XIII ET Symposium

Probing the Large Scale Structure with the third generation Gravitational Wave detectors

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8 - 12 May 2023

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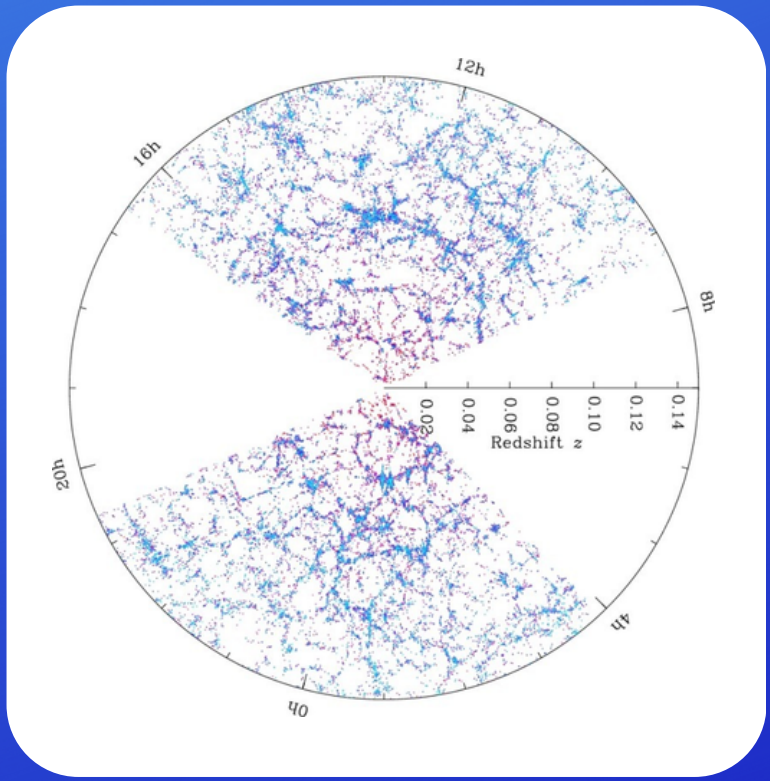
Large Scale Structure

Uniform universe at the largest scales
ΛCDM model: background cosmology

At smaller scales: clustering
Primordial density fluctuations

Evolution through gravity
Mostly Dark Matter driven



Large Scale Structure

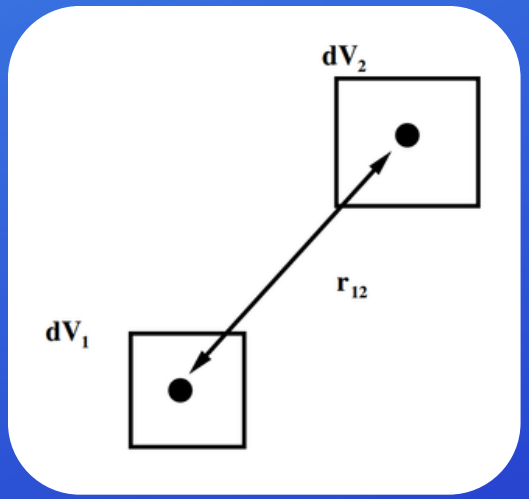
How do we describe structure?

- Correlation function

$$d^2P(r) = \frac{1}{V^2}(1 + \xi(r))dV_1 dV_2$$

- Power spectrum

$$\xi(\vec{r}) = \frac{1}{(2\pi)^3}\int P(\vec{k})e^{-i\vec{k}\cdot\vec{r}}d\vec{k}$$



Large Scale Structure

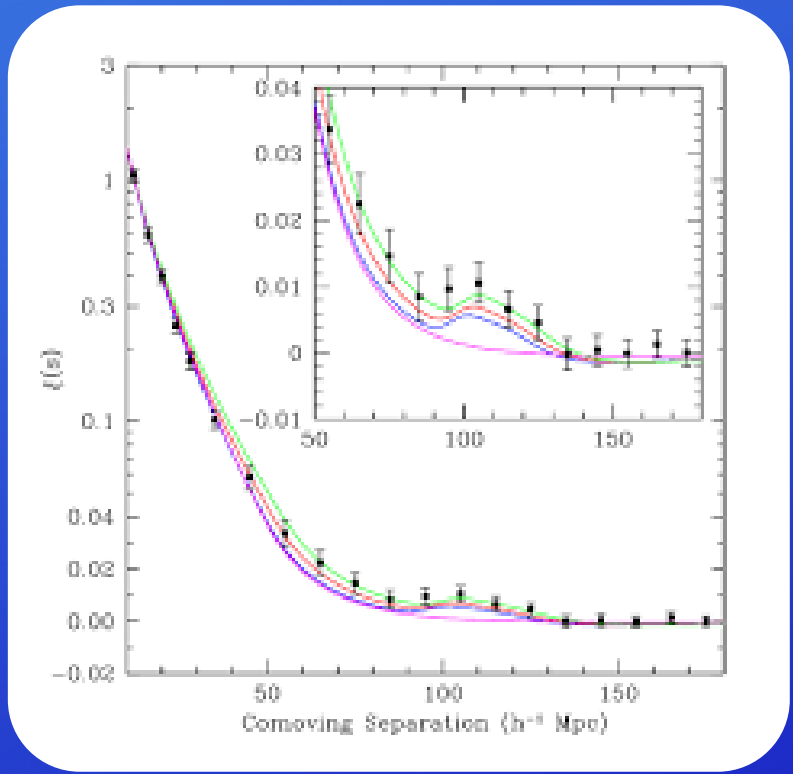
How does matter follow the DM distribution?

