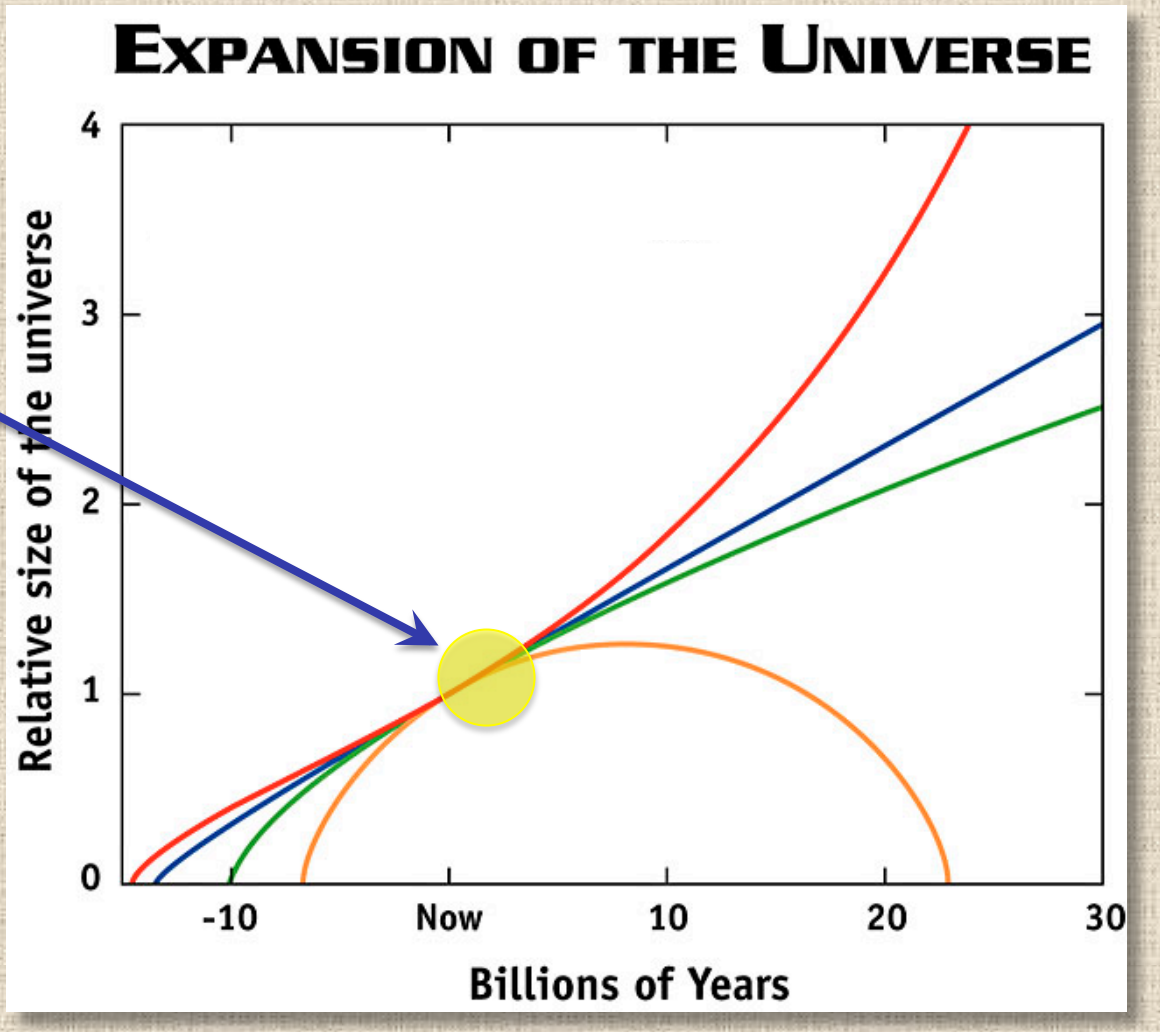
Luigi Guzzo

INAF - Osservatorio di Brera, Milan

The motivations

- (The few) cosmological measurements from existing z~1 samples (VVDS, ZCOSMOS) are cosmic-variance limited
- Look for best compromise between largest possible volume (reduce cosmic variance) and good sampling (reduce Poissonian noise in field reconstructions)
- Exploit VIMOS high multiplexing on moderately large field of view: focus on LSS and clustering, completing and extending the original VVDS-Wide concept
- Use new techniques to maximize volume and sampling in redshift range of interest
- The next step of large-scale structure studies at z~1: in practice, a 2dFGRS at z~1 (but with 5-band photometry)
- But first, let's step back a few years…

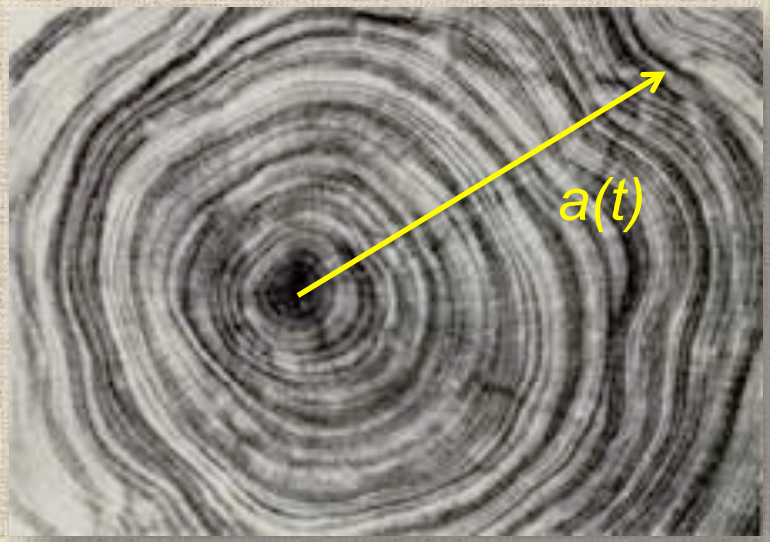
The discovery of cosmic acceleration: going beyond Hubble



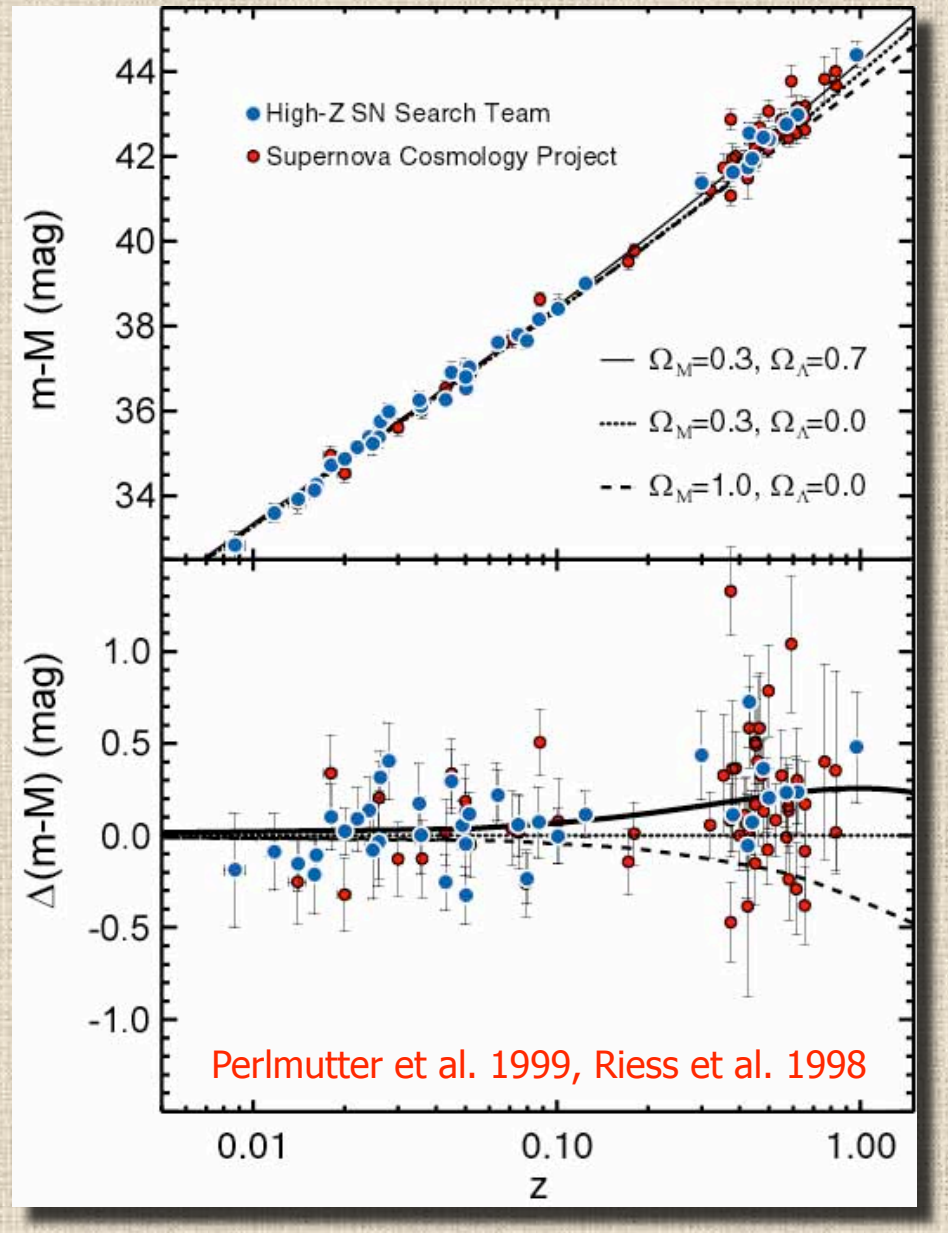
The "Hubble diagram" of Type Ia supernovae tells us that matter is not enough…

$$d_L = (1+z)\int_0^z \frac{c\, dz'}{H(z',\Omega_m,\Omega_\Lambda)}$$

$$H \equiv \frac{\dot{a}}{a}$$



log(Distance d_L)



Redshift of spectral lines

… i.e. that the *expansion history* $H(z)$ given by the Friedmann equation:

$$H^2(z) = H_0^2\{\Omega_m(1+z)^3 + \Omega_k(1+z)^2 + \Omega_\gamma(1+z)^4 + \Omega_x(1+z)^{3(1+w_x)}\}$$

Matter ***Curvature*** ***Radiation*** ***Generic component***

$$\left(H \equiv \frac{\dot{a}}{a};\quad w_x \equiv \frac{p_x}{\rho_x c^2};\quad \Omega_i \equiv \frac{\rho_i}{\rho_c}\right)$$

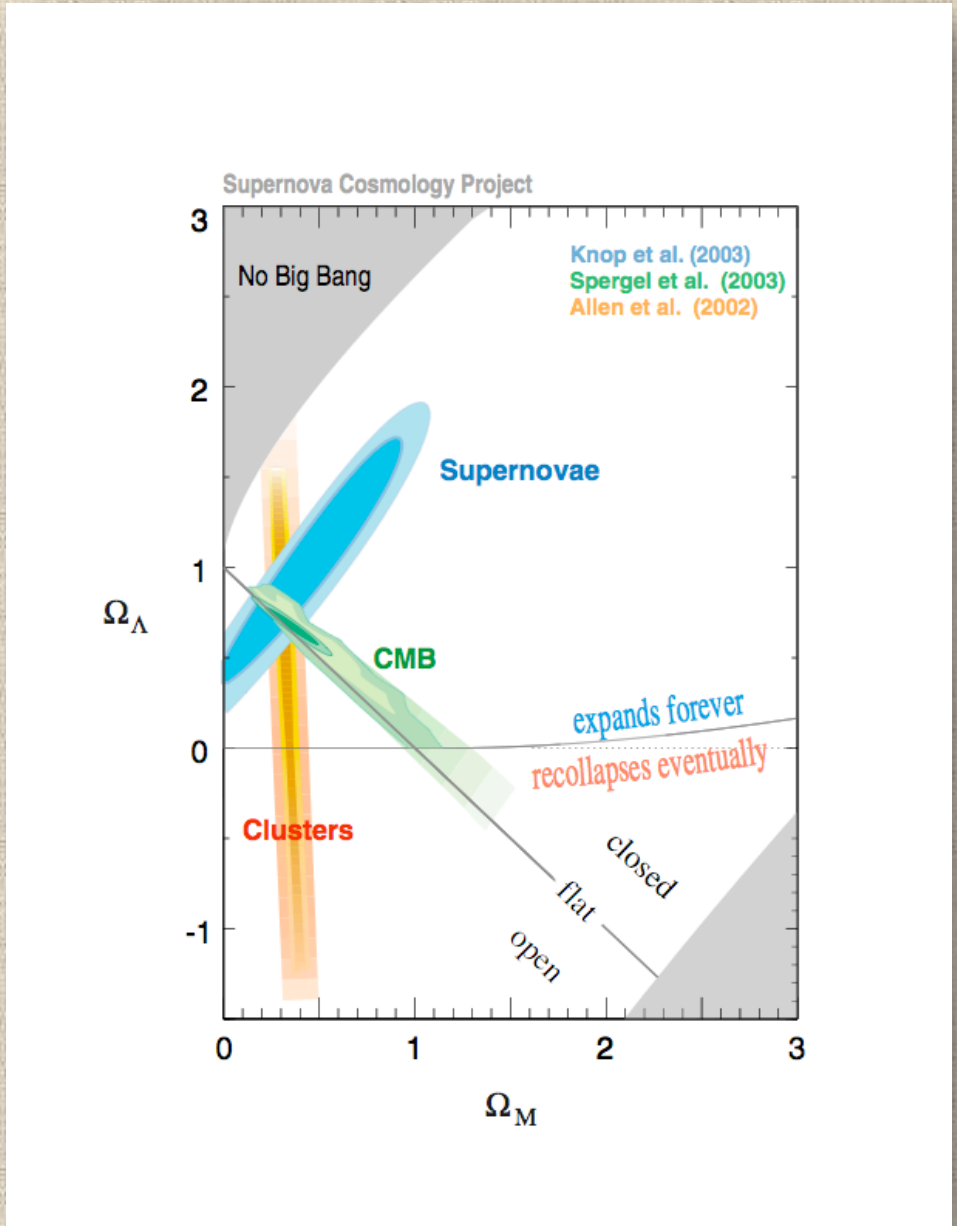
matches the observations only if we add an extra component with *equation of state* $w_x = p/c^2\rho = -1$ corresponding to a cosmological constant Λ with energy density $\Omega_\Lambda \sim 3\Omega_m$:

$$H^2(z) = H_0^2\{\Omega_m(1+z)^3 + \Omega_\Lambda\}$$

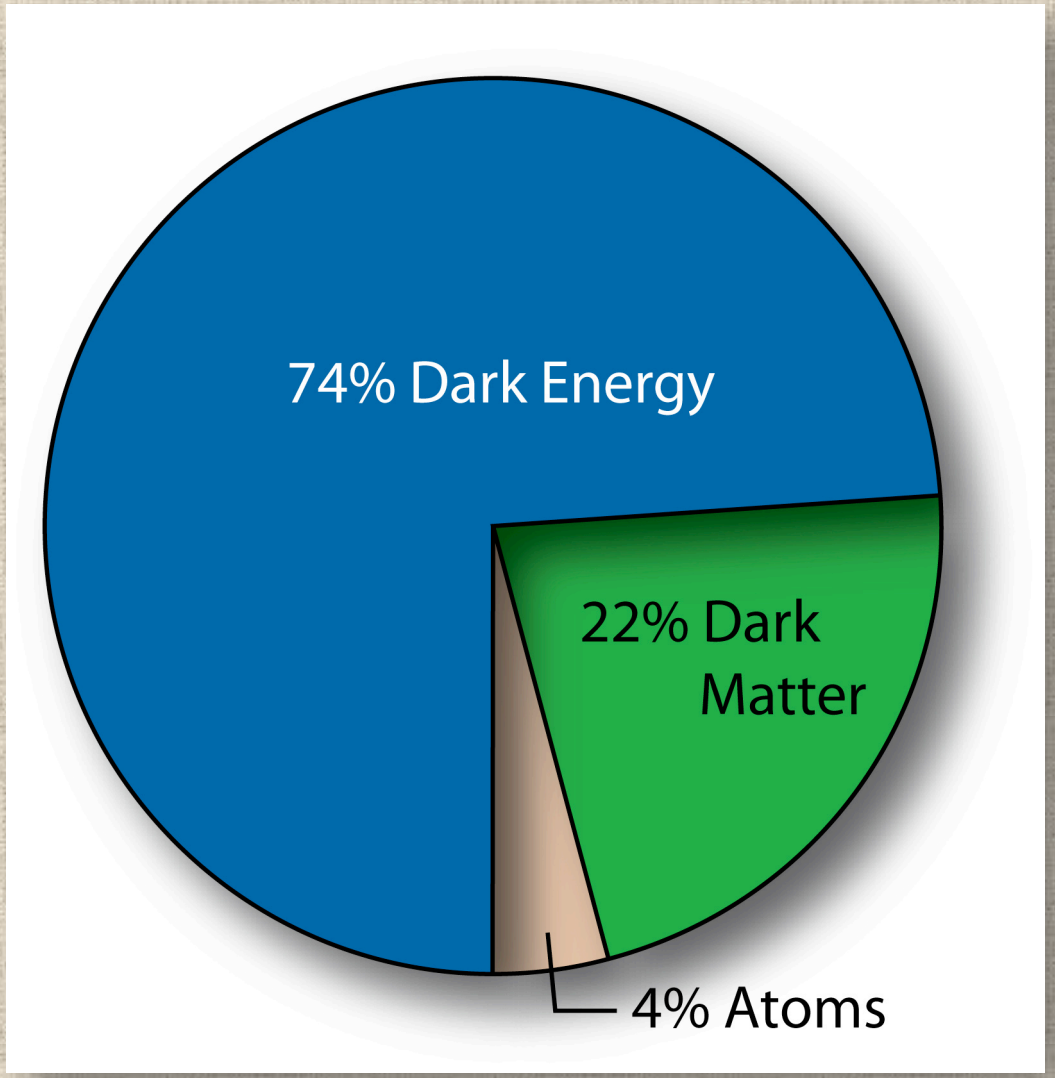
Such that the second equation implies an accelerated Universe:

$$\frac{\ddot{a}}{a} = -\frac{H_0^2}{2}(\Omega_m - 2\Omega_\Lambda)$$

Cosmic concordance



The cosmic mass-energy budget



Is dark energy the only solution? As usual, we need to look at both sides of the story…

