The cosmic web as a cosmological probe

Jaime E. Forero-Romero (Uniandes)
in collaboration with: **Diego Barbosa, Valentina García, John Suárez, Felipe Gómez, David Paipa, Jairo Saavedra, Yeimy Camargo** (UNAL), Xiao-Dong Li (Sun Yat-Sen) and the DESI collaboration
CoCo, May 2019

What kind of cosmology are we working on?

astroandes

Computational astrophysics at Universidad de los Andes (Colombia)

Bogota, Colombia http://astroandes.github.io/

Repositories 35 People 6 Teams 0 Projects 0 Settings

Pinned repositories

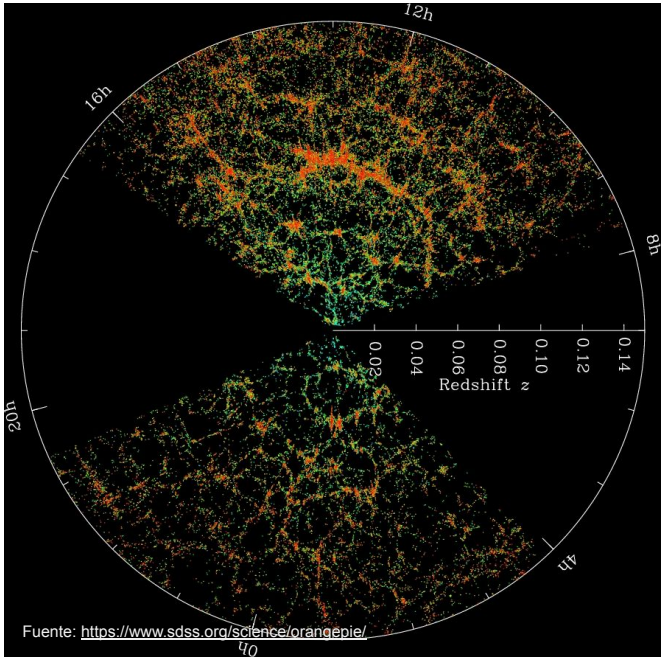
StochasticityCALIFA
Trying to measure SFR stochasticity effects from CALIFA data
Jupyter Notebook ★ 2

SatelliteShapeLG
Alineaciones en Illustris Sims
Jupyter Notebook ★ 1

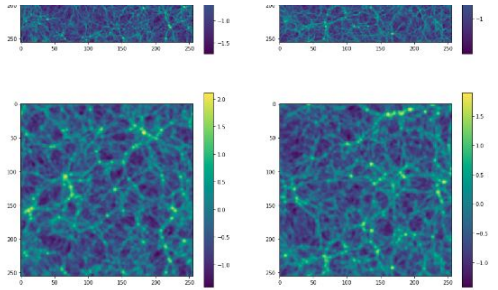
CLARA_RotationOutflows
Repository to run CLARA implementing rotation and outflows together.

