The VIPERS View of Large-scale Structure at Redshift 1

Ben Granett

Osservatorio Astronomico di Brera, INAF, Merate/Milano

On behalf of the VIPERS collaboration

LSS, Garching, 21 July 2015
VIPERS aims

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

<table>
<thead>
<tr>
<th>Survey</th>
<th>Scale</th>
</tr>
</thead>
<tbody>
<tr>
<td>6dFGS</td>
<td>1 m</td>
</tr>
<tr>
<td>SDSS</td>
<td>2 m</td>
</tr>
<tr>
<td>2dFGRS</td>
<td>4 m</td>
</tr>
<tr>
<td>VIPERS</td>
<td>8 m</td>
</tr>
</tbody>
</table>

- 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
VIPERS in summary

- **Flux limit** $i_{AB} < 22.5$
- **~90 000 redshifts**
- **Area**: 24 square degrees
- **Volume**: $0.05 \ h^{-3}\text{Gpc}^3$
- **Density**: $8 \times 10^{-3} \ h^{3}\text{Mpc}^{-3}$

Guzzo et al (2014)
Garilli et al (2014)
Team VIPERS


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


★ 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. Schimdt

★ 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

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

(Here in Garching)
Team VIPERS
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)
VIMOS at ESO Very Large Telescope

VLT at Paranal

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

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

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
Slit exclusion effects

★ Single-pass observations
★ Spectra cannot overlap on the focal plane
★ Suppression of the correlation function on all scales

\[
\begin{align*}
\sigma(\xi_{0,\text{obs}}/\xi_{0,\text{par}} - 1) \\
\text{No correction} & \quad \text{rect}(60'',100'') \\
& \quad \text{circ}(30'') \\
& \quad \text{circ}(20'')
\end{align*}
\]

Pezzotta, Granett, de la Torre et al
**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%
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)
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)
Anisotropic survey window function

- Window function structure corresponds to scale of pointings
- Anisotropic in the RA, Dec and line-of-sight

\[
P_{\text{CONV}}(k) = \int P_s(k') |W(k - k')|^2 \frac{d^3k'}{(2\pi)^3}.
\]

See Mike Wilson’s poster

... for a different approach using moments of the window in configuration space.
Redshift-space distortions

Distance in redshift-space: \[ s = r + \frac{v_{\text{los}}}{aH} \]

Redshift-space power spectrum (Kaiser formula):
\[ P^s(\vec{k}) = (b + f \mu^2)^2 P(\vec{k}) \]

Linear growth factor: \[ f \equiv \frac{d \ln D}{d \ln a} \approx \Omega_m(z)^\gamma \]

Transform to the correlation function:
\[ \xi^s(\vec{r}) = \int \frac{d^3k}{(2\pi)^3} e^{i\vec{k} \cdot \vec{r}} P^s(k, \mu) \]
Growth of structure with RSD

★ Analysis of full sample underway

★ 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
**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.
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 \( \delta, P(k, \mu), b_g, n(L)/dL \)

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

Granett+2015
Joint reconstruction
$\delta, P(k, \mu), b_g, n(L)/dL$

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

- 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)

Fig. 9: The galaxy bias measured from the full (red and blue combined) VIPERS galaxy sample in luminosity threshold bins. Reference data are taken from the VIPERS projected correlation function analysis (Marulli et al., 2013) and counts-in-cells probability distribution function analysis (Di Porto et al., 2014). Note that the redshift ranges differ.

Fig. 10: The galaxy luminosity function inferred from the mean density Markov chain for red, blue and combined samples in redshift bins. Markers are plotted at the median value of the chain and the height of the rectangles indicates the 68% confidence interval. The Schechter function fits from Fritz et al. (2014) are overplotted for comparison.

6. Conclusions
Using VIPERS we have demonstrated a method to reconstruct the galaxy density field jointly with the redshift-space power spectrum, galaxy biasing function and galaxy luminosity function with minimal priors on these parameters. The Bayesian framework naturally accounts for the correlations between these observables. We adopt a likelihood function for the galaxy number counts that is given by a multivariate Gaussian and set a Gaussian prior on the density field. The solution that maximises the posterior distribution is given by the classical Wiener filter. To sample from the posterior distribution we add a Gaussian...
Cosmic voids in VIPERS

Void finding algorithm based upon empty spheres
Micheletti, lovino+(2014)
New test of growth of structure

- Anisotropic void profiles normalised to void radius
- Constraints on growth rate

See Adam Hawken (poster)
Summary

- VIPERS exploits VIMOS capabilities for LSS study, unique at z~1: volume $6 \times 10^7 \ h^{-3} \ Mpc^3$, 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
http://vipers.inaf.it
A. Iovino