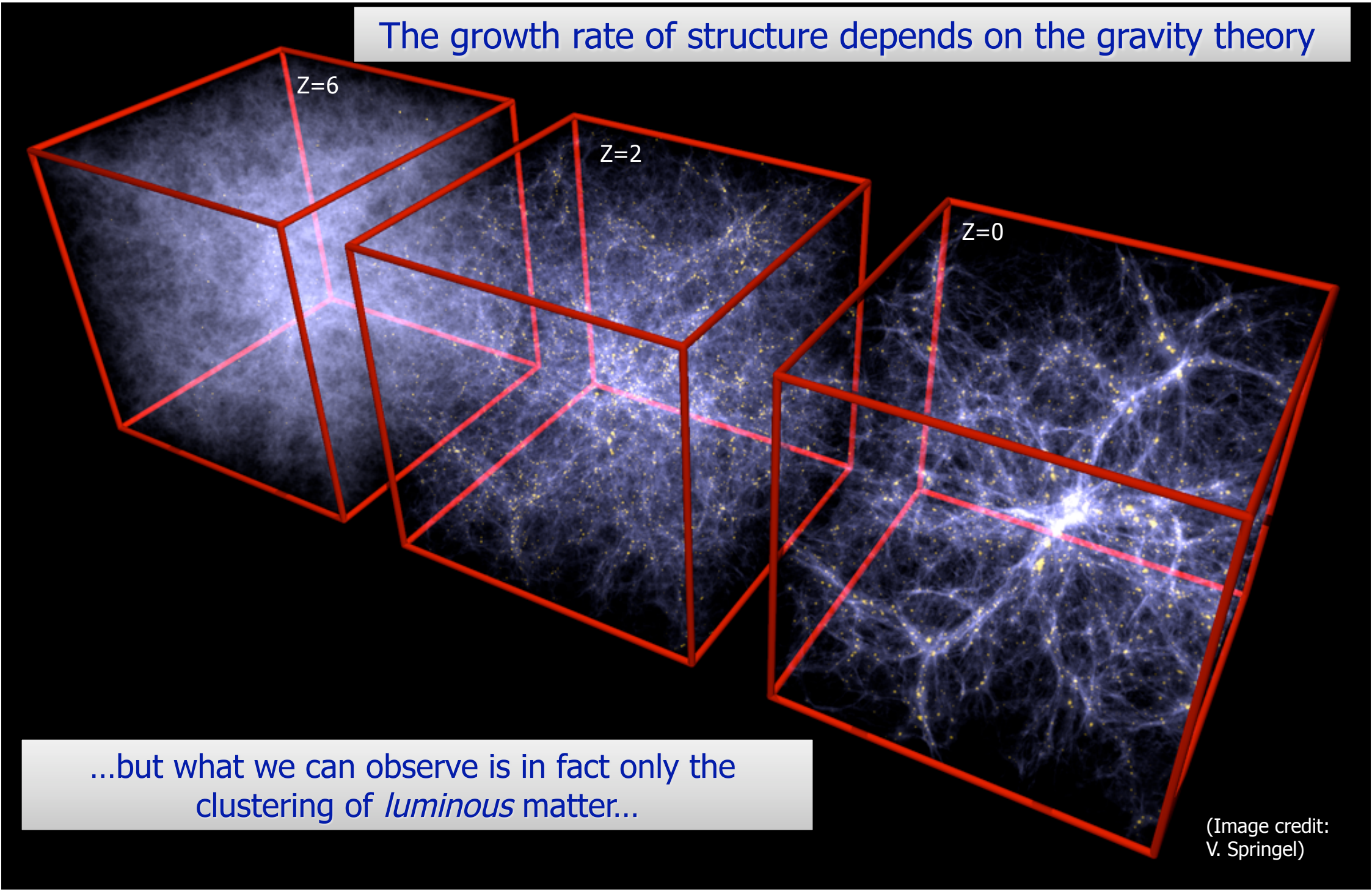
$$R_{\mu\nu} - \frac{1}{2} g_{\mu\nu} R = -\frac{8\pi G}{c^2} T_{\mu\nu} + \Lambda g_{\mu\nu}$$

Modify gravity theory

"…the Force be with you"

Add dark energy

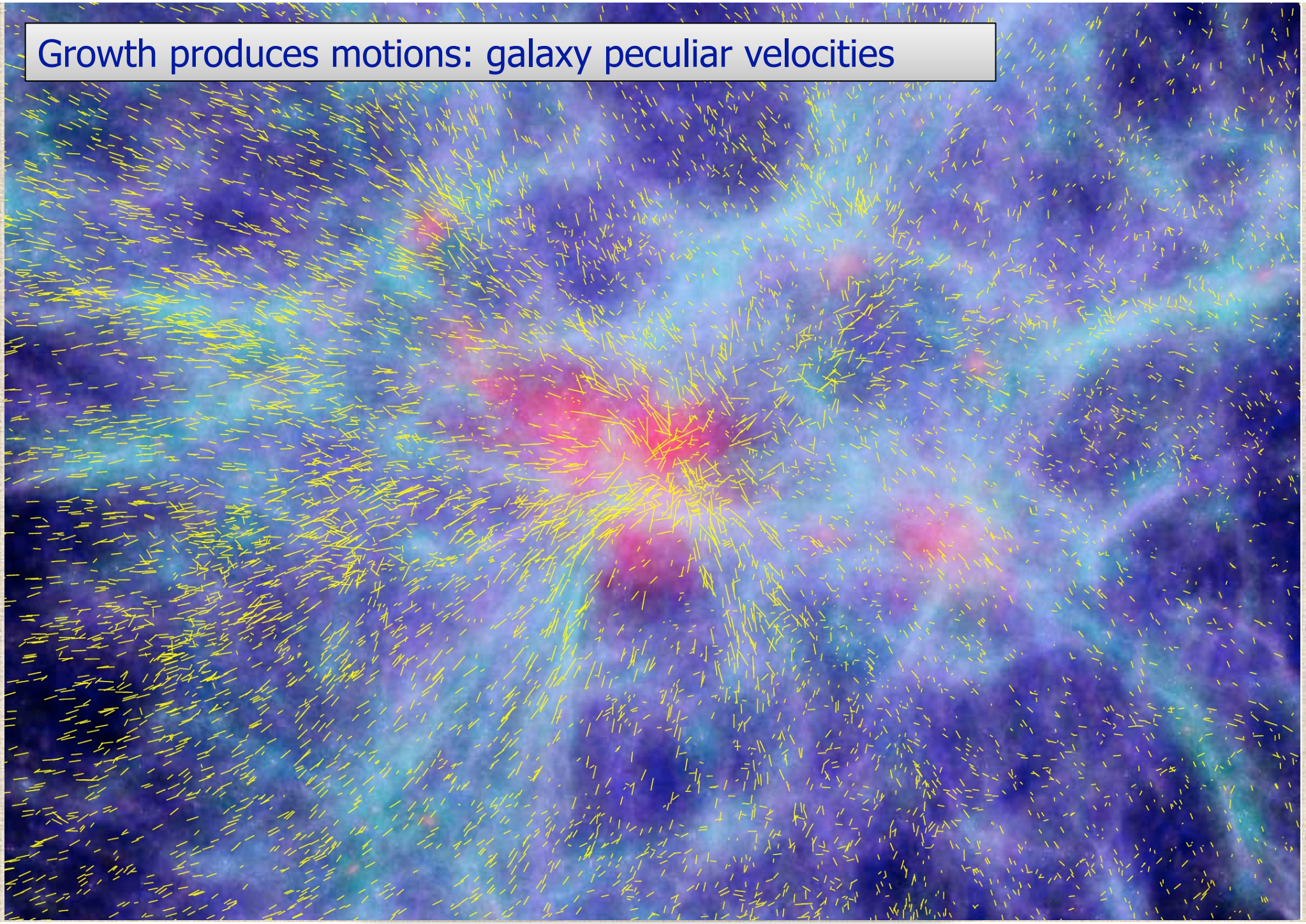
The growth rate of structure depends on the gravity theory



…but what we can observe is in fact only the clustering of *luminous* matter…

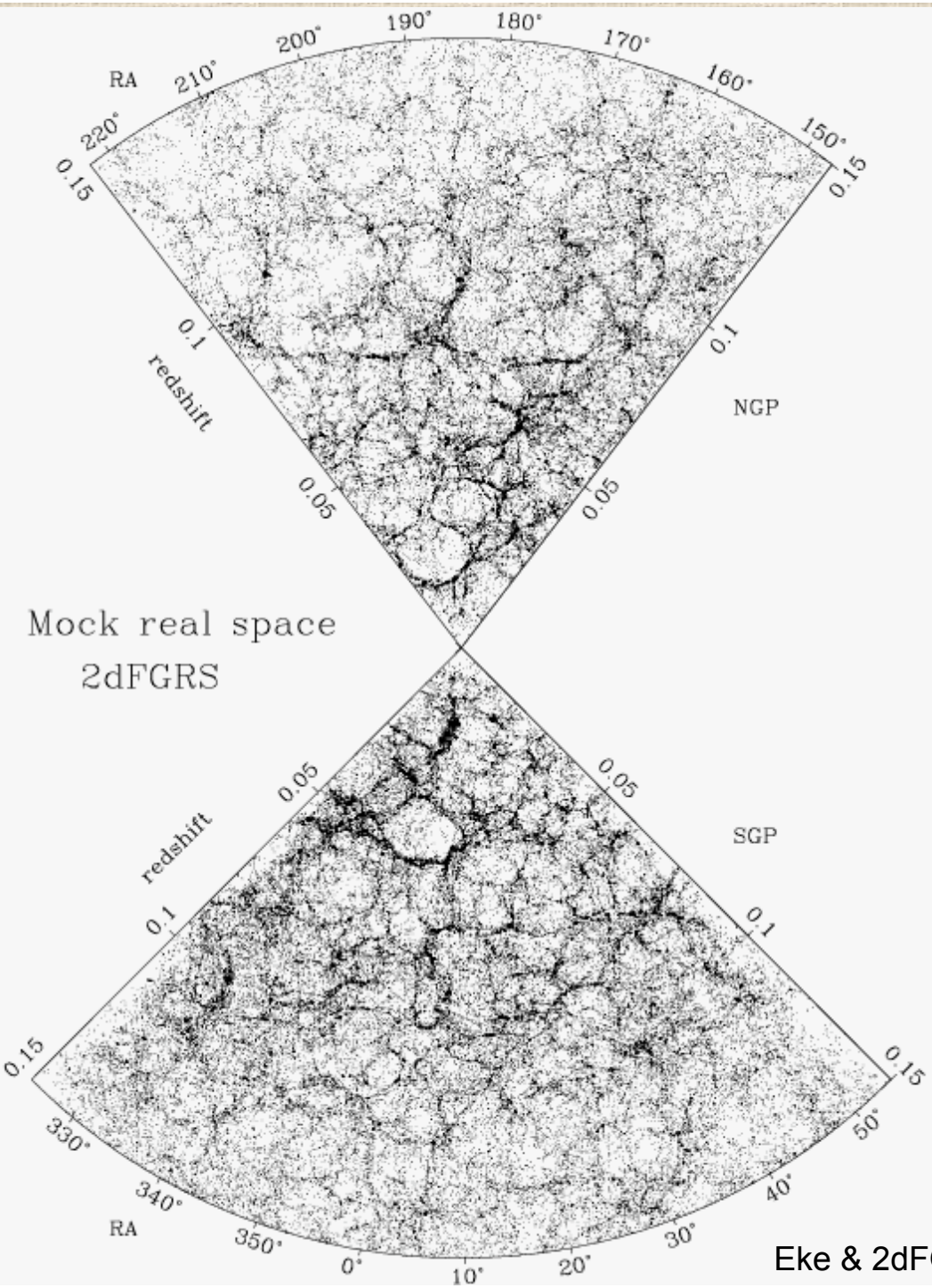
(Image credit: V. Springel)

