Cosmological constraints from the galaxy power spectrum of VIPERS

PDR-1 +

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Theoretical and Observational Progress on Large-scale Structure of the Universe
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1. Model power spectrum
2. Test of systematics
3. VIPERS PDR1 +
4. Comparison with other surveys
5. Conclusions
Local Universe, z~0: 2dFGRS

k-range fitted: $0.02 < k < 0.15 \, h \, \text{Mpc}^{-1}$
Measuring the power spectrum

decompose the density field on the Fourier basis

\[ \delta(x) = \int \delta(k) e^{i k \cdot x} \, d^3 x \]

the power spectrum is the amplitude squared of the coefficients

\[ \delta(k) = \int \delta(x) e^{-i k \cdot x} \, d^3 k \]

FKP, \( P(k) \) estimator

\[ \hat{\delta}(x_P) = w(x_P) \frac{n_G(x_P) - \alpha n_R(x_P)}{\alpha \sum_R \bar{n}(x_R) w^2(x_R)} \]

\[ \hat{P}(k) = |\hat{\delta}_{FKP}(k)|^2 - P_{\text{shot}} \]
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VIPERS window function
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\[ \hat{P}_{\text{obs}}(k) = \int P(k') |W(k - k')|^2 \frac{d^3 k'}{(2\pi)^3} = P \ast |W|^2 \]

MultiDark (Prada et al. 2012) HOD mock catalogues made by S. de la Torre
VIPERS window function

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Possible BAO reconstruction? (Angela Burden and Will Percival)
Redshift-space distortions

\[ P_s(k) = P_r(k)(1 + \beta \mu_k^2)^2 e^{-[\mu_k k \sigma_v]^2} \]

\[ P_{\text{conv}}(k) = \int P_s(k') |W(k - k')|^2 \frac{d^3k'}{(2\pi)^3} \]
Test of systematics

Obtained from 200 Pinocchio mock catalogues (Monaco et al. 2002)

\[
C_{ij} = \frac{1}{N_R - 1} \sum_{m}^N R \left[ P_m(k_i) - \bar{P}(k_i) \right] \left[ P_m(k_j) - \bar{P}(k_j) \right]
\]
Test of systematics

\[ \chi^2(p) = \sum_{ij} [P_{\text{obs}}(k_i) - P_M(k_i; p)] C_{ij}^{-1} [P_{\text{obs}}(k_j) - P_M(k_j; p)] \]

Error on the average of 26 (W1) and 31 (W4) N-body based mock catalogues

\[ C_{ij} = \frac{1}{N_R - 1} \sum_m [P_m(k_i) - \bar{P}(k_i)] [P_m(k_j) - \bar{P}(k_j)] \]

Obtained from 200 Pinocchio mock catalogues

(Monaco et al. 2002)
$P(k)$ from the VIPERS PDR-1
$P(k)$ from the VIPERS PDR-1
Cosmology

- CAMB ($\Omega_M, f_B$) + HALOFIT non-linearities
- linear and scale-independent bias ($b$)

- redshift-space distortions: KAISER + DISPERSION MODEL ($\sigma_v$)
- window function
Cosmological results: $\Omega_M$ and $\Omega_B/\Omega_M$

**ASSUMPTIONS:**
- flat $\Lambda$CDM Universe

**COSMOLOGICAL PARAMETERS FIXED TO PLANCK:**
- $h$, Hubble constant
- $n_s$, spectral index
- $A_s$, primordial amplitude

**FREE PARAMETERS:**
- $\sigma_v$, velocity dispersion
- $b$, linear bias
- $f_b=\Omega_B/\Omega_M$, baryonic fraction
- $\Omega_M$, matter density

**FIT:**
- $0.01 < k < 0.3 \, h \, \text{Mpc}^{-1}$
- $(500 \lesssim \lambda \lesssim 20 \, h^{-1} \, \text{Mpc})$
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Comparison with $z \sim 0$, 2dFGRS

$h = 0.72$
Comparison with $z \sim 0$, 2dFGRS vs SDSS

$h = 0.72$

Fitting to the SDSS power spectrum
By Tegmark et al. (2004)
Cole et. al. (2003)
Percival et al. (2001)
Comparison with $z \sim 0$, VIPERS vs 2dFGRS

$h = 0.72$
Internal consistency check: $\Omega_M$

\begin{align*}
\eta_{g,R}(r) &= \frac{\xi_{g,R}(r)}{\sigma_{g,R}^2} \\
\text{Bel et al. (VIPERS Team) 2013}
\end{align*}

**Clustering ratio:**

**Gaussian prior on:**

- $h=0.738$ (HST prior)
- $\Omega_B h^2$ (BBN prior)
- $n_s, A_s$ (Planck prior)