Bias factor
Redshift dependent

$$\rho_{\rm gal} = b_{\rm gal}\rho_{\rm DM}$$

$$\xi_{\rm gal}(r) = b^2_{\rm gal}\xi_{\rm DM}(r)$$

$$\xi_{\rm BBH}(r) = b^2_{\rm BBH}\xi_{\rm DM}(r)$$



The correlation function

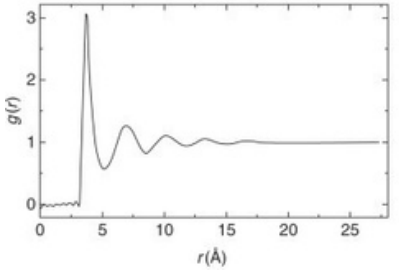
How do you calculate the correlation function?

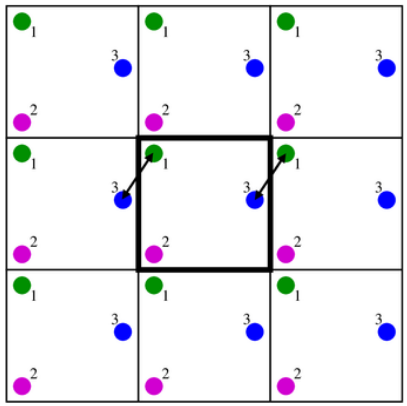
- Statistical physics

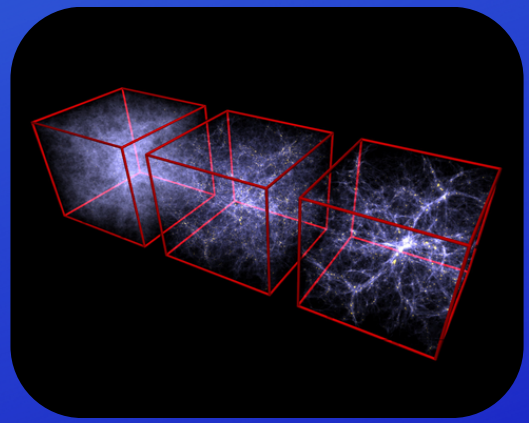
Compare number of data pairs with random distribution
Use cubes with periodic boundary conditions

- Cosmology

Structure evolves through time
We see the Universe at different times
Take shell per cube at $d_l(z)$







ETcosmo

Codebase for simulating the reconstruction of the correlation function using GW observations

Why GWs?

- Up to higher redshifts
- Different probe

Goals:

- Bias factors and its dependencies (redshift, astrophysics)
- Recover the BAO peak

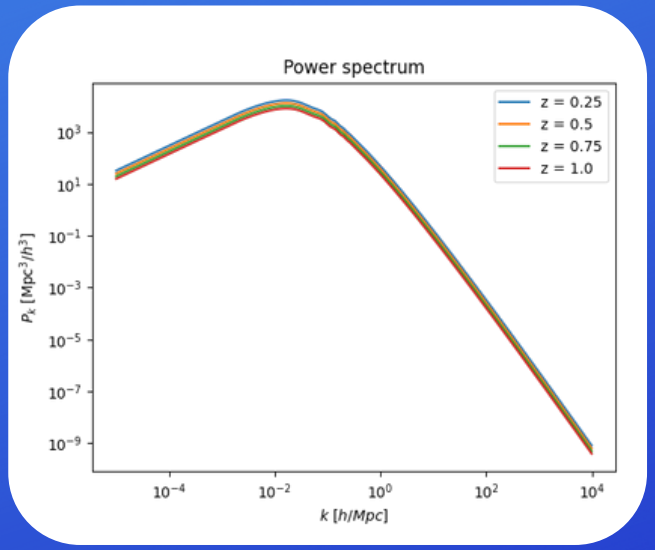
ETcosmo

Step 1: Generate GW injections with lognormal_galaxies

Step 2: Perform parameter estimation with gwbench
Fisher matrix

Detector configurations:

