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VIPERS Team

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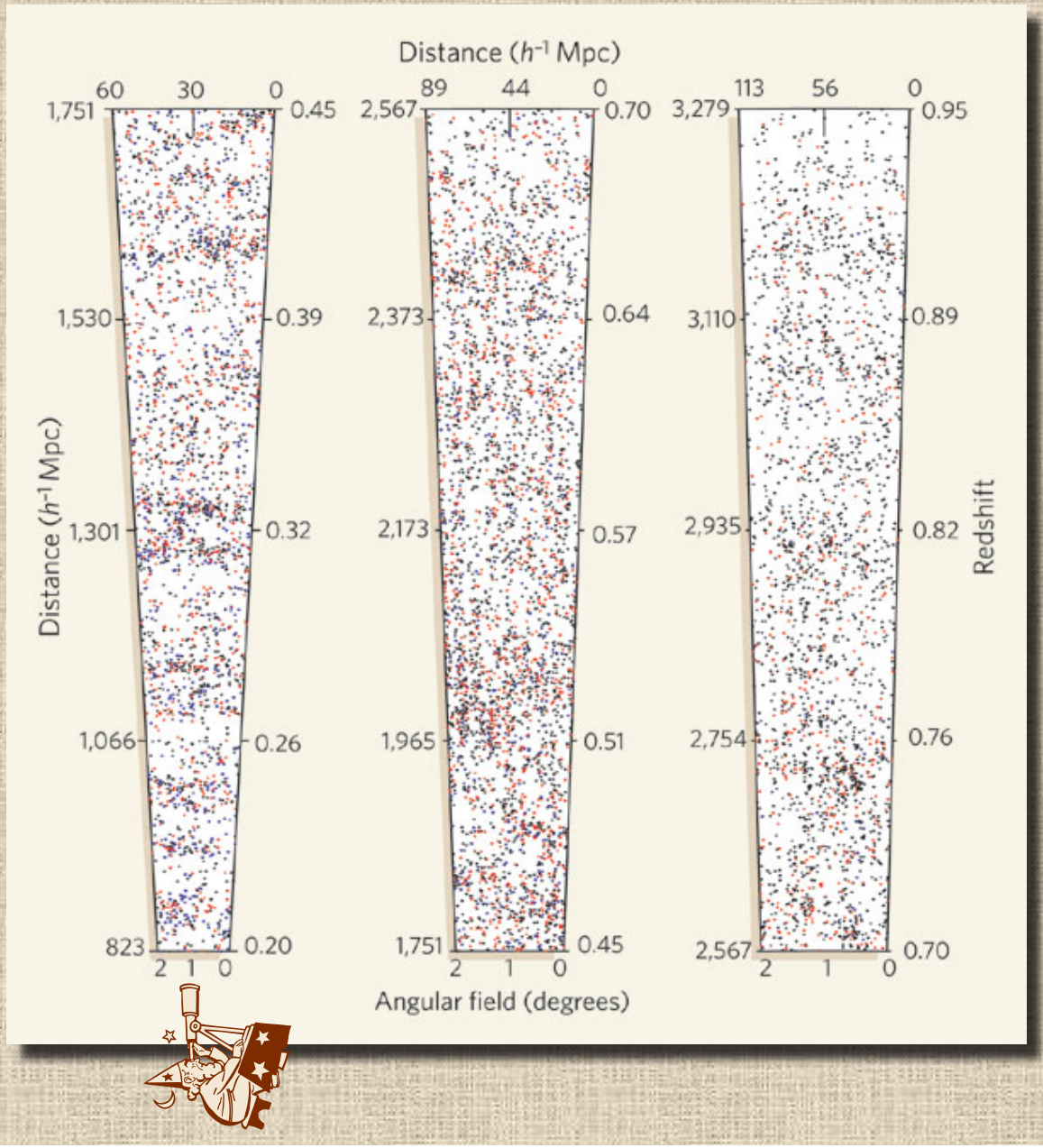
- **PORTSMOUTH**: W. Percival, R. Tojeiro, R. Nichol
- **WARSAW**: A. Pollo, K. Malek, J. Krywult (Kielce)

Motivations and boundary conditions

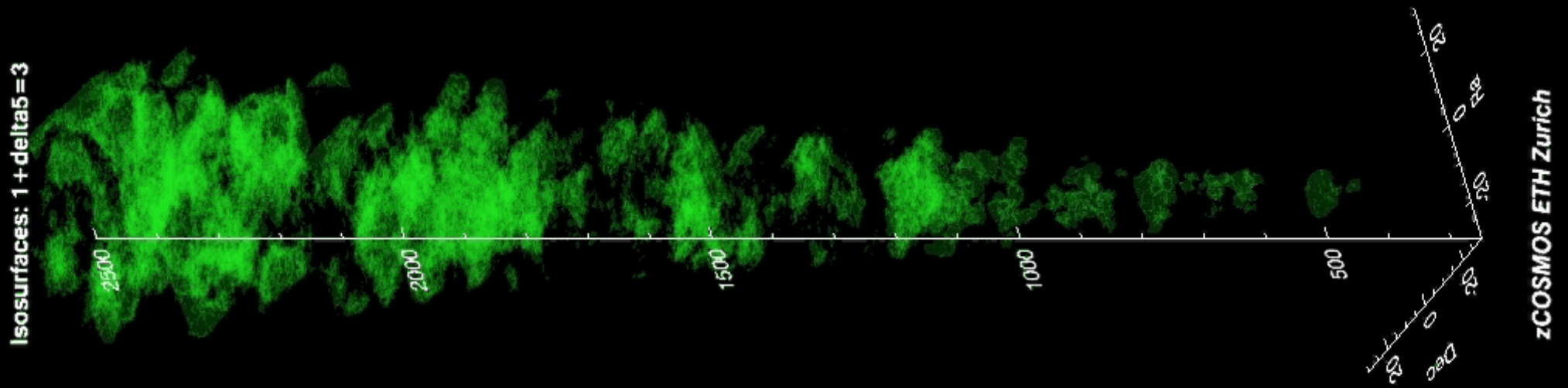
- Really map large-scale structure at z~1 on scales ~100 h^{-1} Mpc (the original VVDS-Wide goal): clustering measurements from existing z~1 samples (VVDS, ZCOSMOS) are cosmic-variance limited
- Exploit VIMOS high multiplexing on moderately large field of view: focus on growth of structure and clustering building upon VVDS early results on redshift distortions
- Optimize largest possible volume (reduce cosmic variance) while having good sampling
- Benefit of previous experience: maximize efficiency
- The next step of large-scale structure studies at z~1: in practice, a 2dFGRS at z~1 (but with 5-band photometry)

VVDS-Wide F22 field: 10,000 redshifts to I_{AB}=22.5 (z~1.2), over 4 deg^2



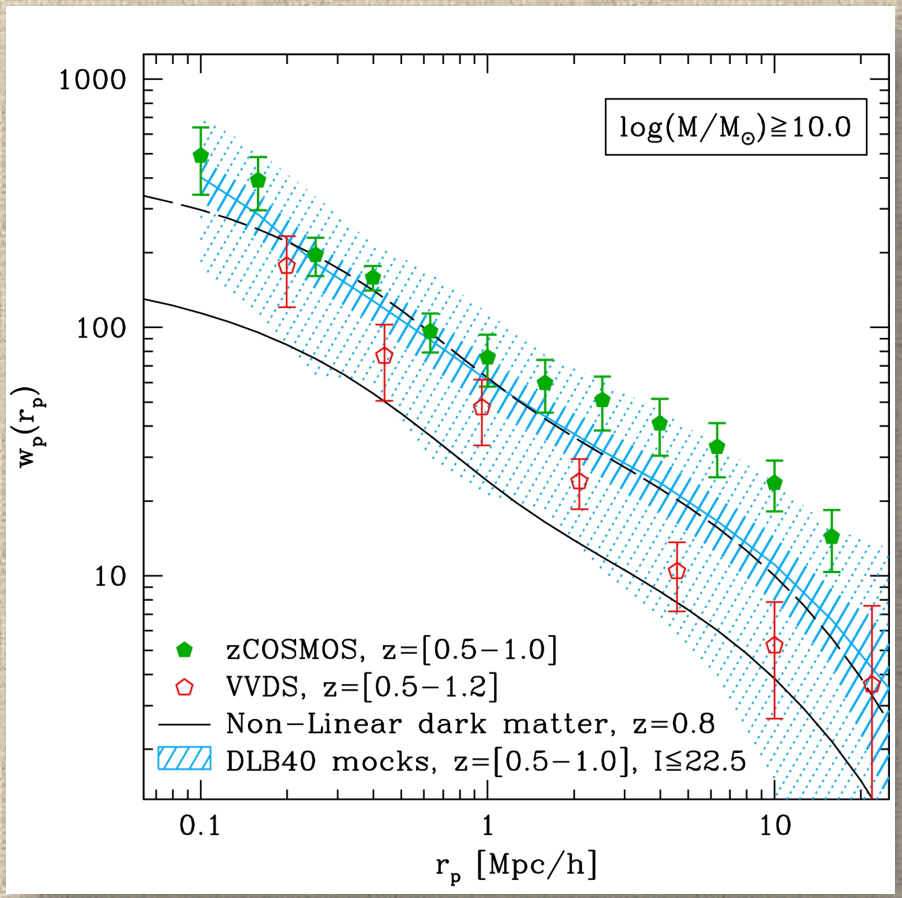
(Garilli et al. 2008, A&A 486, 683)

zCOSMOS: 10,000 redshifts to to I_{AB}=22.5 (z~1.2), over 1.7 deg^2

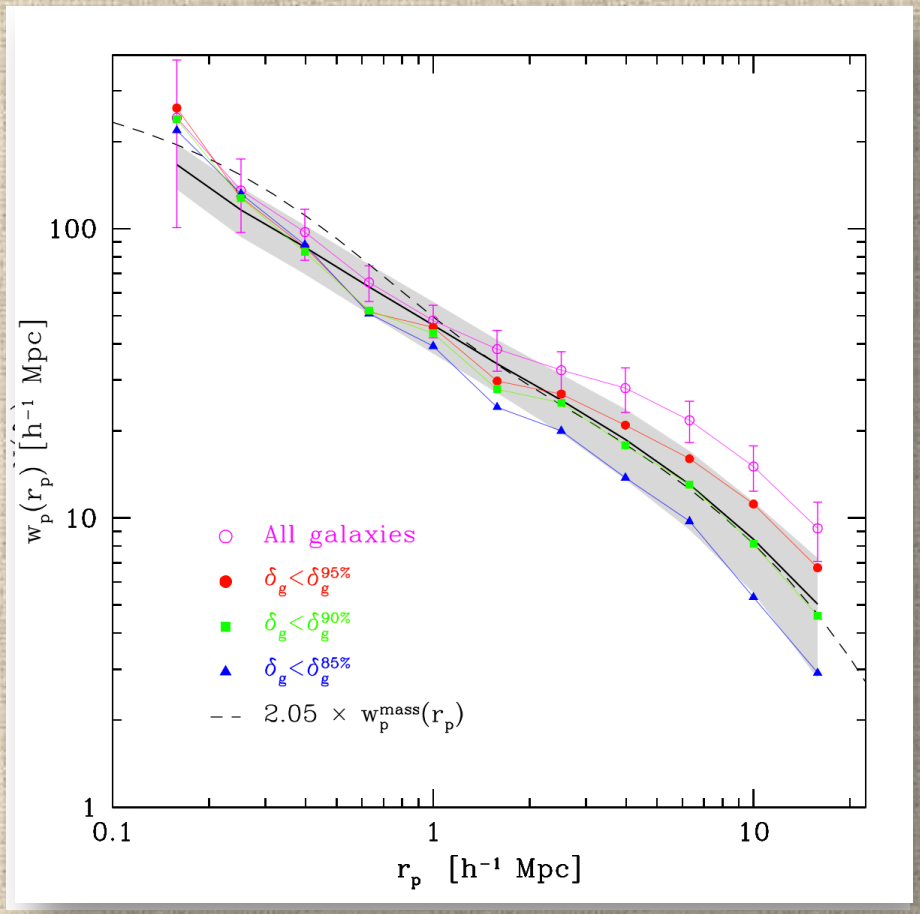


(Lilly et al. 2009 – Density field from Kovac et al. 2010)

Small volumes and low statistics at z>0.5



Meneux, LG & ZCOSMOS Collaboration, 2009



De la Torre, LG & ZCOSMOS Collaboration, 2010, MNRAS, 409, 867

→ Enviromental dependence of clustering in hierarchical models (Abbas & Sheth 2005)

Vol 451|31 January 2008|doi:10.1038/nature06555

nature

LETTERS

A test of the nature of cosmic acceleration using galaxy redshift distortions

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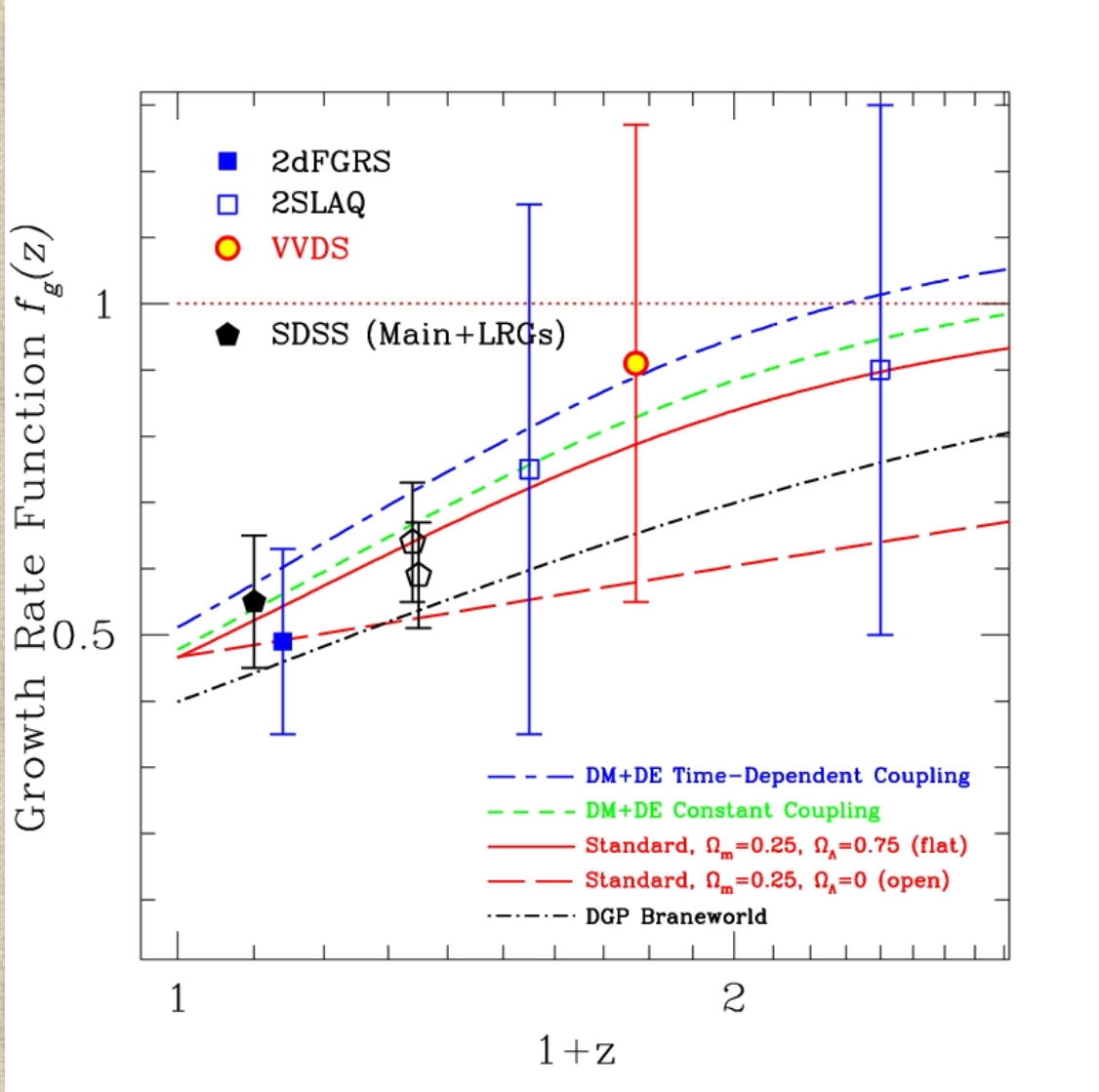
Observations of distant supernovae indicate that the Universe is now in a phase of accelerated expansion[1,2] the physical cause of which is a mystery[3]. Formally, this requires the inclusion of a term acting as a negative pressure in the equations of cosmic expansion, accounting for about 75 per cent of the total energy density in the Universe. The simplest option for this 'dark energy' corresponds

linear growth rate f that measures how rapidly structure is being assembled in the Universe as a function of cosmic time, or, equivalently, of the redshift. The redshift $z = \lambda_{meas}/\lambda_{emis} - 1$ of the radiation emitted by a distant object is a measure of the time of emission through its dependence on the cosmic scale factor $a(t)$, which is $1 + z = 1/a(t_{emis})$. $f(z)$ essentially depends on the value of the mass

