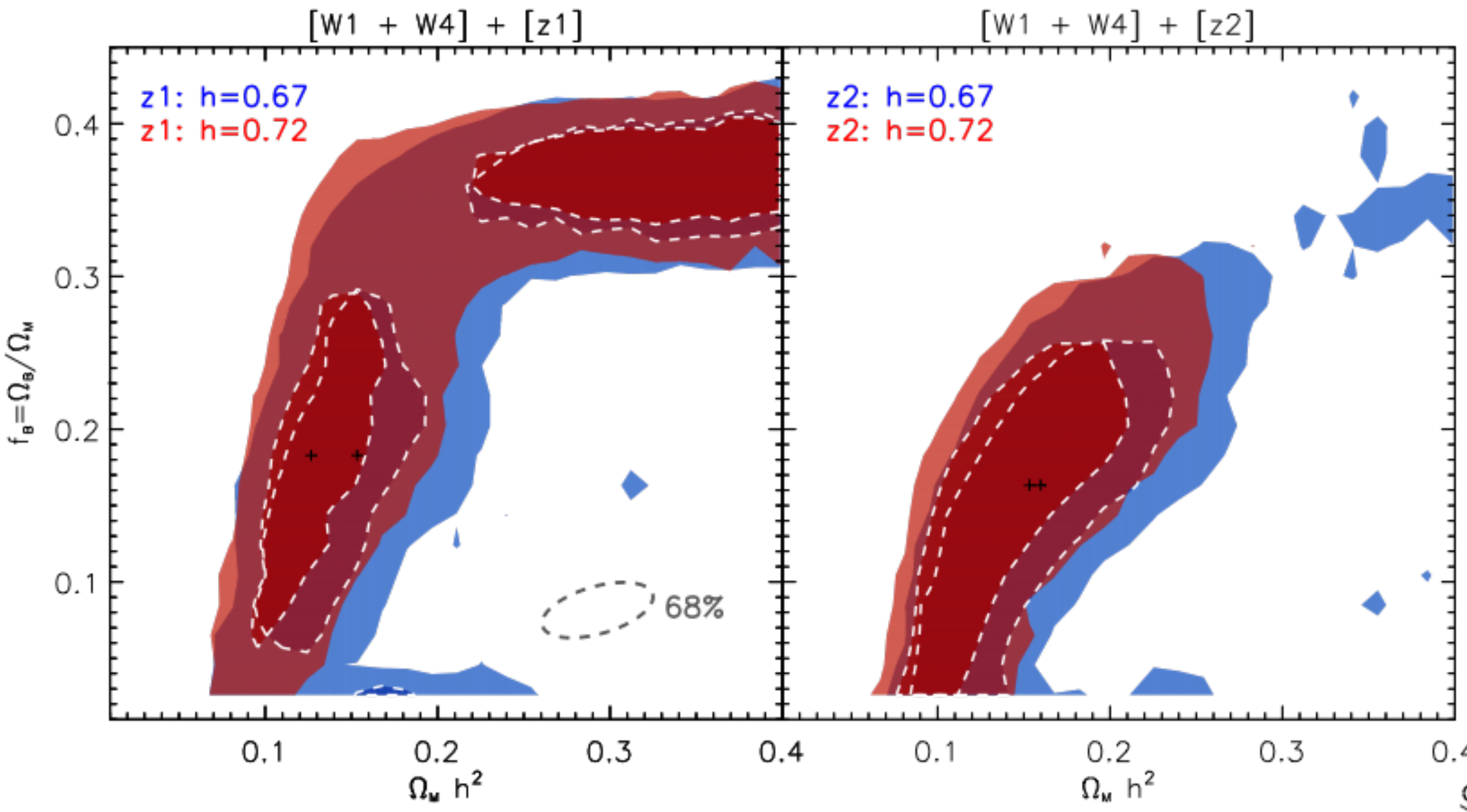
- At low redshift: Similar degeneracy in the Ω_M-f_B plane found in 2dFGRS and SDSS

- Consistency with the Planck results for Ω_M-f_B, even assuming a different cosmology (h=0.72 instead of h=0.67)

