Probing the growth rate of structure with VIPERS survey

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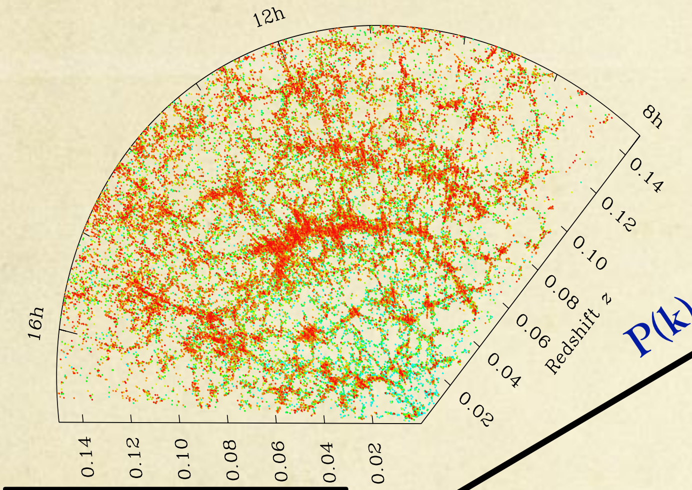
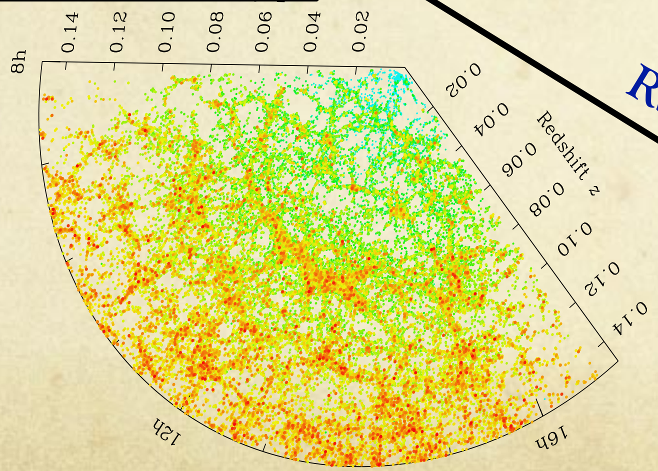
Galaxy redshift survey to probe cosmology



Galaxy redshift survey



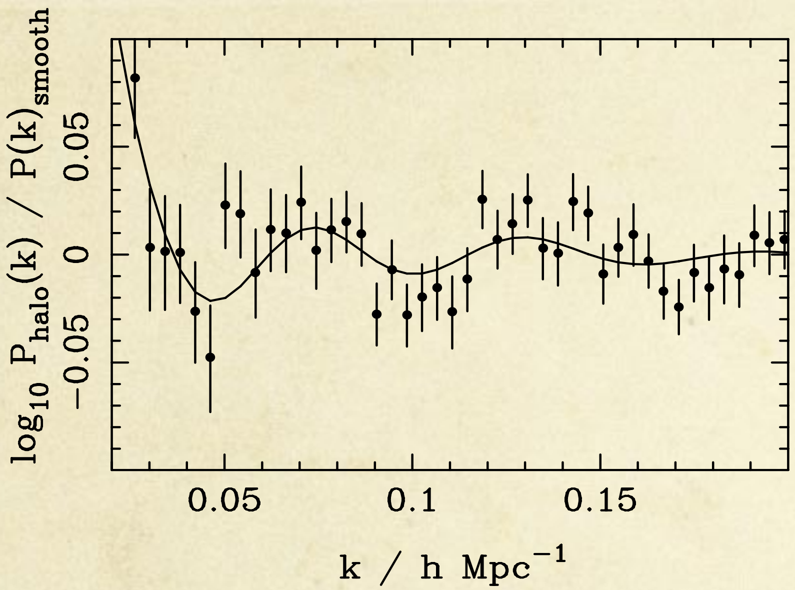
P(k) shape → Is the Universe homogeneous on large scales? Constituents?
e.g. spectral index, non-gaussianity, neutrinos

BAO → What is the expansion rate of the Universe?
e.g. quintessence, Λ

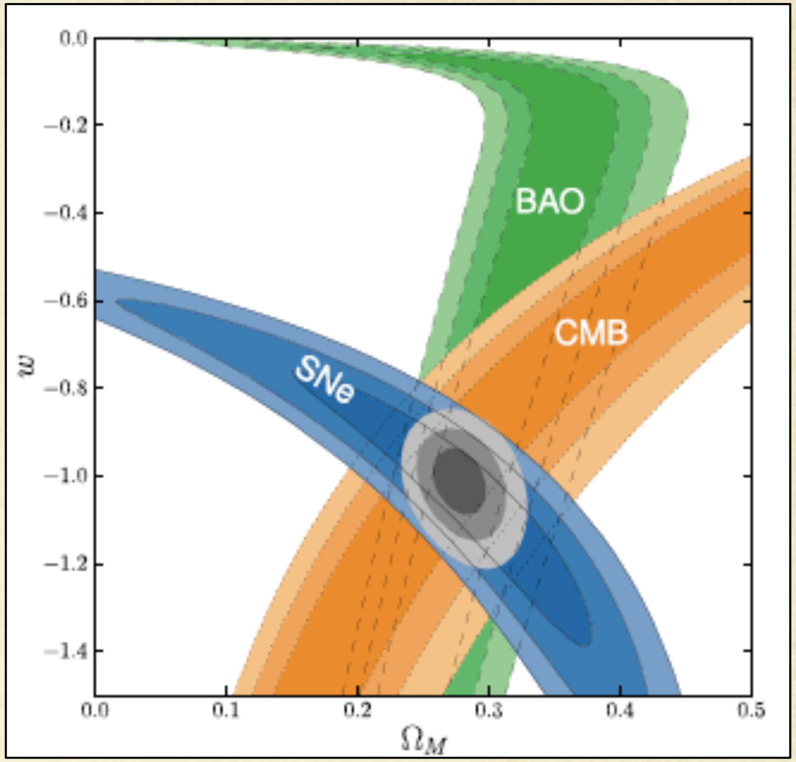
RSD → How does structure form and grow within this background?
e.g. GR, modified gravity