Growth rate of structure from redshift distortions at z~1



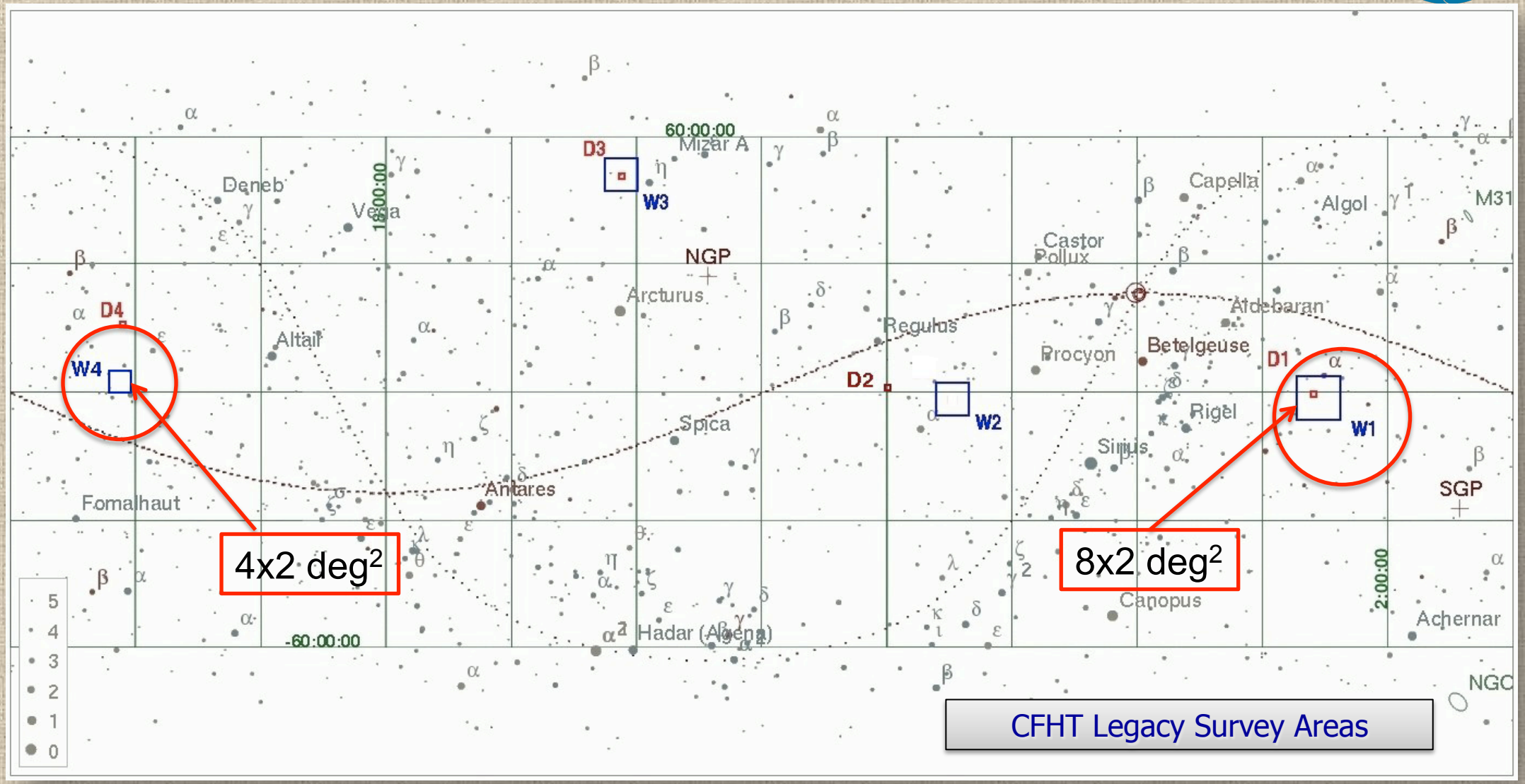
- 2dFGRS: Hawkins+ 2003
- SDSS main: computed from Tegmark+ 2005
- SDSS-LRG: Tegmark+ 2007, Cabre & Gaztanaga 2008 (see also Yamamoto+ 2008)
- 2SLAQ: Ross+ 2007 (gal), da Angela+ 2007 (QSO)
- VVDS: Guzzo+ 2008

DGP: Lue et al. 2004; DM+DE models: Di Porto & Amendola 2007

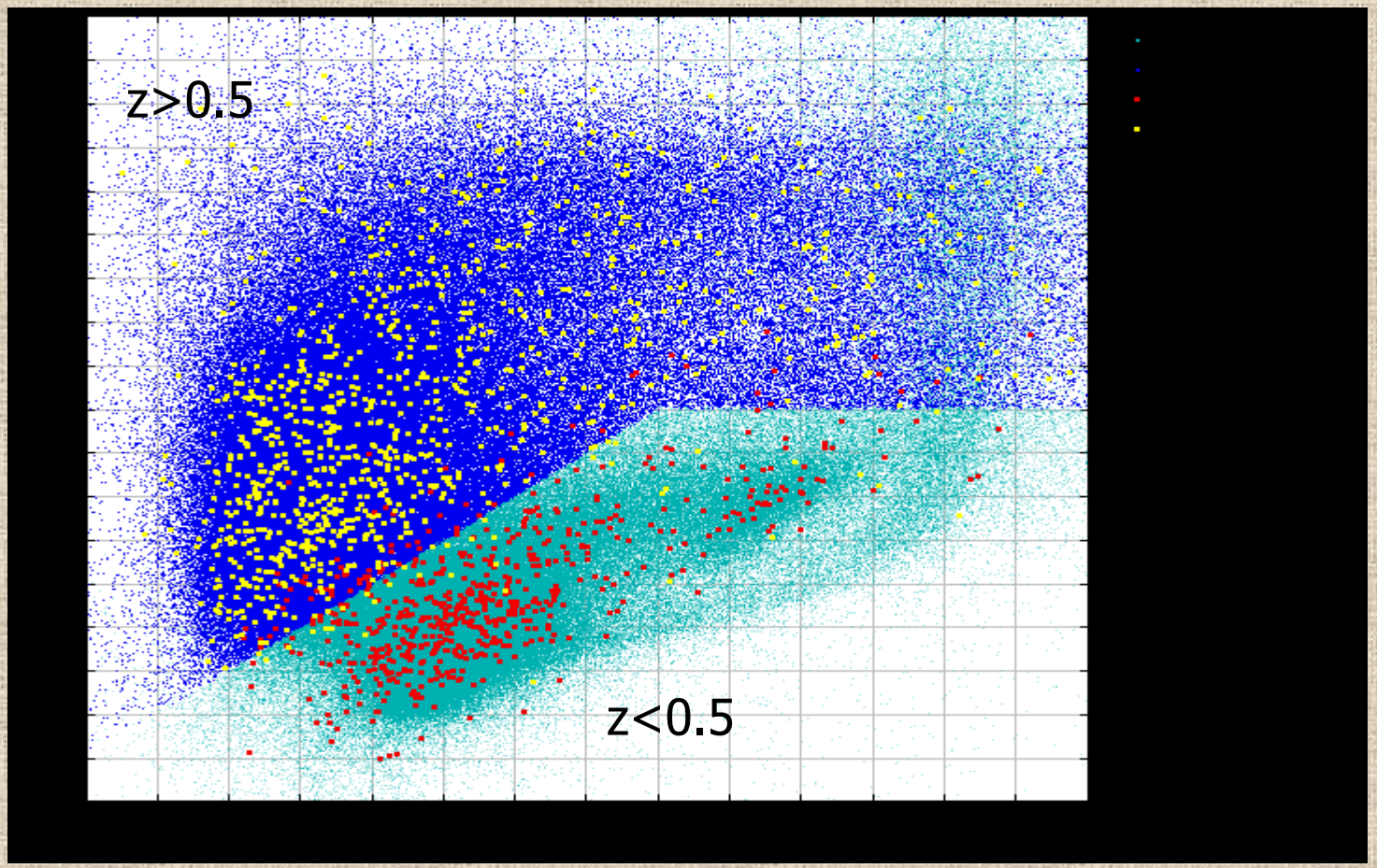
VIPERS in a nut-shell

- 440.5 VLT hours
- ~24 deg^2 over W1 and W4 CFHTLS wide fields (~16 + 8)
- I_{AB}<22.5, LR Red grism, 45 min exp.
- 288 VIMOS pointings
- z>0.5 color-color pre-selection
- PSF + SED –based star-galaxy separation (+AGN color recovery)
- **~100,000 redshifts, >40% sampling**
- **Density and volume comparable to 2dFGRS, but at <z>~0.8**

An ideal starting sample: 5-band CFHT Legacy Survey

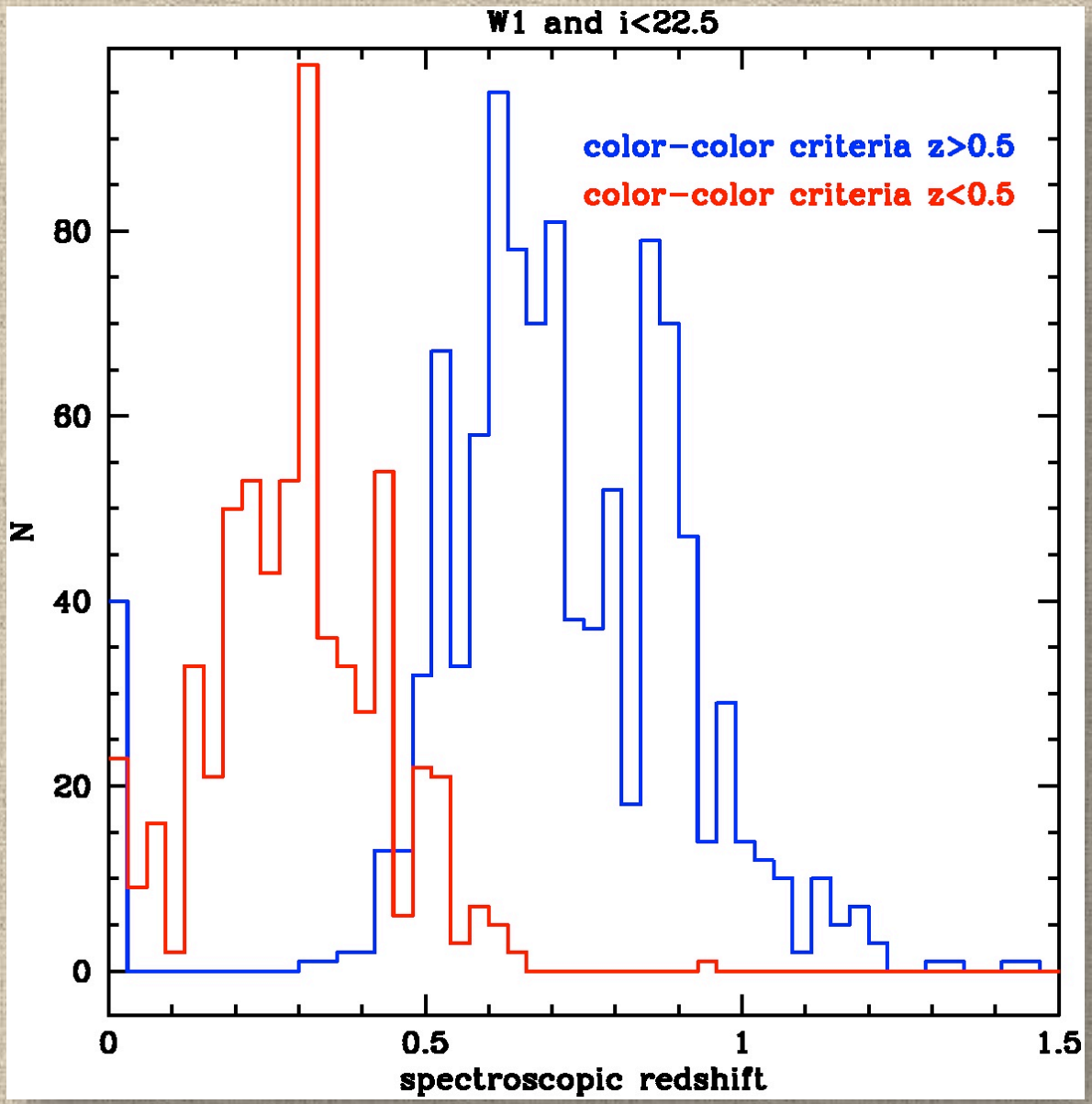


VIPERS COLOR-COLOR SELECTION: ISOLATING z>0.5 GALAXIES



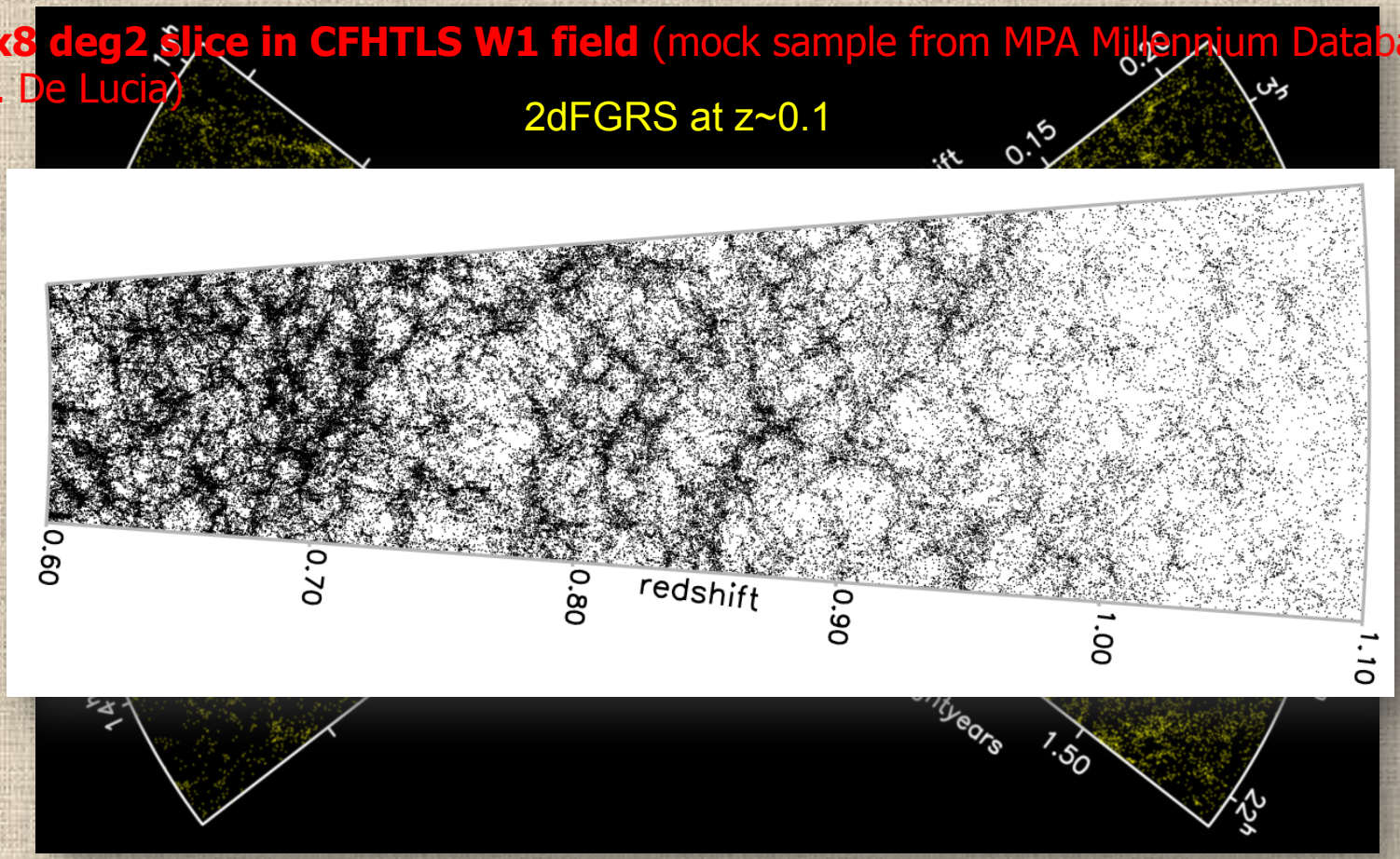
VIPERS target catalogue with VVDS check sample

Completeness/contamination of color-color selection



VIPERS: a 2dFGRS at 0.5<z<1.2

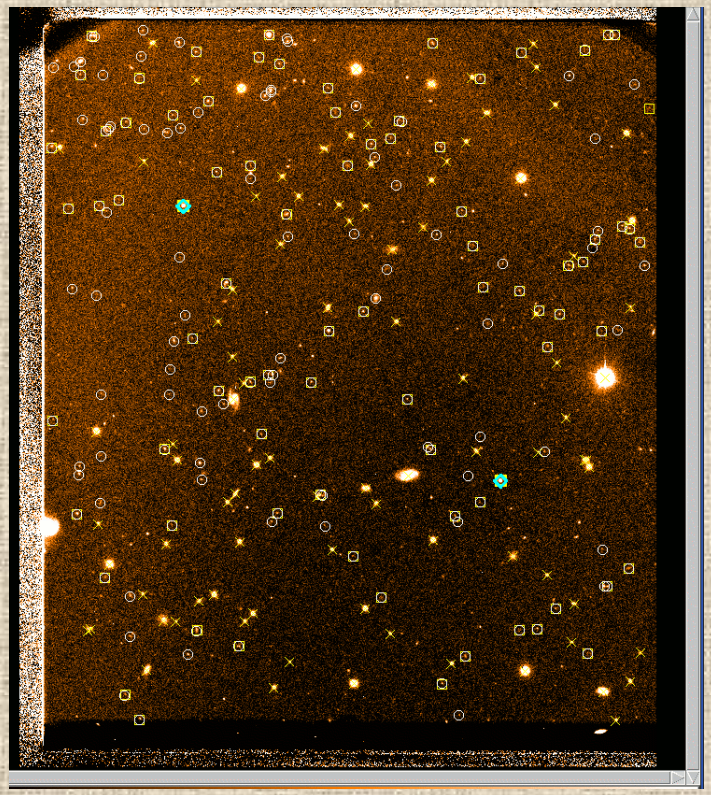
VIPERS 2x8 deg2 slice in CFHTLS W1 field (mock sample from MPA Millennium Database, by J. Blaizot & G. De Lucia)