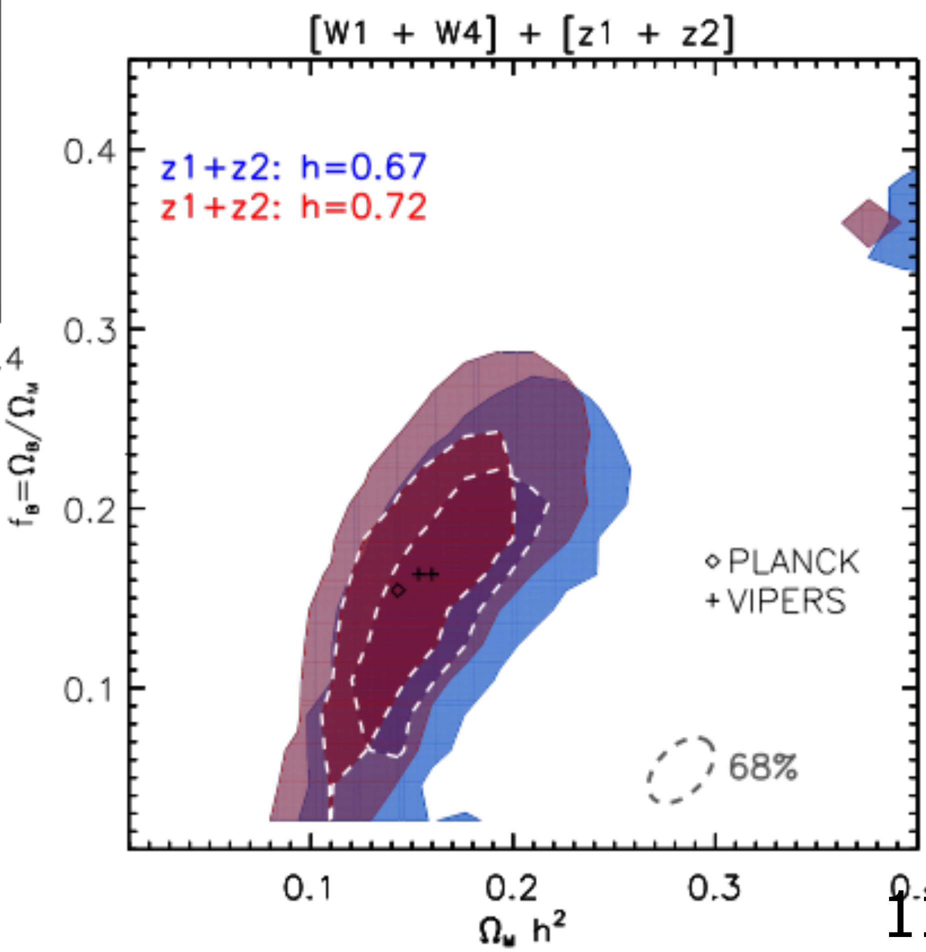
- Constraint on $\Omega_M = 0.272^{+0.027}_{-0.030}$, consistent with VIPERS measurements in configuration space

- Next: Use the final release of VIPERS to constrain also the total neutrino mass