<table>
<thead>
<tr>
<th>$\Omega_M$</th>
<th>$\Omega_b h^2$</th>
<th>$h$</th>
<th>$n_s$</th>
<th>$\ln(10^{10} A_s)$</th>
<th>$\sigma_{TOT}$ [km s$^{-1}$]</th>
<th>$b(z_1 / z_2)$</th>
</tr>
</thead>
<tbody>
<tr>
<td>prior</td>
<td>0.1 − 0.9</td>
<td>0.0213 ± 0.0010</td>
<td>0.738 ± 0.024</td>
<td>0.9616 ± 0.0094</td>
<td>3.103 ± 0.072</td>
<td>514 ± 24</td>
</tr>
<tr>
<td>best fit</td>
<td>$0.272^{+0.027}_{-0.031}$</td>
<td>$0.0211^{+0.0010}_{-0.0004}$</td>
<td>$0.735^{+0.018}_{-0.016}$</td>
<td>$0.9630^{+0.0054}_{-0.0088}$</td>
<td>$3.096^{+0.046}_{-0.057}$</td>
<td>$522^{+16}_{-18}$</td>
</tr>
</tbody>
</table>
Conclusions

- Measure of the VIPERS galaxy power spectrum including all the selection effects of the survey

- At low redshift: Similar degeneracy in the $\Omega_M$-f$_B$ plane found in 2dFGRS and SDSS

- Consistency with the Planck results for $\Omega_M$-f$_B$, even assuming a different cosmology (h=0.72 instead of h=0.67)

- Constraint on $\Omega_M = 0.272^{+0.027}_{-0.030}$, consistent with VIPERS measurements in configuration space

- Next: Use the final release of VIPERS to constrain also the total neutrino mass
Consistency with Planck

$h = 0.67$ (Planck)

$h = 0.72$
Impact of the minimum scale

$P(k)$ more linear
fiducial cosmology

assuming two different fiducial cosmologies

Correcting the wrong fiducial cosmology

\[ \Omega_{M=0.27} \]

\[ \Omega_{M=0.40} \]

\[ P'(k') = P(k) \times \alpha^2 \alpha' \]

\[ k'_\parallel = \alpha' \parallel \times k' \parallel \]

\[ k'_\perp = \alpha' \perp \times k'_\perp \]
VIPERS window function:
cone-like geometry and angular mask

\[ \hat{P}_{\text{obs}}(k) = \int P(k') |W(k - k')|^2 \frac{d^3k'}{(2\pi)^3} = P * |W|^2 \]
cone-like geometry

W1 and W4 MultiDark mocks in 0.6<z<0.9

theoretical model $P(k)$:

MultiDark cosmology in real space +
linear regime at $<z>\sim 0.7$ +
HALOFIT (non-linearities) +
linear and scale-independent bias
cone-like geometry and angular mask

W1 and W4 MultiDark mocks in 0.6<z<0.9

**theoretical model P(k):**

- MultiDark cosmology in real space +
- linear regime at $<z>\approx 0.7$ +
- HALOFIT (non-linearities) +
- linear and scale-independent bias

![Graph showing theoretical model P(k)]

- **model P(k)**
- **measured P(k) in W1**
- **measured P(k) in W4**
Power spectrum statistic: Fourier space

\[ \hat{P}(k) = \frac{1}{N_k} \sum_{k < |k'| < k + \delta k} |\delta(|k'|)|^2 , \]

\[ P(k) = \frac{\hat{P}(k_x, k_y, k_z) - S(k_x, k_y, k_z)}{\left[ \text{sinc} \left( \frac{\pi k_x}{2k_N} \right) \left[ \text{sinc} \left( \frac{\pi k_y}{2k_N} \right) \text{sinc} \left( \frac{\pi k_z}{2k_N} \right) \right]^{2p} \right]. \]  

with \( p = 2 \) for the CIC assignment scheme.

\[ S = P_{SN} \times \prod_{i=1}^{3} \left[ 1 - \frac{2}{3} \sin^2 \left( \frac{\pi k_i}{2k_N} \right) \right] \quad P_{SN} = \frac{\sum_{G=1}^{N_G} w^2(x_G) + \alpha^2 \sum_{R=1}^{N_R} w^2(x_R)}{N^2} . \]

\[ \hat{W}(x_P) = w(x_P) \frac{N(x_P)/H^3}{N} , \]
Directly predicted by theory

\[ P(k, z) = P_{\text{prim}}(k) D^2(z) T^2(k) \]

\[ T(k) = f(k, \Omega_M h^2, \Omega_B h^2) \]

varying \( \Omega_M \)

varying \( f_B = \Omega_B / \Omega_M \)