Measuring the growth rate through cross-correlations: First application to VIPERS

Faizan Gohar Mohammad
Osservatorio Astronomico di Brera, INAF, Merate/Milano

Ben Granett, Julien Bel, Sylvain de la Torre, Luigi Guzzo
& VIPERS Team

Garching, 20-24 July 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
• RSD from multi-tracers cross-correlation;

• The VIPERS survey: selecting blue/red galaxies;

• First growth rate results from full survey;
**BACKGROUND**

- Observations: accelerated expansion;
- GR+DE or modified gravity?
- Expansion history alone cannot distinguish between gravity models;
- Breaking degeneracy: Growth of structure;
- Use Redshift Space Distortions (RSD);

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de la Torre et al. 2013
RSD Modelling Limitations

\[
P^\Lambda(k, z) = \left[ 1 + \frac{f(z)}{b(z)} \mu_k^2 \right] P(k, z) \frac{1}{1 + (k \mu / \sigma_{12})^2}
\]

(Mohammad et al. 2015 (arxiv 1502.05045))

(see also e.g. Okumura & Jing 2011, Bianchi et al. 2012)
Redshift range: $0.5 < z < 1.2$

Large comoving volume: $\sim 4 \times 10^7 \, [h^{-3} \text{Mpc}^3]$

Spectroscopic redshifts of $\sim 90,000$ galaxies

Highly sampled $\sim 10^{-2} \, [h^3 \text{Mpc}^{-3}]$

Blue population to trace coherent flow

Red population: virialized component

select vol. lim. catalogues (in $0.6 < z < 1.0$)
**Blue/Red Classification**

- **Bimodality** in (U-V) colours
- **Double gaussian model**
- **Redshift dependence**
  (Fritz et al. 2014)
- **Bimodality** in (U-V) colours

- **Double gaussian model**

- **Redshift dependence**
  (Fritz et al. 2014)
Luminosity Evolution

- Assume rare mergers;
- Constant comoving number density;
- Linear evolution (in $M_B$);

\[
M_B(z) = M_B(z = 0) + \mathcal{A} \cdot z
\]
Redshift range: 0.6<z<1.0 ($z_{\text{eff}} \sim 0.83$)

~5,000 luminous red galaxies
Redshift range: $0.6 < z < 1.0$ ($z_{\text{eff}} \sim 0.83$)

~17,000 blue galaxies
**Covariance Matrices**

- 306 HOD VIPERS mocks from BigMDPL by Sylvain de la Torre;
- Hard to reproduce blue/red distributions;
- Split $C_{ij}$ into shot-noise and sampling variance;
- Tune galaxy selection in mocks to match amplitude of 2PCF;
- Consequence: mismatch of galaxy numbers;
- Remove mock shot noise;
- Add data shot noise;

\[ C_{ij} = C_{ij}^{SV} + C_{ij}^{SN} \delta_{ij} \]

\[ C_{ij}^{SV} = f[\xi] \]

<table>
<thead>
<tr>
<th>Mocks</th>
<th>Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>$&lt;N_{\text{blue}}&gt;$ $\sim$ 11.300</td>
<td>$N_{\text{blue}}$ = 16.745</td>
</tr>
<tr>
<td>$&lt;N_{\text{red}}&gt;$ $\sim$ 2.700</td>
<td>$N_{\text{red}}$ = 5.550</td>
</tr>
</tbody>
</table>

\[ C_{ij}^{\text{data}} = C_{ij} - [C_{ij}^{SN} \delta_{ij}]_{\text{mocks}} + [C_{ij}^{SN} \delta_{ij}]_{\text{data}} \]
• Generalize the RSD model to cross-correlation in redshift space (Mountrichas et al. 2009, Blake et al. 2013);

\[
P^{s}_{cr}(k, z) = [b_{blue}(z)\sigma_8(z)+f(z)\sigma_8(z)\mu_k^2][b_{red}(z)\sigma_8(z)+f(z)\sigma_8(z)\mu_k^2]P_m(k, z)\frac{1}{1+(k\mu_k\sigma_{12})^2}
\]