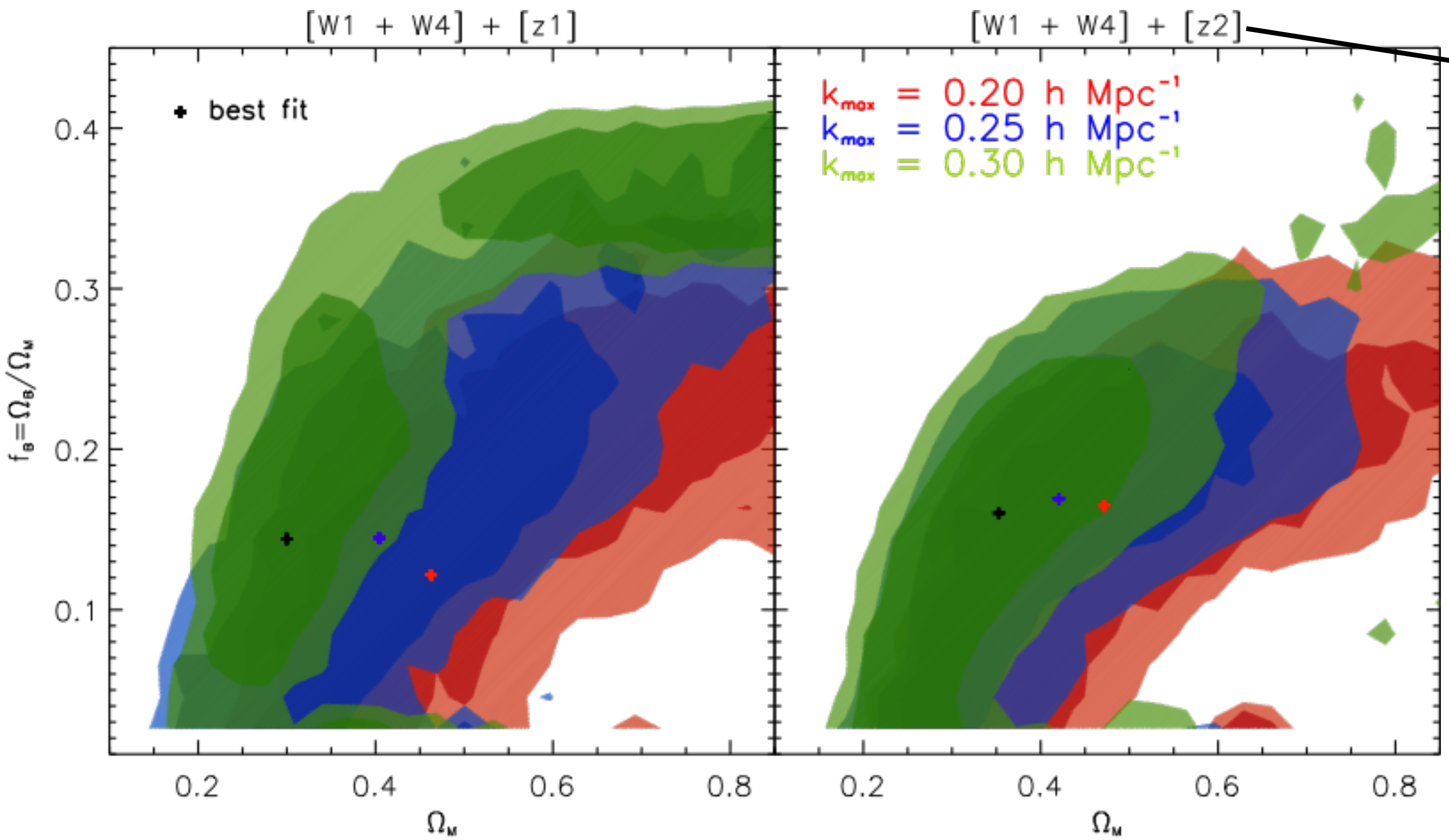
Consistency with Planck



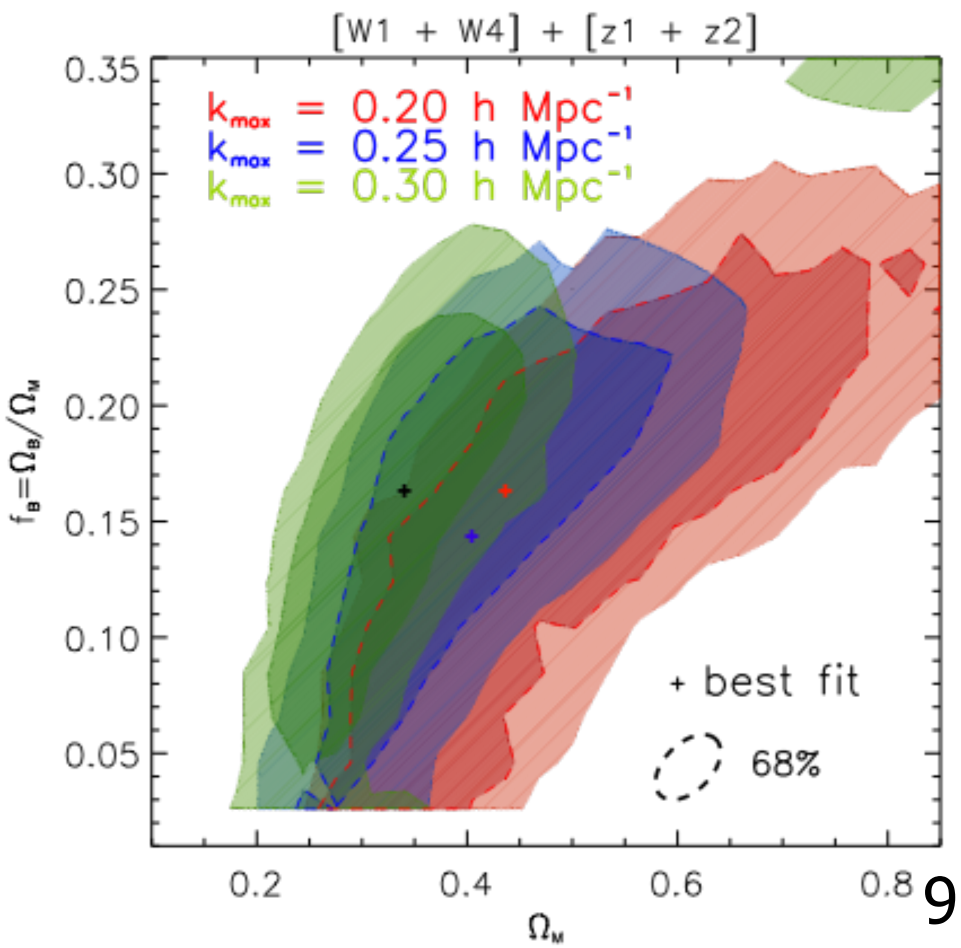
h=0.67 (Planck)
h=0.72



Impact of the minimum scale

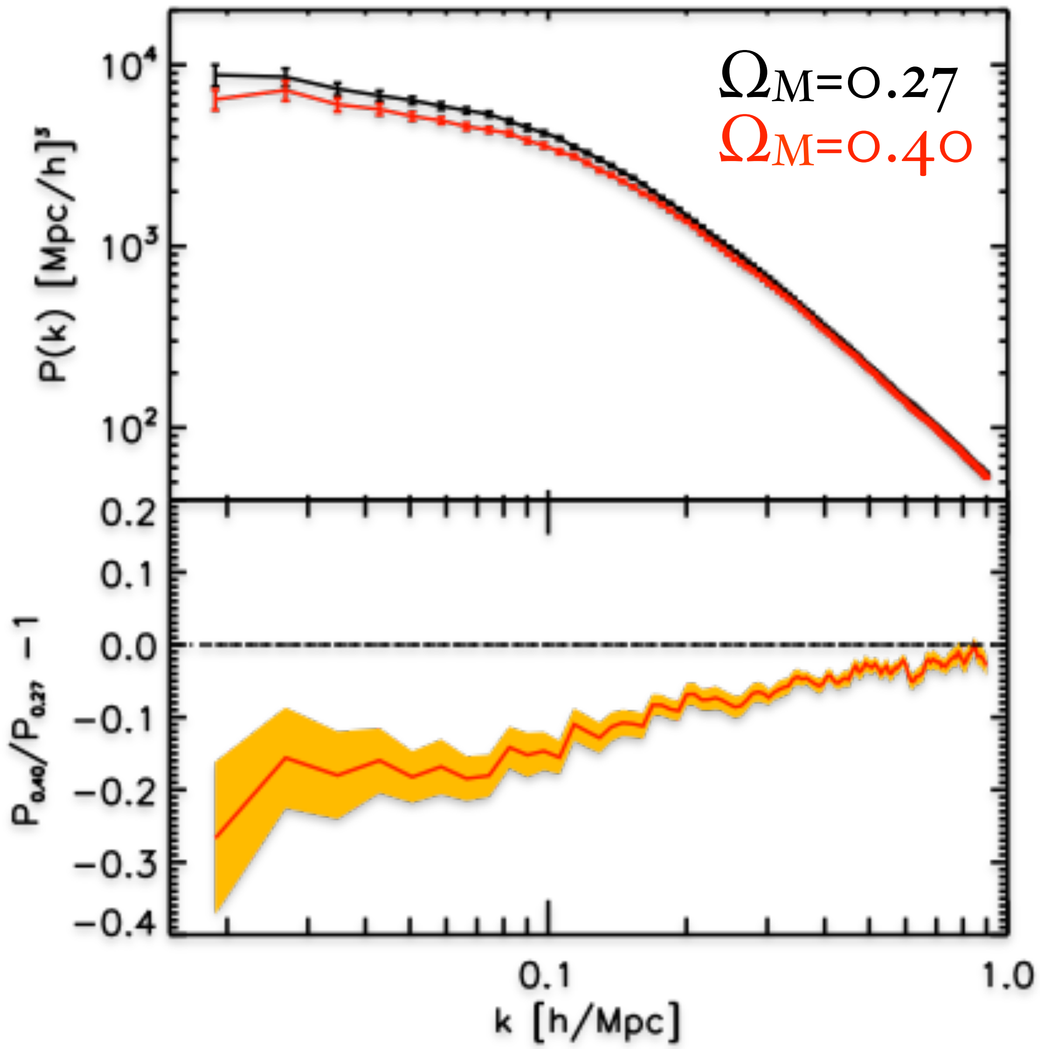


P(k) more linear