Growth produces motions: galaxy peculiar velocities



Peculiar velocities manifest themselves in galaxy redshift surveys as *redshift-space distortions*

real space

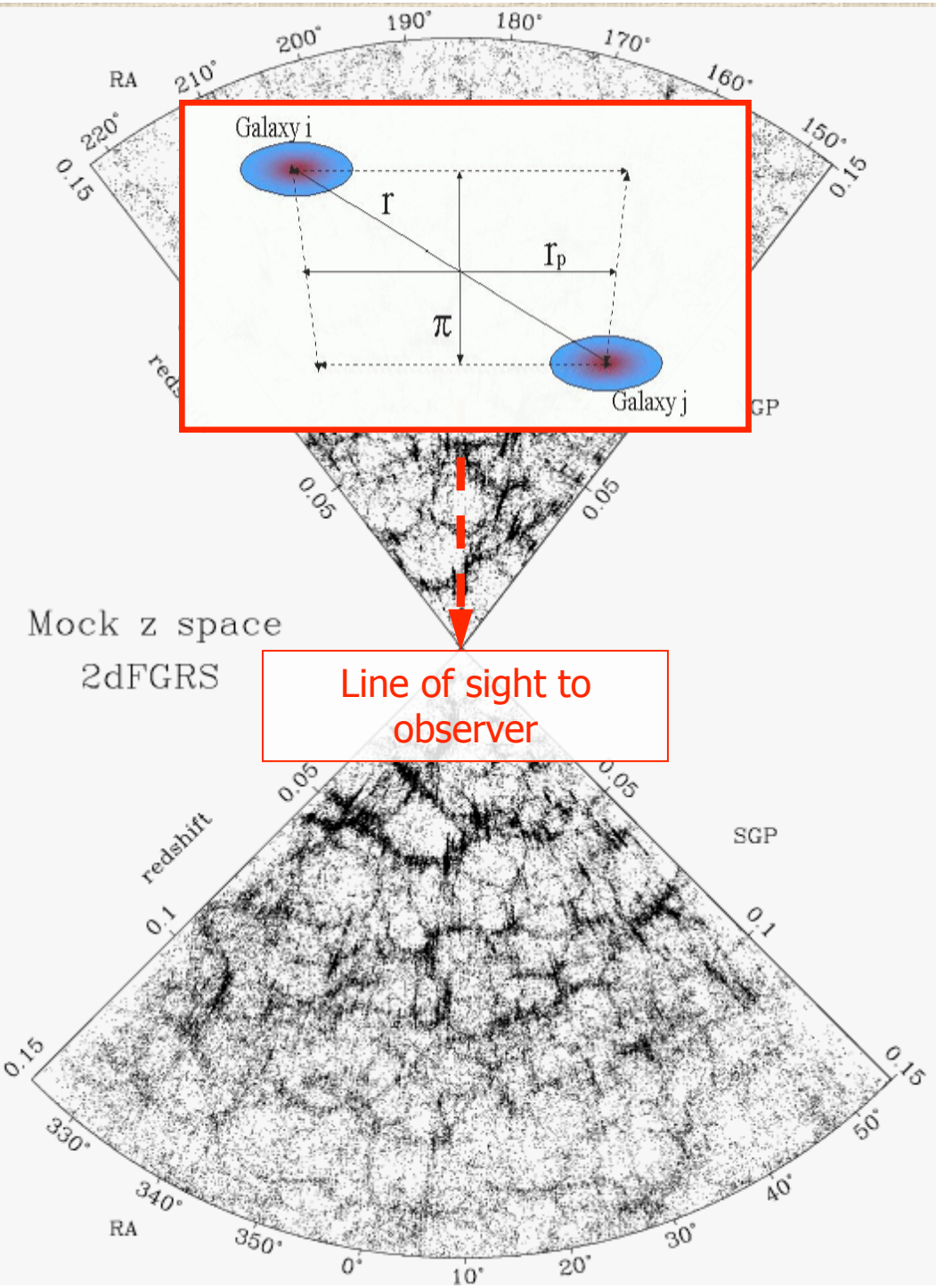


Eke & 2dFGRS 2003

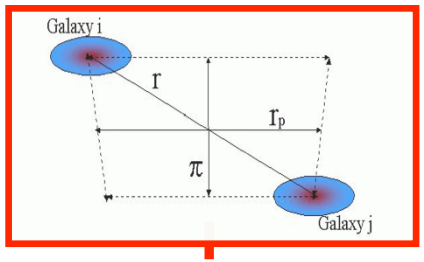
Peculiar velocities manifest themselves in galaxy redshift surveys as *redshift-space distortions*

redshift space

(Kaiser 1987 milestone paper)



Redshift-space galaxy-galaxy correlation function $\xi(r_p,\pi)$



Line of sight to observer

Pair separation perpendicular to line-of-sight $\mathbf{r_p}$ (h^{-1} Mpc)

Pair separation along line-of-sight π (h^{-1} Mpc)

20
15
10
5
0
-5
-10
-15
-20

-20 -15 -10 -5 0 5 10 15 20

No redshift distortions

Full distortions, including small-scale "spindle" due to clusters of galaxies, Ω_m=0.25, Ω_Λ=0.75

s

π

r_p

Linear distortions only, flattening proportional to growth rate: depends on amount and kind of dark matter and dark energy

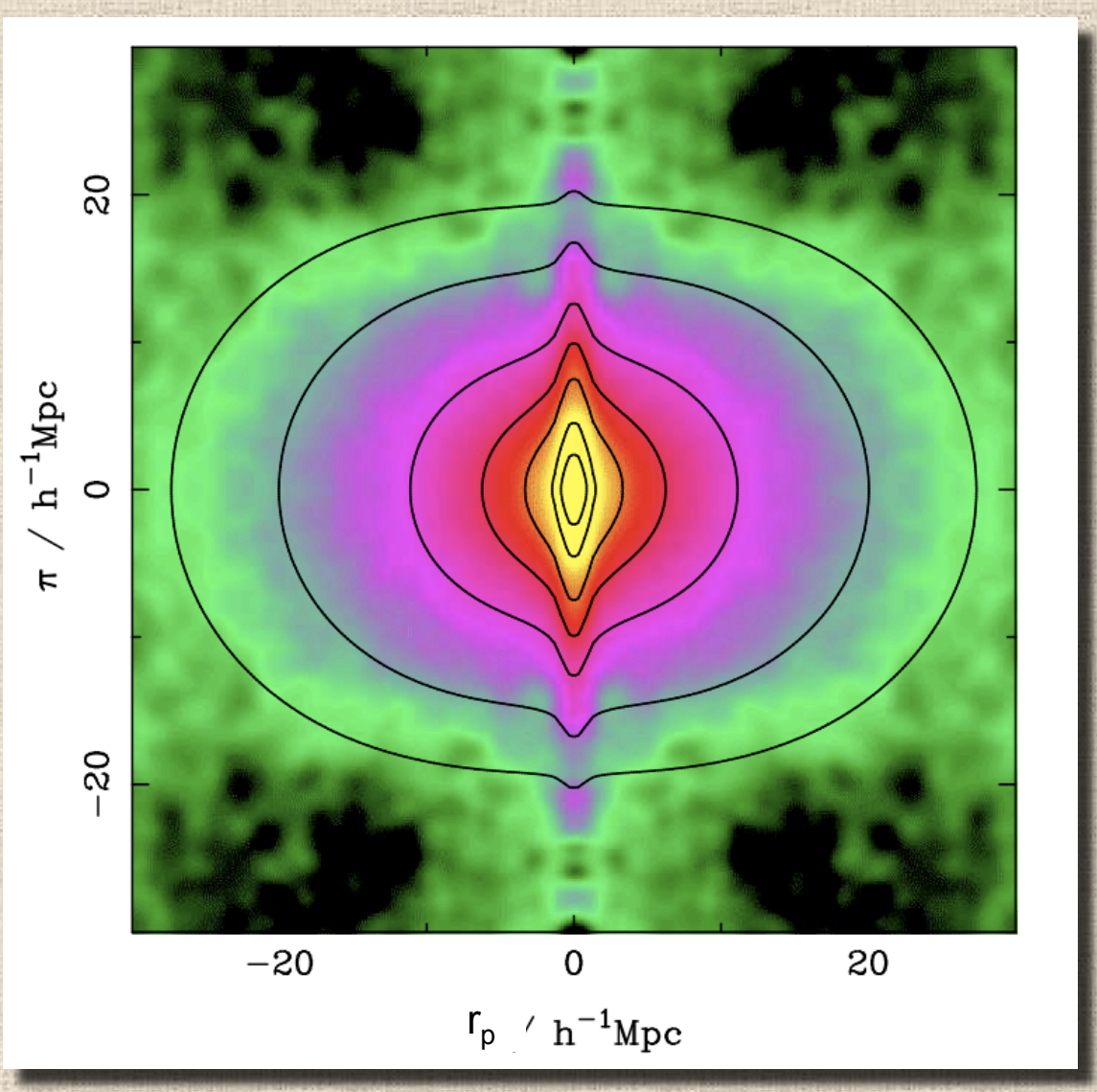
1
0.1
0.01

$f = b_L \beta$

Compression parameter β (Kaiser 1987)

Redshift-space galaxy-galaxy correlation function $\xi(r_p,\pi)$

2dFGRS, z~0.1

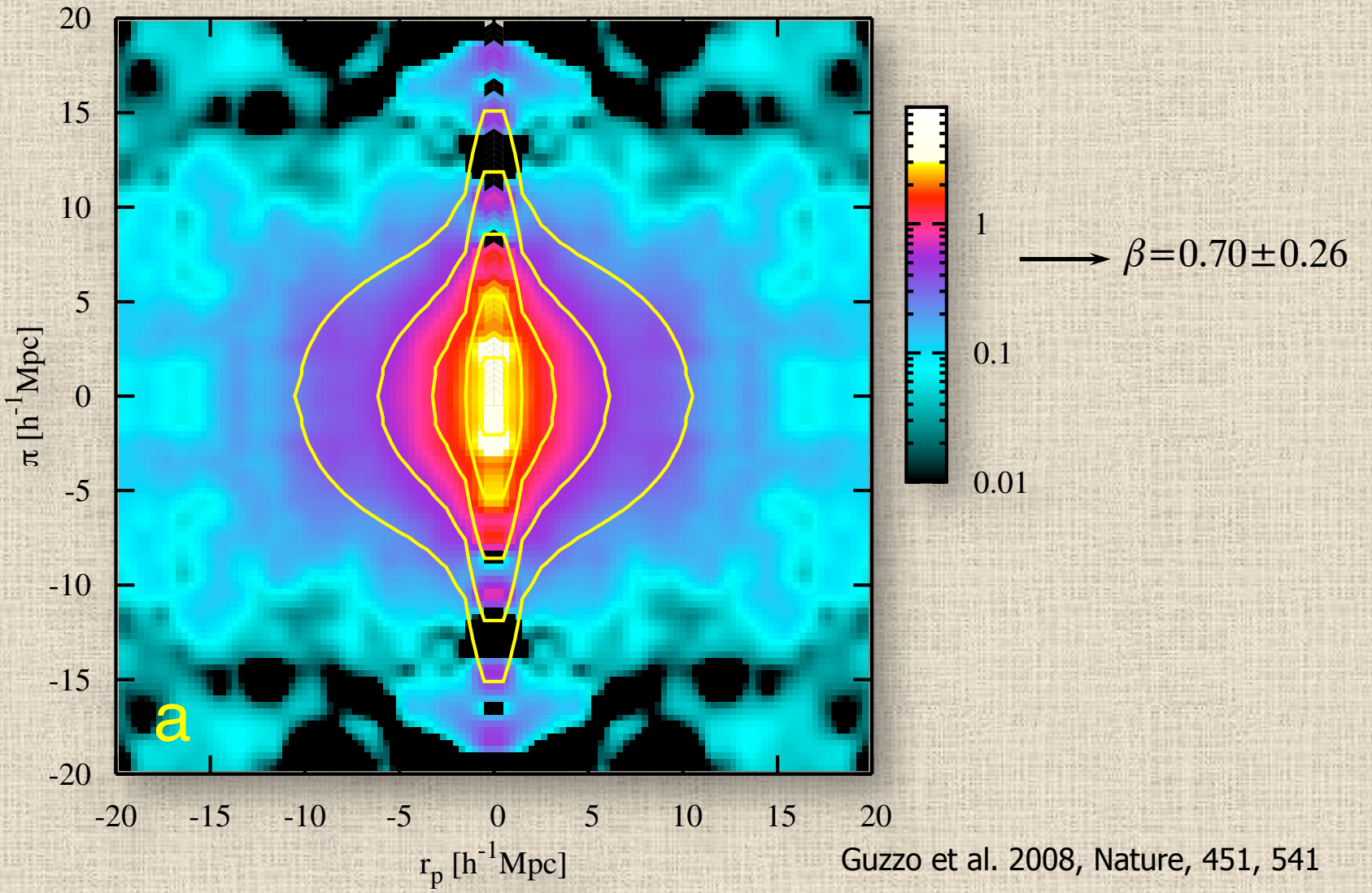


→ Compression parameter $\beta = 0.49 \pm 0.09$

Peacock et al. 2001,
Hawkins et al. 2003

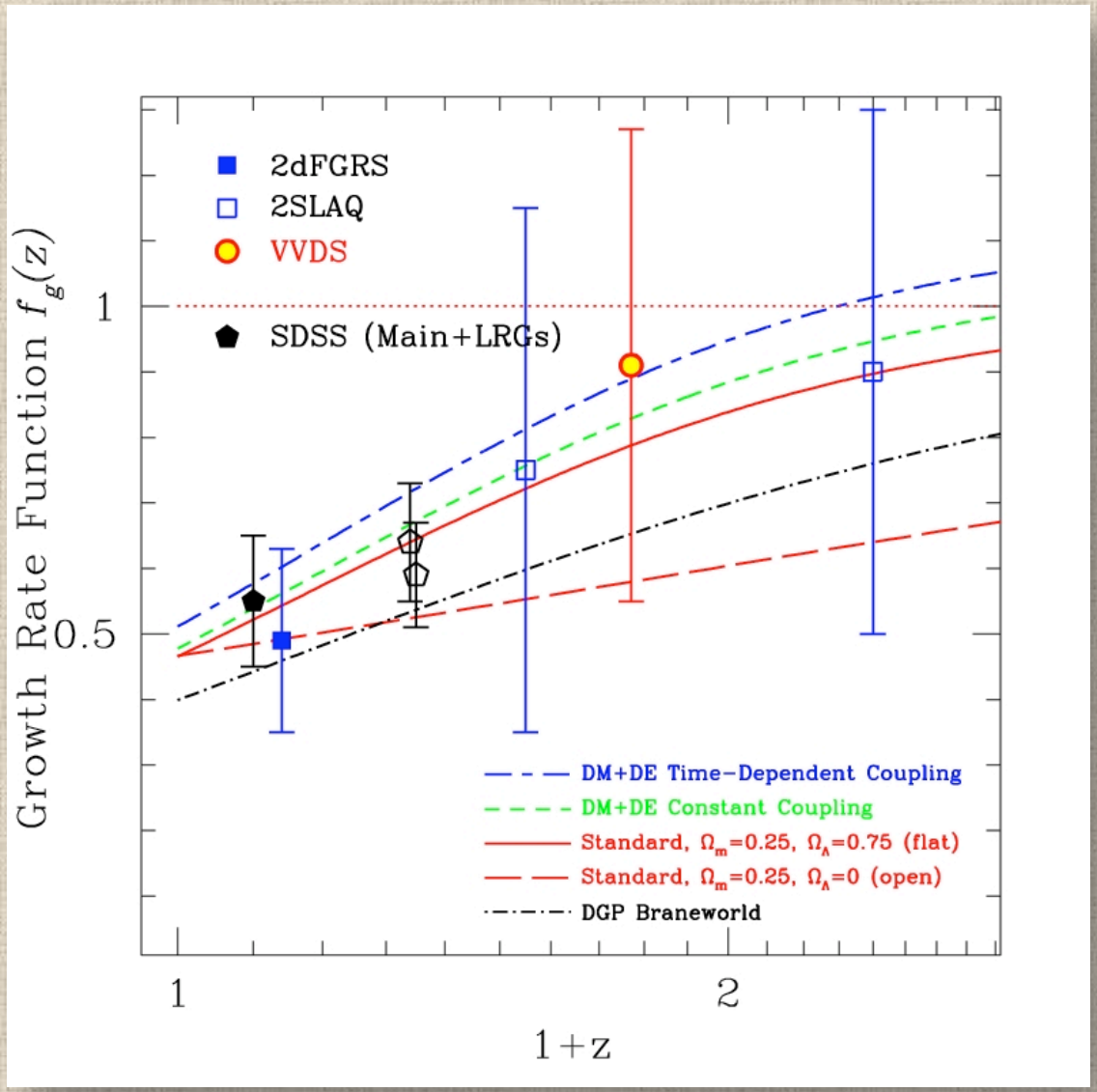
Measuring this (well known) effect at different redshifts provides us with a new important probe to discriminate dark energy from modified gravity