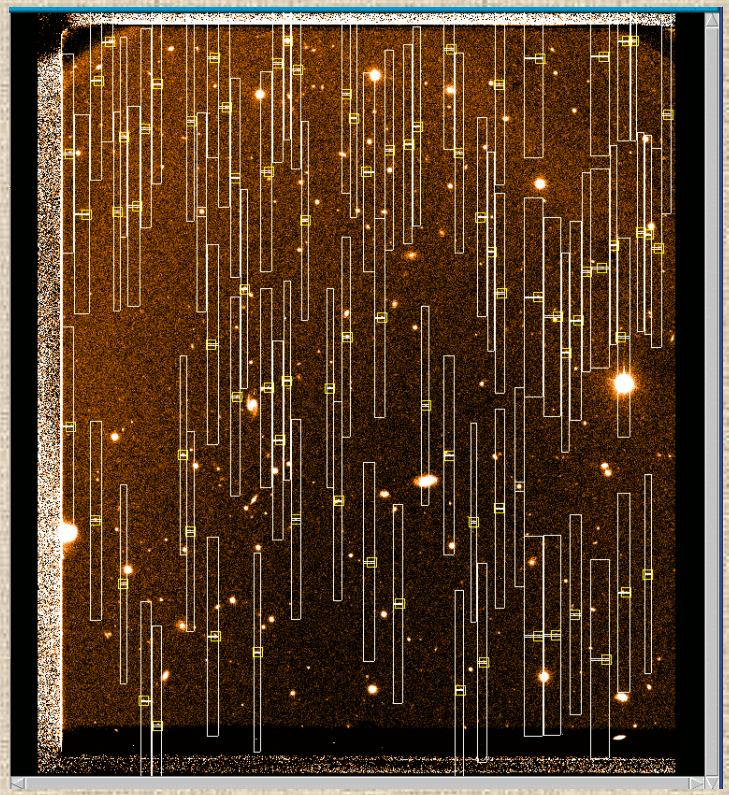


+2x4 deg2 slice in CFHTLS W4 field (VVDS F22)

Advantages of VIPERS selection strategy

- Sampling >40% of all I_{AB}<22.5 galaxies between z=0.5 and 1.2 in only one VIMOS pass:
  1. Get high density of tracers where you really need it
  2. Avoid multiple passes, thus maximize volume for given telescope allocation
  3. Targets are not dense: preserve most of angular clustering signal



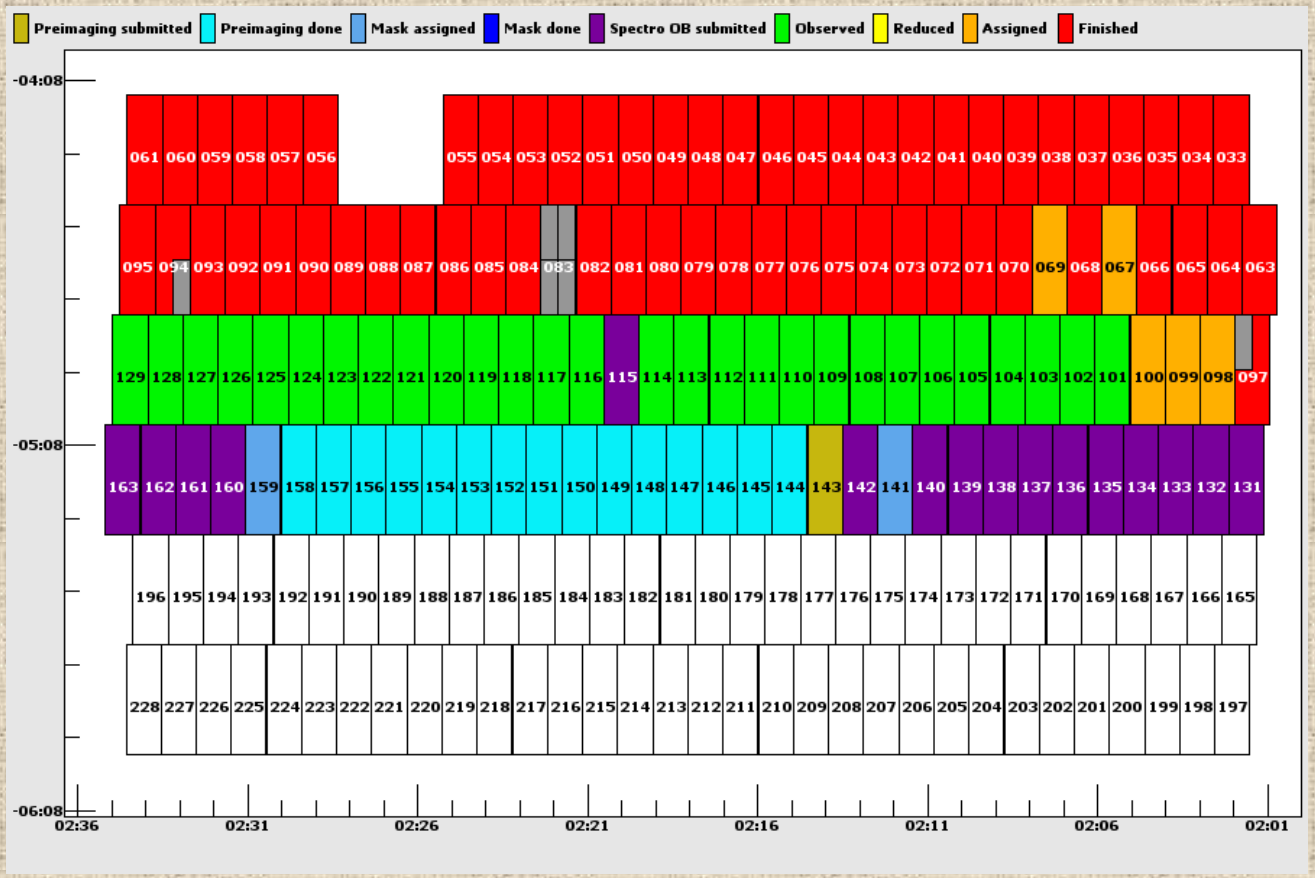


VIPERS broader scientific goals

- Growth rate from redshift-space distortions
- Galaxy clustering at z~1:
  - Evolution of $\xi(r)$ and P(k) (Ω_m, Ω_b at z~1)
  - Dependence on galaxy properties
  - Galaxy-DM relations (HOD modeling)
- Galaxy biasing
- Massive clusters and super-clusters of galaxies
- Evolution of galaxy colors and dependence on local density
- Bright/massive/rare galaxies and the galaxy luminosity and stellar mass functions
- Evolution of AGN's
- Weak-lensing (photo-z calibration)
- Multi-wavelength investigations (SWIRE, XMM, UDS)

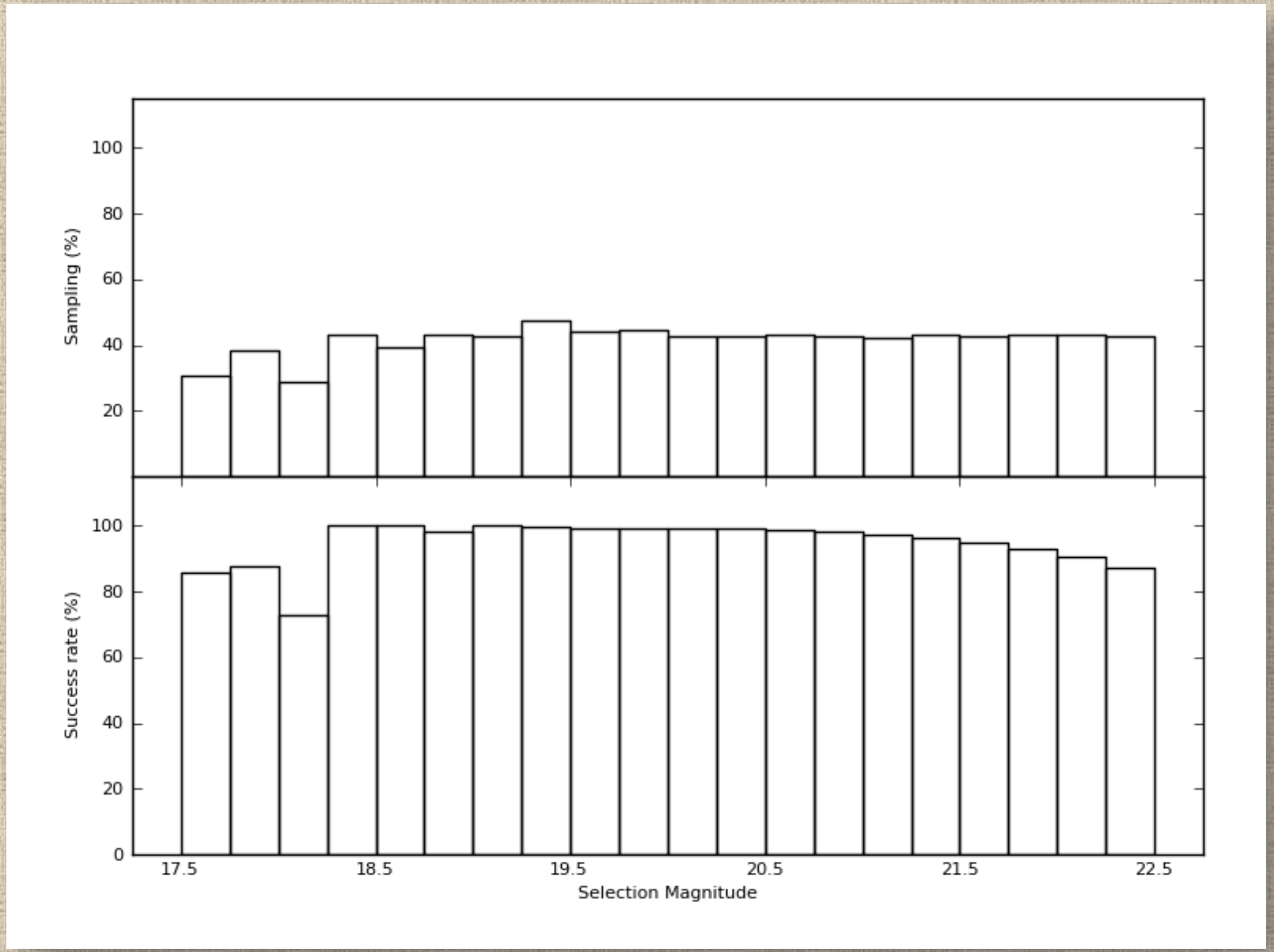
VIPERS coverage (as of Dec 2011): ~55,000 spectra observed; ~35,000 redshifts reduced and validated (v2.0 internal release)