MACH
MCMC Adjuster for Concentrations in Halos

3D maps (real and simulated) are our main focus



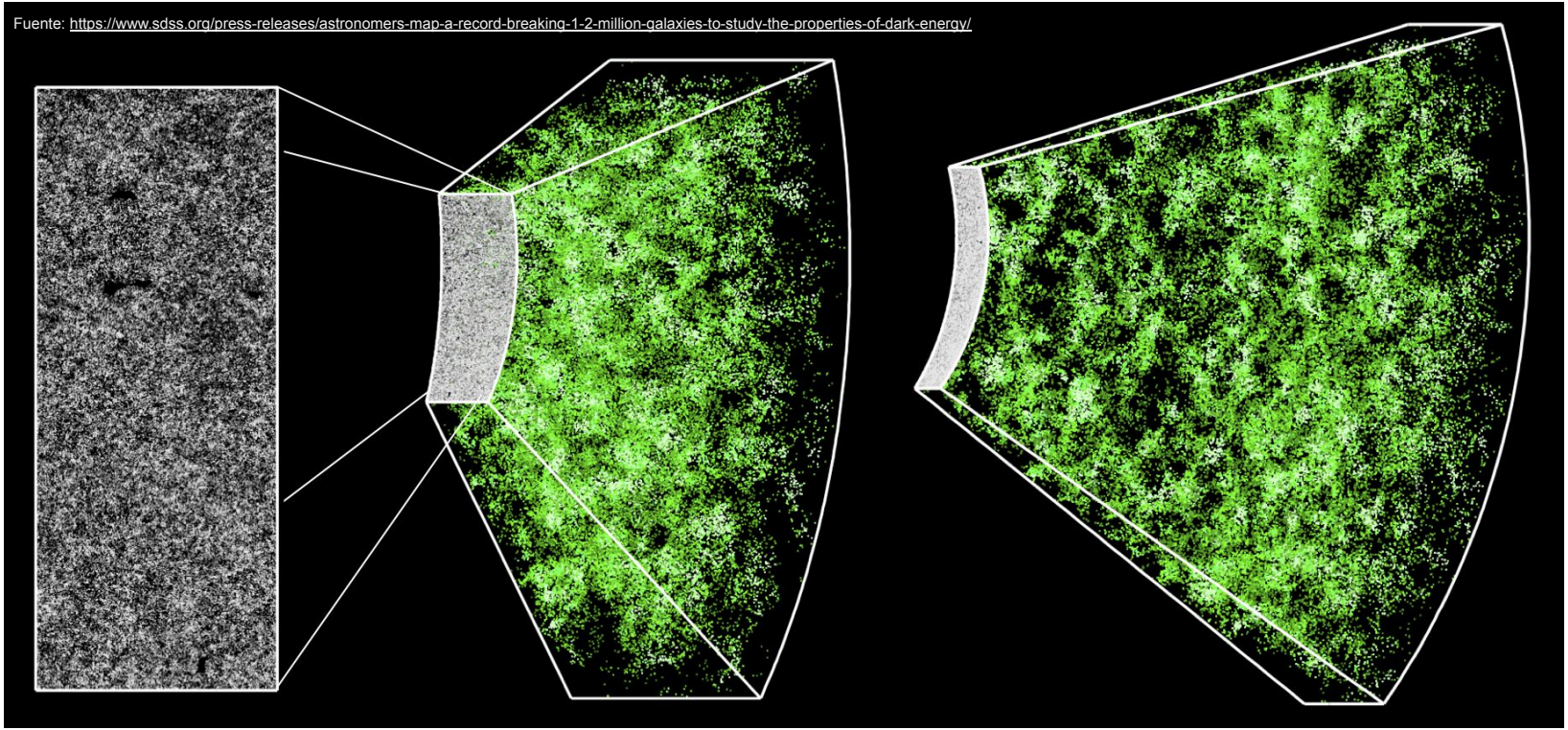
Fuente: https://www.sdss.org/science/orangepie/



```
In [8]: fft_lowres = np.fft.fftn(data_smooth)
        fft_lowres[0,0,0]=0.0
        back_data = np.fft.ifftn(fft_lowres)
```