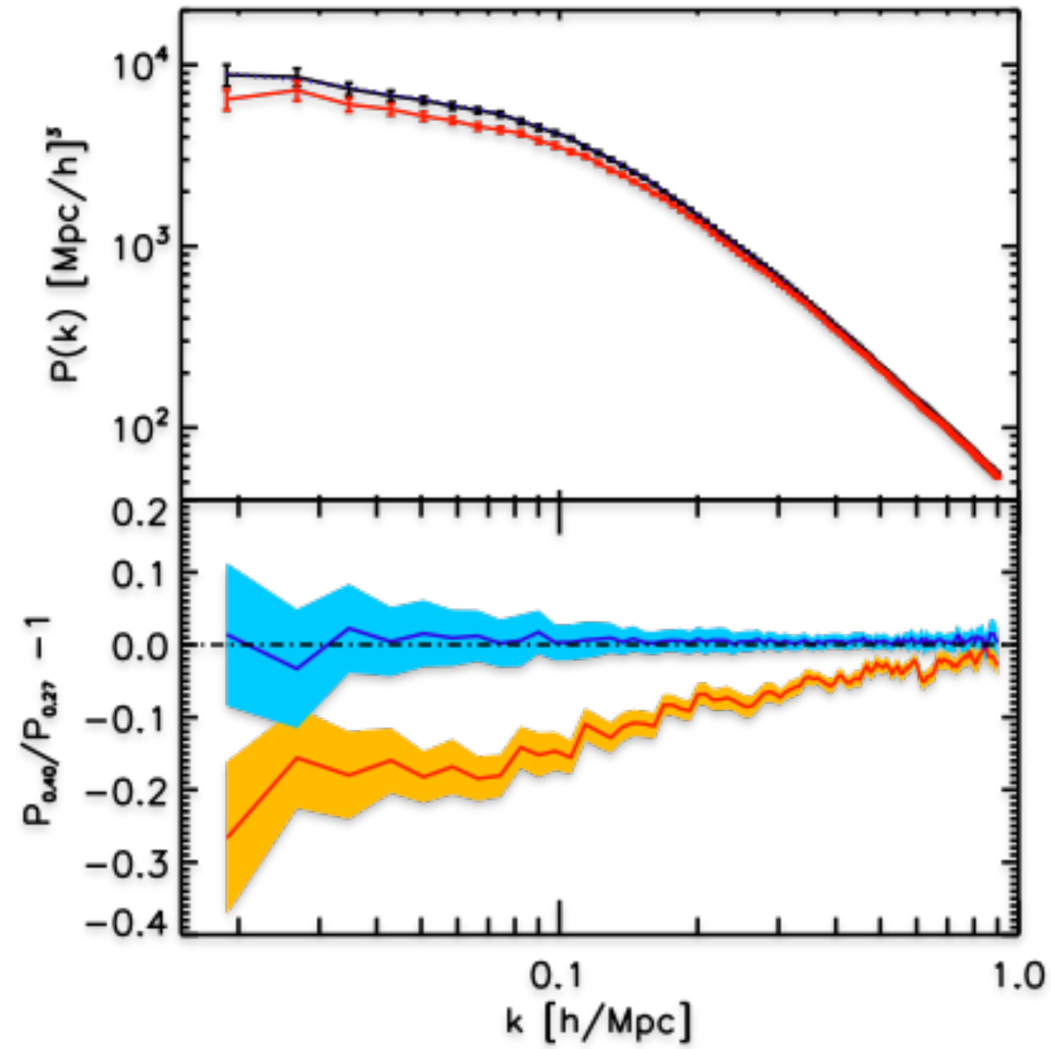
fiducial cosmology

assuming two different fiducial cosmologies



$$P'(k') = P(k) \times \alpha_\perp^2 \alpha_\parallel$$

correcting the wrong fiducial cosmology