W1

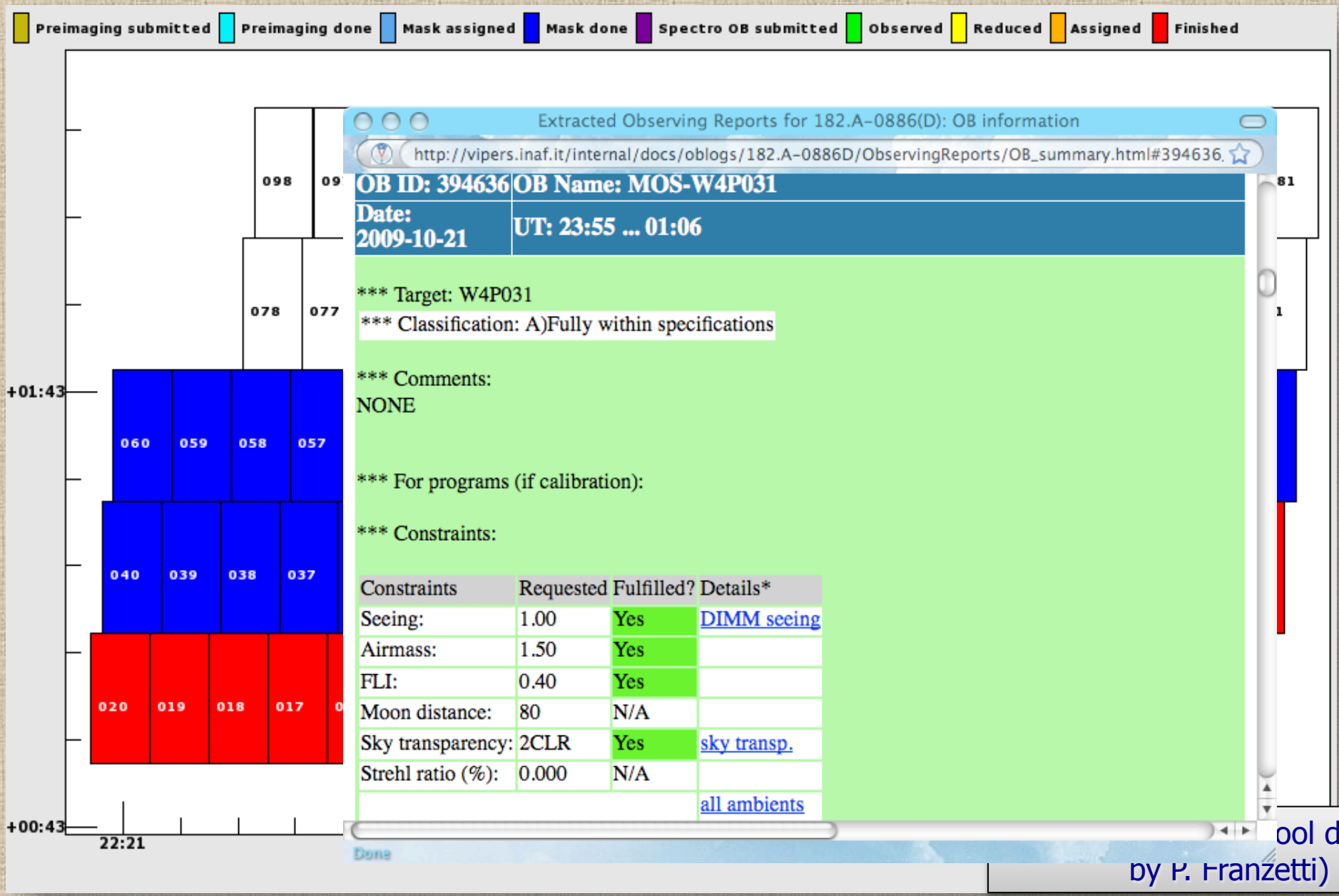


W4

Sampling rate and efficiency

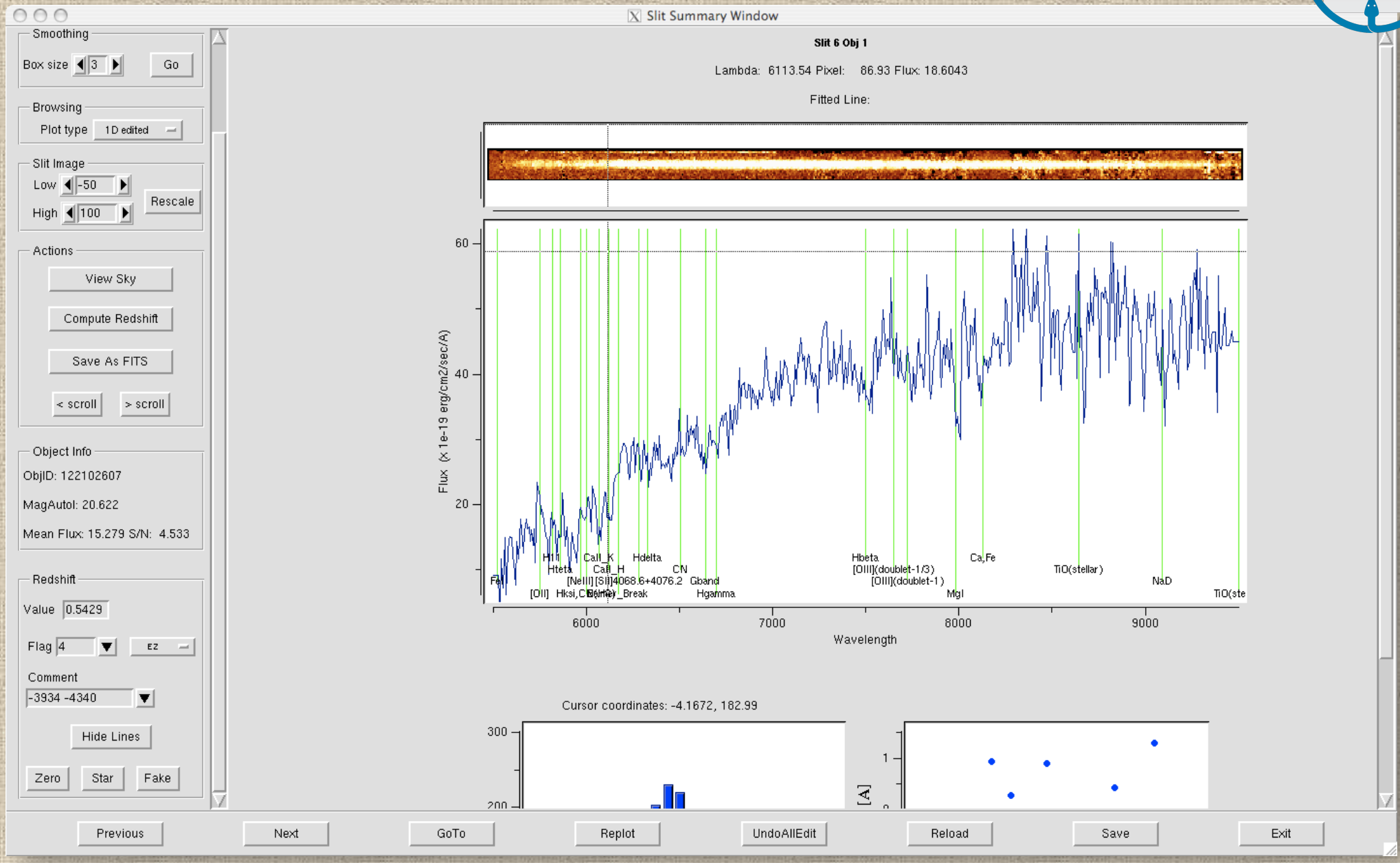


Fully automated web-based archive

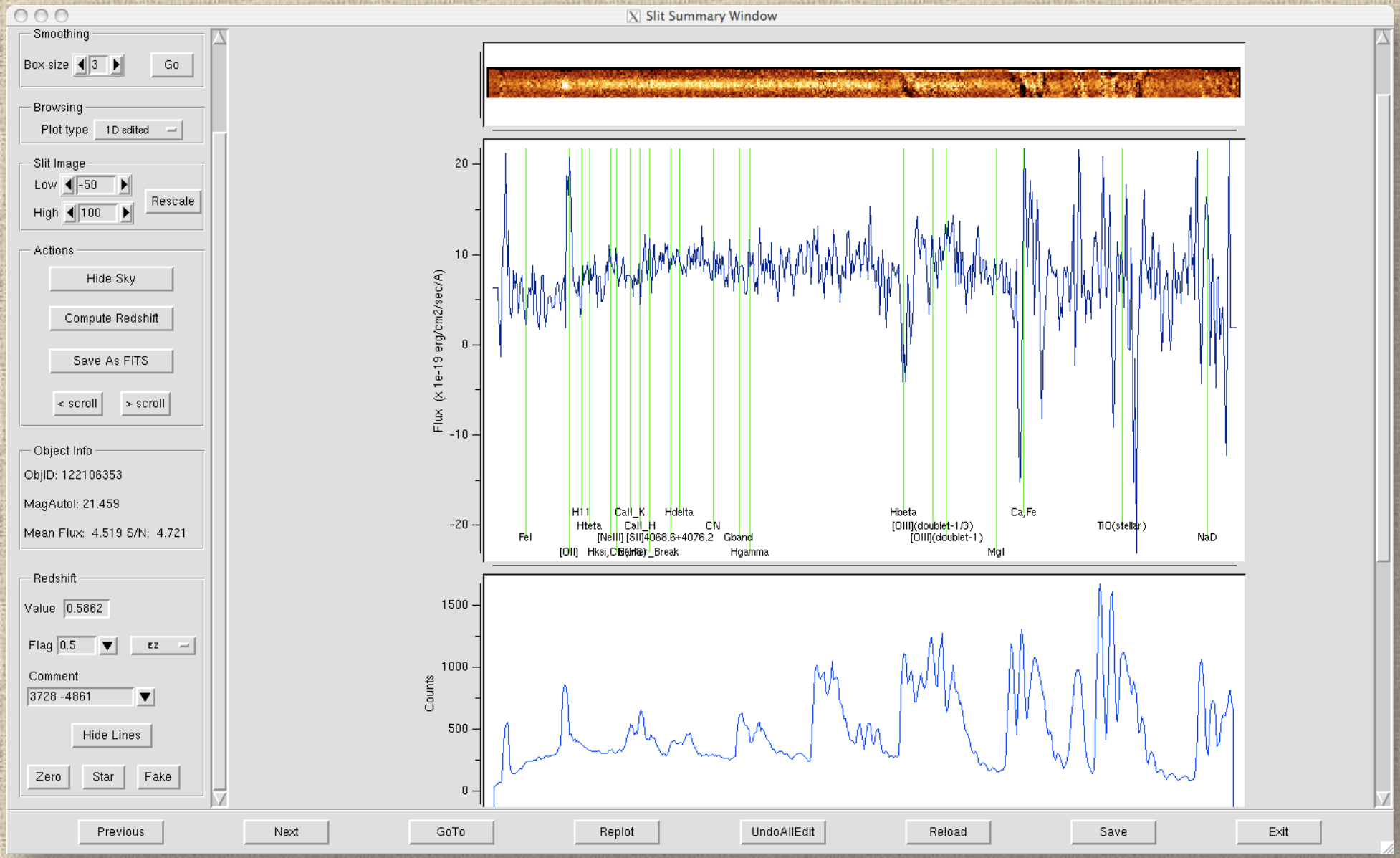


ool developed by P. Franzetti)

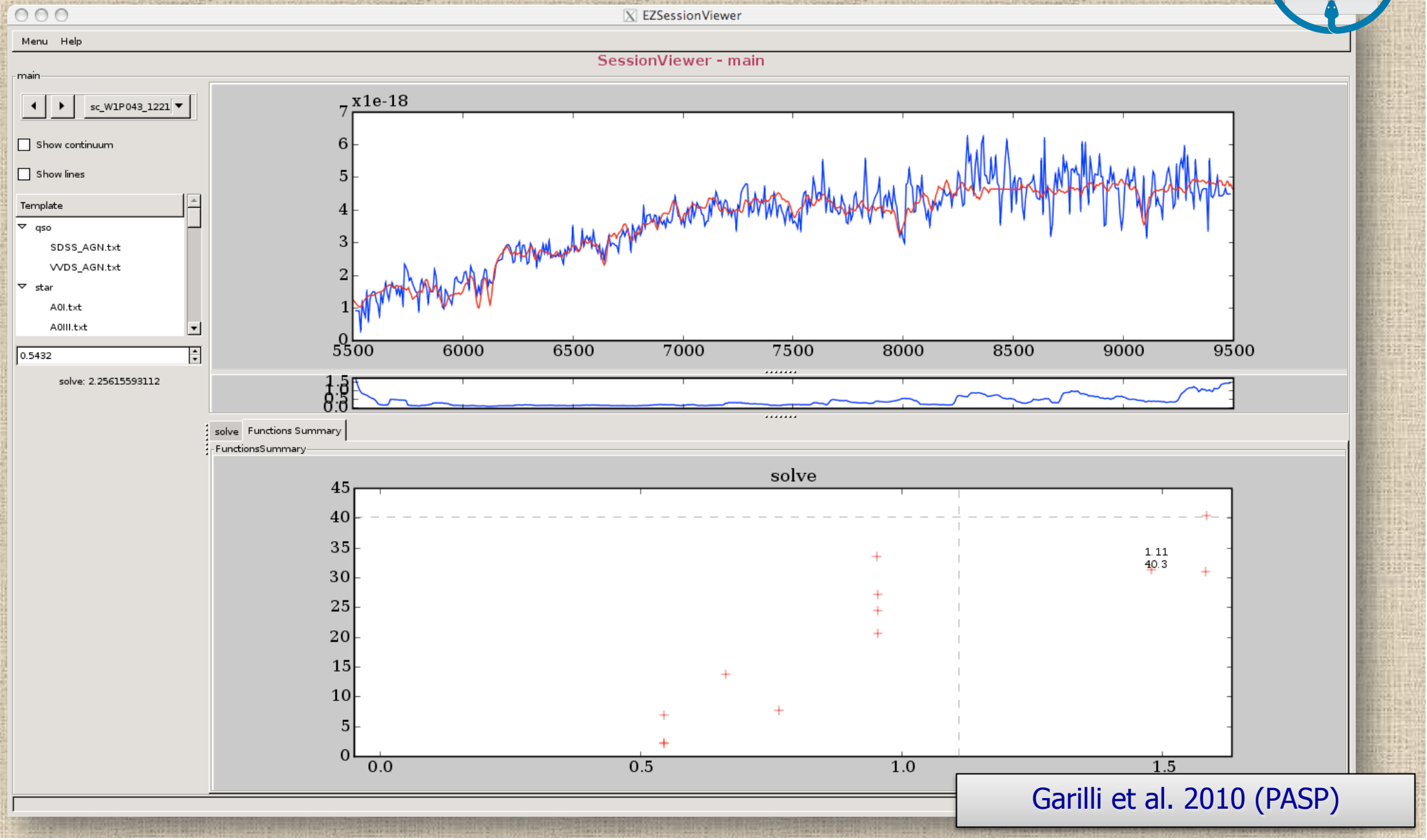
Spectral review/measurement environment: VIPGI+EZ



Spectra are (or at least were…) dirty when they come out of VIMOS…

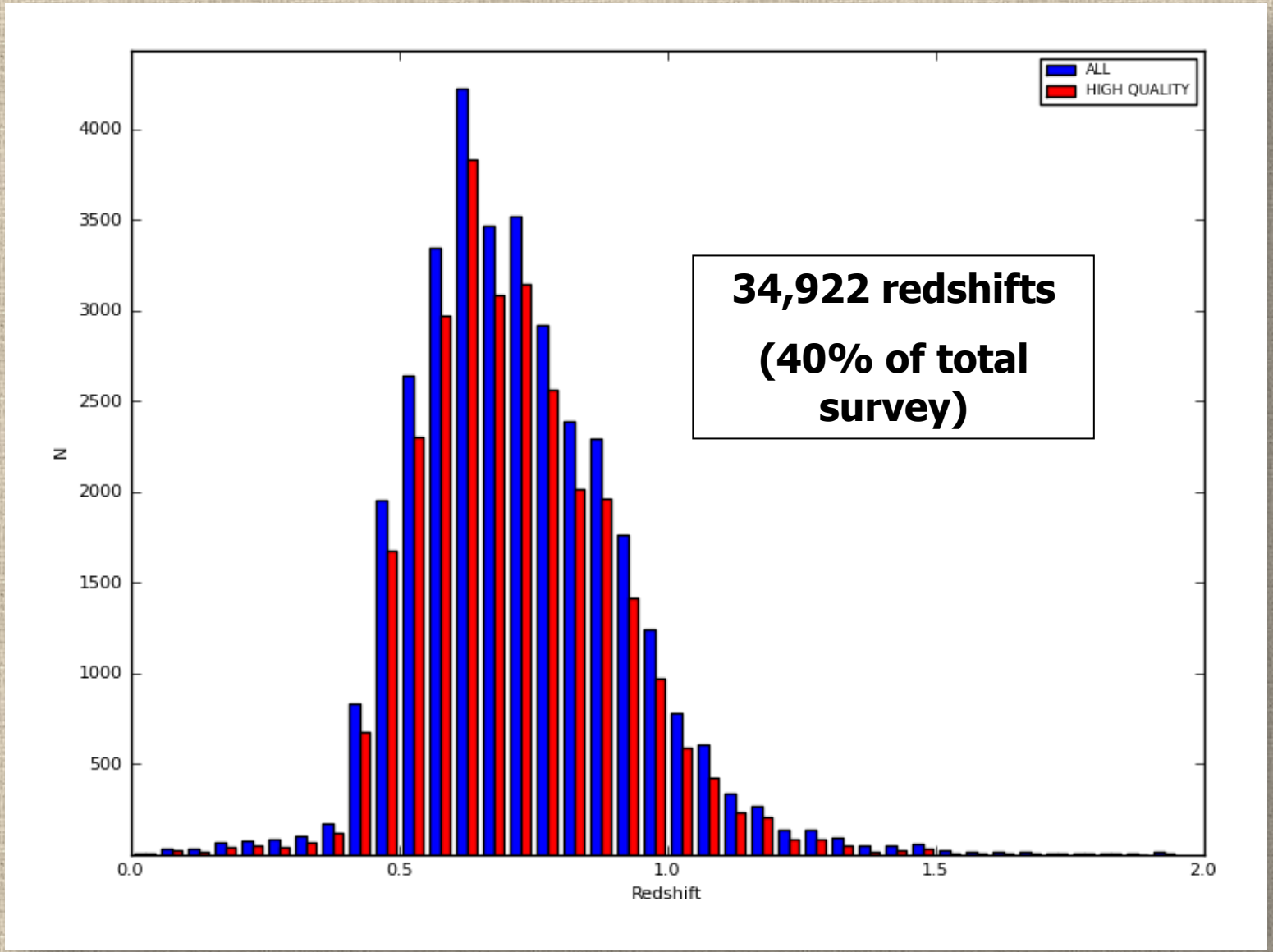


EZ: a redshift measurement tool

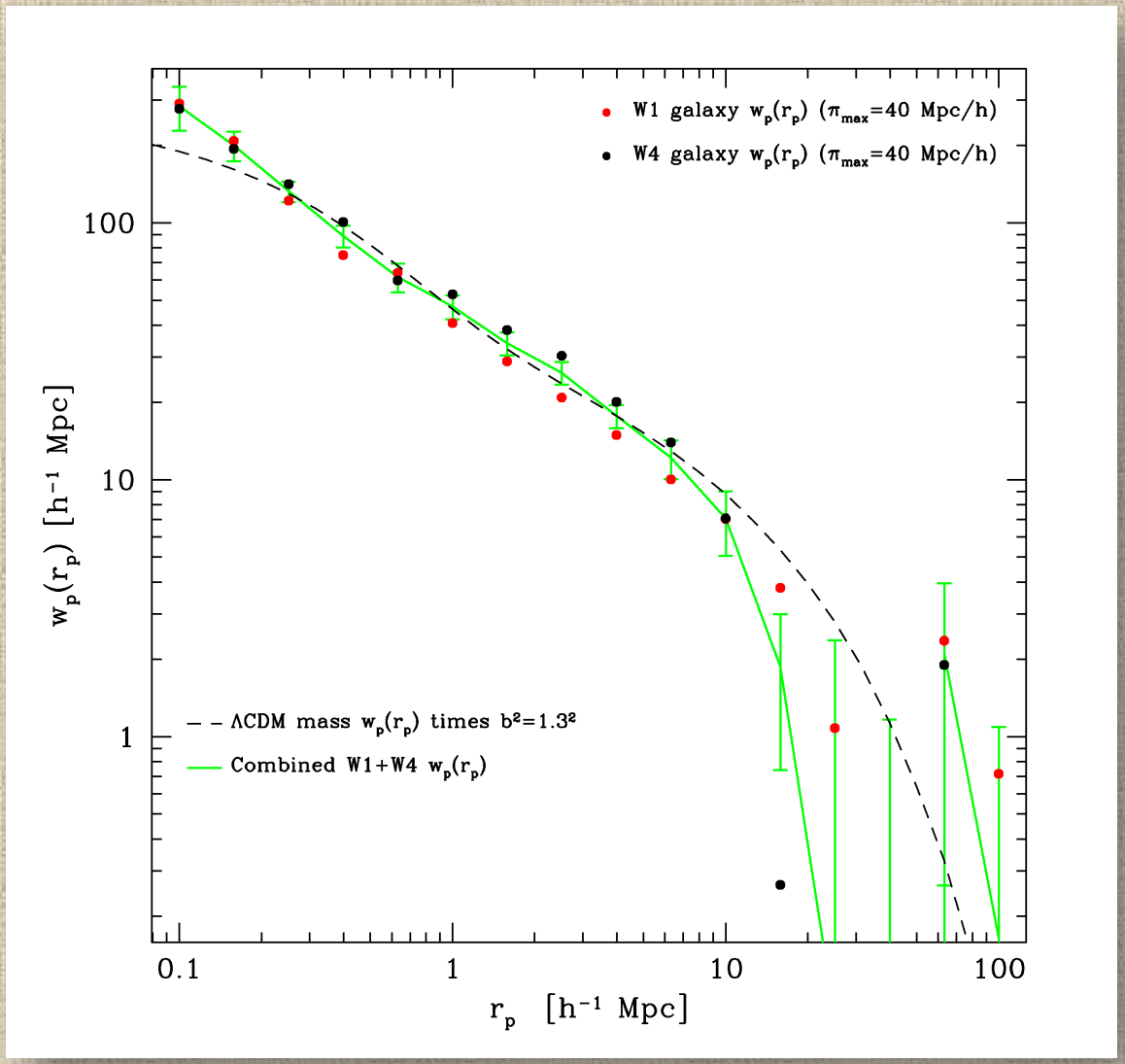


Garilli et al. 2010 (PASP)