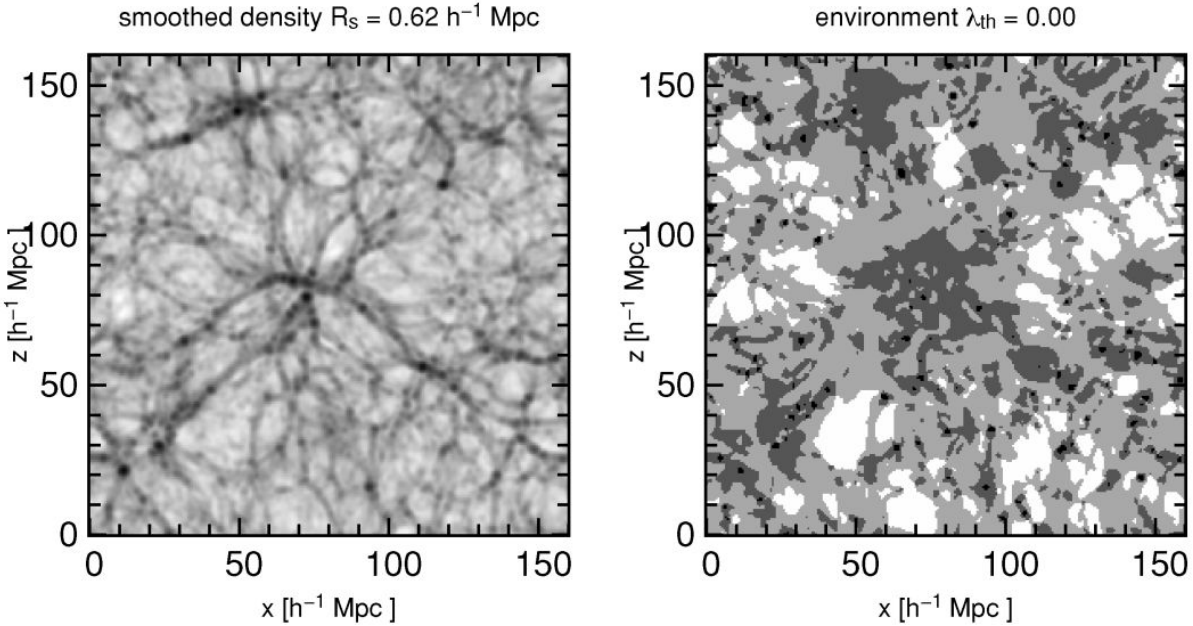
```
In [9]: n_side = np.shape(fft_lowres)[0]
        print(n_side)

        L_box = 205.0 # in Mpc/h
        delta = L_box/n_side
        k_2_values = np.ones((n_side, n_side, n_side))
        for i in range(n_side):
            for j in range(n_side):
                for k in range(n_side):
                    k_i = i
                    k_j = j
                    k_k = k
```

3D maps of the Universe are key elements in cosmology



In simulations we use the tidal tensor to find the cosmic web

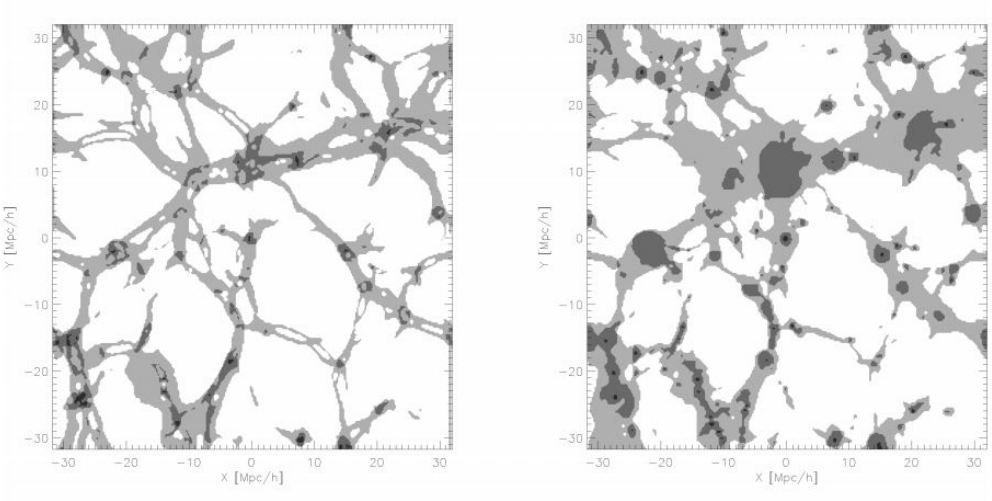
$$T_{\alpha\beta} = \frac{\partial^2 \phi}{\partial r_\alpha \partial r_\beta}$$



Forero-Romero et al. (2009)

