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eBOSS Power Spectrum via Wavelet Packets

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FaST Research Program

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Background

Large Scale Structure (LSS)

- LSS is clustering that is different than a random distribution.
- Caused by gravitational interaction and the expanding universe.

Baryonic Acoustic Oscillation (BAO)

- A BAO is an example of LSS
- It is a pressure wave that emanates from a dark matter gravitational well

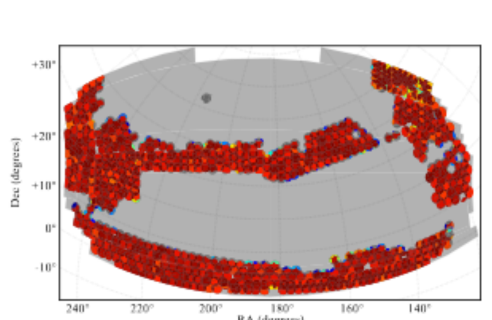
Basic Cosmology

- The location of the BAO tells us about the basic cosmological parameters such as the Hubble constant, density of curvature energy, and the dark energy equation.

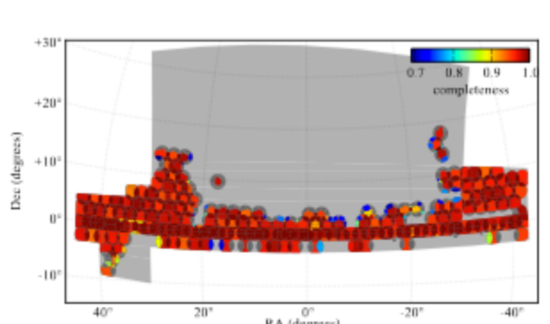
Sloan Project

- Sloan Digital Sky Survey (SDSS) III: SDSS provides us with data that shows us the distribution of luminous and non-luminous matter in the Universe
- Extended Baryonic Oscillation Spectroscopic Survey (eBOSS): maps galaxies and quasars up to redshift z=6

Northern Data



Southern Data



Procedure

The SDSS-III data is mapped on a sphere, but in order to use it we needed it to be on a square matrix. We translated the spherical data onto a square matrix using a technique called HEALPix

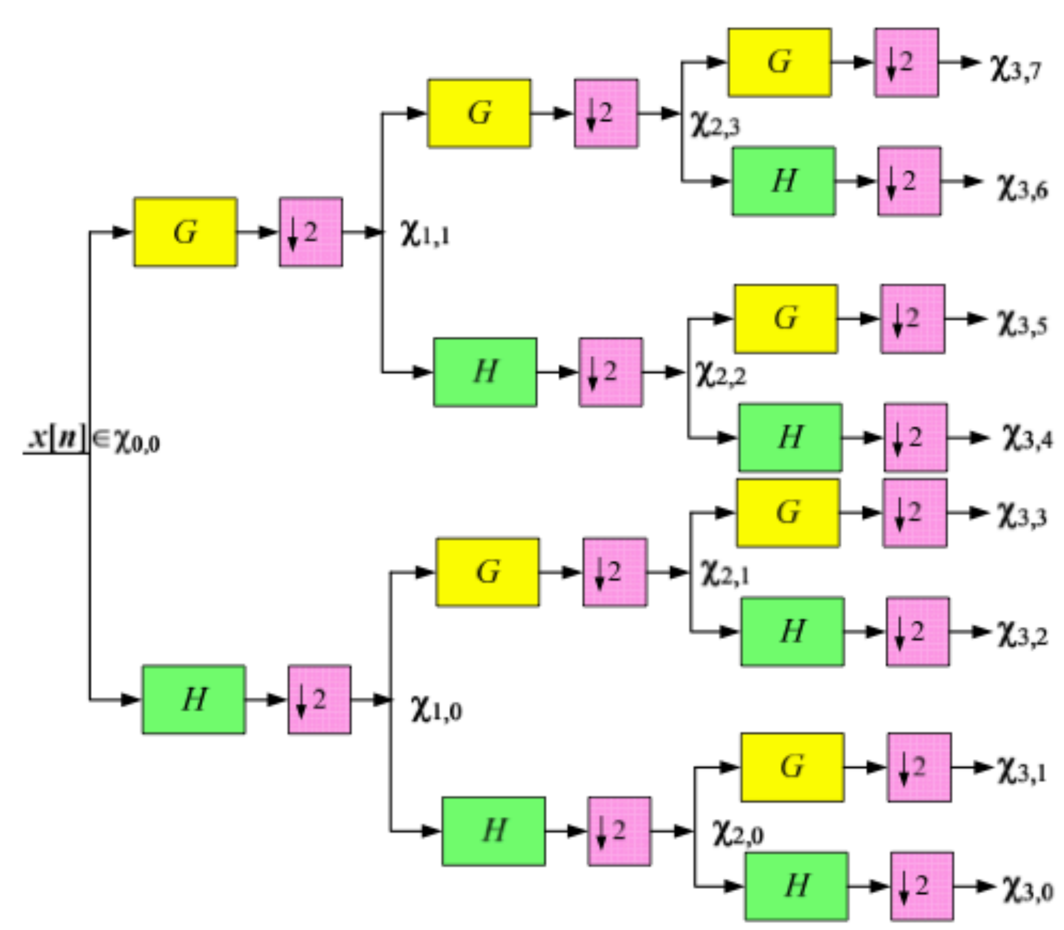
- Chose the largest square matrix on the northern and southern skies
- Chose a resolution
- Submitted data to wavelet packet analysis
- Computed the power spectrum and two-point correlation function