Understanding acceleration

Baryonic Acoustic Oscillations



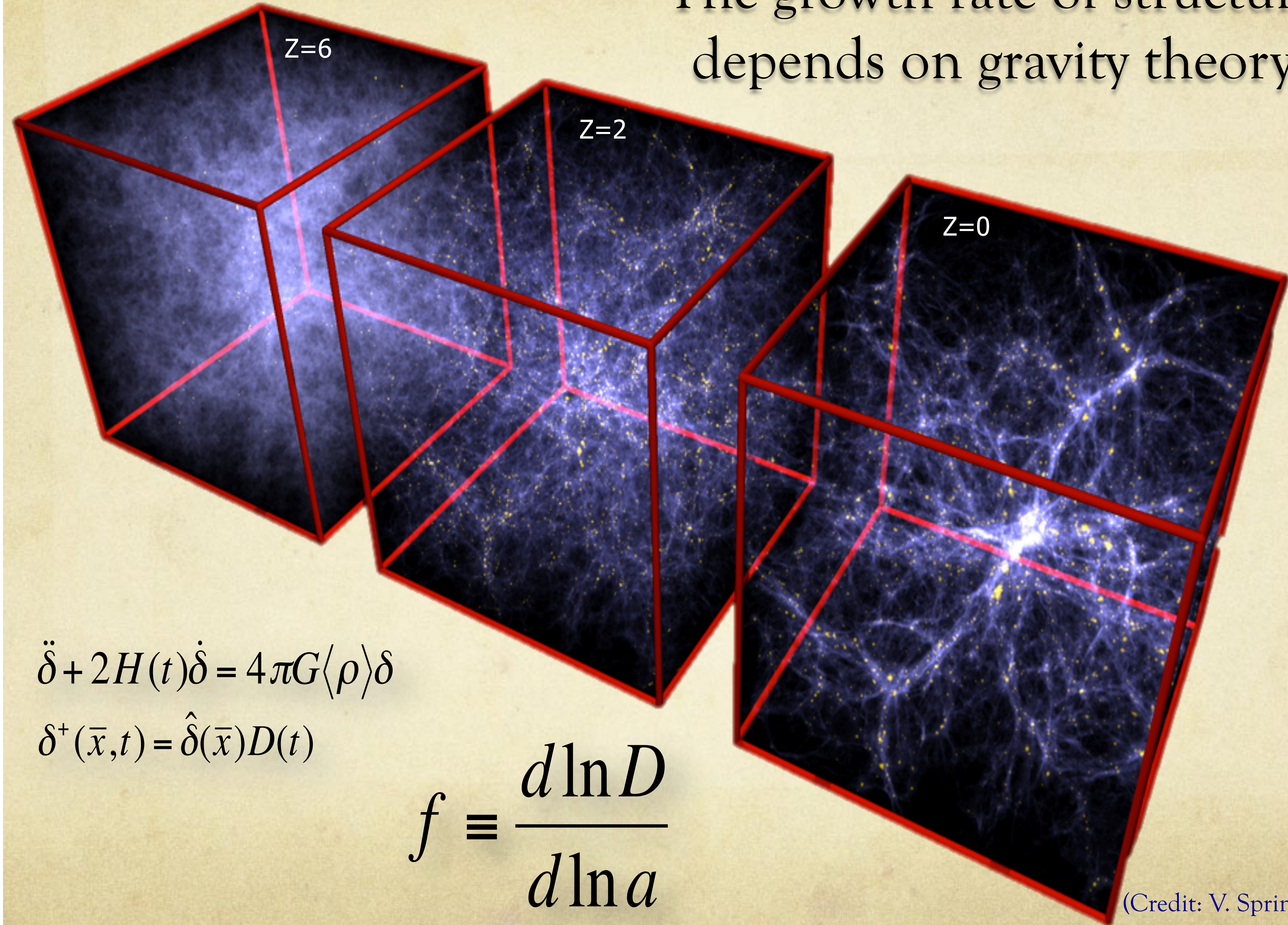
(SDSS, e.g. Percival et al. 2010)



(Amanullah et al. 2010)

- **BAO** very useful to constrain the expansion history and dark energy EoS
- **but …** not sufficient to lift the *degeneracy between dark energy and modified gravity models*