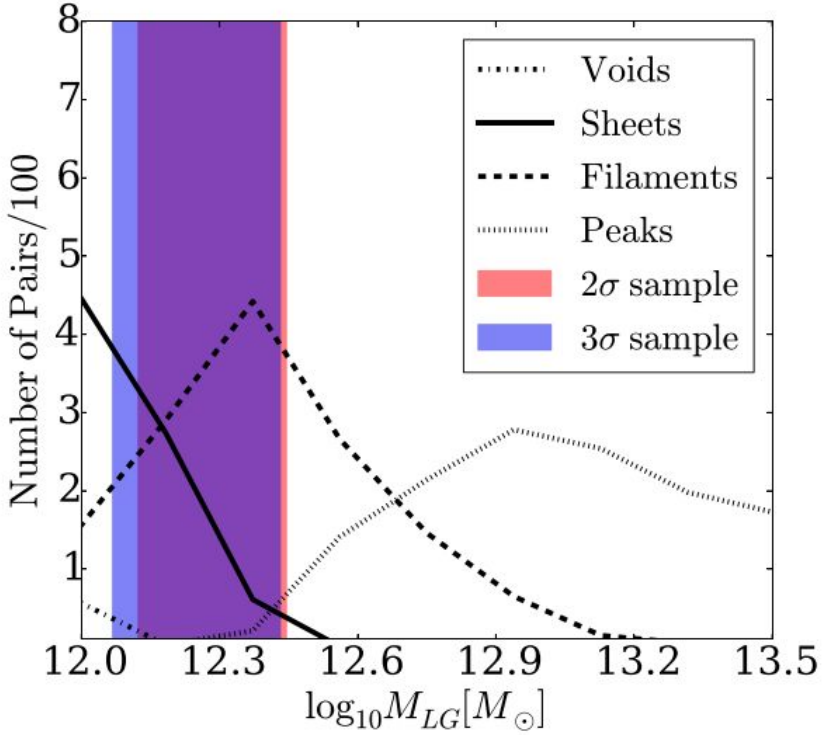
The velocity shear tensor is another way to find the cosmic web

$$\Sigma_{\alpha\beta} = -\frac{1}{2}\left(\frac{\partial v_\alpha}{\partial r_\beta} + \frac{\partial v_\beta}{\partial r_\alpha}\right) \Big/ H_0$$



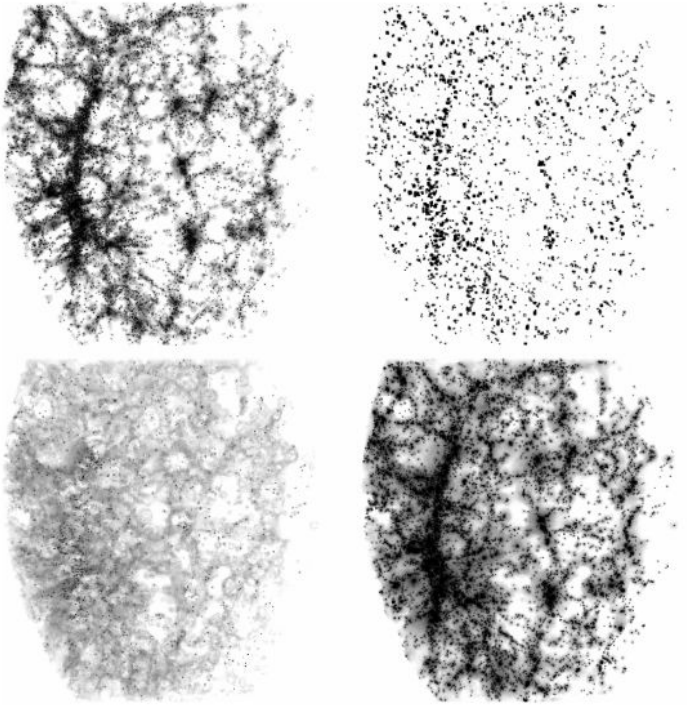
Hoffman et al. (2012)

Finding the place of our galaxy in the cosmic web



Gonzáles & F-R (2015)