- Δ + 2CE
- 2L 0° + 2CE
- 2L 45° + 2CE



Step 3: Reconstruct the correlation function with Corrfunc
Landy Szalay estimator

A. Vijaykumar et al.

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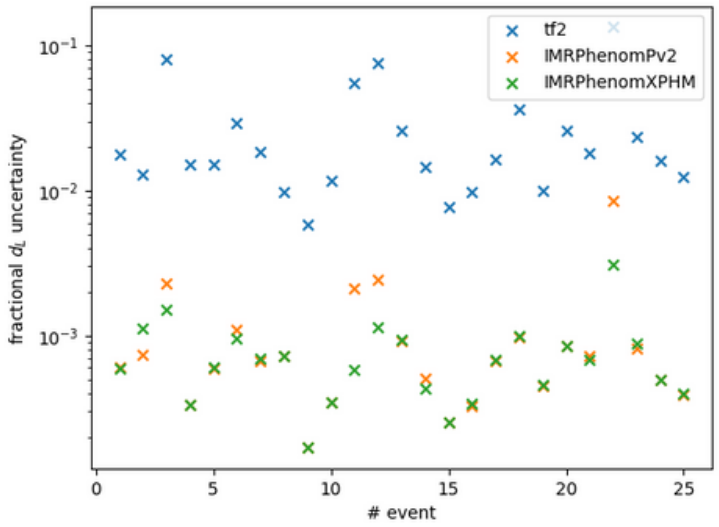
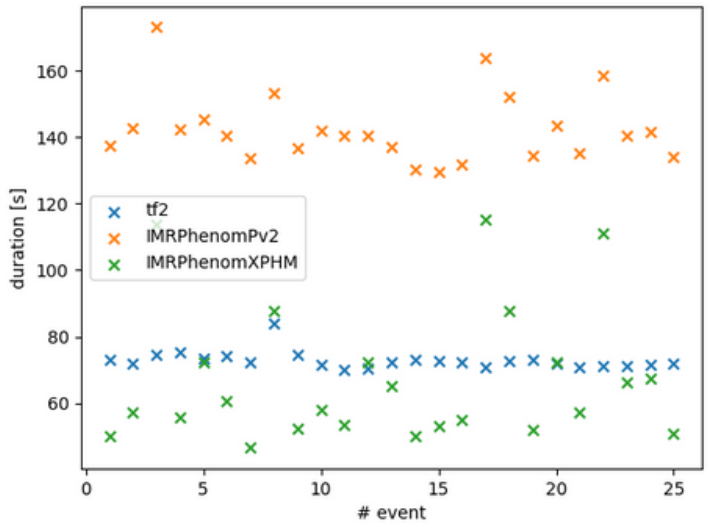
PE: Waveform comparisons
25 random events from a shell at *z = 0,5*

tf2 yields large uncertainties
IMRPhenomPv2 and IMRPhenomPXHM: comparable uncertainties
Higher modes do not always give a better result