Power Spectrum

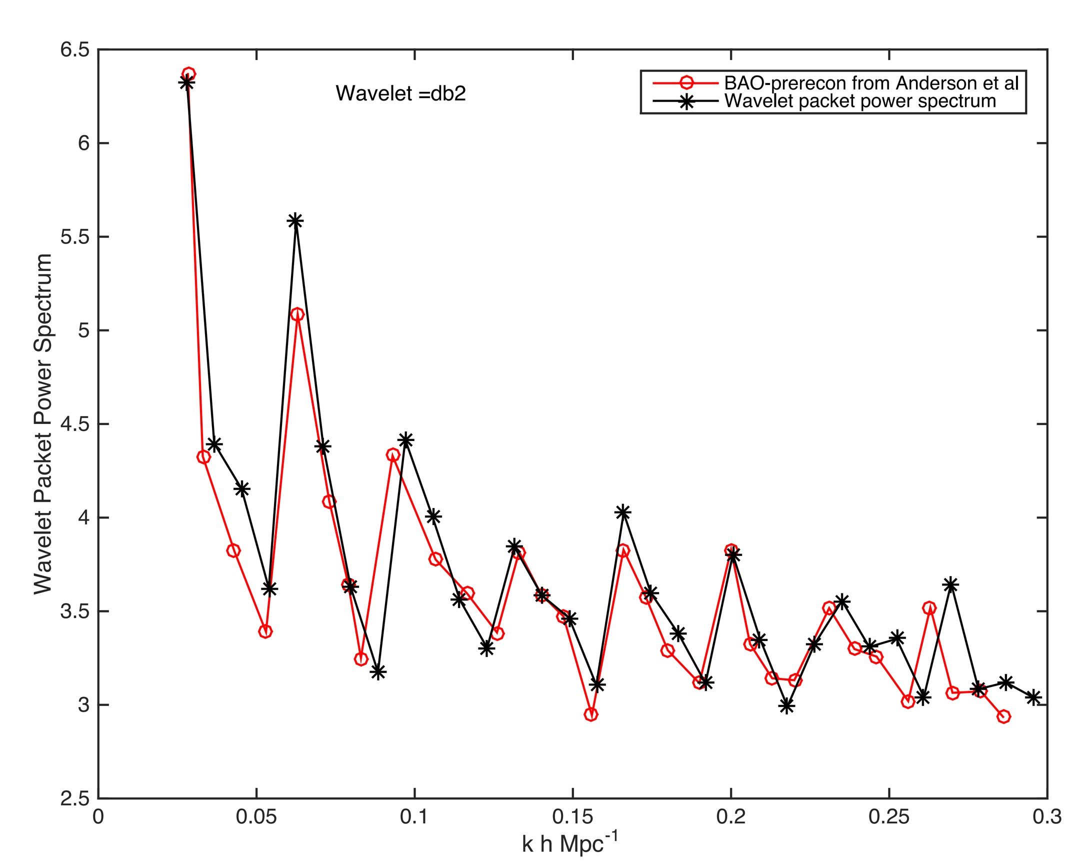
- The Power Spectrum give the variance as a function of scale (or frequency).
- Here the power spectrum shows how much galaxy clustering is happening and at which scales it is occurring.
- The power spectrum is the basic tool in studying large scale clustering in cosmology.