The cosmic web on a reconstructed dark matter distribution



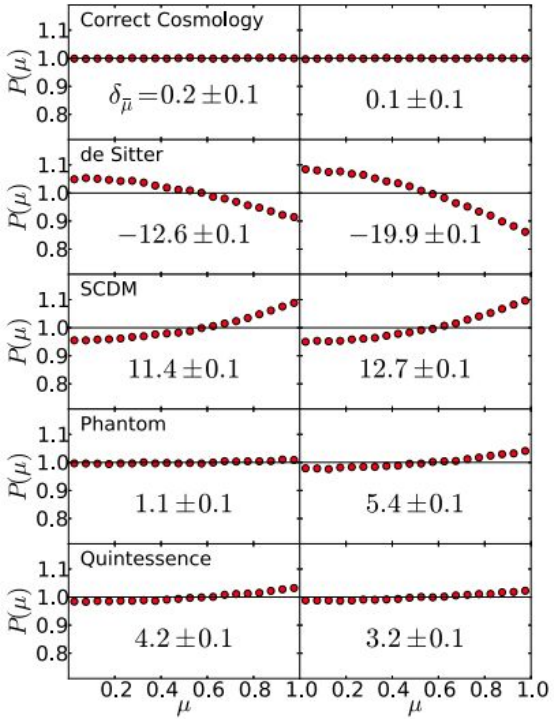
Muñoz-Cuartas et al. (2011)

Divergence fields can be used to find directions in the web

$$\rho(\mathbf{r}) = \sum_i m_i W(\mathbf{r} - \mathbf{r}_i, h),$$

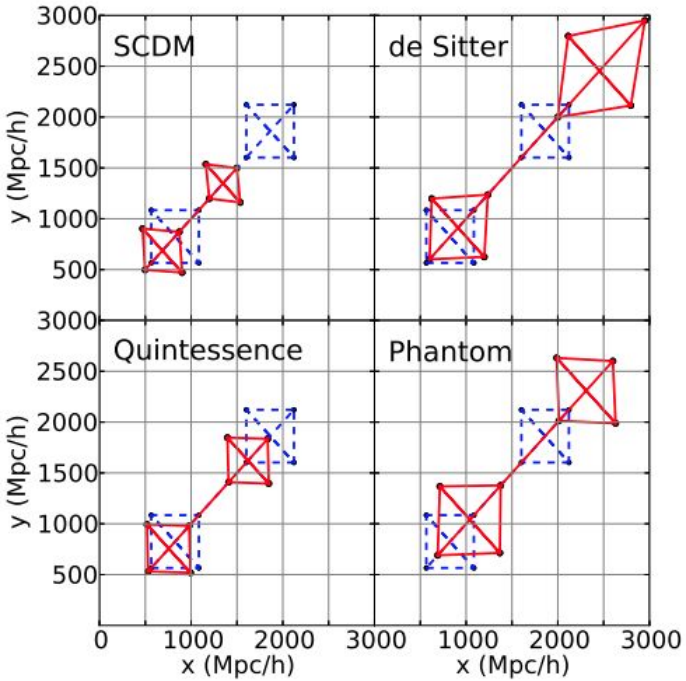
$$\nabla\rho(\mathbf{r}) = \sum_i m_i \nabla W(\mathbf{r} - \mathbf{r}_i, h),$$

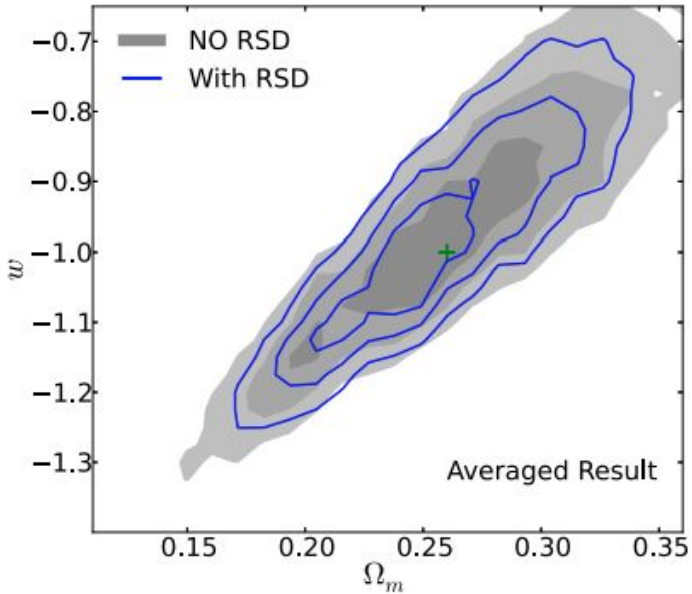
$$\mu \equiv |\cos\theta| = \frac{|\mathbf{r} \cdot \nabla\rho(\mathbf{r})|}{|\mathbf{r}| \times |\nabla\rho(\mathbf{r})|}.$$