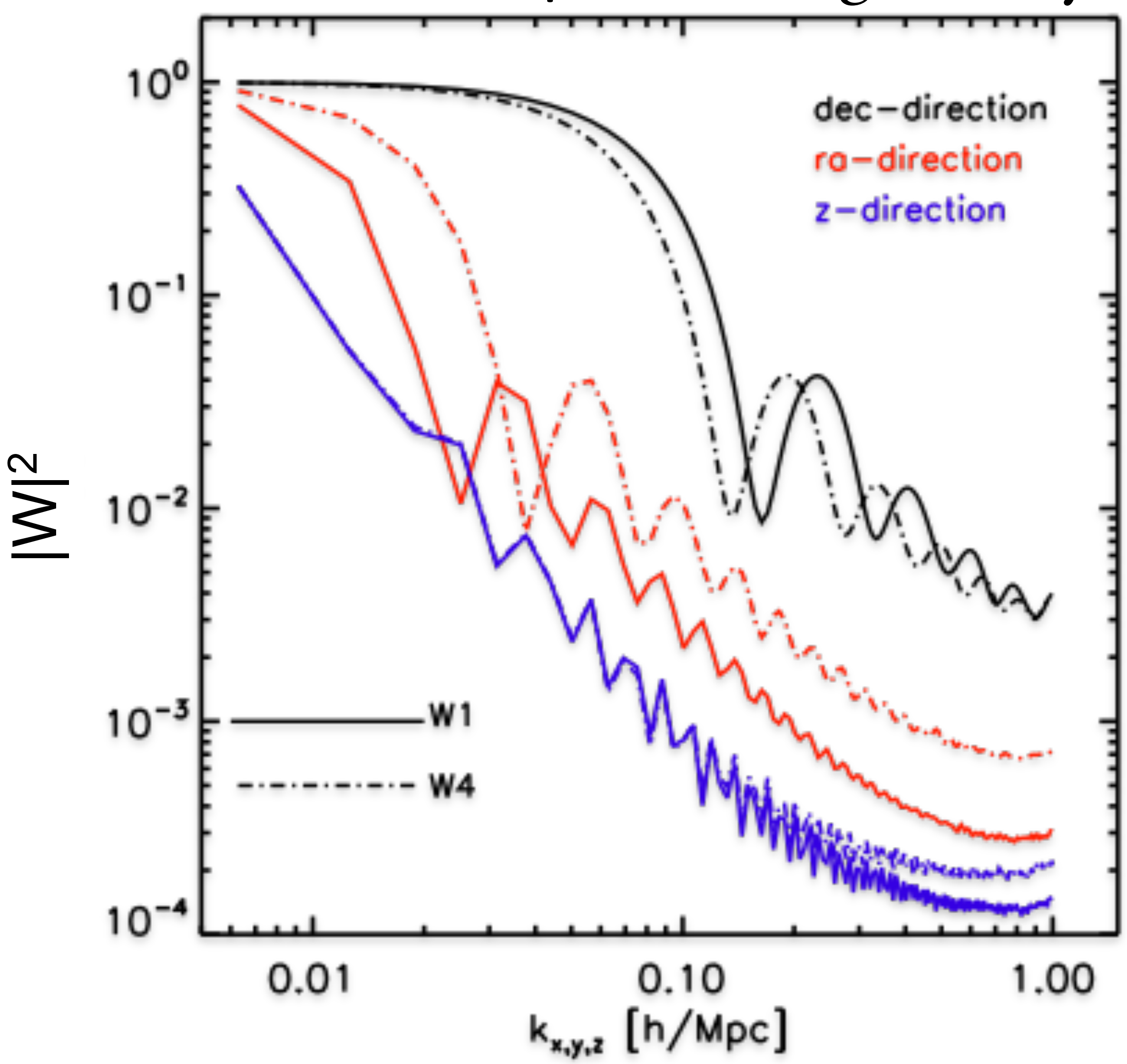
$$k'_\parallel = \alpha_\parallel \times k_\parallel$$

$$k'_\perp = \alpha_\perp \times k_\perp$$

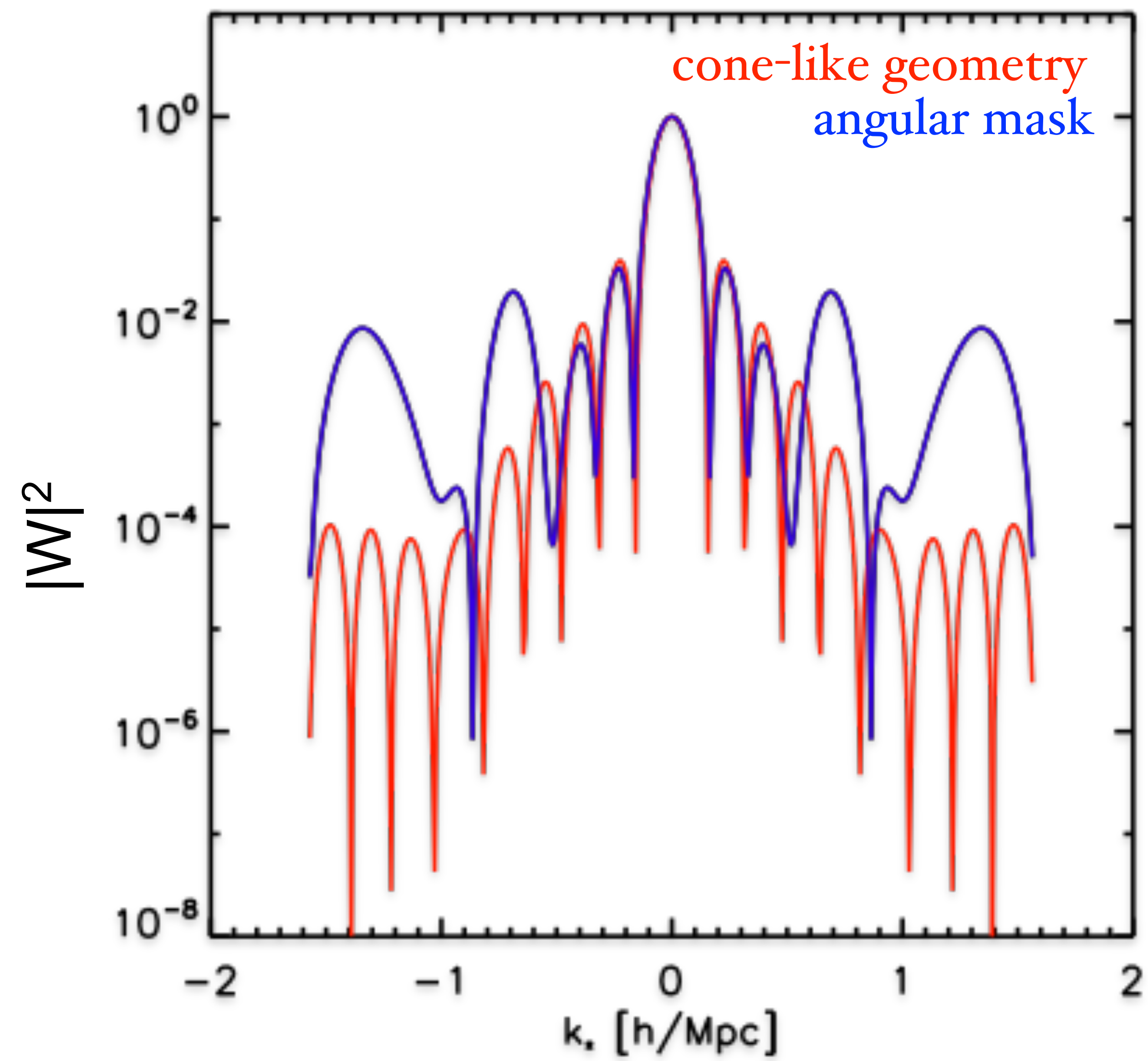
VIPERS window function: cone-like geometry and angular mask