VVDS-Wide, z~0.8



Guzzo et al. 2008, Nature, 451, 541

f(z) from redshift distortions: error bars are large

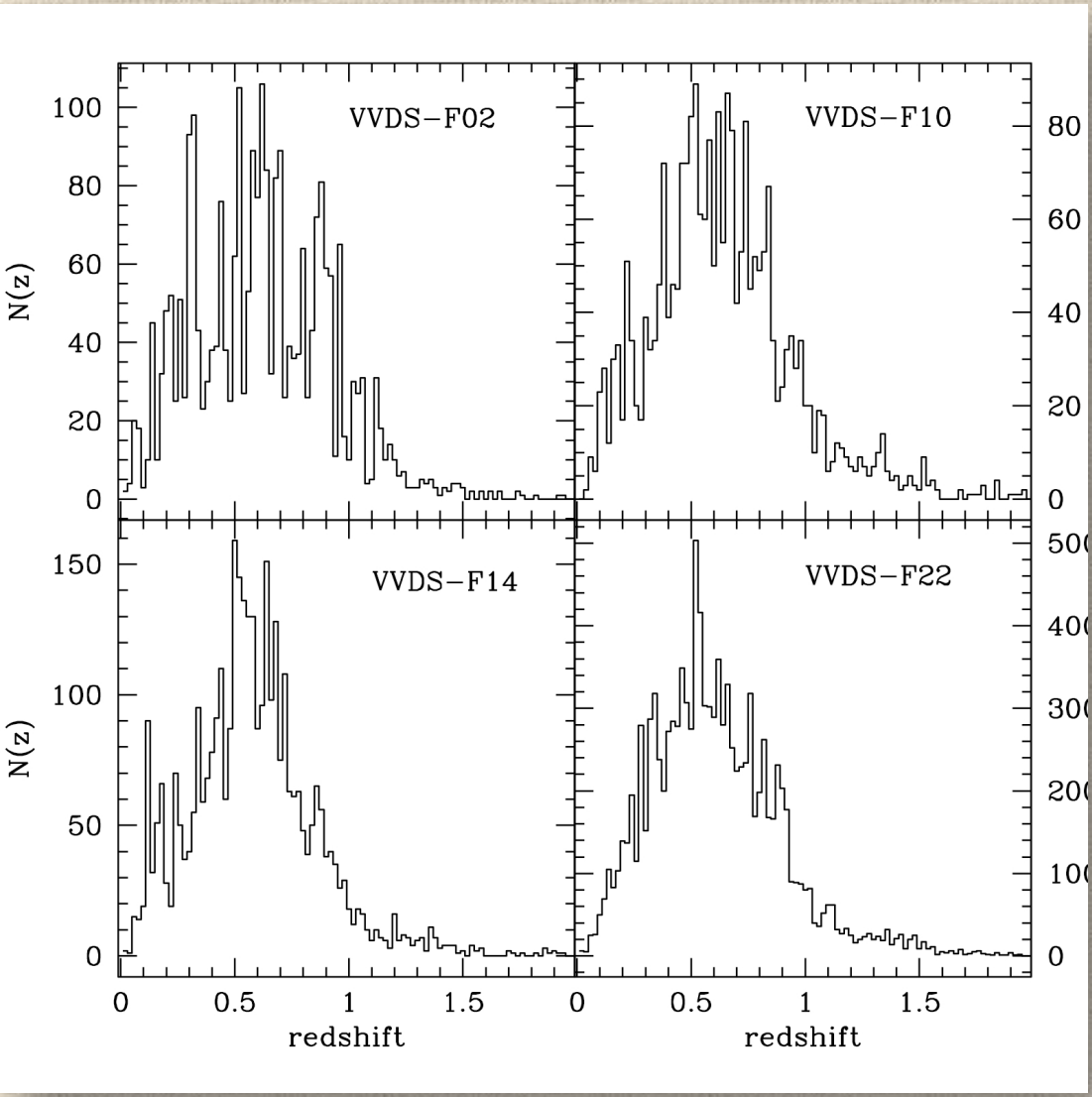


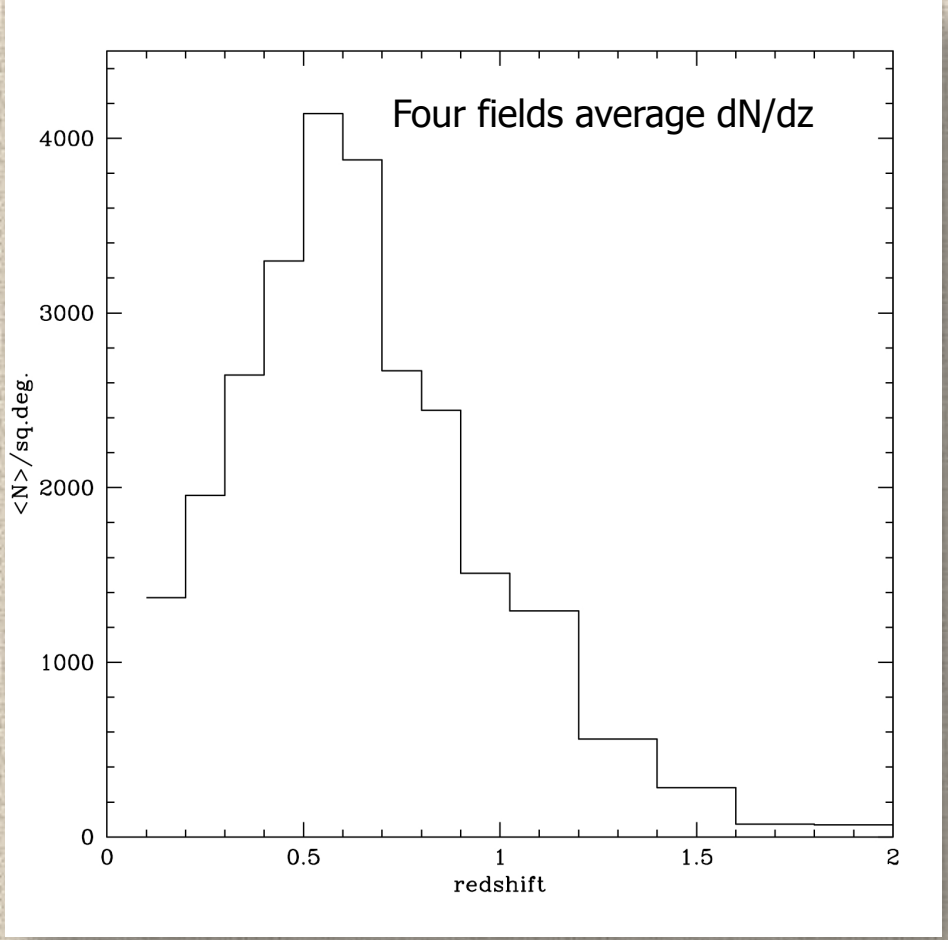
$$f = b_L \beta$$

- 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

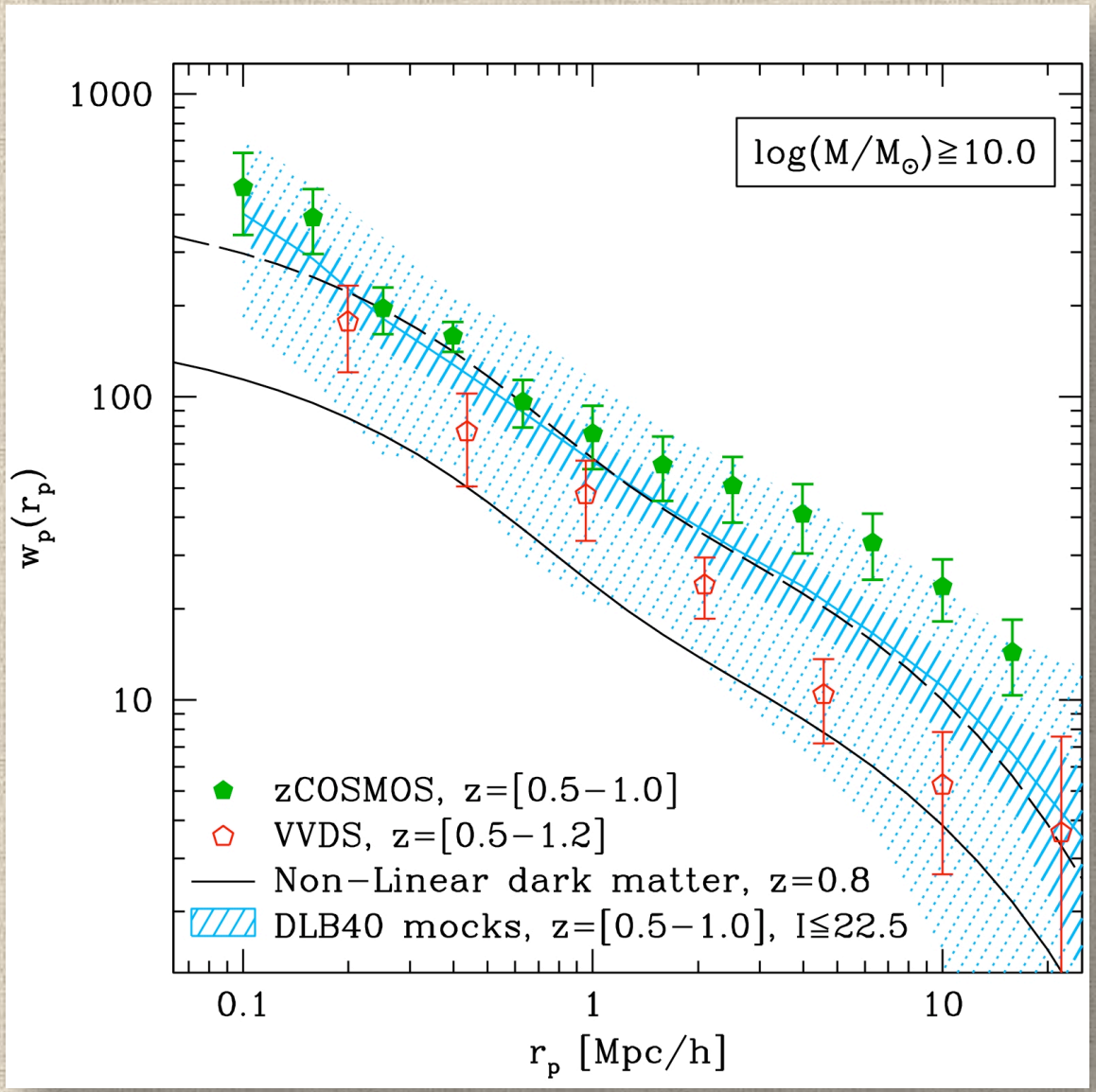
Cosmic variance in VVDS-Wide $I_{AB}<22.5$ fields





Garilli et al. 2008 (Final VVDS Deep + Wide, 33,536 galaxy redshifts)

Cosmic variance in z~1 clustering measurements



Meneux & ZCOSMOS Collaboration, 2009, in press

VVDS: Meneux et al. 2008

Mock samples: Millennium simulation + semi-analytic (Blaizot & De Lucia 2006)

European Organisation for Astronomical Research in the Southern Hemisphere

Organisation Européenne pour des Recherches Astronomiques dans l'Hémisphère Austral
Europäische Organisation für astronomische Forschung in der südlichen Hemisphäre

VISITING ASTRONOMERS DEPARTMENT • Karl-Schwarzschild-Straße 2 • D-85748 Garching bei München • e-mail: visas@eso.org • Tel. : +49-89-32 00 64 73

APPLICATION FOR OBSERVING TIME LARGE PROGRAMME PERIOD: **82A**

Important Notice:

By submitting this proposal, the PI takes full responsibility for the content of the proposal, in particular with regard to the names of CoIs and the agreement to act according to the ESO policy and regulations, should observing time be granted

1. Title Category: **A–3**

The large-scale structure and growth rate of the Universe at $z \sim 1$ from a survey of 100,000 galaxy redshifts

2. Abstract / Total Time Requested

Total Amount of Time: 0 nights VM, 423.0 hours SM Total Number of Semesters: 4

We propose to use VIMOS to realize the first concrete step towards a public ESO redshift survey of the $z \sim 1$ Universe, observing more than 100,000 galaxies with $I_{AB} < 22.5$ over a total area of 24 deg^2. This represents a ten-fold increase over current samples at comparable redshifts and exploits the still unsurpassed multi-plexing capabilities of VIMOS. Such an unprecedented data set will allow us to address a broad range of open problems in large-scale structure and galaxy evolution, with a *legacy* value comparable to that of the 2dFGRS at low redshifts. We shall accurately measure galaxy clustering and redshift-space distortions, quantifying the evolution of the growth rate of structure $f(z)$ between $z = 0.5$ and $z = 1.2$. Through a robust and carefully tested pre-selection of galaxies with $z > 0.5$, we reach an effective sampling rate of $\sim 40\%$ with only one VIMOS shot. Together with the large volume (5×10^7 h^{-3} Mpc^3), such high sampling brings the error on the global growth function in this range below $\sim 8\%$, nearly a factor of five increase with respect to current measurements. This will provide a direct test of the nature of cosmic acceleration, distinguishing dark energy models from modifications of the gravity theory. The measured redshifts will also provide a unique calibration set for next-generation photometric redshift surveys. To maximize its broader impact, the survey areas coincide with the two key fields of the CFHTLS and UKIDSS surveys, where accurate multi-band photometry is available.

VIPERS Team

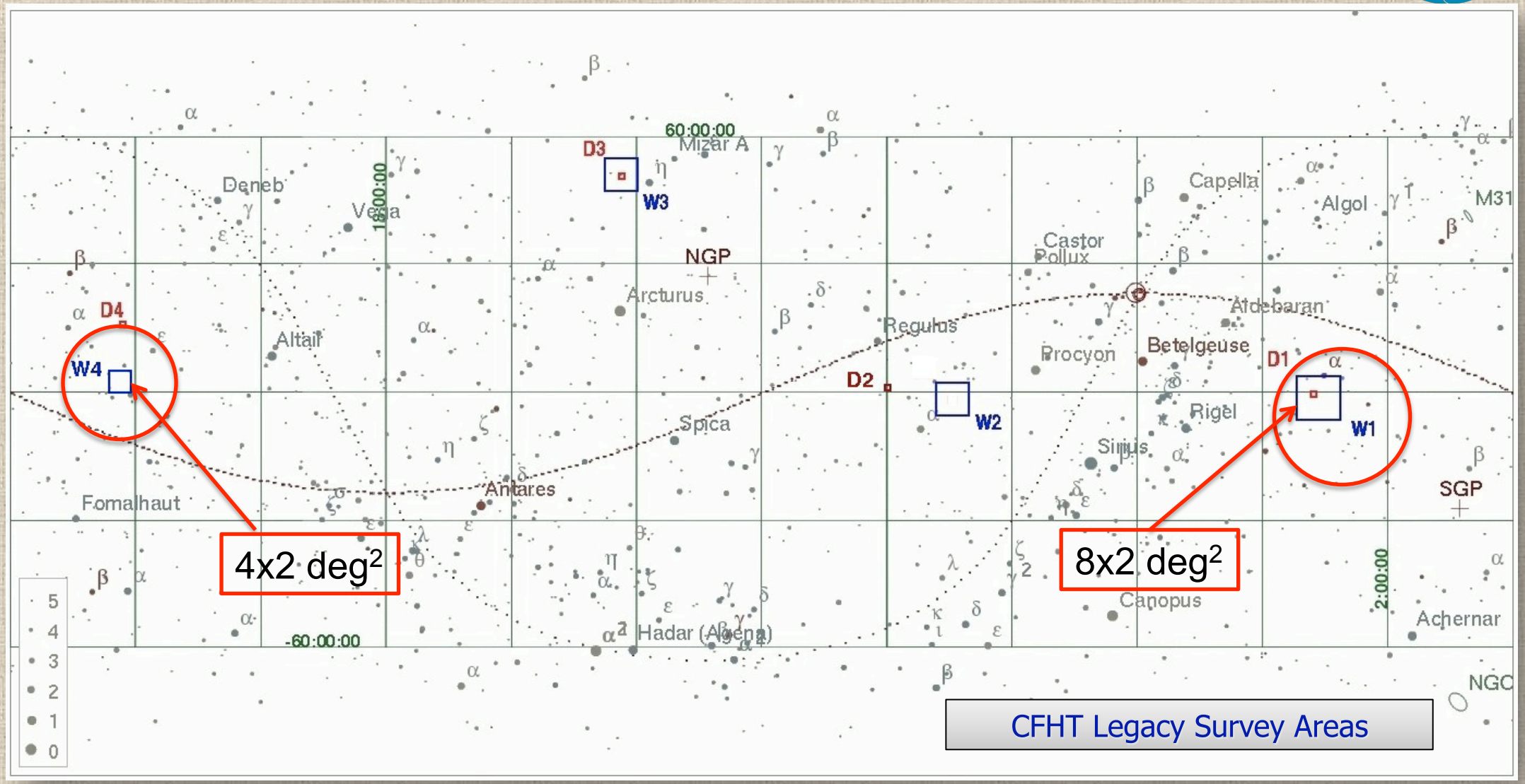
- **MILANO OAB (PI)**: L. Guzzo, S. de la Torre, A. Iovino, U. Abbas (Turin), (E. Majerotto)
- **MILANO IASF** (data reduction center): B. Garilli, M. Scodeggio, D. Bottini, P. Franzetti, D. Maccagni, L. Paioro, M. Polletta, L. Tasca
- **BOLOGNA**: M. Bolzonella, L. Moscardini, A. Cappi, E. Branchini (Rome), F. Marulli, D. Vergani, G. Zamorani, A. Zanichelli
- **EDINBURGH**: J. Peacock
- **GARCHING MPE**: B. Meneux, S. Phleps, H. Schlagenhaufer
- **MARSEILLE**: O. Ilbert, O. Le Fevre, V. Le Brun, C. Adami, O. Cucciati, C. Marinoni
- **PARIS** (TERAPIX CFHTLS center): H. McCracken, J. Coupon, Y. Mellier
- **PORTSMOUTH**: W. Percival, R. Nichol, R. Tojeiro, A. Raccanelli
- **LYON/TRIESTE**: J. Blaizot, G. de Lucia
- **WARSAW**: A. Pollo, J. Krywult, K. Malek