The growth rate of structure depends on gravity theory



$$\ddot{\delta} + 2H(t)\dot{\delta} = 4\pi G\langle\rho\rangle\delta$$

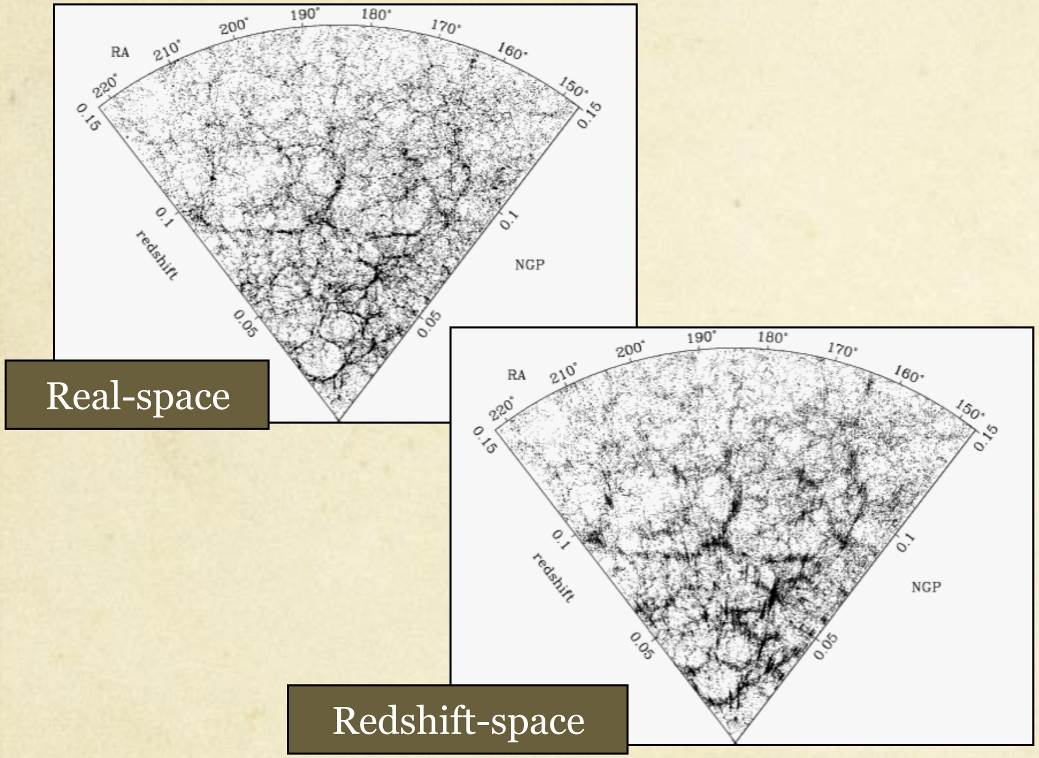
$$\delta^{+}(\bar{x},t) = \hat{\delta}(\bar{x})D(t)$$

$$f \equiv \frac{d\ln D}{d\ln a}$$

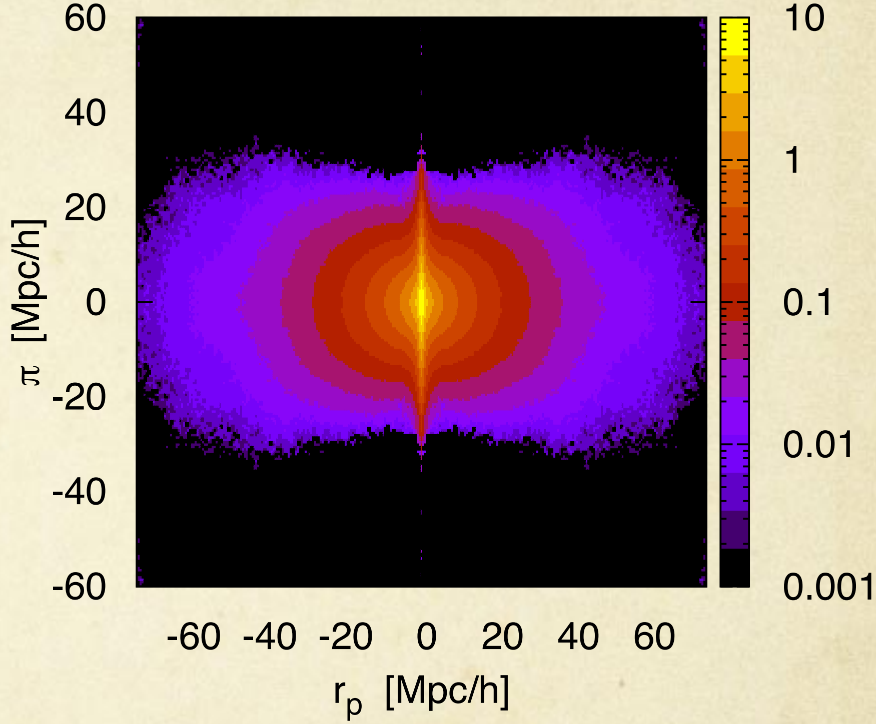
(Credit: V. Springel)

Redshift-space distortions

- Measured correlation functions from *z*-surveys are distorted due to galaxy peculiar motions



- The linear component of these distortions maps the motions due to the **growth rate of structure**



Elongation on small scales:

« Finger-of-God » effect

Flattening on large scales:

« Kaiser » effect

Redshift-space distortions

- Commonly used model: the so-called "dispersion model"