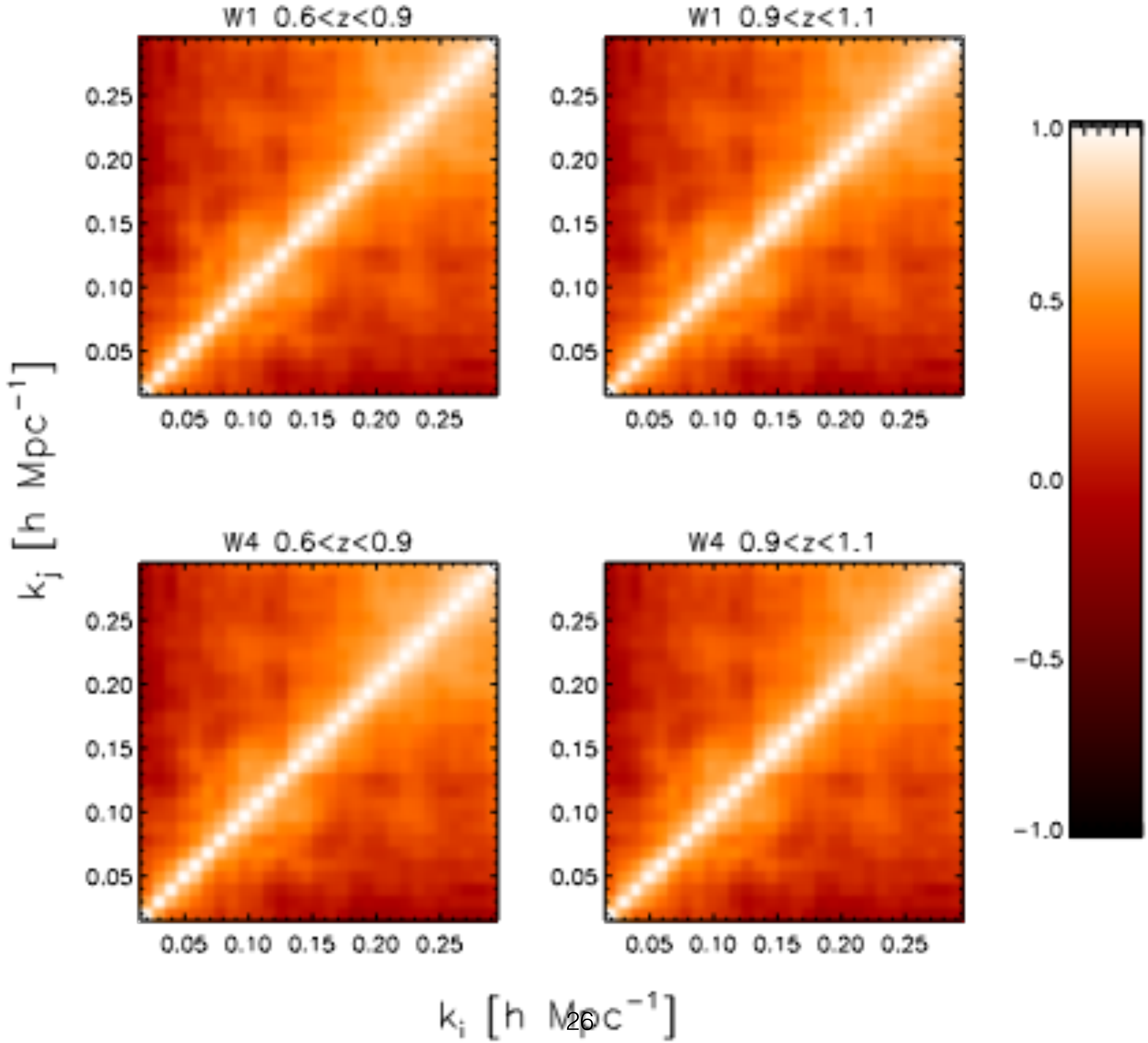
$$\hat{P}_{obs}(\mathbf{k}) = \int P(\mathbf{k}')\,|W(\mathbf{k}-\mathbf{k}')|^2 \frac{d^3\mathbf{k}'}{(2\pi)^3} = P * |W|^2$$