VIPERS redshift distribution



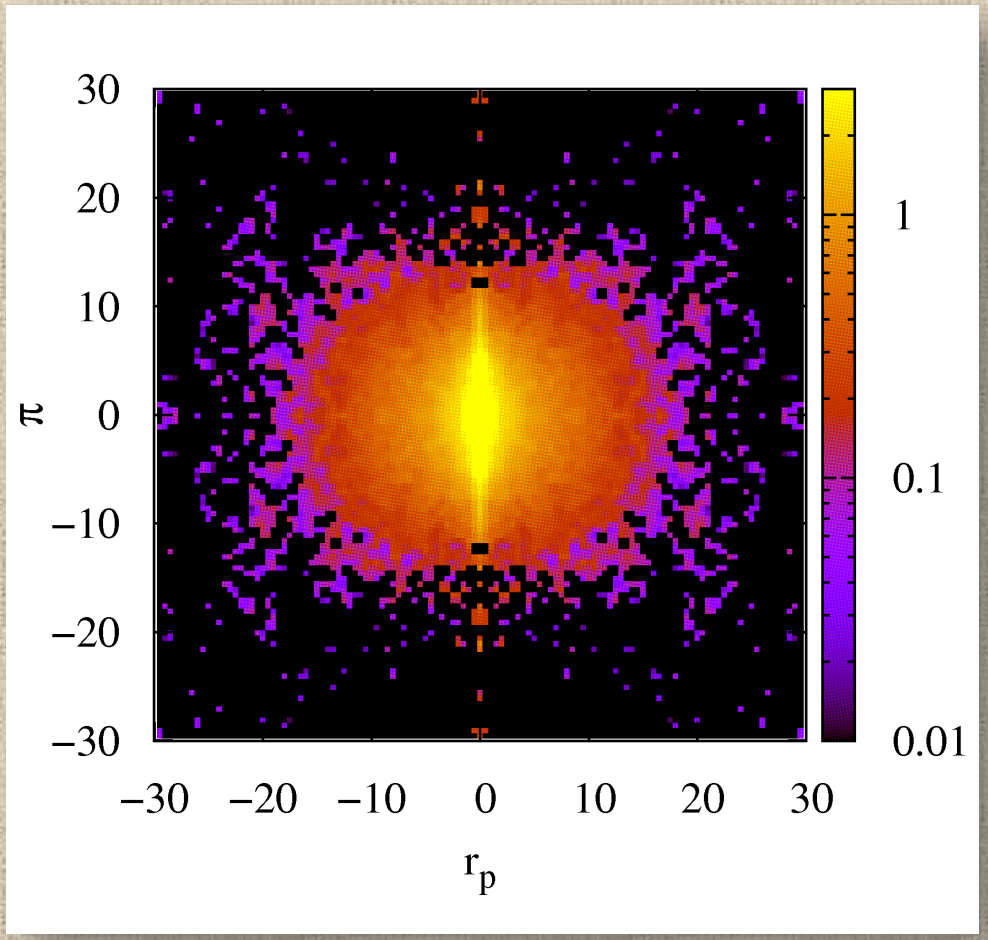
Early projected correlation function wp(rp) from early ~12,000 high-quality VIPERS redshifts



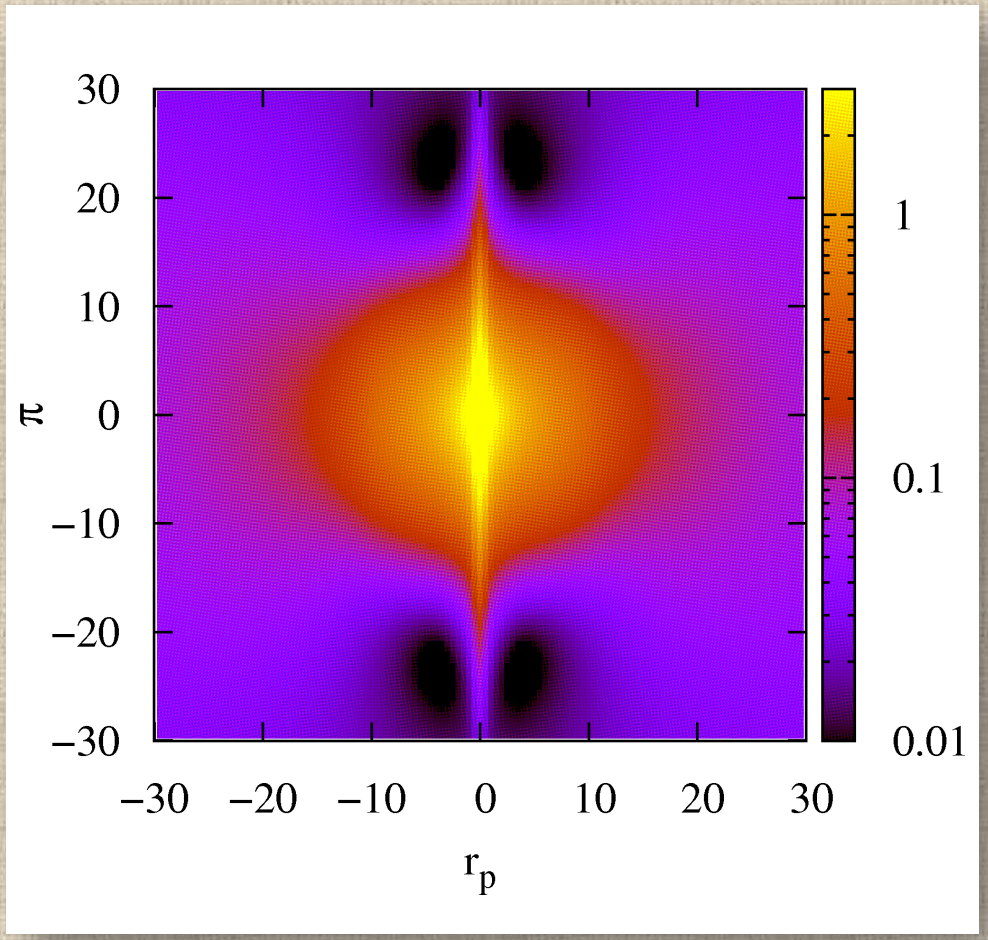
- Remarkably small difference of clustering (amplitude and shape) between the two fields
- Well-defined correlation function on $0.1<r_p<\sim15$ scales
- Galaxy bias b~1.35 (assuming ΛCDM)

Early $\xi(r_p,\pi)$ from first ~12,000 high-quality VIPERS redshifts at 0.5<z<1

Data



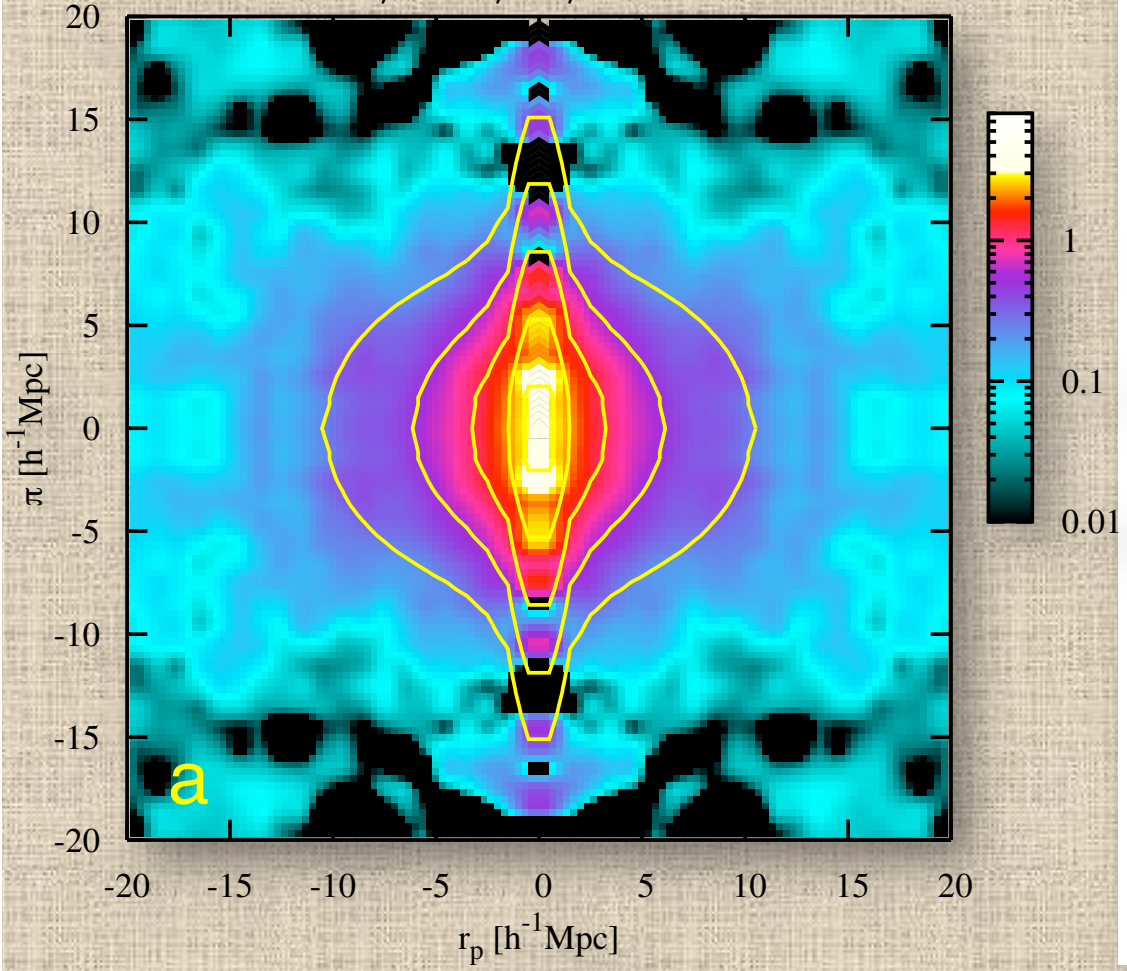
Best-fitting model (β=0.62)



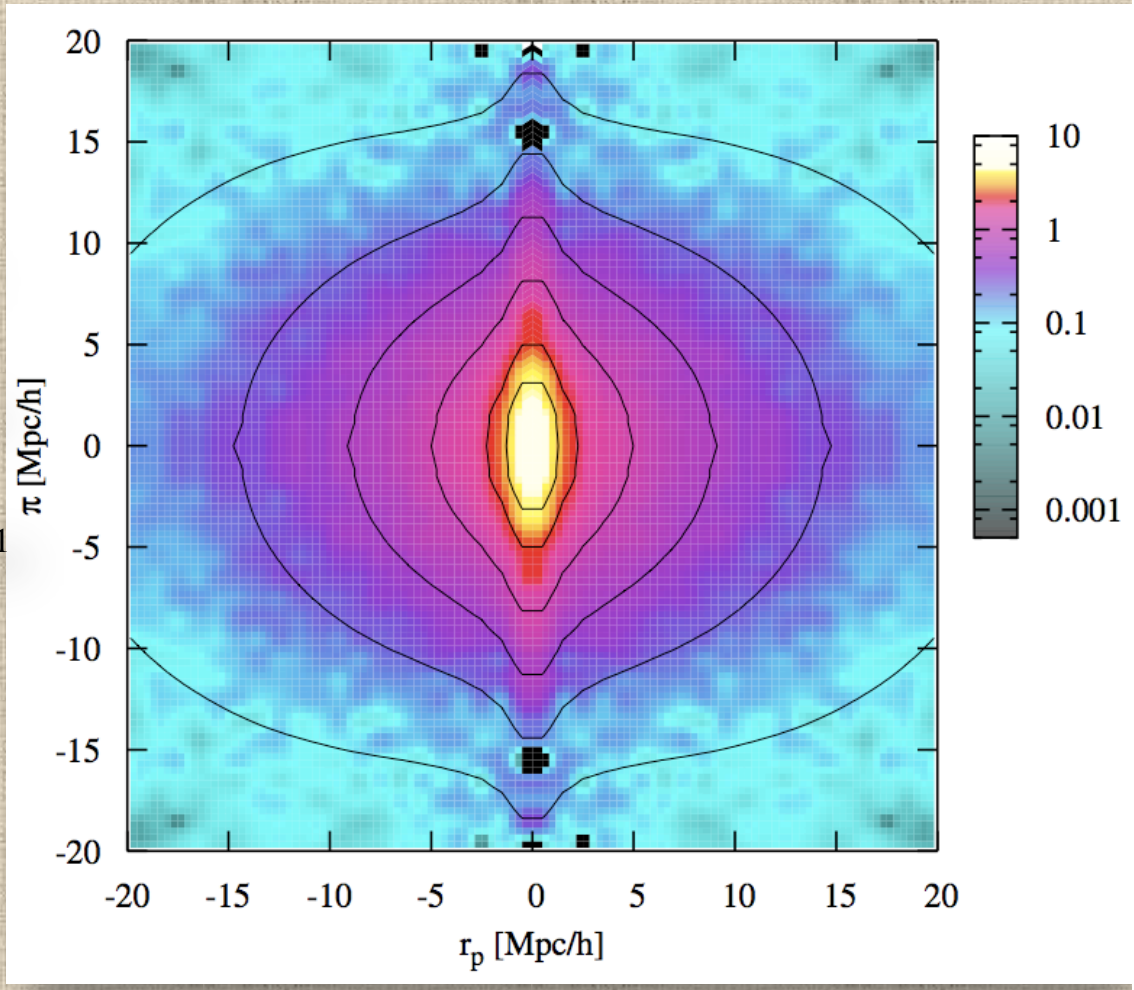
2 parameter fit of the full shape of $\xi(r_p,\pi)$ on $0<r_p<20$ scale (S. de la Torre, & the VIPERS Collaboration)

Expectations from fully completed survey

Guzzo et al 2008, Nature, 451, 541

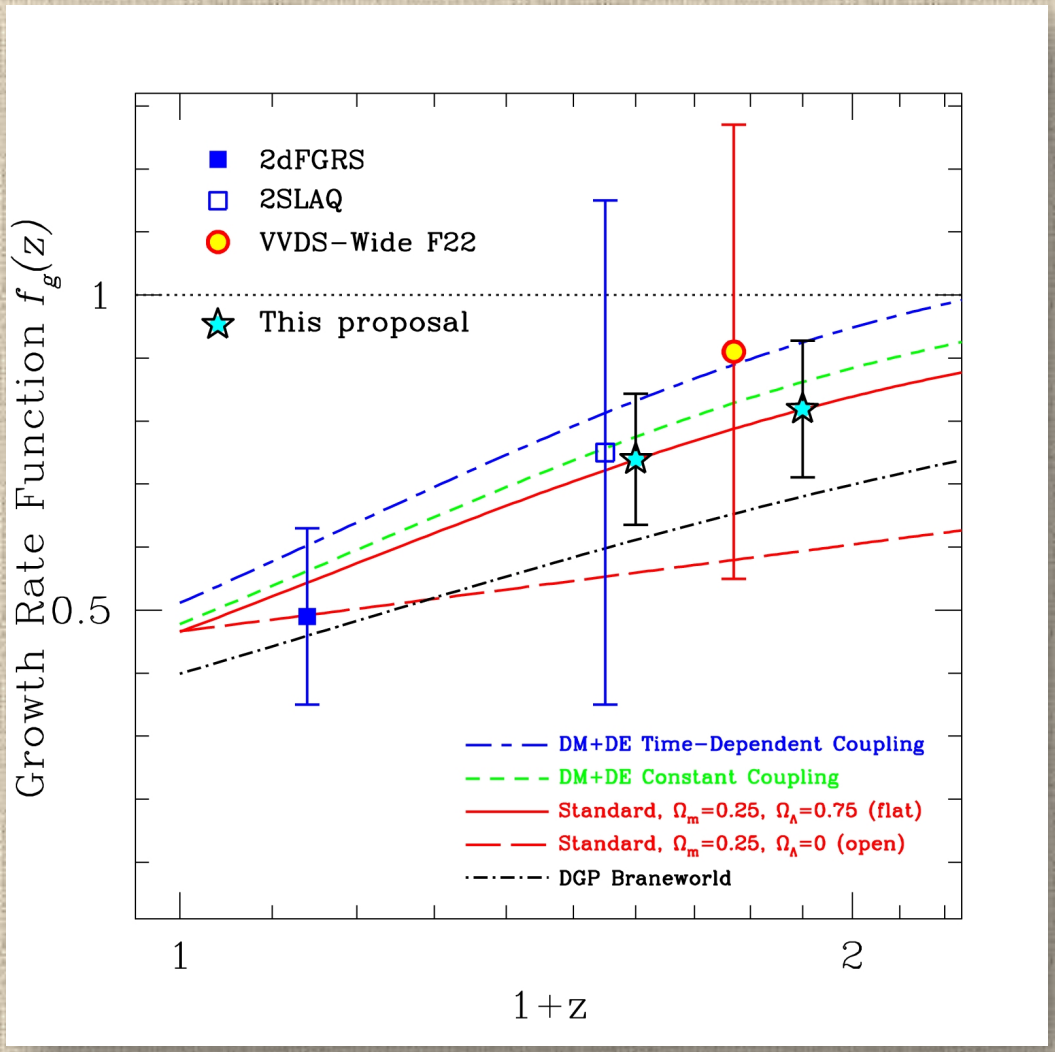


VVDS F22 (~6000 gals)



VIPERS (~100,000 gals)

