Homogeneity test of the large-scale structure using SDSS DR7 Luminous Red Galaxies

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1. Cosmological principle

The standard model of the cosmology assumes that the matter distribution on sufficiently large scale is statistically **homogeneous** and **isotropic**.
Homogeneity test

• Homogeneity test of galaxies have been studied by using fractal dimension that is counting the number of galaxies at galaxy centered sphere.

• If fractal dimension is 3, that means galaxy distribution is homogeneous.

• Radius is larger than 70Mpc/h, fractal dimension is approximately 3. (Hogg et al. 2004)

• The Universe continues to look fractal (not homogeneous) as far out as our telescopes can see. (Labini et al. 2009)

\[ R^D = \frac{N_{LRGs}}{N_{Random}} \]

\[ D \sim 3 \]
2. Data

- SDSS DR7 LRGs

- 105,831 galaxies
- $0.16 < z < 0.47$
- $M_g = (-23.2, -21.2)$
  (Kazin et al. 2010)
LRG Angular selection function
(Kazin et al. 2010)

- Observed area is calculated by LRG Angular selection function
  Observed area $\sim 1$
  Not observed area $\sim 0$
## 2. Data

<table>
<thead>
<tr>
<th>Mock catalogs</th>
<th>Random catalogs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mock SDSS-III survey</td>
<td>Using SDSS DR7 LRGs catalog</td>
</tr>
<tr>
<td>N-body simulation, HR3 (Kim, J. et al. 2012)</td>
<td>(Kazin et al. 2010)</td>
</tr>
<tr>
<td>All-sky ($4\pi$)</td>
<td>Observed area $\sim \pi$</td>
</tr>
<tr>
<td>$0 &lt; z &lt; 0.7$</td>
<td>$0.16 &lt; z &lt; 0.47$</td>
</tr>
<tr>
<td>Generate 1,000 mock catalogs considering <strong>angular</strong> and radial selection function</td>
<td>Generate 1,000 random catalogs considering <strong>angular</strong> and radial selection function</td>
</tr>
</tbody>
</table>
0.237 < z < 0.263

SDSS DR7 LRGs
(N=6972)

Mock catalog
(N=6957)

Random catalog
(N=6813)
3. Data analysis

\[ \xi = \frac{N_{\text{circle}}}{N_{\text{tot}}} \cdot \frac{A_{\text{circle}}}{A_{\text{tot}}} \]

\[ \xi = 1 \rightarrow \text{homogeneous!!} \]

where

- \( N_{\text{circle}} \): number of galaxies within circle
- \( A_{\text{circle}} \): area of circle
- \( N_{\text{tot}} \): total number of galaxies in redshift slice
- \( A_{\text{tot}} \): area of observed region
<table>
<thead>
<tr>
<th>Previous study</th>
<th>Our study</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean number of neighbors of a given galaxy within a spherical volume of radius $R$ is proportional to $R^D$</td>
<td>Test is conducted by counting the number of galaxies within galaxy centered 2-dimensional space.</td>
</tr>
<tr>
<td>Highly affected by cosmological model</td>
<td>Less-affected by cosmological model</td>
</tr>
</tbody>
</table>

\[
R^D = \frac{N_{LRGs}}{N_{Random}}
\]

\[
\xi = \frac{N_{circle}/A_{circle}}{N_{tot}/A_{tot}}
\]
3. Data analysis

HEALPix—
The Hierarchical Equal Area iso-Latitude Pixelization (Gorski et al. 2005)

- LRGs correspond to each pixel
- Observed area of LRGs is obtained by the number counting of each pixel
3. Data analysis

Observed area > 95%

Radius: $50 \sim 300 \, h^{-1}\text{Mpc}$

$z \sim 0.225$

$R = 100 \, h^{-1}\text{Mpc}$

Galaxy centered circle

- 2-Dimensional Homogeneity test
3. Data analysis

- Redshifts are sliced for 2D analysis
- In order to find out how the thickness of redshifts can affect the result.
4. Results

$z \sim 0.25$

$R=50\text{Mpc}/h$

$R=100\text{Mpc}/h$

$R=150\text{Mpc}/h$

$R=200\text{Mpc}/h$

$R=250\text{Mpc}/h$

$R=300\text{Mpc}/h$

$z \sim 0.35$

$R=50\text{Mpc}/h$

$R=100\text{Mpc}/h$

$R=150\text{Mpc}/h$

$R=200\text{Mpc}/h$

$R=250\text{Mpc}/h$

$R=300\text{Mpc}/h$

$z \sim 0.40$

$R=50\text{Mpc}/h$

$R=100\text{Mpc}/h$

$R=150\text{Mpc}/h$

$R=200\text{Mpc}/h$

$R=250\text{Mpc}/h$

$R=300\text{Mpc}/h$
5. Summary

(1) The $\langle \xi \rangle$ distribution of mock data approaches to that of Random data at the radius of circular disk increases.

(2) $\langle \xi \rangle$ distribution of LRGs data tends to overlap with that of Mock data, but significant deviation from the prediction of Random data.

(3) Our results are robust because the behavior of $\xi$ statistics is insensitive to the redshift and the thickness of redshift-slice.

The large-scale structure is consistent with mock data but not consistent with random data as the radius approaches $300h^{-1}$Mpc.
6. Future works (2D+3D)

- Center galaxies selected in redshift-slice (2D)
- Counting the number of galaxies in circle at radius $R$ within redshift-slice (2D)

- Center galaxies selected in redshift-slice (2D)
- Counting the number of galaxies in sphere at radius $R(3D)$
Thank you!

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