W1 and W4 cone-like geometry



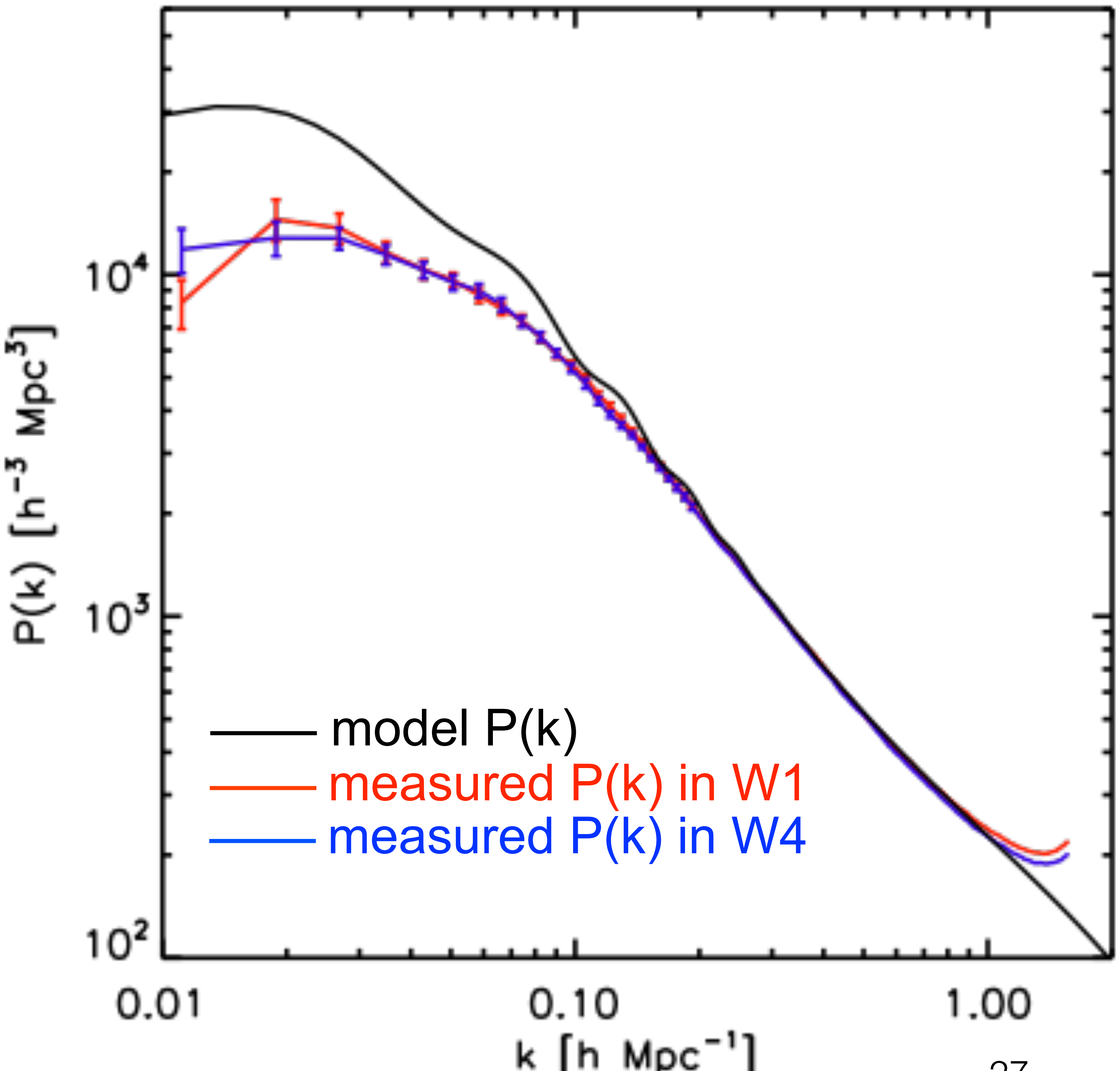
declination direction W1




W1 0.6<z<0.9
W1 0.9<z<1.1
W4 0.6<z<0.9
W4 0.9<z<1.1
0.05 0.10 0.15 0.20 0.25
1.0
0.5
0.0
−0.5
−1.0
k_j [h Mpc^-1]
k_i [h Mpc^-1]