The project in a nut-shell

- 440.5 VLT hours
- ~24 deg^2 in the CFHTLS wide fields:
  - ~2x8 deg^2 slice in W1
  - ~2x4 deg^2 slice in W4
- 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)
- >50% sampling
- >100,000 redshifts

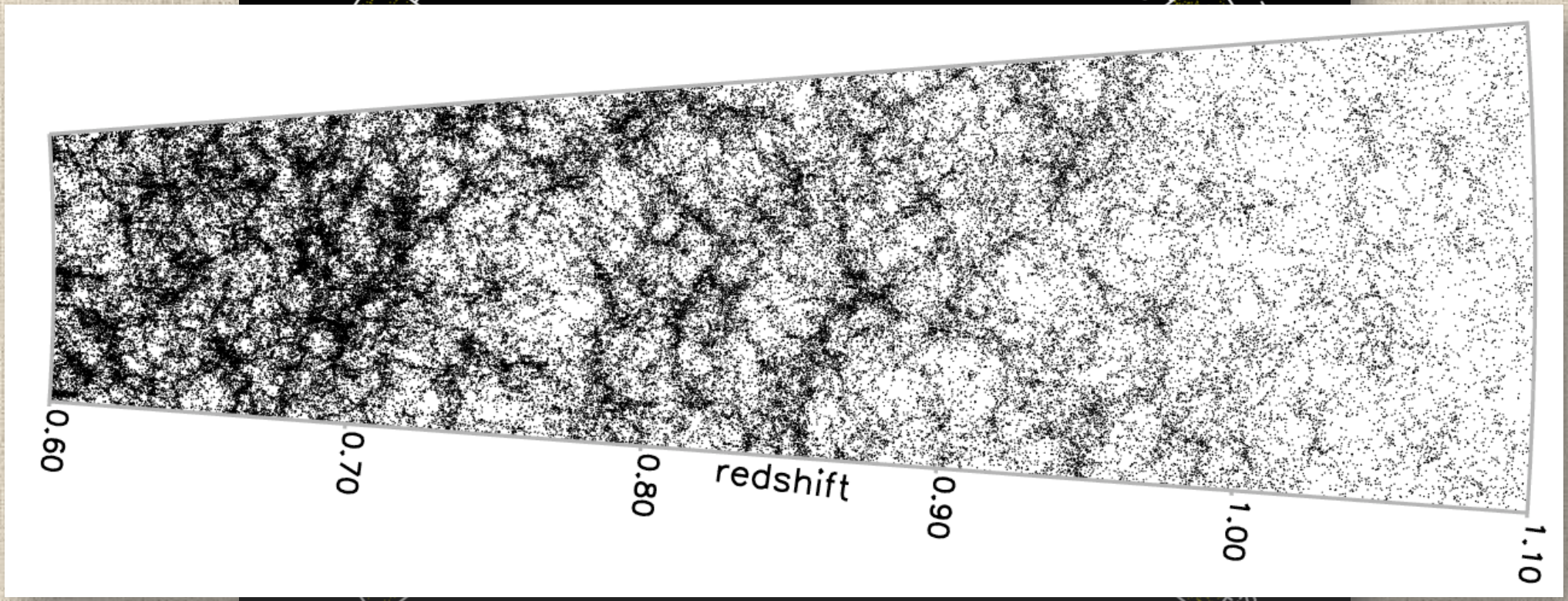
A	82	18.5 h	oct	IMA
B	82	13.0 h	oct	MOS
C	82	43.0 h	nov	MOS
D	82	45.0 h	dec	MOS
E	83	12.5 h	jul	IMA
F	83	23.0 h	aug	IMA
G	83	39.0 h	aug	MOS
H	83	33.5 h	sep	MOS
I	84	33.0 h	oct	MOS
J	84	43.0 h	nov	MOS
K	84	45.0 h	dec	MOS
L	85	8.5 h	jul	IMA
M	85	6.0 h	aug	IMA
N	85	39.0 h	aug	MOS
O	85	40.0 h	sep	MOS

Location of VIPERS fields



VIPERS: a 2dFGRS at 0.5<z<1.2

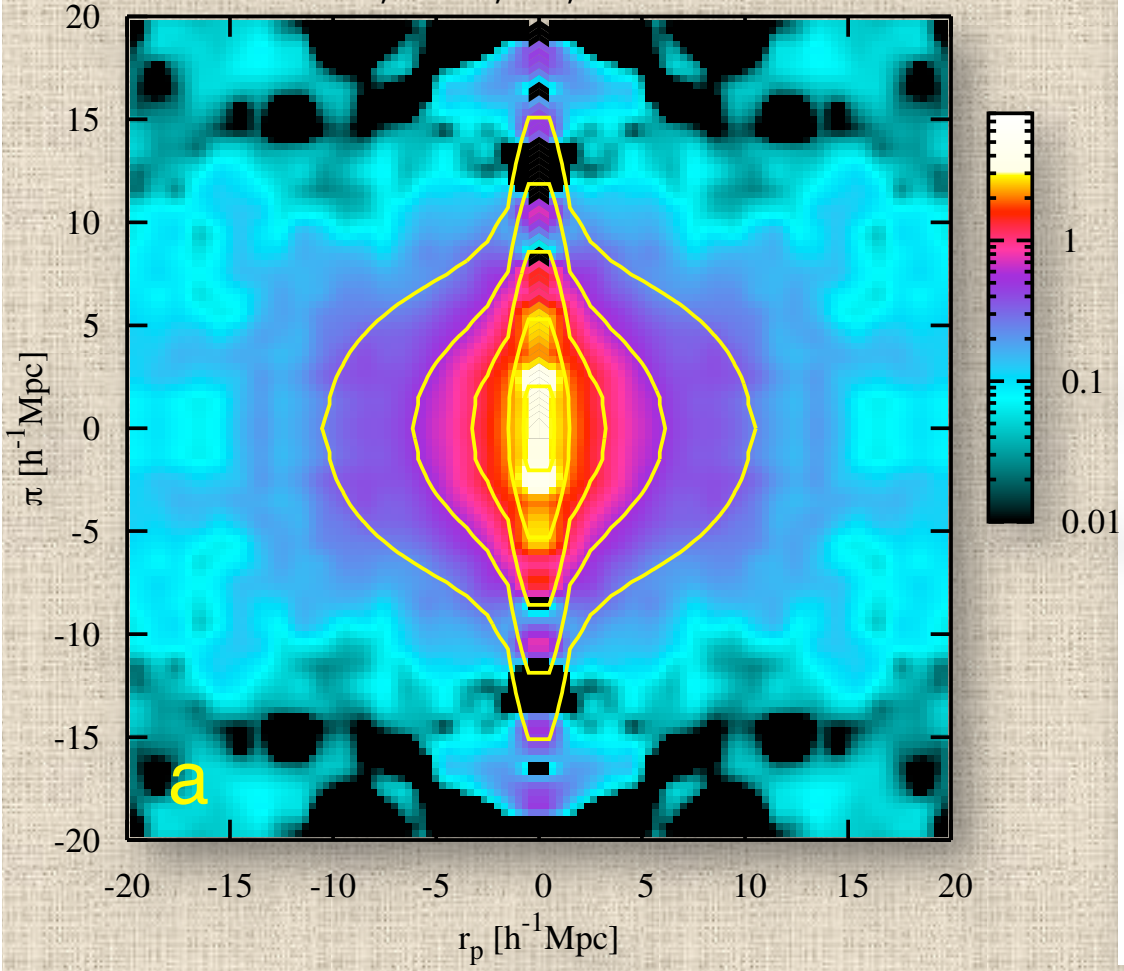
VIPERS 2x8 deg2 slice in CFHTLS W1 field (mock sample by J. Blaizot & G. De Lucia)



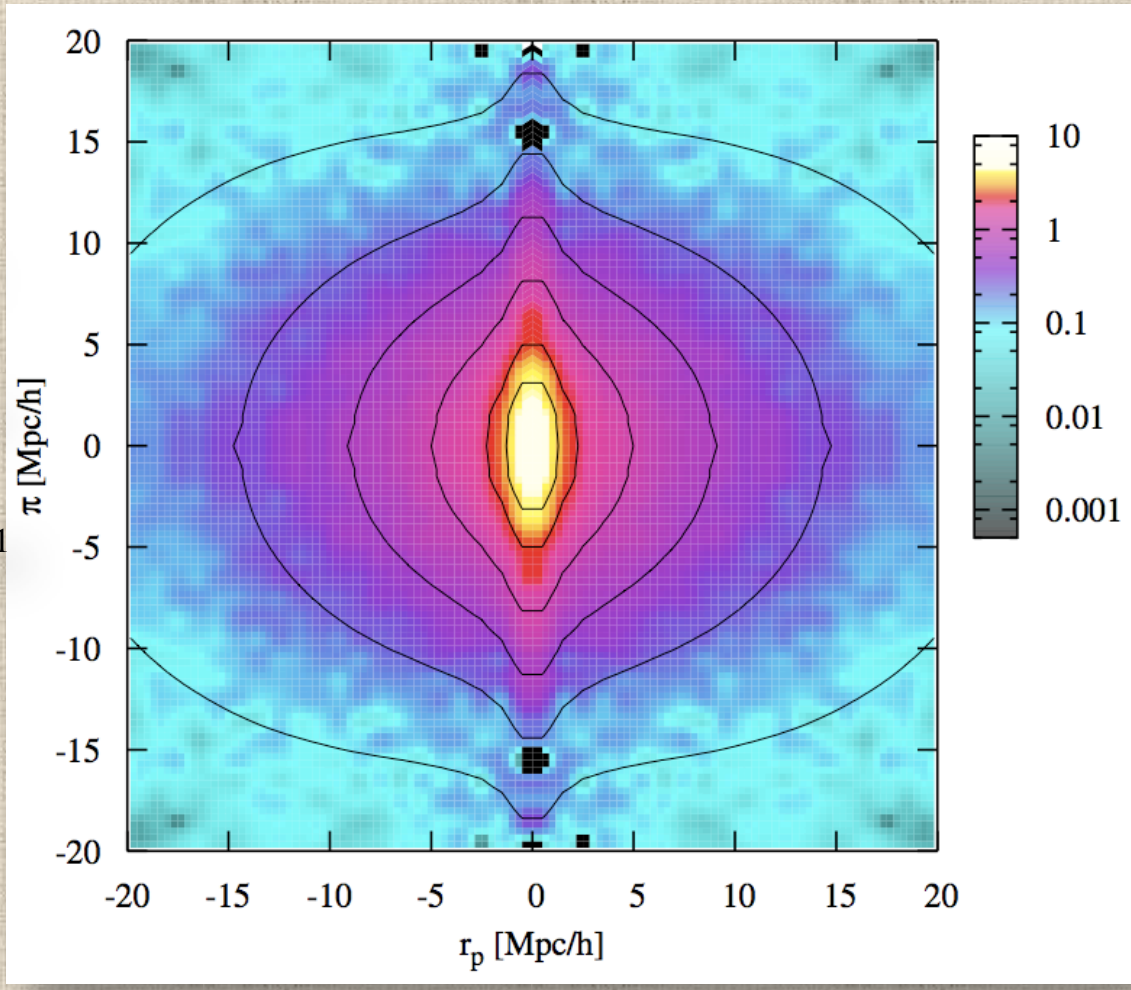
+2x4 deg2 slice in CFHTLS W4 field (VVDS F22)

Growth rate from redshift-space distortions

Guzzo et al 2008, Nature, 451, 541



VVDS F22 (~6000 gals)



VIPERS (~100,000 gals)

(Conservative) forecast on f(z) in two bins from VIPERS

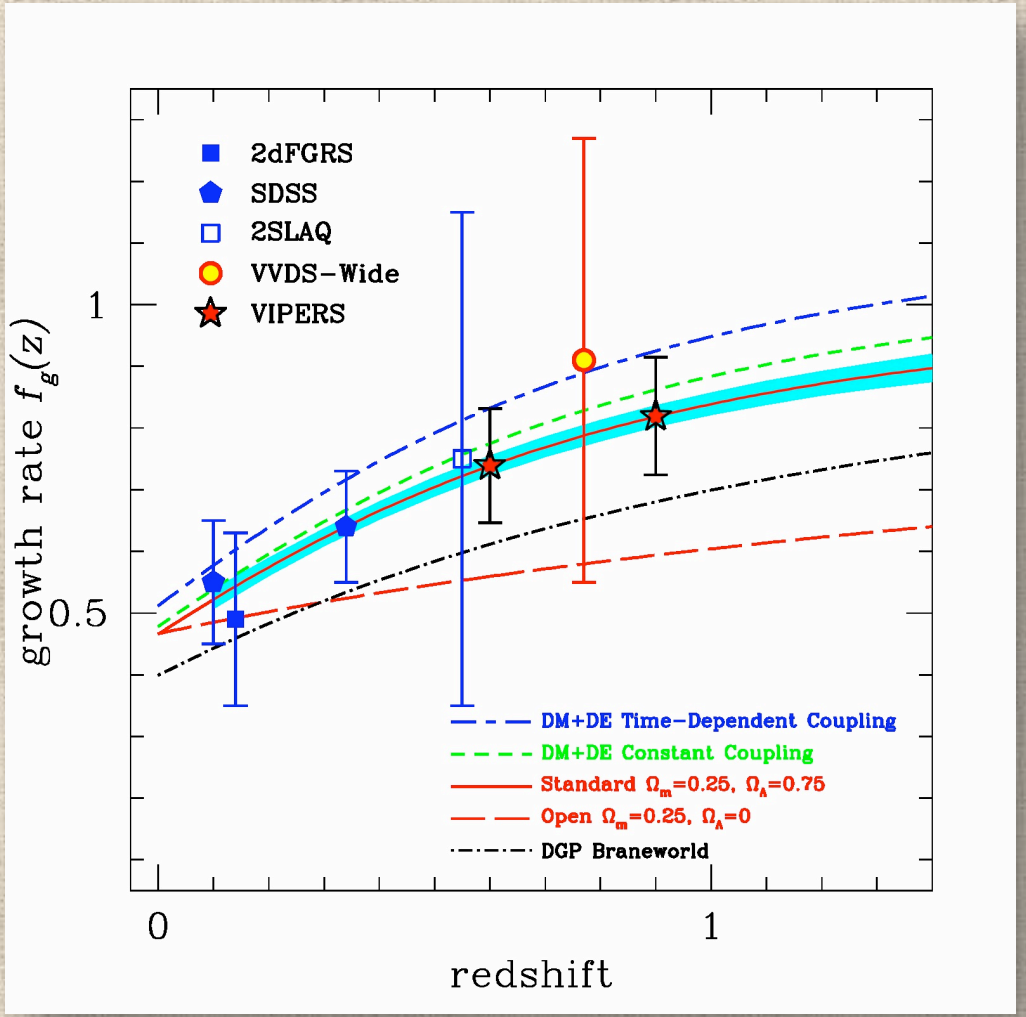
→Scaling relation for errors from Monte Carlo tests (Guzzo et al. 2008):

$$\frac{\sigma_\beta}{\beta} \approx \frac{C}{V^{0.5}} b^{0.7} \exp\left\{\frac{B}{b^4 \langle n \rangle^2}\right\}$$

(D. Bianchi, Master thesis UniMi, 2010)