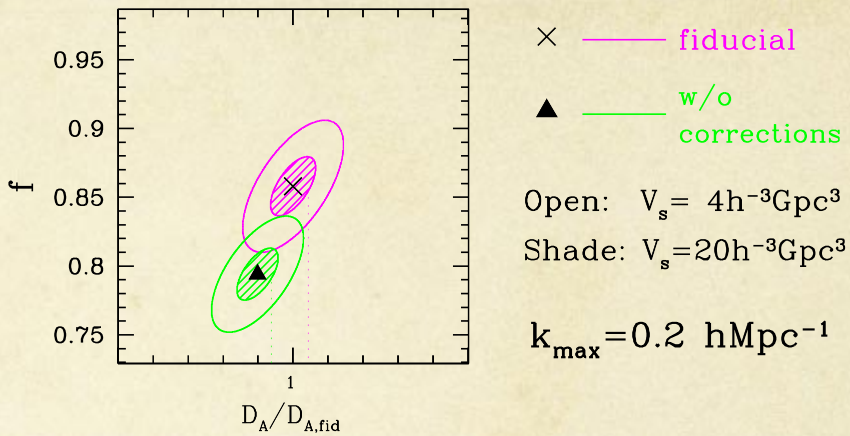
$$P_Z(k,\mu) = P_R(k)(1+\beta\mu^2)^2\left(1+\frac{k^2\sigma_k^2\mu^2}{2}\right)^{-1}$$

- However introduces **systematic error** on β or f (>10%)

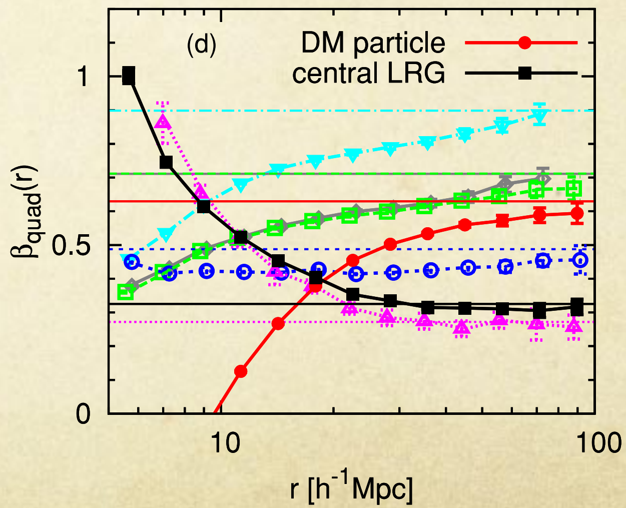
- Need to improve the modelling to enter "*precision RSD cosmology era*"!

➔ **EUCLID: percent accuracy on *f* (stat.)**

- Significant work (mostly theoretical) done in the last 2 years to improve RSD models



(Taruya et al. 2010)

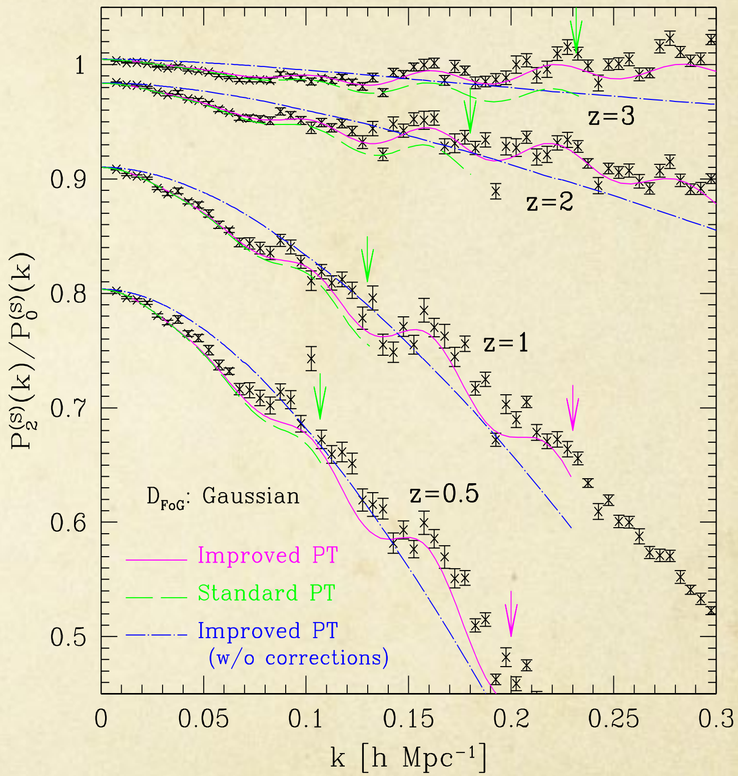


(Okumura & Jing (2011)

Improving RSD modelling

To reduce systematic errors on parameters: need to account to some extent for **non-linear evolution** of galaxy clustering