cone-like geometry

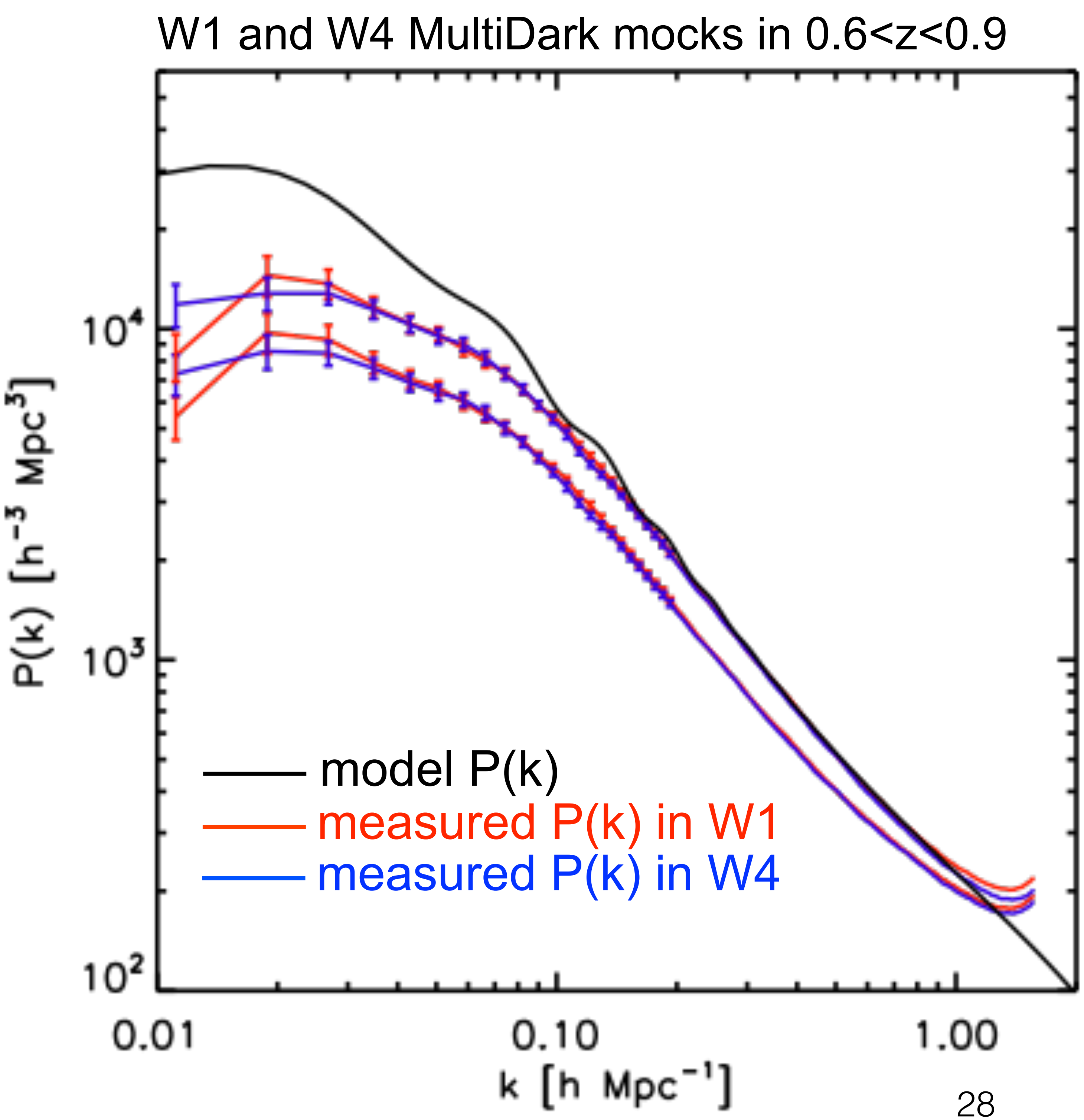
W1 and W4 MultiDark mocks in 0.6<z<0.9



theoretical model P(k):

MultiDark cosmology
in real space +
linear regime at <z>~0.7 +
HALOFIT (non-linearities) +
linear and scale-independent bias

cone-like geometry and angular mask



theoretical model P(k):

MultiDark cosmology
in real space +
linear regime at <z>~0.7 +
HALOFIT (non-linearities) +
linear and scale-independent bias

Power spectrum statistic: Fourier space

$$\hat{P}(k) = \frac{1}{N_k} \sum_{k<|\mathbf{k}'|<k+\delta k} |\delta(|\mathbf{k}'|)|^2 ,$$

$$\mathrm{P}(\mathbf{k}) = \frac{\hat{\mathrm{P}}(\mathrm{k_x}, \mathrm{k_y}, \mathrm{k_z}) - \mathrm{S}(\mathrm{k_x}, \mathrm{k_y}, \mathrm{k_z})}{\left[\mathrm{sinc}\left(\frac{\pi \mathrm{k_x}}{2\mathrm{k_N}}\right) \mathrm{sinc}\left(\frac{\pi \mathrm{k_y}}{2\mathrm{k_N}}\right) \mathrm{sinc}\left(\frac{\pi \mathrm{k_z}}{2\mathrm{k_N}}\right)\right]^{2\mathrm{p}}} . \qquad (8)$$

with $\mathrm{p} = 2$ for the CIC assignment scheme.

$$\mathrm{S} = \mathrm{P_{SN}} \times \prod_{\mathrm{i}=1}^{3} \left[1 - \frac{2}{3} \sin^2\left(\frac{\pi \mathrm{k_i}}{2\mathrm{k_N}}\right)\right] \qquad \mathrm{P_{SN}} = \frac{\sum_{\mathrm{G}=1}^{\mathrm{N_G}} \mathrm{w}^2(\mathbf{x}_\mathrm{G}) + \alpha^2 \sum_{\mathrm{R}=1}^{\mathrm{N_R}} \mathrm{w}^2(\mathbf{x}_\mathrm{R})}{\mathrm{N}^2} .$$

$$\hat{W}(\mathbf{x}_P) = w(\mathbf{x}_P) \, \frac{N(\mathbf{x}_P)/H^3}{N} ,$$

Directly predicted by theory

$$P(k,z) = P_{prim}(k)\, D^2(z)\, T^2(k)$$

$$T(k) = f(k, \Omega_M h^2, \Omega_B h^2)$$

varying Ω_M varying $f_B = \Omega_B/\Omega_M$