→Measure $\beta \sim f\sigma_8$ with better than ~10% uncertainty within two redshift bins: already rule out classes of modified gravity models (e.g. DGP)

→High-sampling survey (<N>~2 10^{-3} h^3 Mpc^{-3}), contrary to most ongoing/planned large-volume surveys at z>0.5 (e.g. WiggleZ, BOSS): can potentially apply 2-population technique (McDonald & Seljak 2009) to abate errors by a factor >3



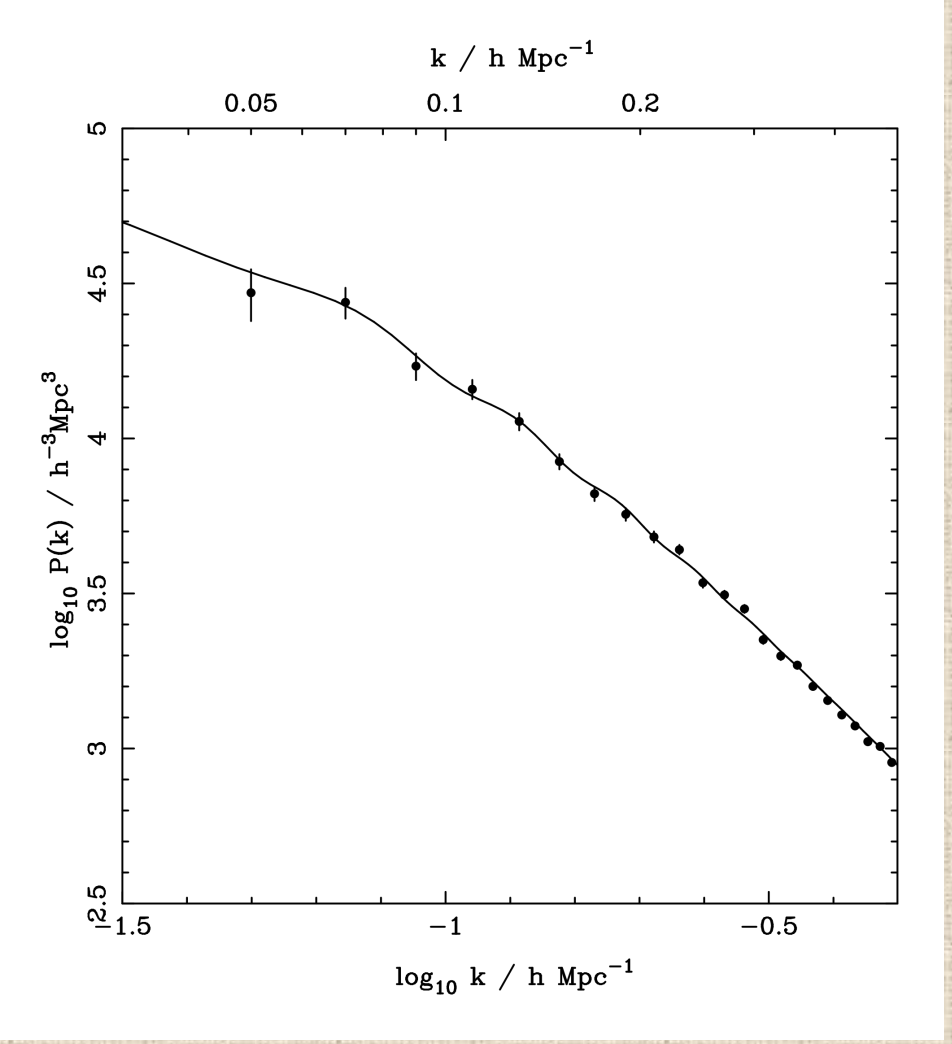
VIPERS broader scientific goals

- 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 of clustering on galaxy properties
  - HOD modeling
- Galaxy bias
- 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)

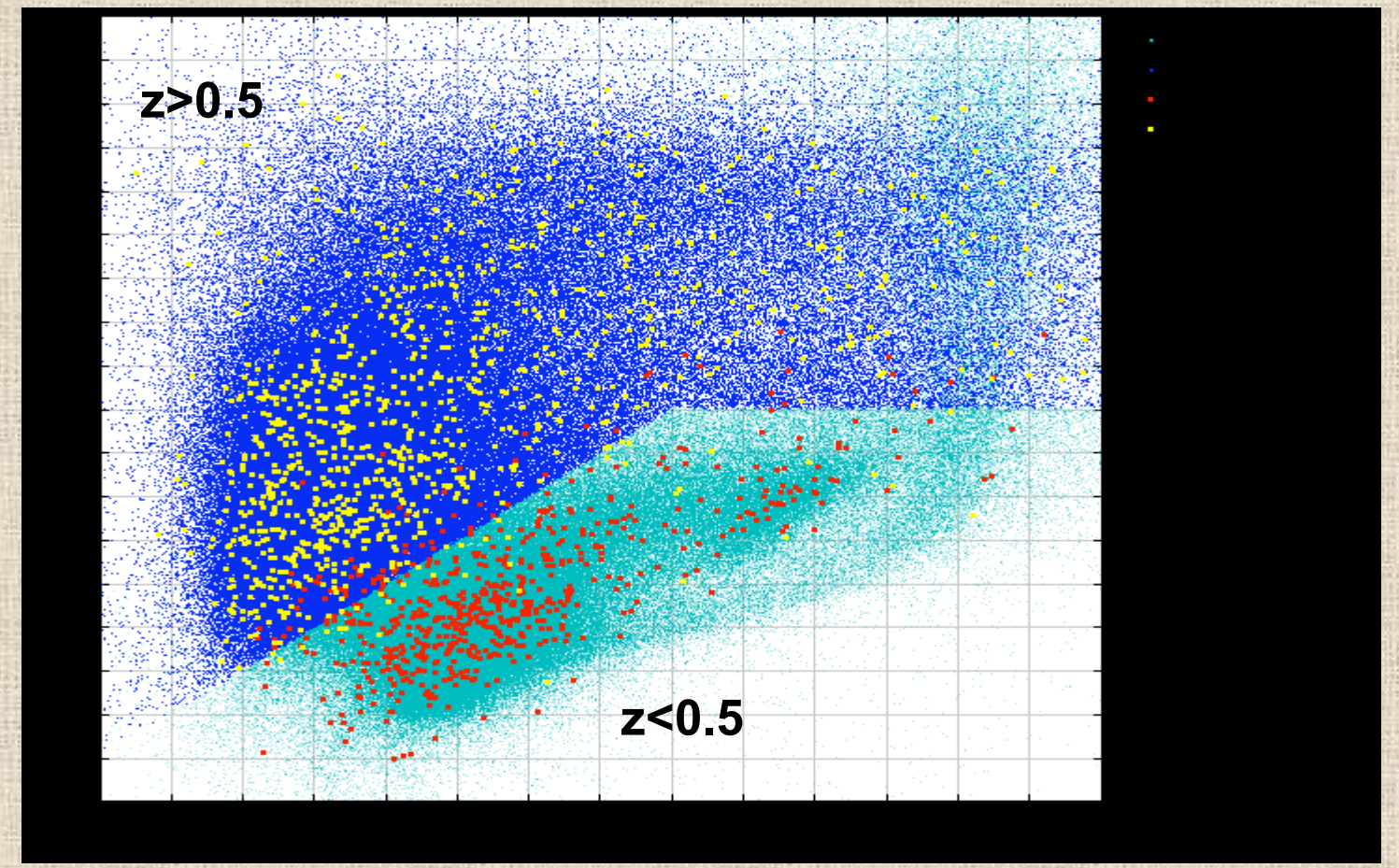
Expected P(k) at <z>~0.8 from VIPERS

(from W. Percival)

- 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

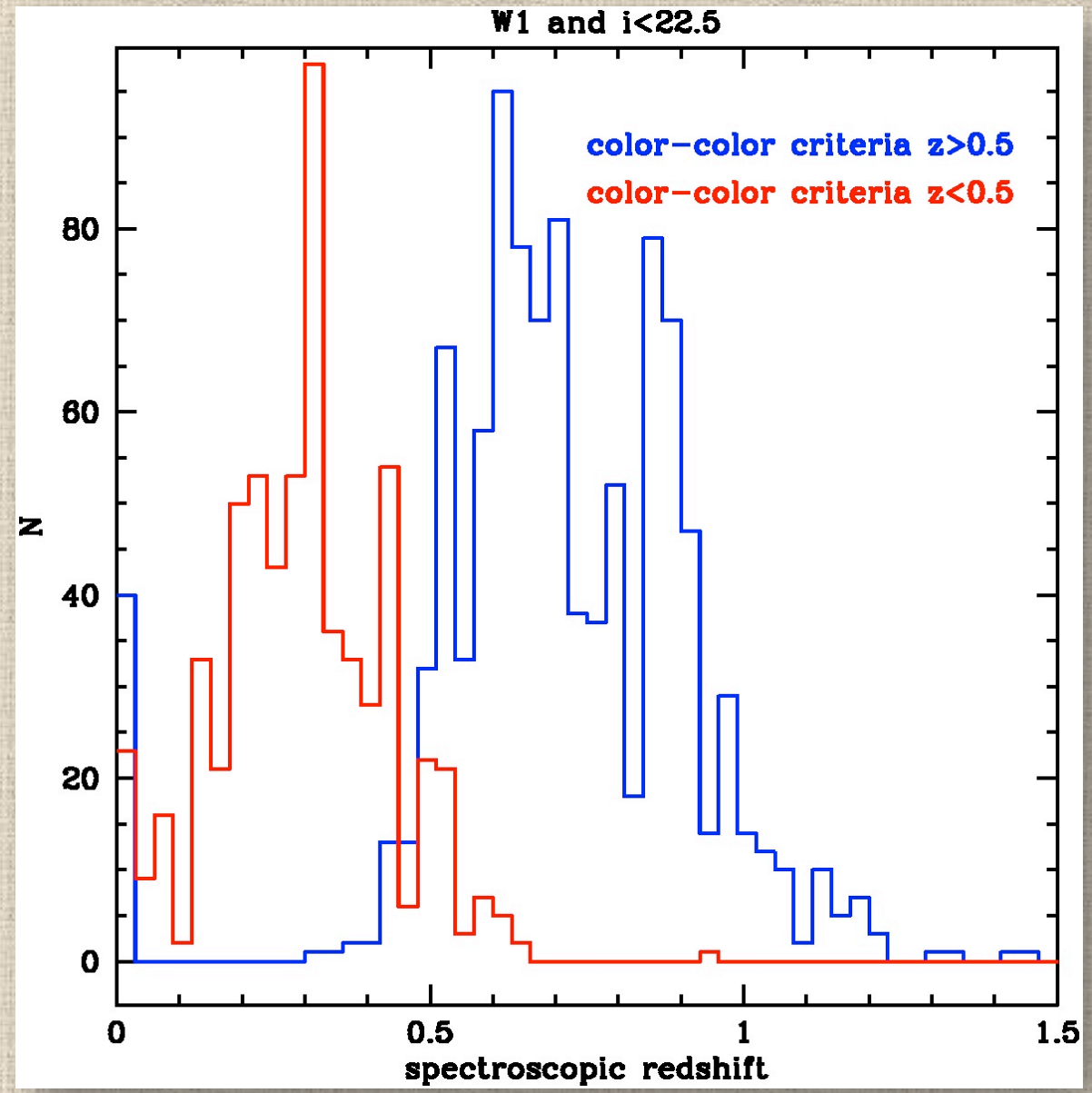


VIPERS COLOR-COLOR SELECTION: ISOLATING z>0.5 GALAXIES



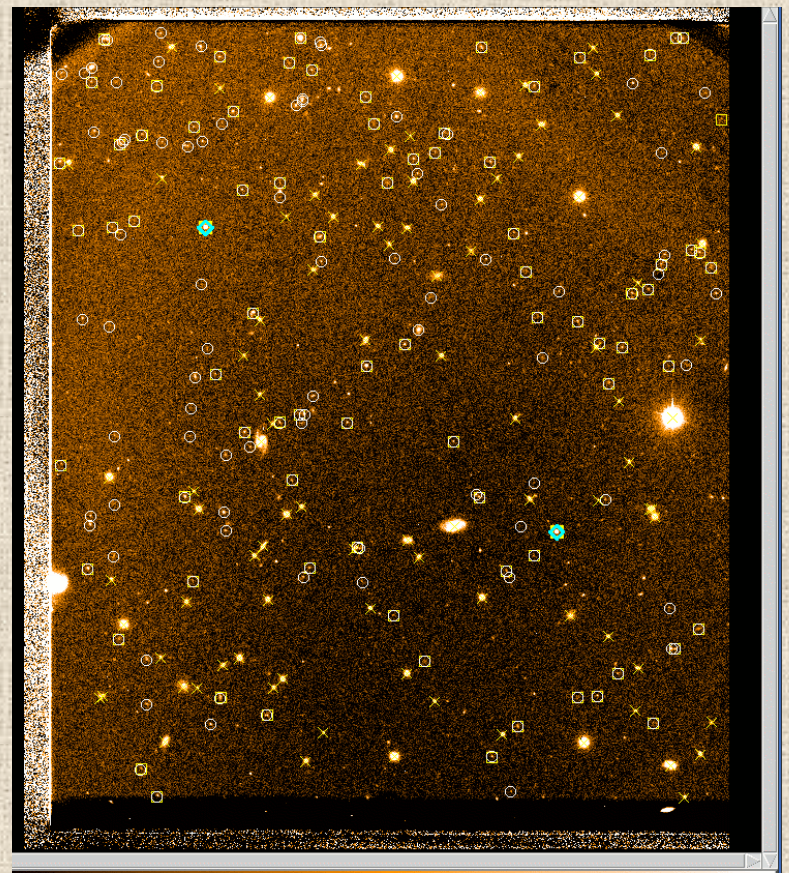
VIPERS catalog and VVDS check sample

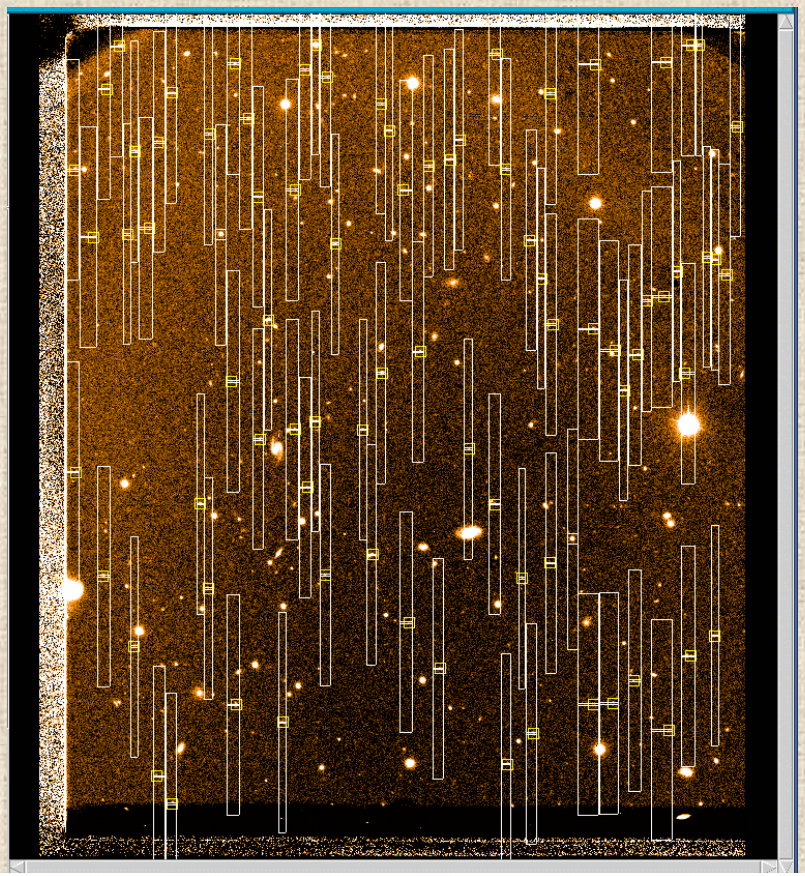
Completeness/contamination of color-color selection