Wavelet Packet Power Spectrum

- Wavelet Packet is a method of signal decomposition that is computationally-efficient, offers rich analysis, and has sufficient resolution.



- Compared to the Fourier transform, Wavelet Packet analysis is compact, takes less processing, and is just as fast.
- Wavelets work by using a compactly supported basis that is convolved with the function.
  - The basis is then translated across the signal
  - This produces two sets of coefficients corresponding to local densities and local fluctuations
  - The basis is then applied to the local densities to get information at the next resolution
  - Wavelet packets differ from wavelets in that the basis is applied to both sets of coefficients.



Wavelet packet power spectrum:

Pj,n = ⟨δ2⟩j,n

where Pj,n is the wavelet packet power spectrum at resolution, j, and leaf n, and δ2 j,n is the mean of wavelet packet coefficients at resolution j and leaf n.

Results in excellent agreement with published works which use Fourier techniques.
However wavelets allowed us to do almost no pre- and post processing of the data unlike Anderson et al.

Two-Point Correlation

Another standard measure of clustering is the Two-point correlation function

In general, the two-point correlation function is a statistical interaction between two variables in two different points in space or time; so in our case the two-point correlation function describes the distribution of galaxies in the universe. It is a function of distance and calculates the probability of how far two galaxies are from each other.
This correlation function is computationally very expensive. However, it and the power spectrum are Fourier transform pairs. That is:

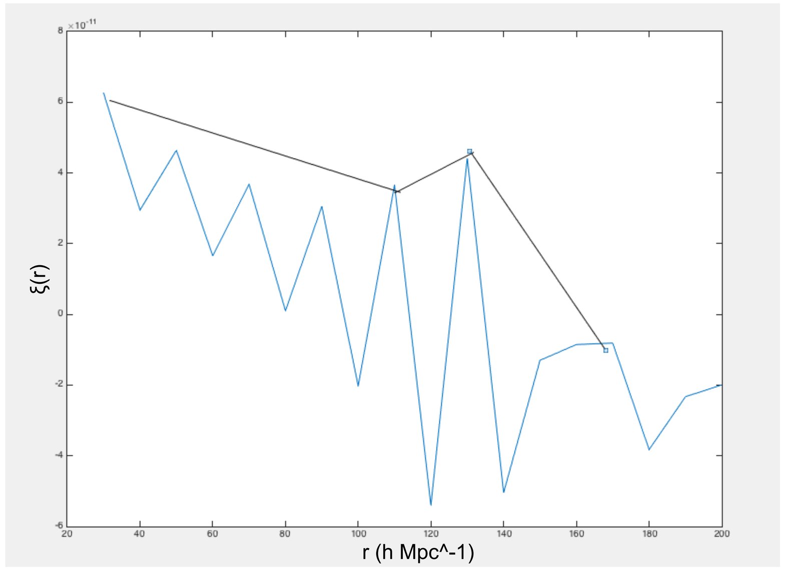
$$\xi(r) = \int \frac{k}{2\pi} P(k) J_0(kr)\, dk$$

However, we have a discrete data set. To perform The integral numerically, we used the result found by Szapudi et al:

$$\int_0^\infty f(x) J_v(x) \cong \pi \sum_{n=1}^{\infty} w_{v,n} f(\pi\psi(hz_{v,n})/h) J_v(\pi\psi(hz_{v,n})/h) \psi'(hz_{v,n})$$

Where, w is the weights, ψ is the double exponential transform, z is the zeros of the Bessel function, and h is the step size.

Our results shown in the figure find the BAO Peak at 130 Mpc. Anderson et al find the peak At 120 Mpc. We are close to theirs, but different.



FUTURE RESEARCH

SDSS IV
Getting from k to j

Acknowledgements

FaST Team.
Anderson et al.
Szapudi et al.

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