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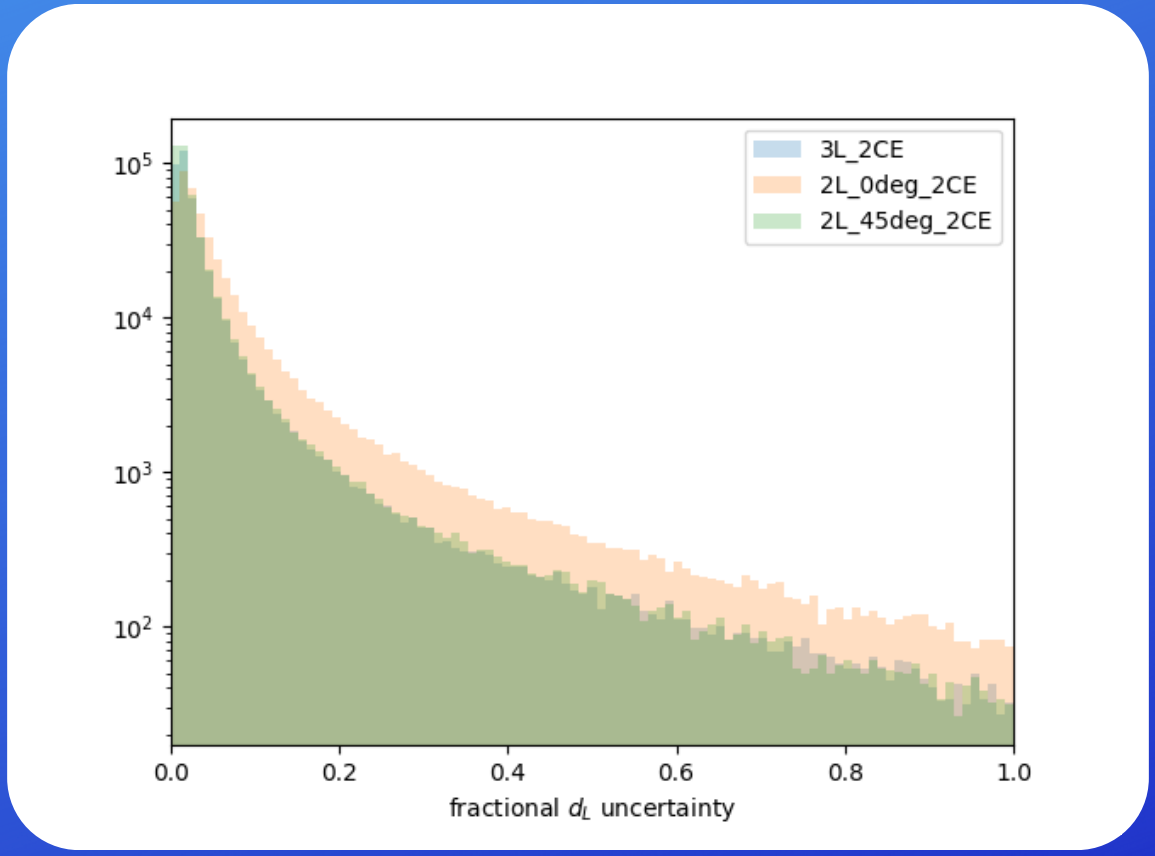
PE: Detector configurations
Distributions of resulting uncertainties using IMRPhenomPv2



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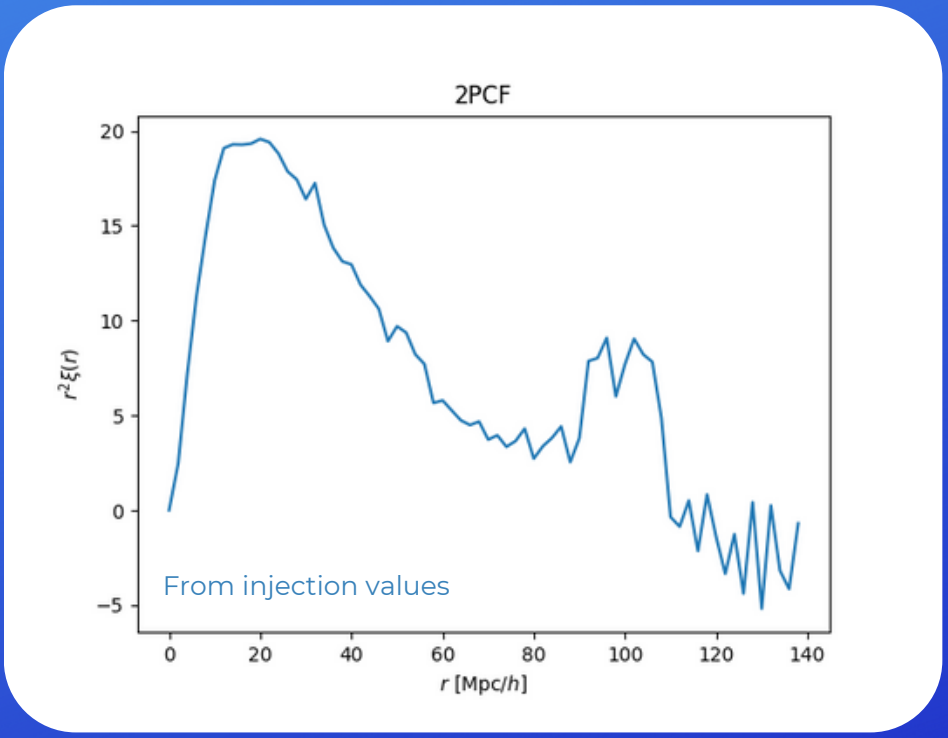
Correlation function reconstruction

Select event with low d_l uncertainties (introduces a selection effect)
Sample one point for each event



Improvements

MDC Universe generation

- Different mass models
- Add galaxy host selection based on galaxy properties

PE

- Add GW selection effects
- Add lensing effects (microlensing)
- Window function for shell taking

Study

- Evolution of GW bias with redshift
- Reconstruct the angular correlation function