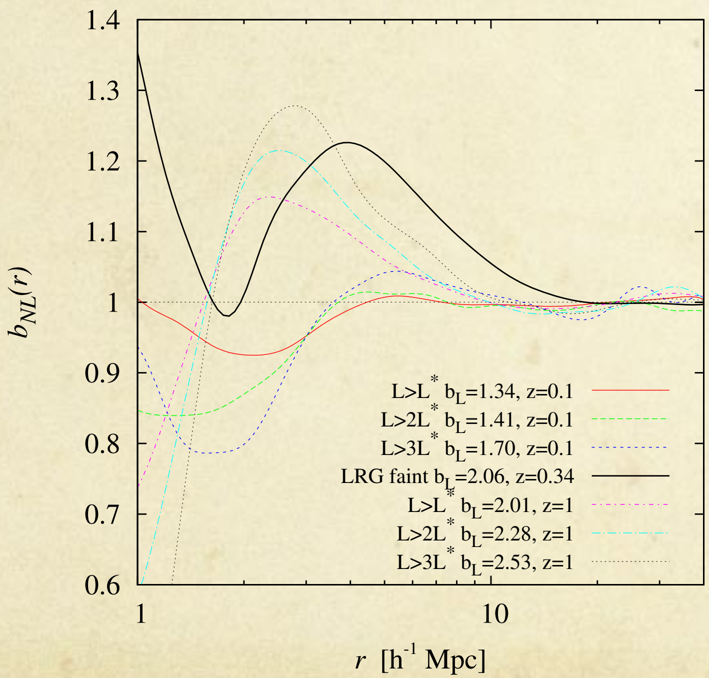
- **[1] Go beyond Kaiser linear model**
  - Non-linear coupling between density and velocity divergence fields (Scoccimarro 2004, Taruya et al.2010)
  - $P_{\theta\theta}(k)$, $P_{\delta\theta}(k)$ from N-body simulations (Jennings et al., 2010) or from improved Perturbation Theory (Crocce & Scoccimarro 2008, Taruya et al. 2009)
- **[2] Better treat highly the non-linear regime (FoG)**
  - Use halo model (e.g. Tinker et al. 2006, 2007)?
  - Add more freedom in the pairwise velocity distribution models (include scale dependence?) (e.g. Kwan et al. 2011)
- **[3] Better treat galaxy (non-linear) bias**
  - Account for bias scale-dependence, how?



(Taruya et al. 2010)

RSD non-linear models for galaxies

- Building an accurate RSD non-linear model for galaxies: **importance of galaxy biasing**



(de la Torre & Guzzo 2012)

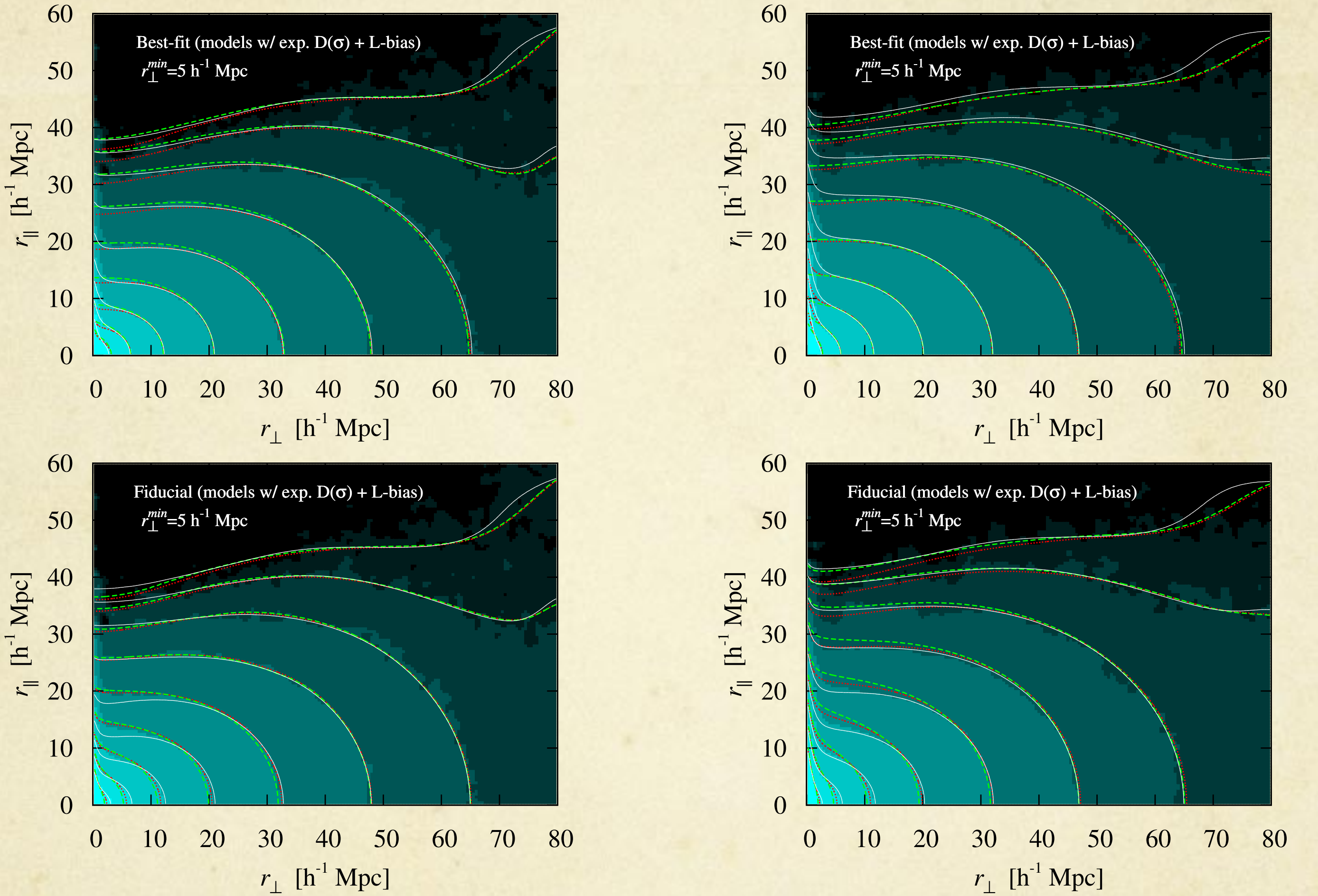
$$P_g^s(k,\mu) = D(k\mu\sigma_v)P_K(k,\mu,b)$$