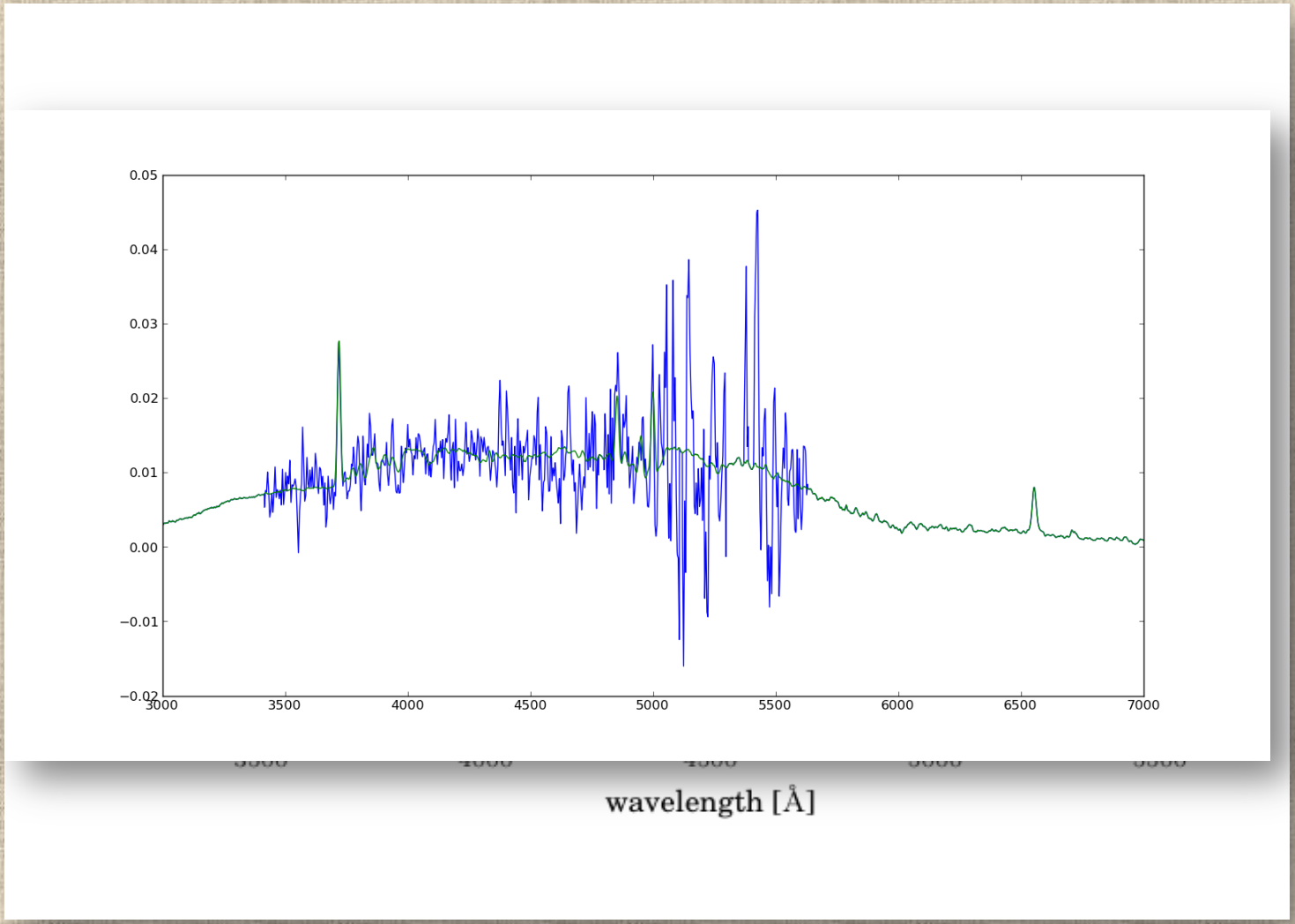
(Conservative) forecast on f(z) from full VIPERS



~10% error using full population of galaxies

- However, specific advantage of VIPERS: high sampling (2 x 10^{-3} h^3 Mpc^{-3})
- It will allow us to select sub-samples with different bias (e.g. luminous early type galaxies)
- Combined 2-population estimate of β to possibly reduce cosmic variance can be (McDonald & Seljak, 2009, JCAP) → but apparently gain not so large as claimed (see Gil-Marin et al. 2010, arXiv: 1003.3238)
- In general, measure β with different populations: PCA classification of VIPERS spectra undergoing (Alida Marchetti PhD Thesis, Marchetti et al., in preparation): select LRG and other sub-samples

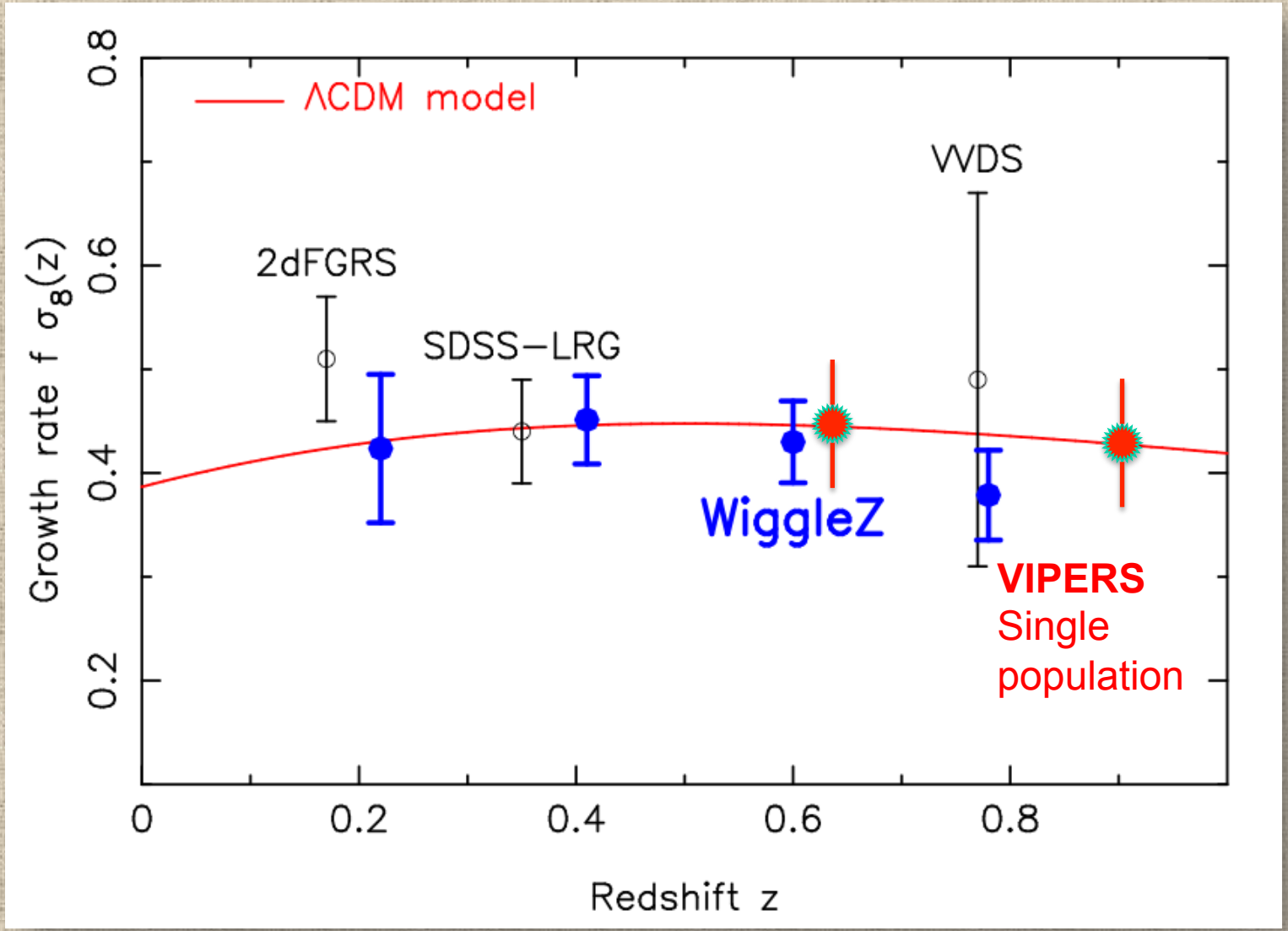
Ongoing work: PCA and classification of VIPERS spectra



- Classify quantitatively sub-populations of galaxies (e.g. LRG-like)
- Build well-defined sub-sample for cosmological analysis
- (e.g. a la McDonald & Seljak 2010)
- Consistently compare clustering/evolution with z~0 samples
- "Repair" damaged spectra

A. Marchetti (PhD project), B. Granett & LG

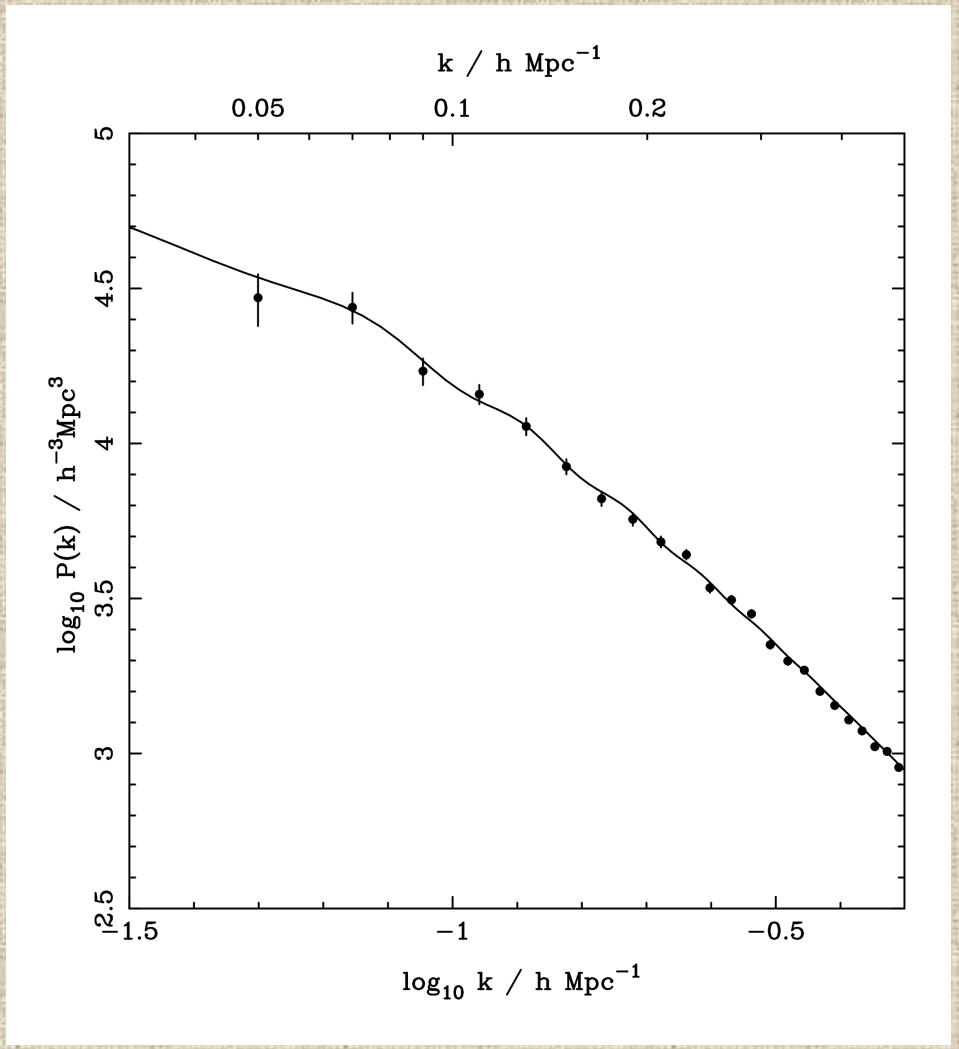
BAO-focused surveys can obviously measure RSD well, with one population



WiggleZ: ~152,000 redshifts over 5000 deg^2 (Blake et al. 2011, arXiv: 1104.2948)

Expected P(k) at <z>~0.8 from VIPERS

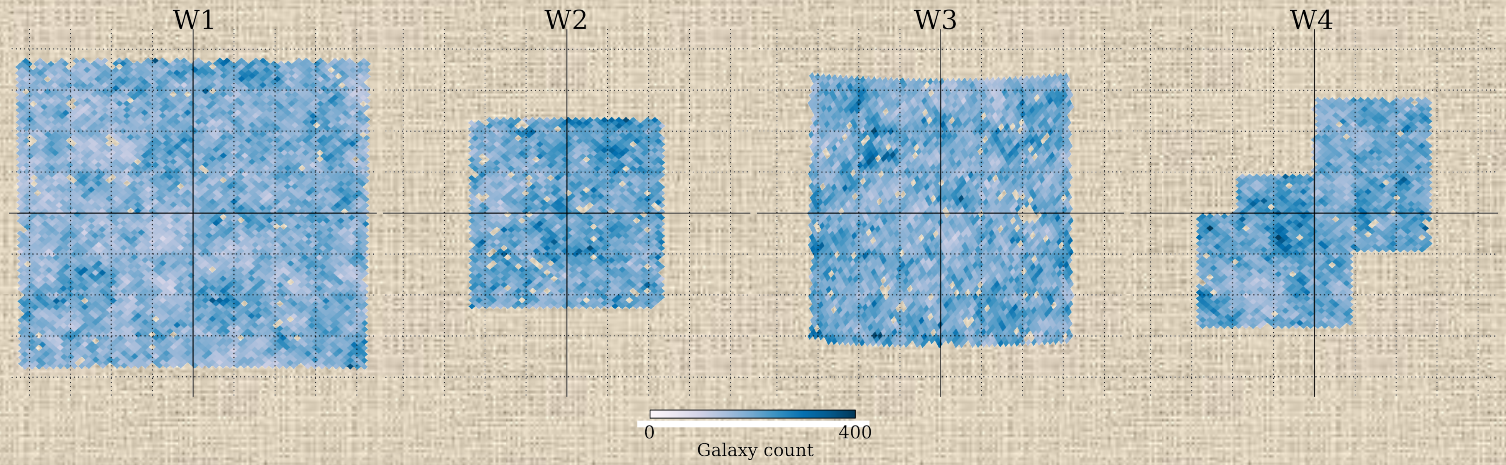
- Measure $\Omega_m h$ from shape of power spectrum
- BAO (baryon fraction, standard ruler?)
- z-space distortions
- neutrino mass?
- large-scale bias vs galaxy properties
- …



(simulation by W. Percival)

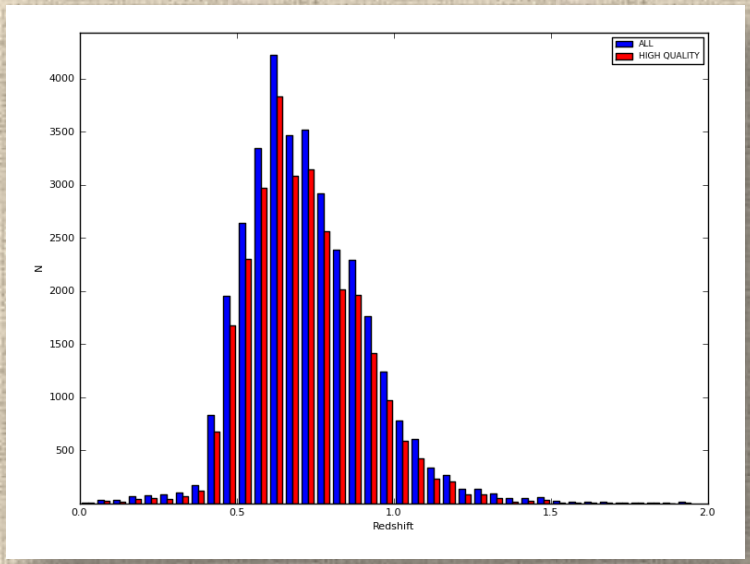
Early results: The real-space galaxy P(k) at <z>~0.8 from the full CFHTLS-Wide data, "sliced" using VIPERS N(z) and color selection

B. Granett & VIPERS Team, MNRAS, in press, **arXiv 1112.0008**



CFHTLS-Wide:

- ~140 deg^2
- 5-bands (ugriz)
- 2.1 million galaxies



- VIPERS mag/color criteria work very well in selecting 0.5<z<1.2
- Characterize VIPERS parent sub-catalogue
- Accurate N(z) crucial for de-projection: provided by VIPERS
- Exploits currently largest available volume of CFHTLS-Wide areas
- Recent Cl angular Thomas

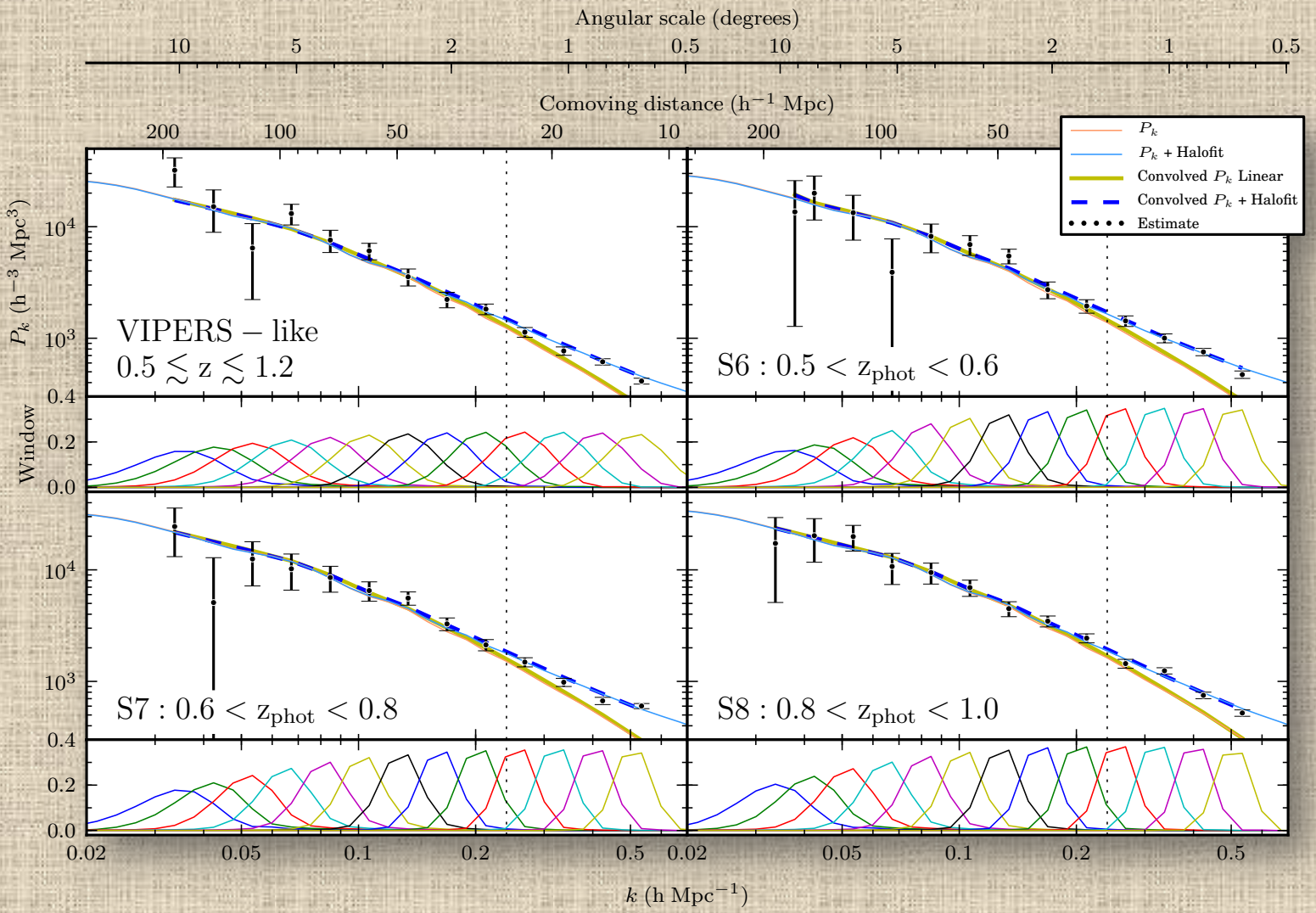
Real space P(k) at z~0.7 from CFHTLS-Wide + VIPERS N(z)