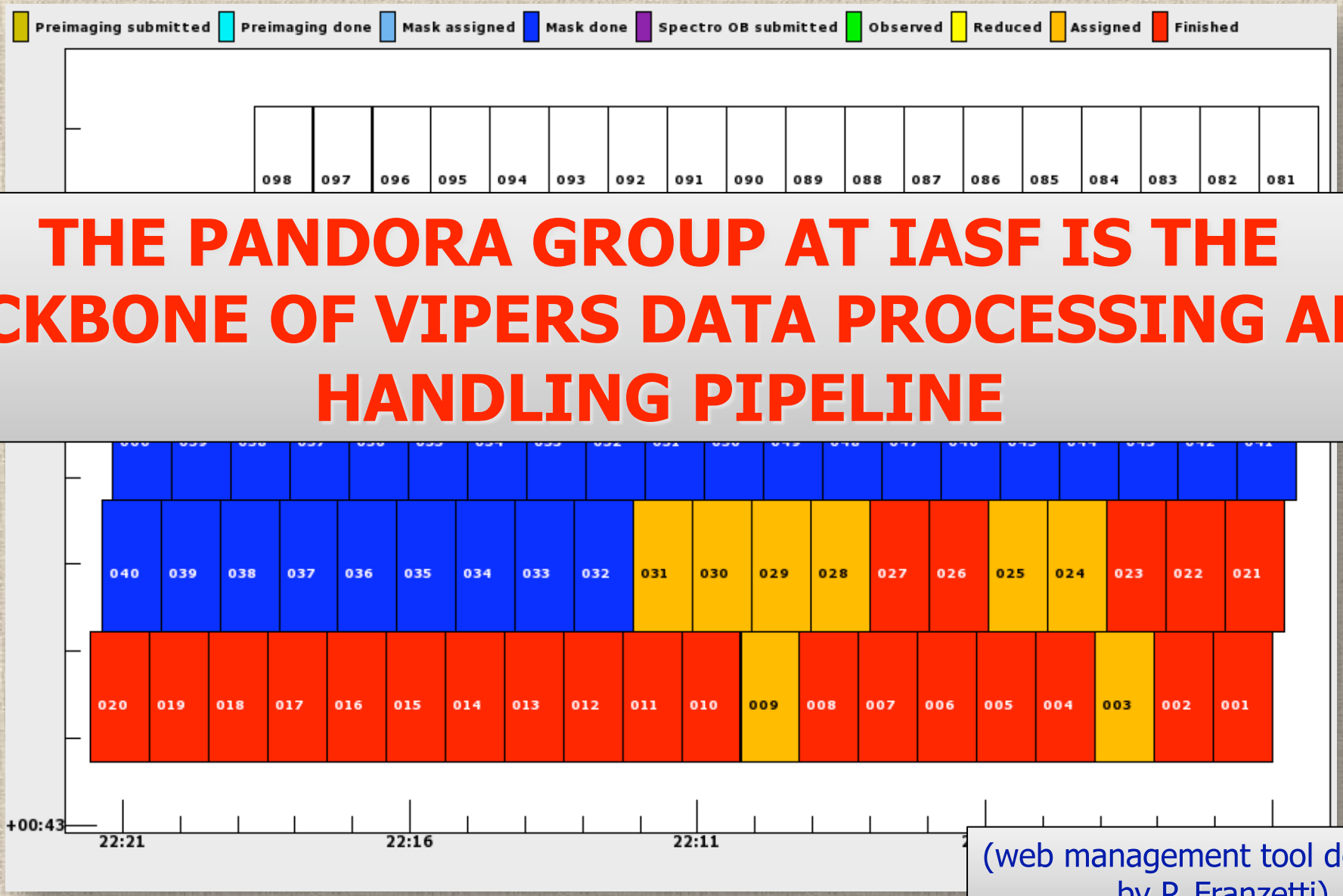
Net effect of VIPERS new selection strategy

- Sampling >50% 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 area for given telescope allocation





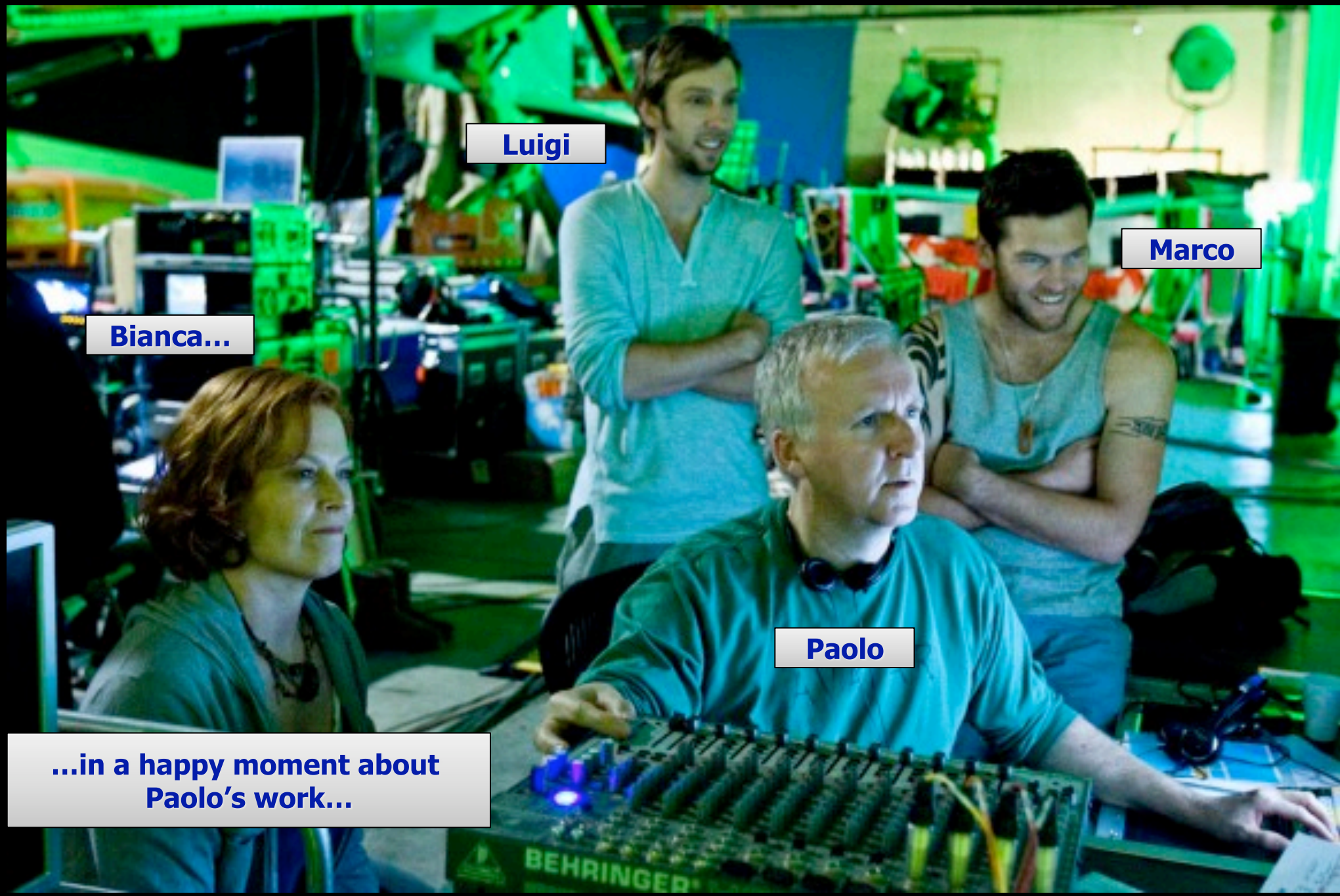
Status: W4 field



THE PANDORA GROUP AT IASF IS THE BACKBONE OF VIPERS DATA PROCESSING AND HANDLING PIPELINE

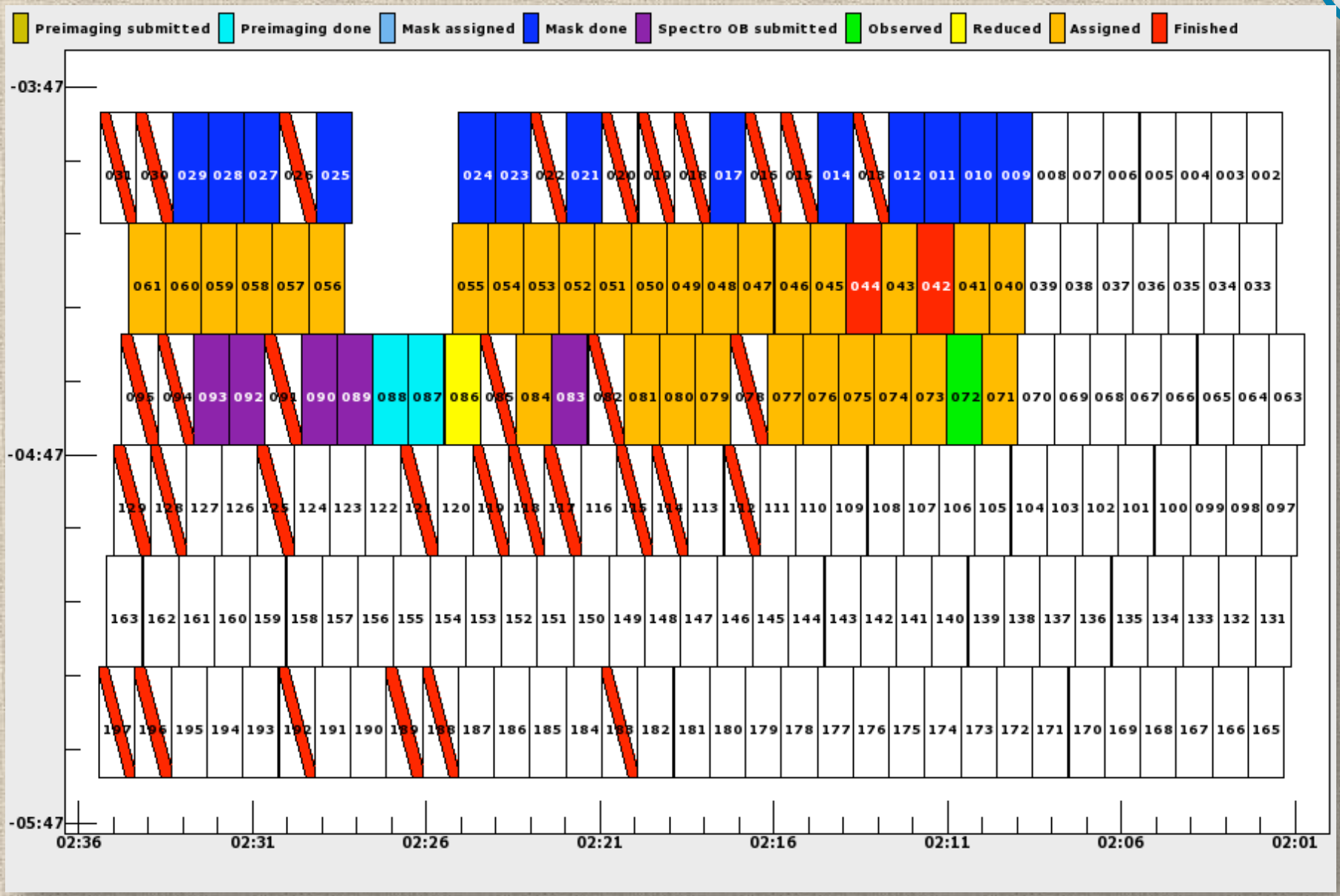
(web management tool developed by P. Franzetti)


PANDORA


Luigi
Marco
Bianca…
Paolo
…in a happy moment about Paolo’s work…
BEHRINGER


The return of Marco F. !!!! ... is he real or is just his AVATAR....?!!!
Bianca.. of course

Status: W1 field

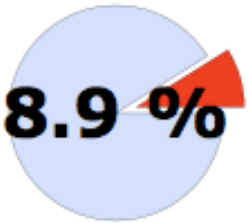


Status: overall

- 2008/2009: 60 VIMOS pointings observed: ~60 x 4 x 85 = **20,400 spectra**
- Data processing status:

SURVEY STATUS AS OF 09/03/2010

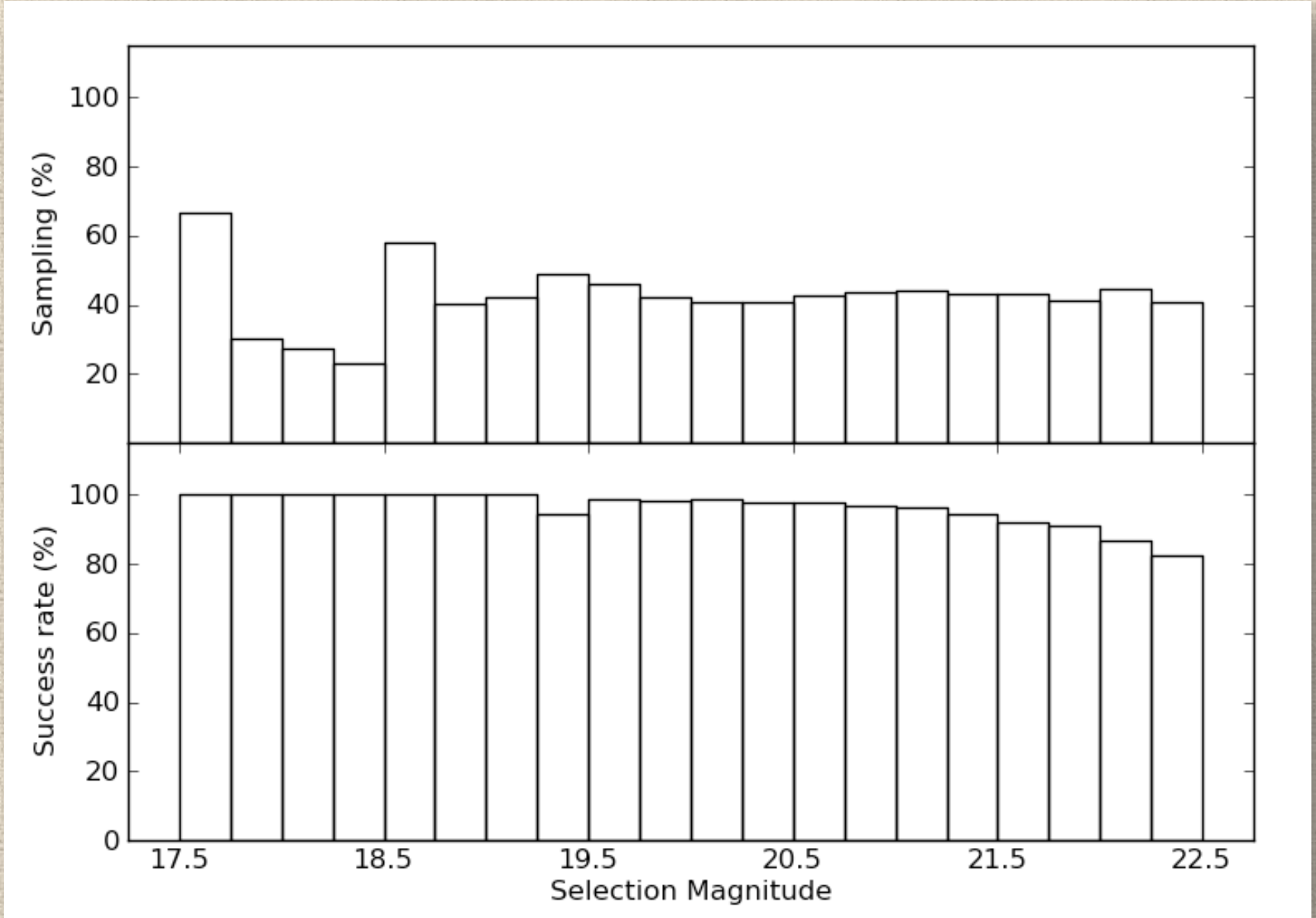
EFFECTIVE GALAXY TARGETS	MEASURED REDSHIFTS	STELLAR CONTAMINATION	COVERED AREA
8482	**7664**	**322** (4.2 %)	**8.9 %**