$$D(k\mu\sigma_v) = \begin{cases} \exp(-(k\mu\sigma_v)^2) \\ 1/(1+(k\mu\sigma_v)^2) \end{cases}$$

$$P_K(k,\mu,b) = \begin{cases} \mathrm{A}: \; b^2(k)P_{\delta\delta}(k) + 2\mu^2 f b(k) P_{\delta\delta}(k) \\ \quad +\mu^4 f^2 P_{\delta\delta}(k) \\ \mathrm{B}: \; b^2(k)P_{\delta\delta}(k) + 2\mu^2 f b(k) P_{\delta\theta}(k) \\ \quad +\mu^4 f^2 P_{\theta\theta}(k) \\ \mathrm{C}: \; b^2(k)P_{\delta\delta}(k) + 2\mu^2 f b(k) P_{\delta\theta}(k) \\ \quad +\mu^4 f^2 P_{\theta\theta}(k) + C_A(k,\mu;f,b) \\ \quad +C_B(k,\mu;f,b) \end{cases}$$

- **Non-linearities:** couplings between density and velocity divergence fields and between damping and Kaiser terms

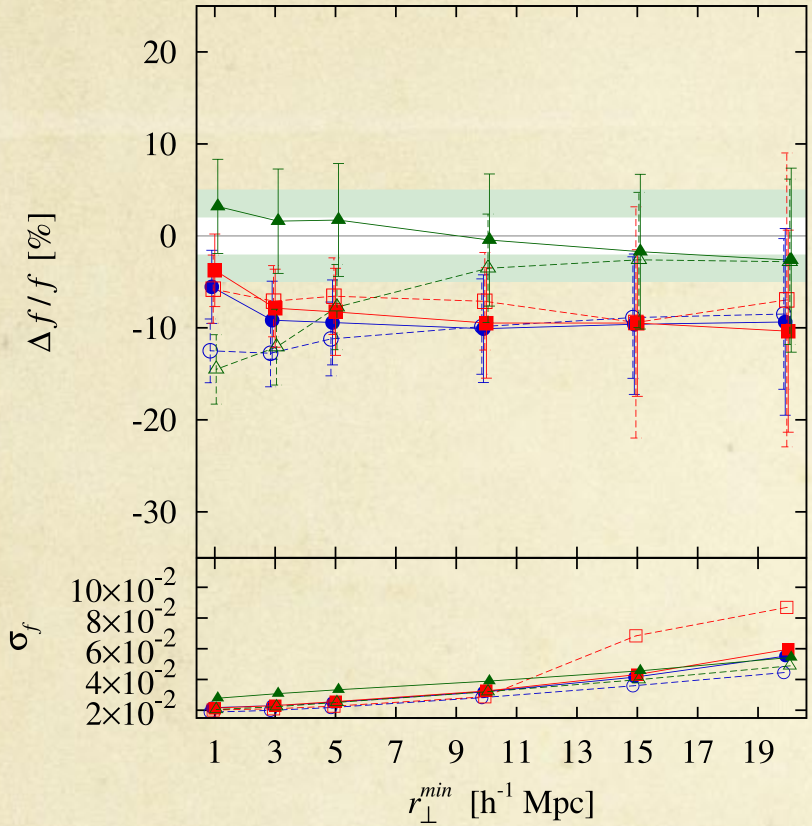
RSD non-linear models

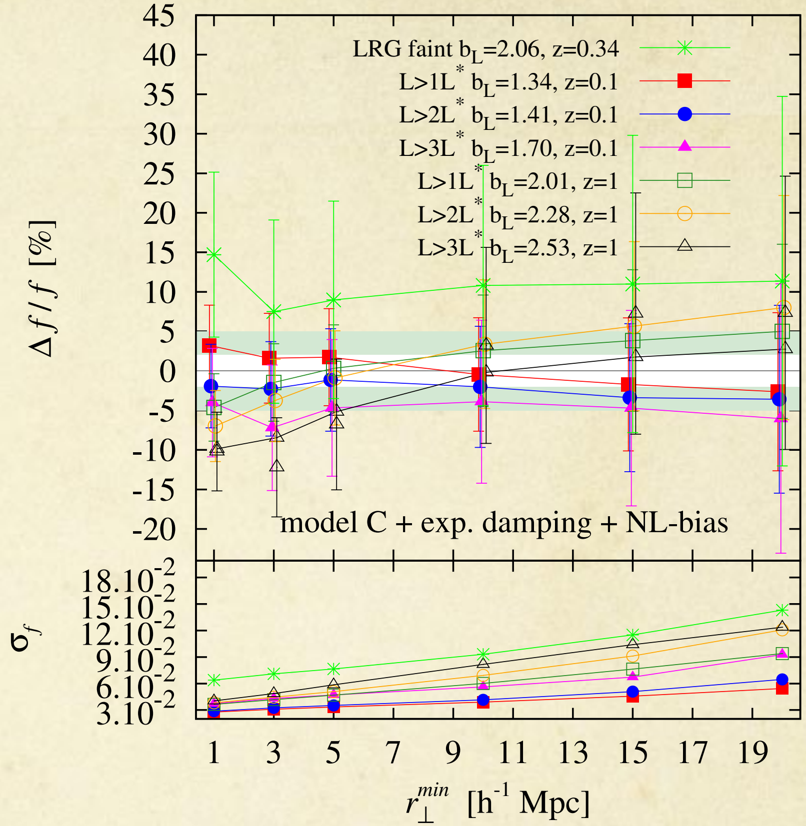


- **Testing models in configuration space with realistic galaxy catalogues** made from populating a Gpc^3 simulation with galaxies (HOD)
- Galaxy linear bias as a free parameter in the fit

