Real-space density profile reconstruction of stacked voids

New Horizons for Observational Cosmology

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Image Credit: Millennium simulation
The standard cosmological model

We don’t understand most of our universe!

The study of large scale structures is a powerful tool to understand the composition of the universe.

Physics Nobel Prize 2011 Perlmutter, Riess, Schmidt

Supernova I a

CMB-Planck collaboration

Albert Einstein

Vera Rubin

Fritz Zwicky
The cosmic web

Sphericity is the key feature!

Voids: different shapes but *spherical* average shape in an isotropic and homogeneous universe!

Voids: complex, filamentary, supercluster structures

emptier (not empty!) regions from 10 to 100 of Mpc/h: VOIDS
Alcock-Paczynski test

The test uses the apparent stretching of spheres in the redshift space coordinates to estimate the local geometry of expansion by comparing the angular size to the radial/redshift size that is affected by cosmology.

Known luminosity

Known length

Known ratio

radial size

angular size

This test can be applied to VOIDS!!
A tension between SN data and Planck?

\[ H_0 = 73.8 \pm 2.4 \text{ Km s}^{-1} \text{ Mpc}^{-1} \]

Local measure of the Hubble parameter?

AP TEST!!
Voids: Dark Energy-dominated objects

universe accelerated expansion
dark energy (FOM one order of magnitude higher than BAO)
cosmological parameters

Sutter et al. 2012, arXiv 1208.1058
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BUT: measures affected by distortion!
We do not know the spherical profile of stacked voids in real space!
How to determine the void spherical density profile?

Line of sight

Peculiar velocities contribute to redshift **DISTORT** the void density profile.

We must **EXCLUDE** distortion!
The method to get the spherical profile

**Key idea**

Projecting the 3D distribution along the line of sight, the contribution of peculiar velocities disappears.

From this projection we reconstruct a 3D profile without the contribution of peculiar velocities.

We can obtain the SPHERICAL density profile of stacked voids in real space.
Abel inverse transform: mathematically well-defined but ill-conditioned!

\[ g(r) = -\frac{1}{\pi} \int \frac{r(y)}{\sqrt{r^2 - y^2}} dy \]
Abel inverse transform: mathematically well-defined but ill-conditioned!

\[ g(r) = -\frac{1}{\pi} \int \frac{r(y)}{r \sqrt{y^2 - r^2}} \, dy \]

RESULT: Very good reconstruction!
The full simulated stacked void

Stacking from 10 to 12 Mpc/h

Simulated void from G. Lavaux
Result III

REAL DATA from SDSS!!!

Dim 2 (5-15 Mpc/h)

Conclusion

• Algorithm for density profile reconstruction.
  ➡ Tested on toy model, simulations.
  ➡ Successfully applied on real voids!
    First density profiles in real space!

• Knowledge about voids: the way to measure the Hubble constant and test cosmological models.
Thank you!