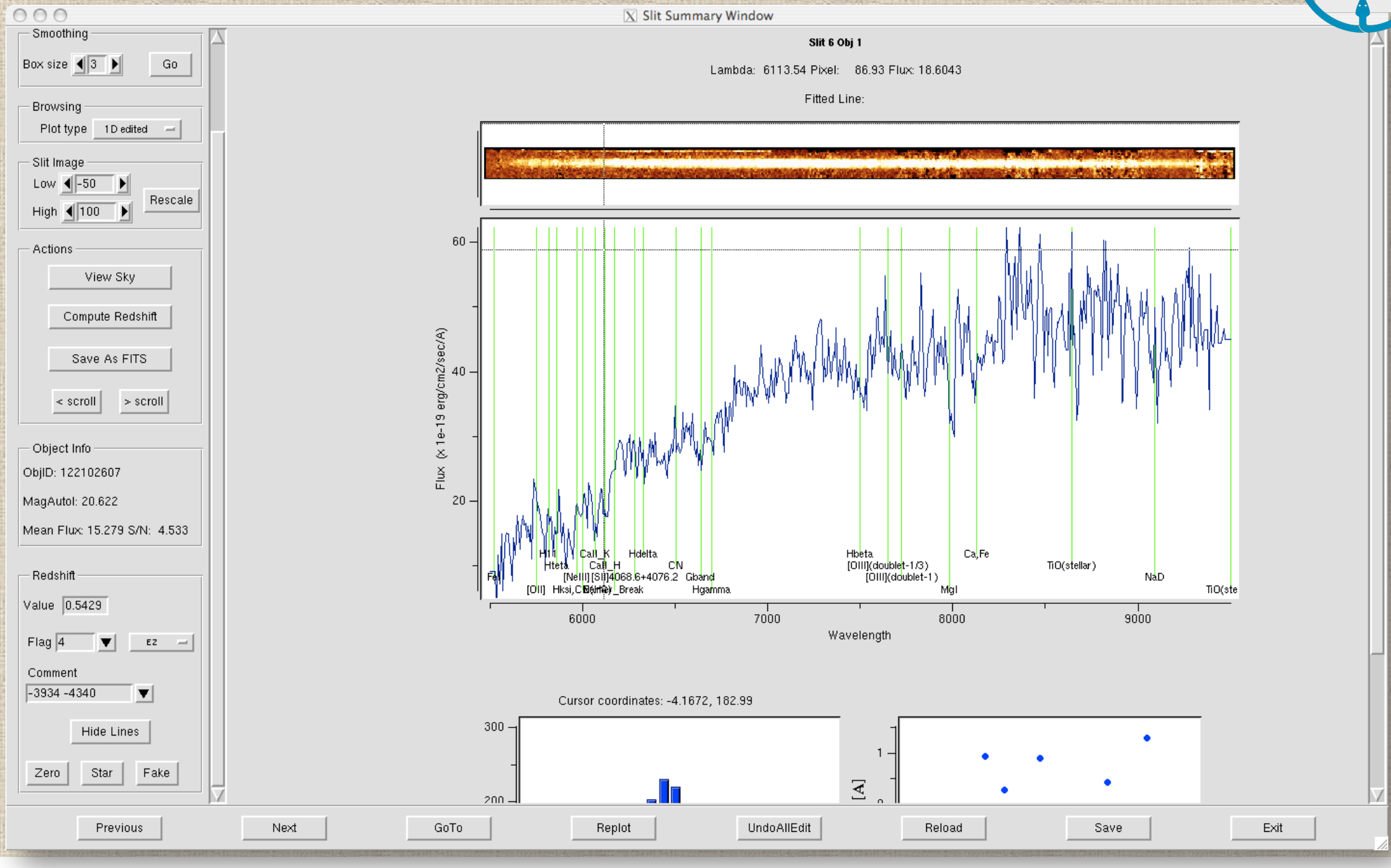
EFFECTIVE GALAXY TARGETS (EGT) are all the primary targeted galaxies with the exclusion of the ones flagged as -10 (undetected). MEASURED REDSHIFTS (MR) are the fraction of EGT for which a redshift has been measured. STELLAR CONTAMINATION are the MR objects which have been identified as stars.

- With current success rate (90%), 18,000 redshifts expected from these data (~1/5 of total survey) by April 2010

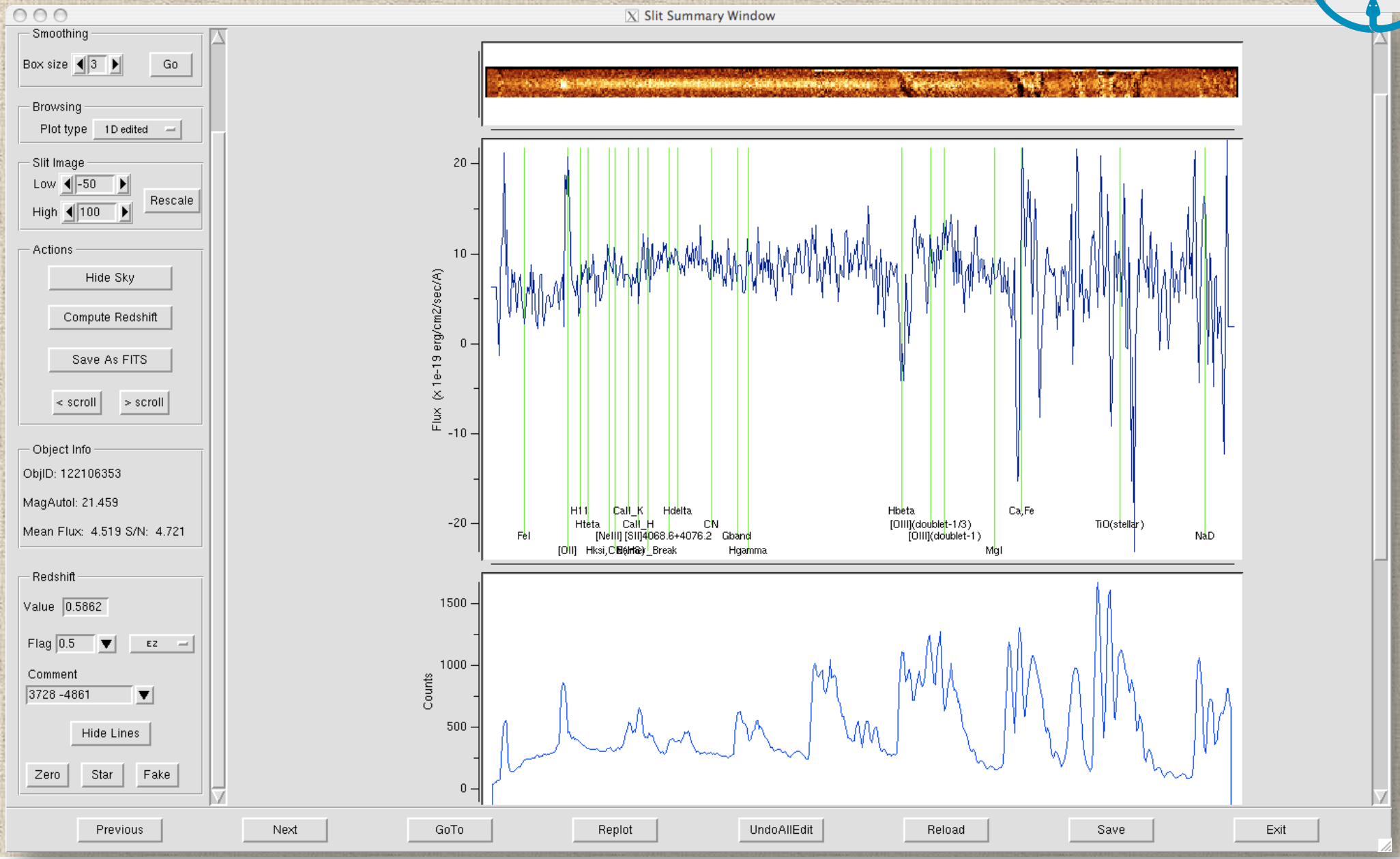
Current survey efficiency



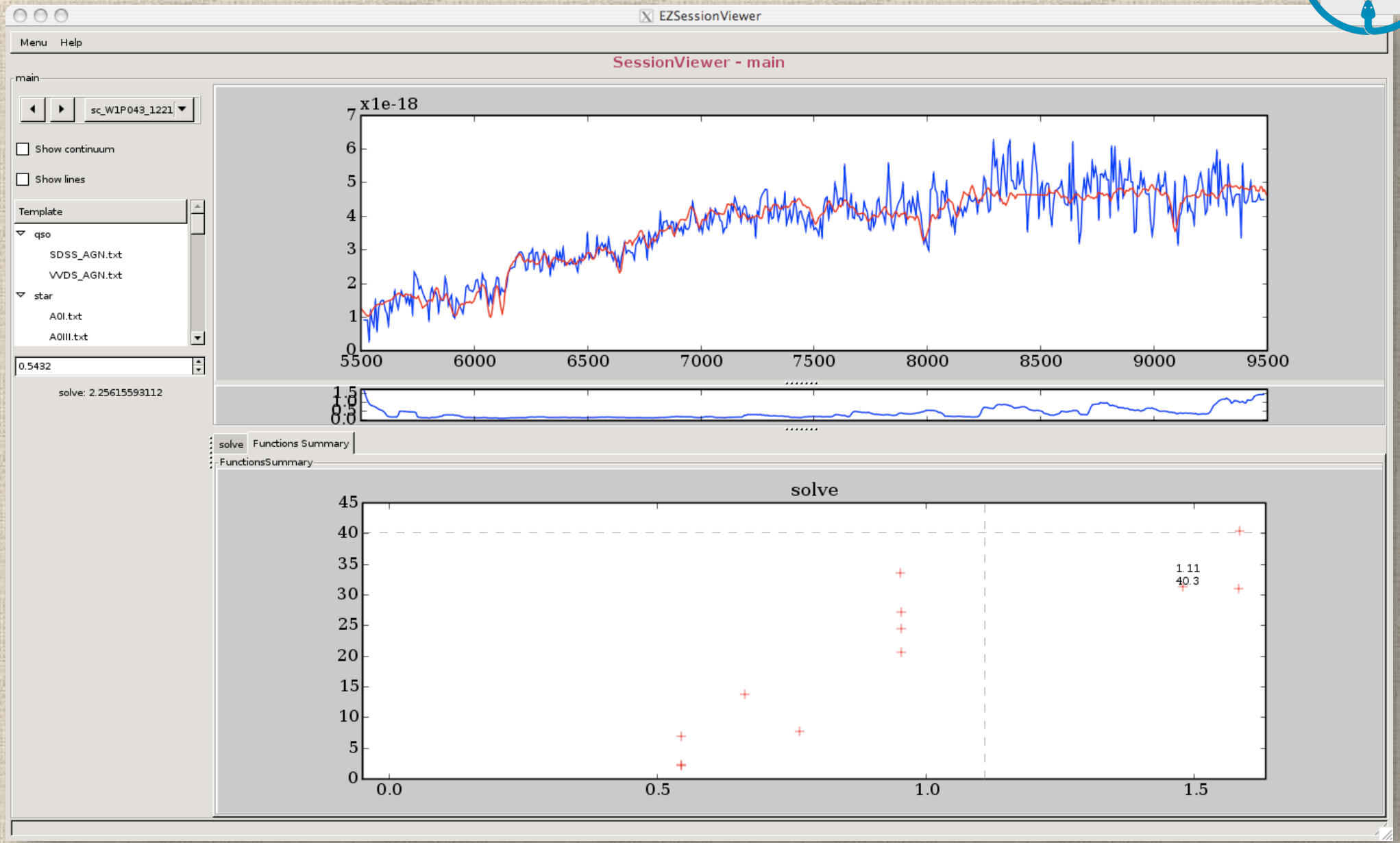
Spectral review/measurement environment: VIPGI+EZ



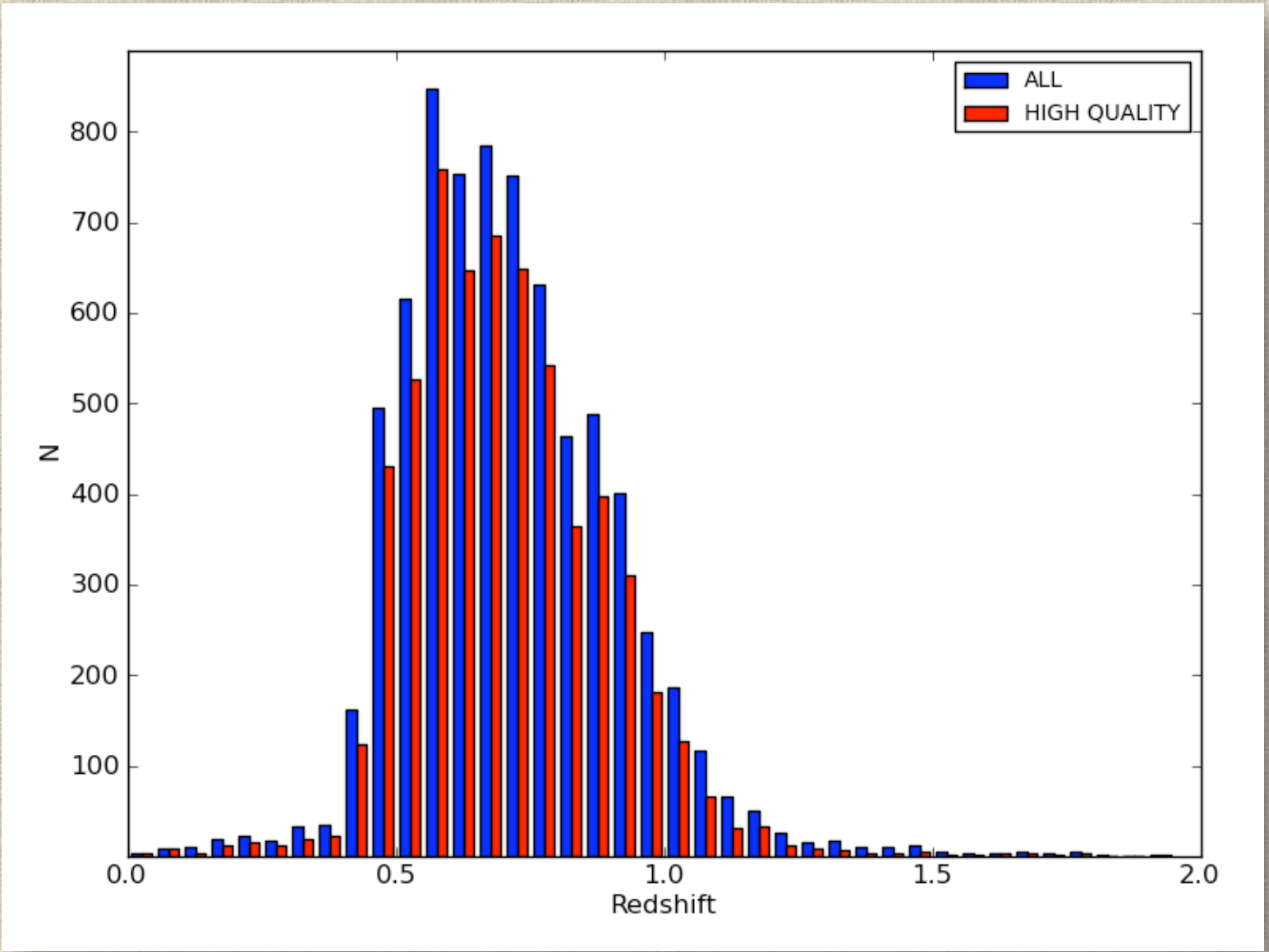
Spectra are dirty when they come out of VIMOS…



EZ: a redshift measurement tool



Status: actual redshift distribution



Summary

- VIPERS finally exploits VIMOS capabilities, filling a specific niche for cosmological surveys at z~0.5-1
- Best compromise between large volume (like 2dFGRS, ~6 x 10^7 h^{-3} Mpc^3) and very good sampling
- Main goal is clustering and cosmology at 0.5<z<1, extending previous smaller-area surveys (more focused on galaxy evolution)
- Very efficient reduction pipeline: automatic data calibration and redshift measurement: ~20,000 spectra secured in first season
- Still needs heavy human review of machine redshifts: this will change with new VIMOS CCDs (Jun/July 2010).
- Public survey: raw data public immediately, redshifts will be released in regular tranches