W1+W2+W3+W4

1) Cl spectrum using Tegmark 1997 quadratic estimator

2) Deconvolved following Efstathiou & Moody 2001

Complementary to recent Cl estimate at z~0.5 from SDSS LRGs (Thomas, Abdalla & Lahav 2011)



B. Granett, LG & VIPERS Team, MNRAS, in press - arXiv 1112.0008

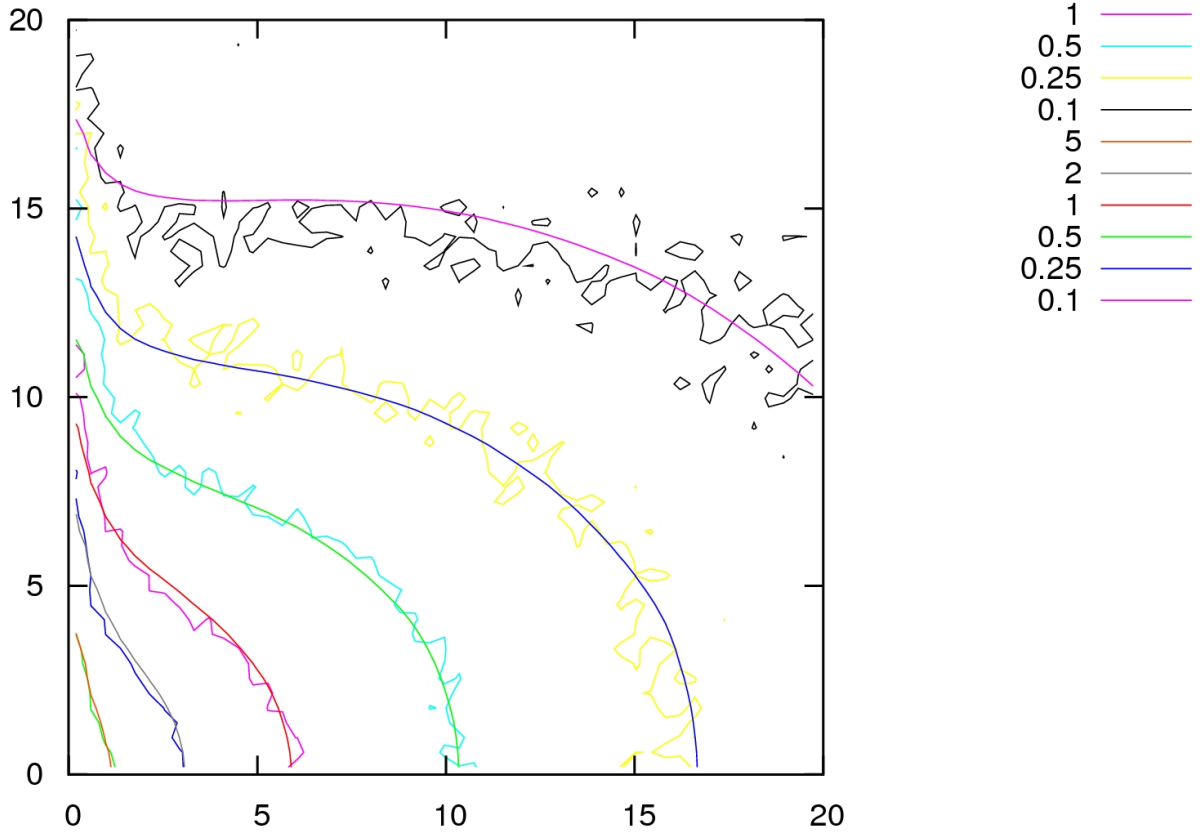
Xia, Granett, Viel et al., submitted to MNRAS: constraints on neutrino masses (preprint on arXiv)

Improving the tool: RSD in the precision cosmology era

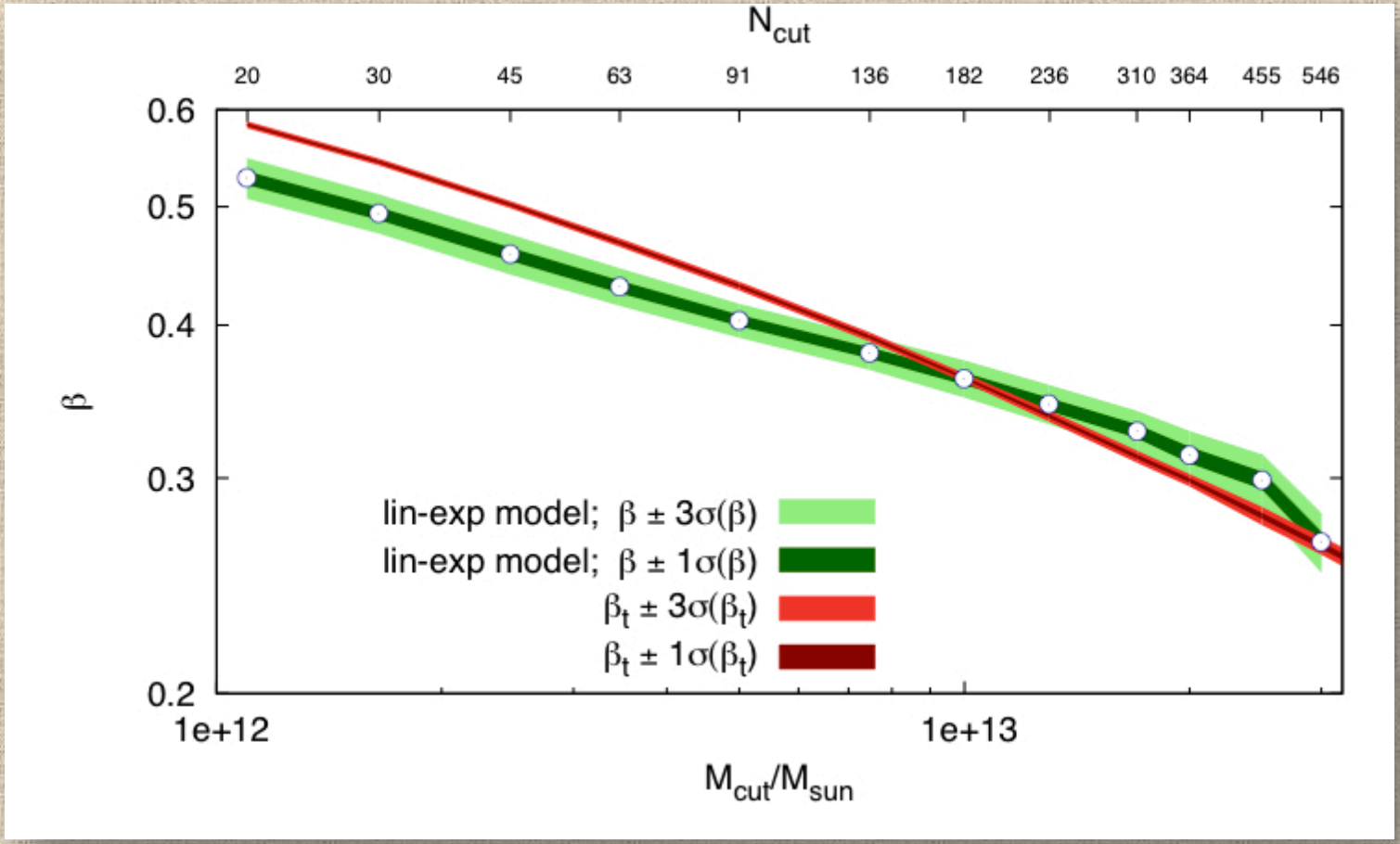
Kaiser/Hamilton linear redshift-distortion model

$$P(k_{||}, k_{\perp}) = P(k)\left(1+\beta\mu^2\right)^2 D(k\mu\sigma_p).$$

$$D(k\mu\sigma_p) = \frac{1}{1+\left(k\mu\sigma_p\right)^2/2}$$



Systematic errors in estimating β with classical linear model + exponential correction

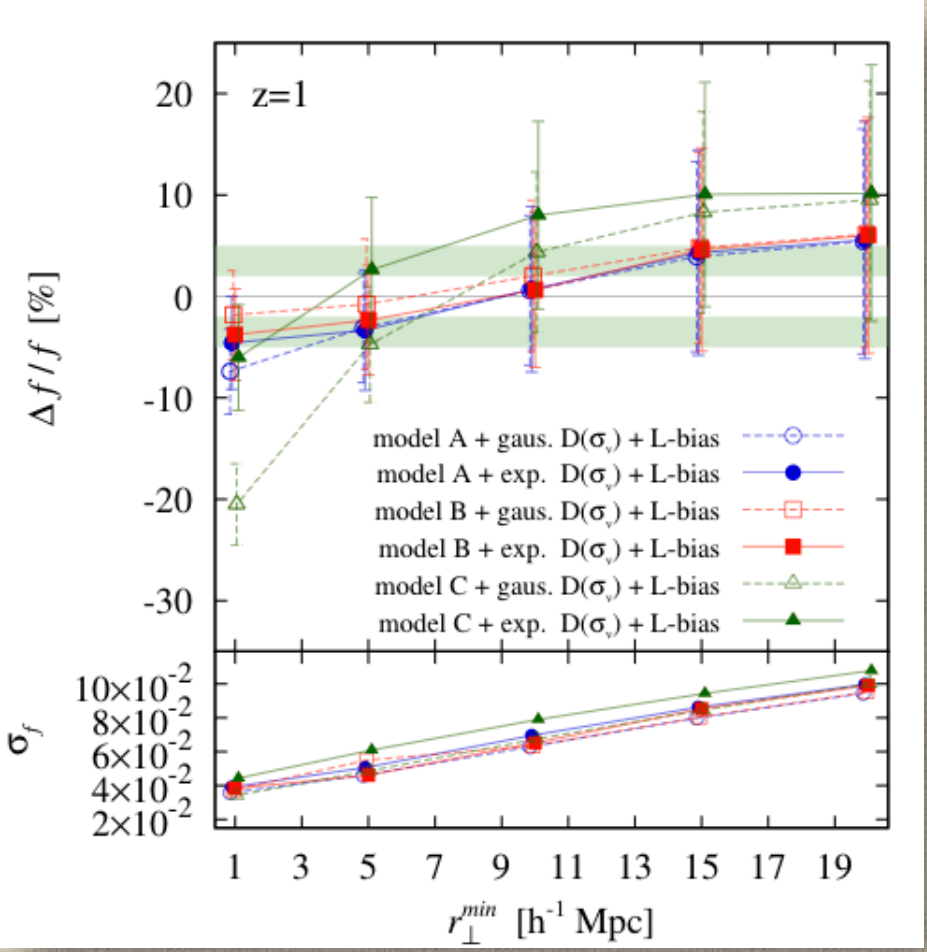


- Based on BASICC simulation halo catalogues (Angulo et al): 3 billion particles in a 1340 h^{-1} Mpc side box
- RESULT: ~5-10% systematic underestimate
- Hints that larger-mass halos do perform better (e.g. LRGs)
- See also Okumura & Jing 2011 using ratios of moments and Kwan et al. 2011
- Calls for improved description of RSD

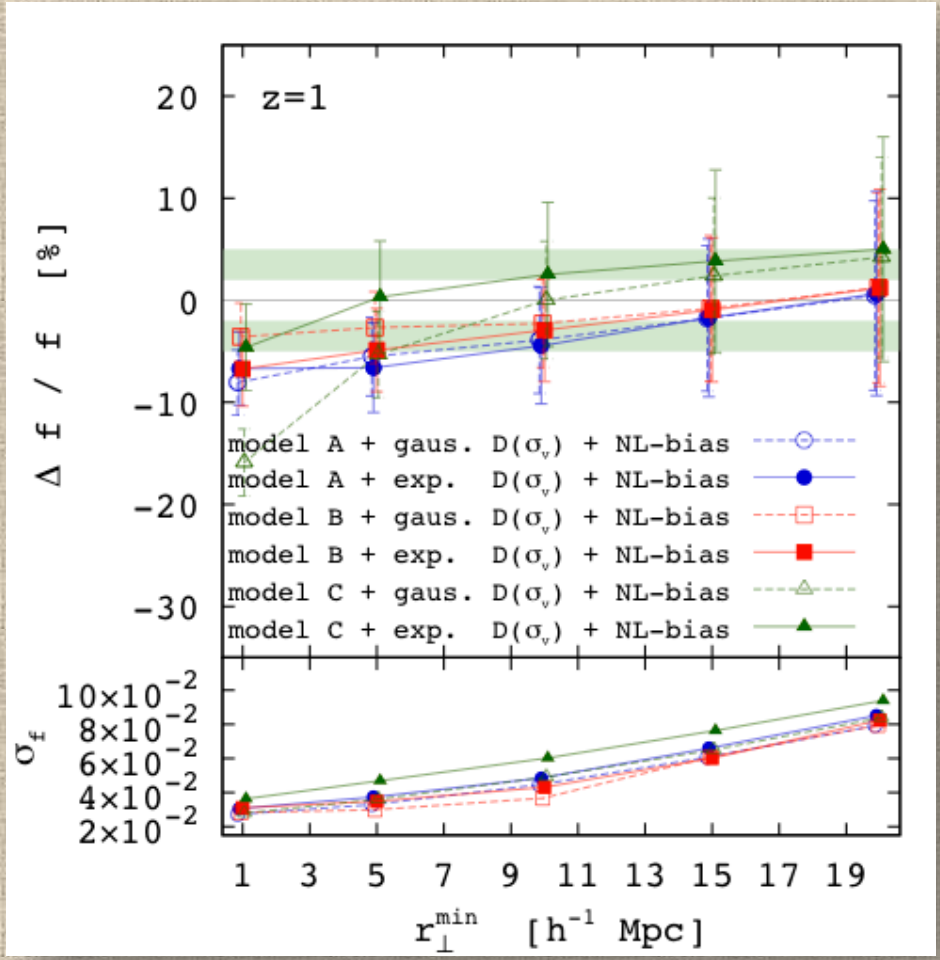
Bianchi, LG, Branchini et al. 2012, arXiv:1203.1545

Improving the linear model: role of galaxy bias

Linear bias

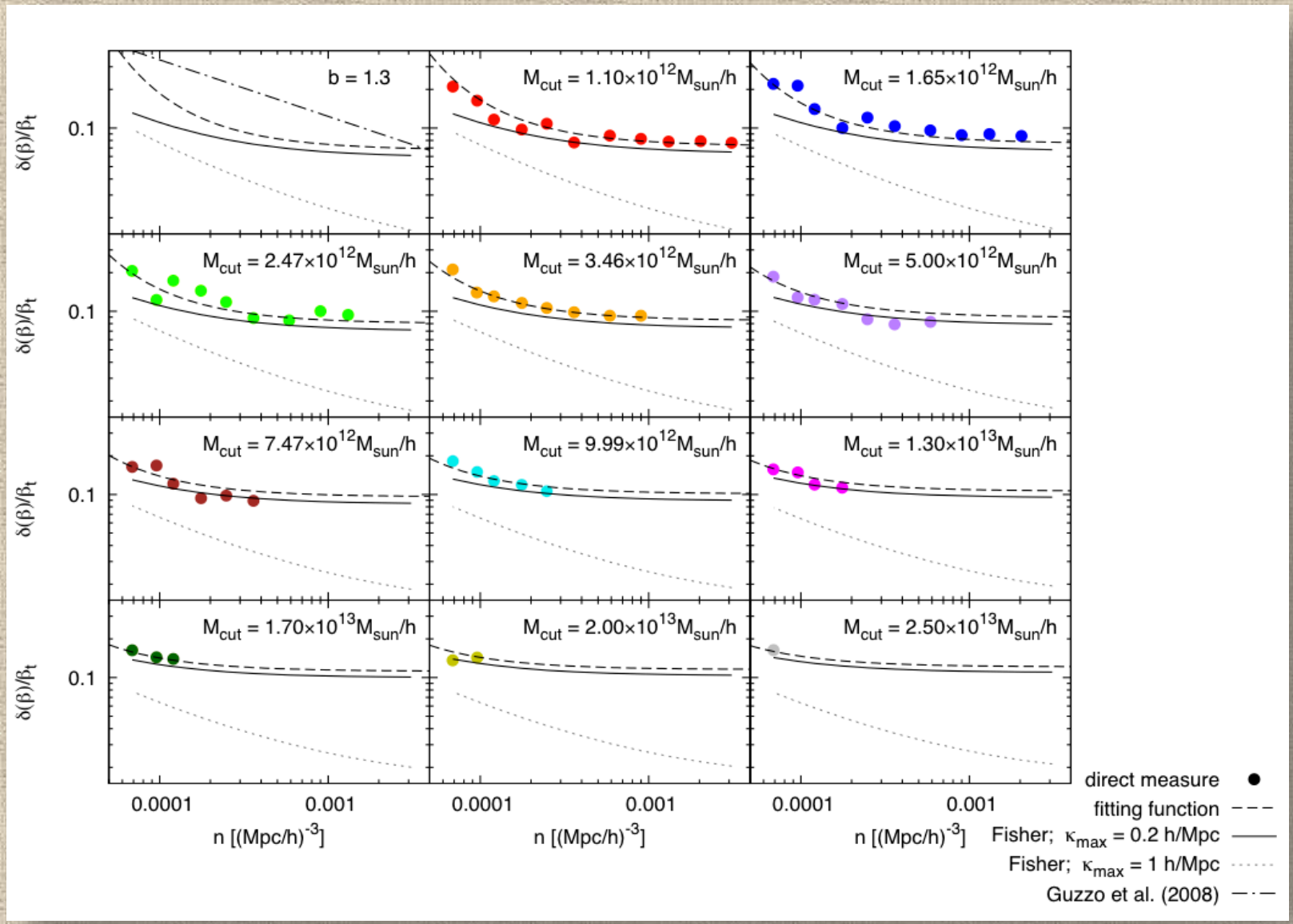


Scale-dependent bias



De la Torre & LG 2012, arXiv:1202.5559

Predicting statistical errors: can we trust Fisher Matrix predictions?