(de la Torre & Guzzo 2012)

RSD non-linear models





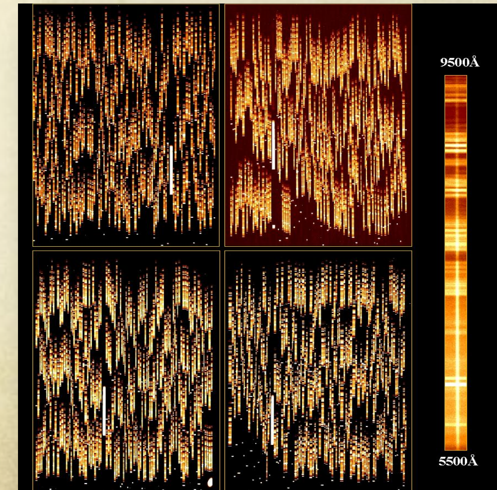
- Most advanced non-linear models allows us to **reach the 4% accuracy on *f***
- To be investigated to reach the percent level:
  - **Velocity bias**: it can introduce 1-3% bias on *f* (towards lower values)
  - **Luminous/massive galaxy populations**: larger systematic errors, bias issue?

(de la Torre & Guzzo 2012)

VIPERS overview

- PI: Luigi Guzzo (Brera observatory, Milan)
- 440.5 VLT hours with VIMOS (started end of 2008)
- 24 deg^2 in the CFHTLS W1 & W4 fields (288 pointings)
- $I_{AB}<22.5$, LR-Red grism with 45 min exposure
- 5-band ugriz + NIR imaging (soon)
- z>0.5 colour pre-selection
- 40% sampling with a new short-slit technique (one-pass strategy)

Final catalogue: 100,000 redshifts at 0.5<z<1.2



Science [*cosmology and galaxy evolution*]:

- Redshift- and real-space clustering, massive clusters of galaxy, density field, galaxy and AGN evolution, etc…

Institutes involved:

- Milan (2), Bologna, Edinburgh, Garching, Marseille, Paris, Portsmouth, Warsaw ➔ 45 people

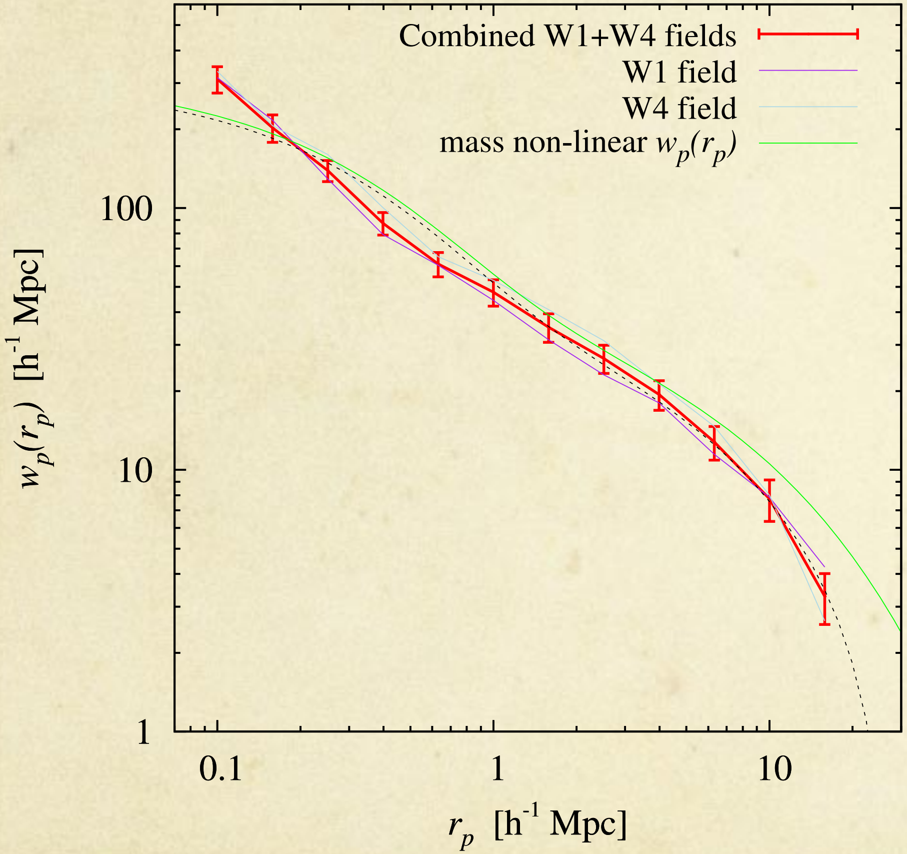
VIPERS current status

- 36,200 good-quality redshifts at $0.5<z<1.2$
- 42% of the survey completed: about 10 deg^2 covered

- First public release: March 2012 (only 20% data)