• Fits to the monopole and quadrupole of 2PCF;

\[
P^{s}(\ell)(k, z) = \frac{2\ell+1}{2} \int_{-1}^{+1} P^{s}(k, \mu_k, z)L_{\ell}(\mu_k)d\mu_k
\]

\[
\xi^{s}(\ell)(s) = i\ell \int \frac{k^2dk}{2\pi^2} P^{s}(\ell)(k)\tilde{j}_\ell(k; s)
\]

• Truncated multipoles (arXiv:1502.05045):

\[
\hat{\xi}^{s}(\ell)(s) = \frac{2\ell+1}{2} \int_{-\tilde{\mu}}^{+\tilde{\mu}} \xi^{s}(s, \mu)L_{\ell}(\mu)d\mu
\]

\[
\tilde{\mu} = \sqrt{1 + \left(\frac{r_p}{s}\right)^2}
\]

See Andrea Pezzotta’s poster.
• Generalize the RSD model to cross-correlation in redshift space (Mountrichas et al. 2009, Blake et al. 2013);

\[ P_{cr}^s (k, z) = \left[ b_{\text{blue}}(z) \sigma_s \right]^2 \]

• Fits to the monopole and quadrupole of 2PCF;

\[ P_m (k, z) \frac{1}{1+(k\mu_k \sigma_{12})^2} \]

• Truncated multipoles

\[ \hat{\xi}^s_{\ell} (s) = \frac{2\ell+1}{2} \int \frac{d\mu}{4\pi} P^s_{\ell} (k, \mu) j_\ell (k s) \]

See Andrea Pezzotta’s poster.
• Generalize the RSD model to cross-correlation in redshift space (Mountrichas et al. 2009, Blake et al. 2013);
• Fits to the monopole and quadrupole of 2PCF;
• Truncated multipoles

\[
P^s_{cr}(k, z) = \left[ b_{blue}(z) \sigma_s \right] \left[ b_{red}(z) \sigma_s \right]
\]

\[
P^s_s(\ell, k, z) = \frac{2\ell+1}{2\pi} \int \left( \hat{\xi}^s_s(\ell, s) \right) \frac{1}{1+(k\mu_k \sigma_{12})^2}
\]

\[
\hat{\xi}^s_s(\ell, s) = \frac{2\ell+1}{2\pi} \int \frac{r_p^2}{2\pi^2} p^s_s(\ell, k) j_\ell(k s)
\]

See Andrea Pezzotta’s poster.
**Model Testing**

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FIRST RESULTS FROM VIPERS FULL SAMPLE

$\frac{b_{\text{red}}}{b_{\text{blue}}} = 1.45$

$f\sigma_8(z=0.83) = 0.39 \pm 0.07$

$b_{\text{red}}/b_{\text{blue}} = 1.45$

$f\sigma_8(z=0.83) = 0.39 \pm 0.07$

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Results

$f_{\sigma_8}(z=0.83) = 0.39 \pm 0.07$

![Graph showing the data points and a curve for $f_{\sigma_8}$ against redshift $z$. The graph includes multiple data sets such as 6dFGS, WiggleZ, GAMA multiple-tracers, SDSS LRG, BOSS, VVDS, VIPERS PDR1, and VIPERS Cross. The graph is marked as preliminary.](image)
SUMMARY

• First application of the multi-tracer analysis to VIPERS final data release;

• Preliminary estimate of $f\sigma_8$ at $z_{\text{eff}} \approx 0.83$

• Future plans:
  1. compare statistical errors between single and multiple tracers (McDonald & Seljak 2009),
  2. group-galaxy cross-corr. application to VIPERS (Mohammad et. al. 2015),
  3. use truncated multipole moments,
  4. combine with more sophisticated RSD models.
Luminosity Evolution

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• 306 HOD VIPERS mocks from BigMDPL by Sylvain de la Torre;

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