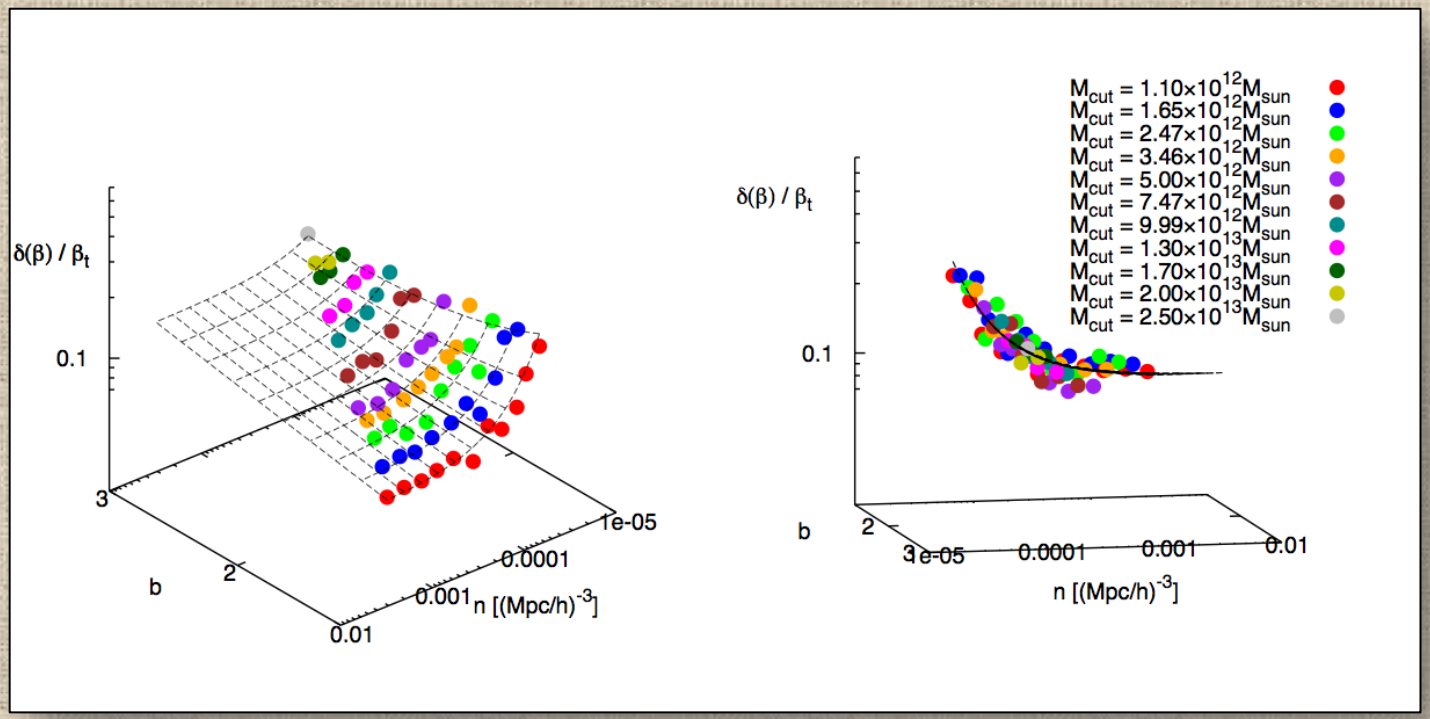


Bianchi, LG et al. 2011, to be submitted to MNRAS

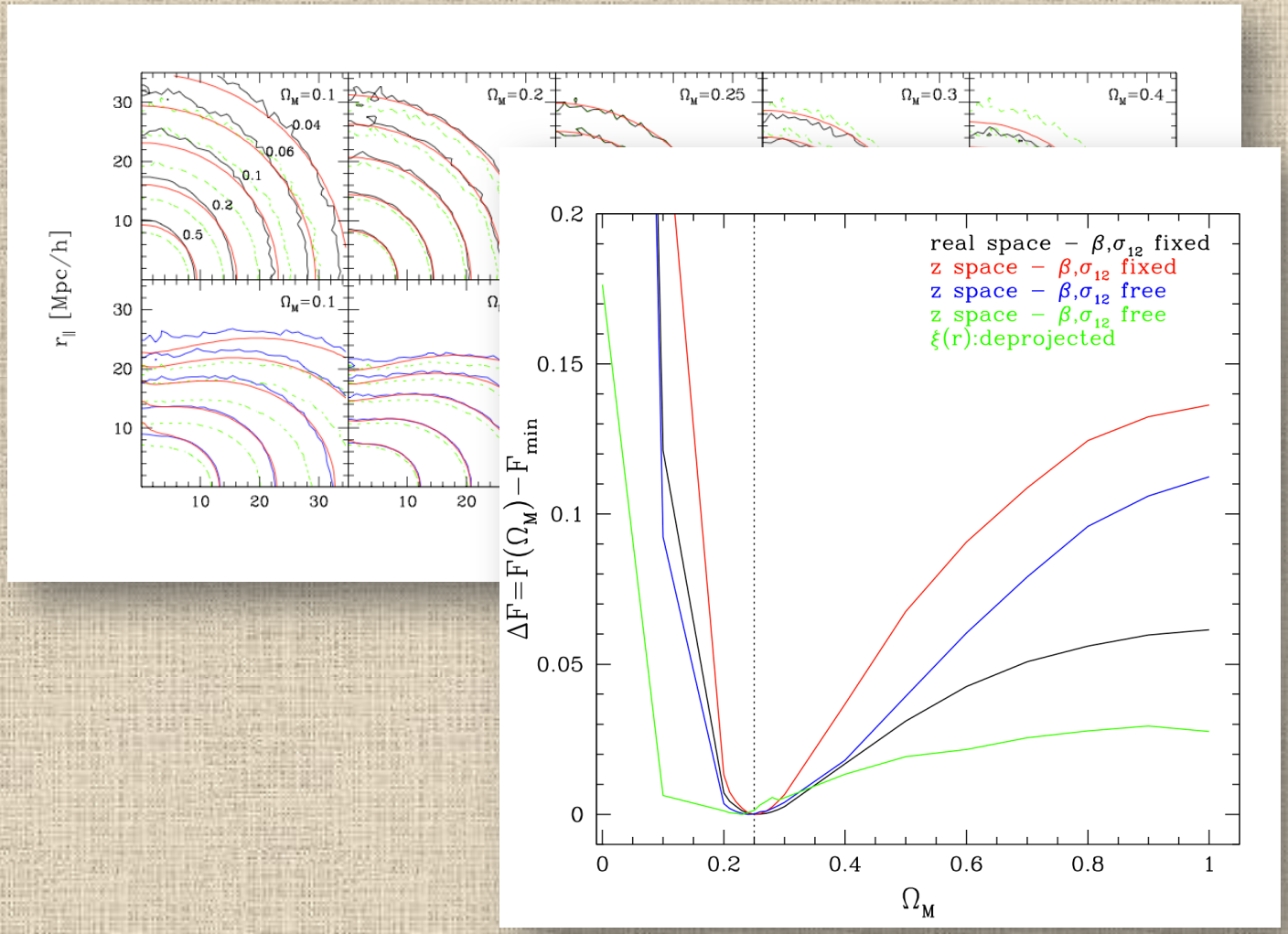
Predicting statistical errors: a handy and accurate scaling formula describing the behaviour found in the Monte Carlo experiments

$$\delta(\beta)/\beta \approx C b^{0.7} V^{-0.5} \exp\left(\frac{B}{b^2 n}\right)$$

Bianchi, LG et al. 2011, to be submitted to MNRAS



Degeneracy of RSD with geometric distortions can be broken

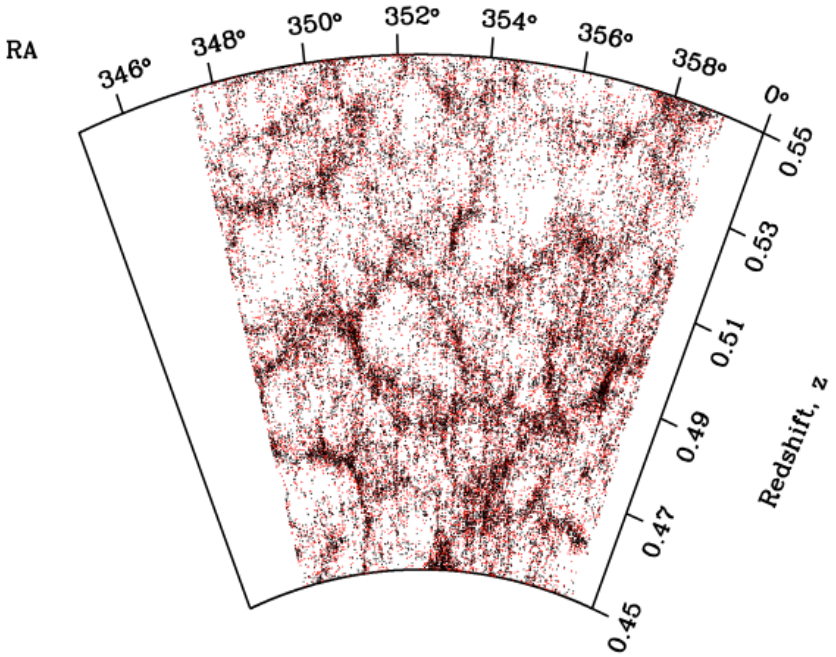


- Based on BASICC simulation halo catalogues (Angulo et al 2009)
- Vary cosmology, ignore geometric distortions, find best-fit RSD model, save its X^2
- Correct cosmology is that giving the "best among the best" X^2
- In other words, RSD are found to be stronger than geometric distortions and drive you to the correct cosmology (see also Guzzo et al. 2008)

Marulli, Bianchi, et al. 2012, arXiv:1203.1002

Growth with Euclid: RSD

- Redshift-space distortions map motions due to structure growth

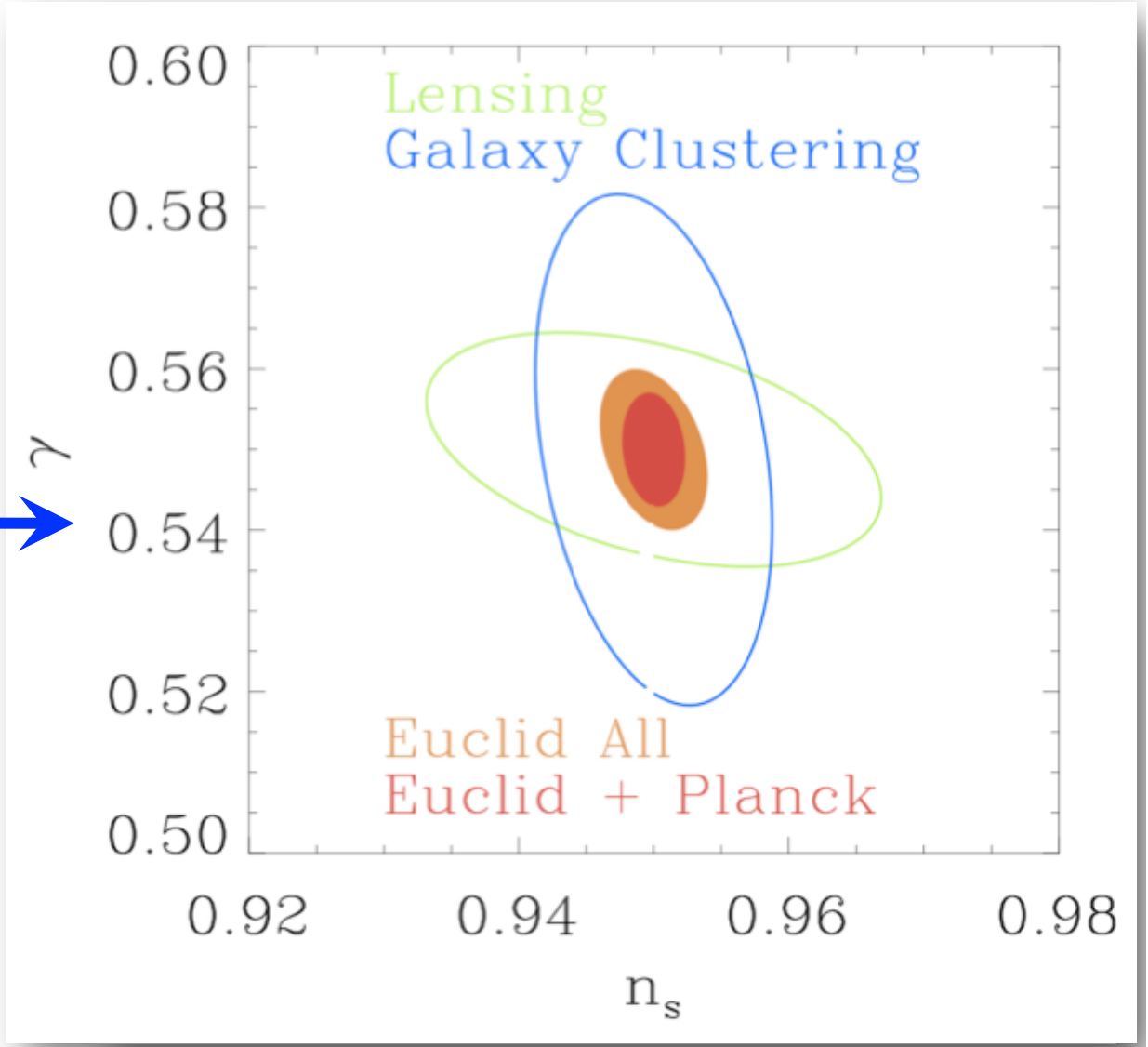


$\sigma_z = 0.001(1+z)$

$\sigma_z = 0.0$

EUCLID lightcone (100deg²)
$S_{H\alpha}<1\times10^{-16}$erg/s/cm²

(sims from Durham group)



Summary

- VIPERS finally exploits VIMOS capabilities for LSS study, filling a specific niche z~1: volume 6 x 10^7 h^{-3} Mpc^3, sampling >40%
- Study large-scale structure, clustering and growth at 0.5<z<1, to an accuracy comparable to local state-of-the-art surveys
- Efficient survey pipeline: automatic data calibration, redshift measurement and database archiving: ~55,000 spectra secured, analyses ongoing on internal V2.0 release (32,000 redshifts)
- After 2010 CCD refurbishment, quality of VIMOS spectra significantly improved (no fringing), requiring reduced human intervention. Still, quality control is necessary to assure uniformity, and VIMOS still complex machine (mask insertion problems)
- With current observing rate, completion expected by 2014
- More photometry being collected (GALEX & WIRCAM coverage nearly complete)
- Public survey: raw data public immediately, redshifts released in regular tranches. First redshift catalogue public release ~fall 2012

More in general, concerning the topic of this meeting:

- A brilliant future for galaxy redshift surveys: measure both w(z) and f(z) using BAOs/P(k) and z-distortions (plus clusters…) → test dark energy vs modified gravity
- A renaissance for redshift-space distortions: not considered in this context before 2008, now accepted as a primary"dark energy probe" (EUCLID)

1) RSD: Improving the data

- Exciting results from WiggleZ. More expected soon come from BOSS
- VIPERS: a 2dFGRS at z~0.8, ~100,000 highly-sampled redshifts; early measurement of real-space P(k) in combination with CFHTLS
- EUCLID is approved and plans to couple a massive (slitless) redshift survey with a high-resolution imaging survey, to combine galaxy clustering and weak lensing (launch 2019)

2) RSD: Improving the estimators

- Need to go beyond Kaiser-Hamilton formalism, if we aim at precision cosmology on f(z)
- Do simultaneous estimate of BAO and z-distortions (including Alcock-Paczynski, see Simpson & Peacock 2010)
- A lot of work ongoing in the community, exciting times ahead
- DARKLIGHT: an ERC Advanced Grant program to improve estimators and apply to early data (look out for postdoc announcements)