VIMOS PUBLIC EXTRAGALACTIC REDSHIFT SURVEY

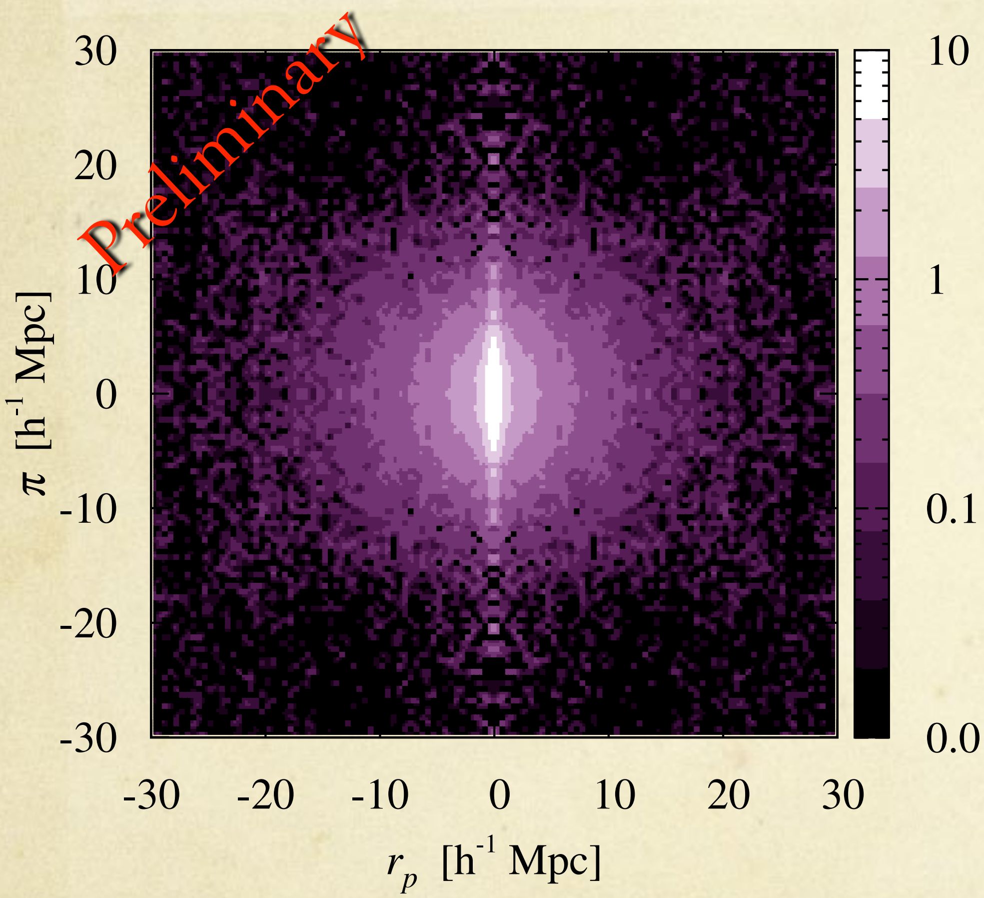
VIPERS: real-space clustering



(de la Torre & VIPERS , in prep.)

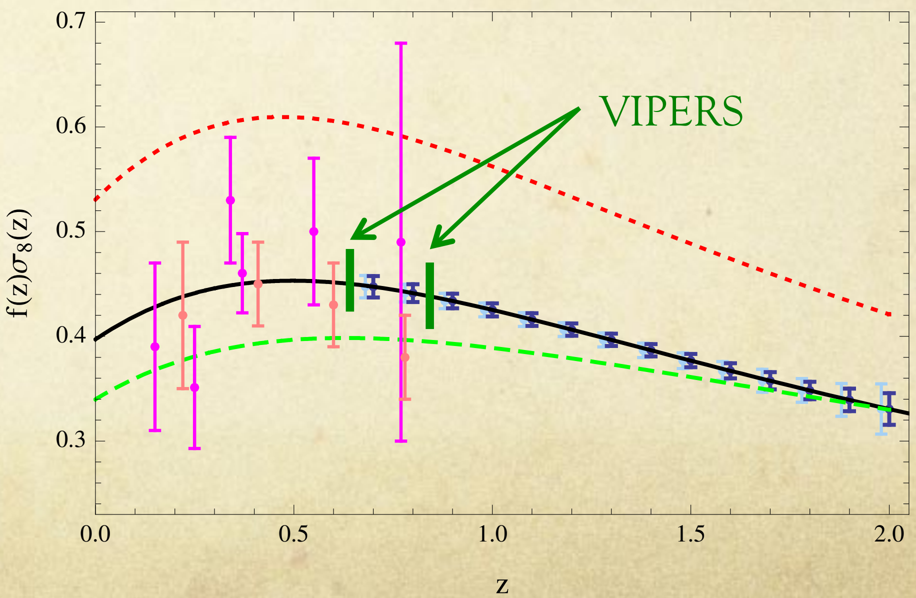
- **Early results**: projected two-point correlation function $w_p(r_p)$
- Well defined correlation function on $0.1<r_p<20$ scales in the early data
- **Very promising** to study how galaxy clustering depend on luminosity, stellar mass, colour, environment ... at $0.5<z<1.2$
- **Dramatically reduce sample variance** on clustering measurements at $0.5<z<1.2$, which affect all current $z=1$ redshift surveys

VIPERS: RSD



(de la Torre & VIPERS, in prep.)

- **Early results**: anisotropic two-dimensional two-point correlation function $\xi(r_p,\pi)$
- VIPERS will provide an (almost) **unbiased measurement of the growth rate**
- VIPERS will measure f with **6-10% accuracy** at $0.5<z<1.0$



(Majerotto, Guzzo & EUCLID, 2012)