Li et al. (2014)

Cosmic web directions can be used as a cosmological test





Li et al. (2014)

The beta-skeleton as a new definition of the cosmic web

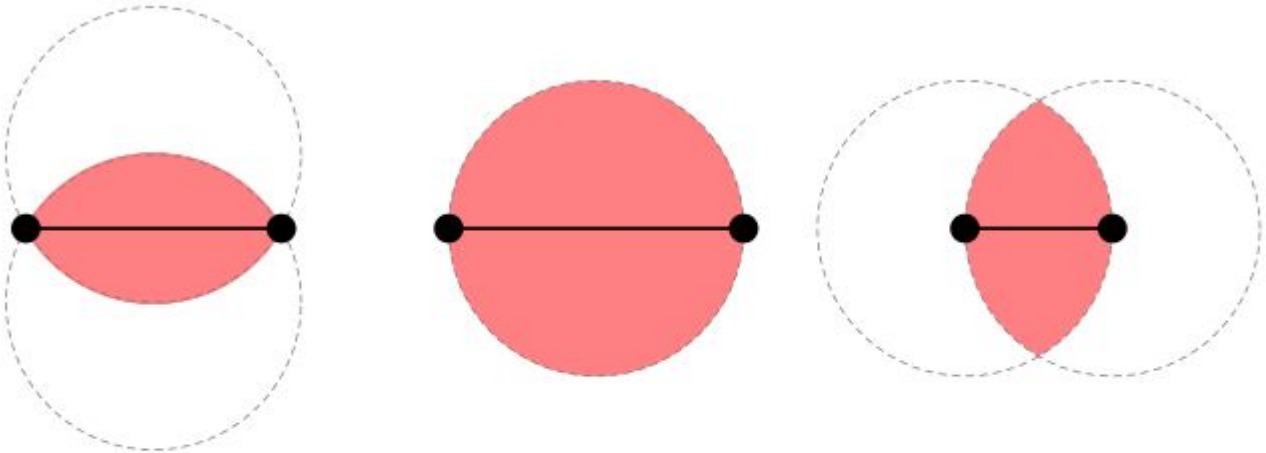
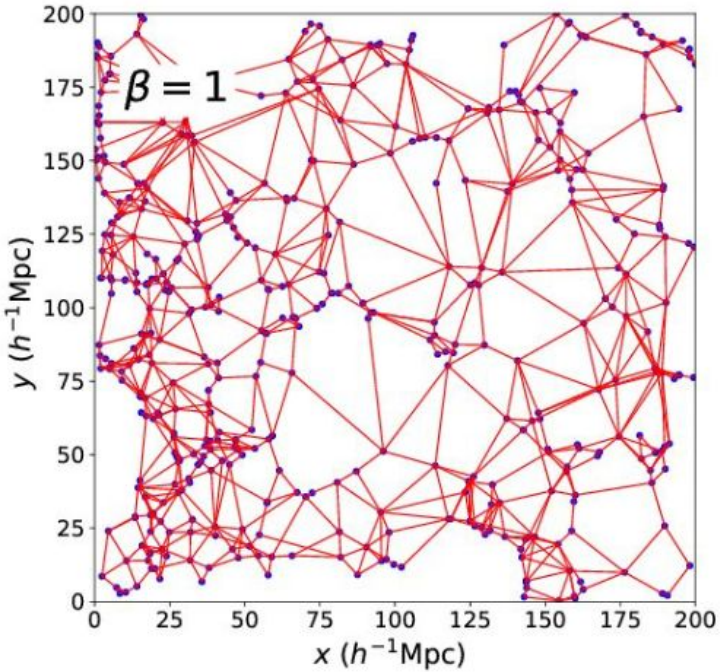
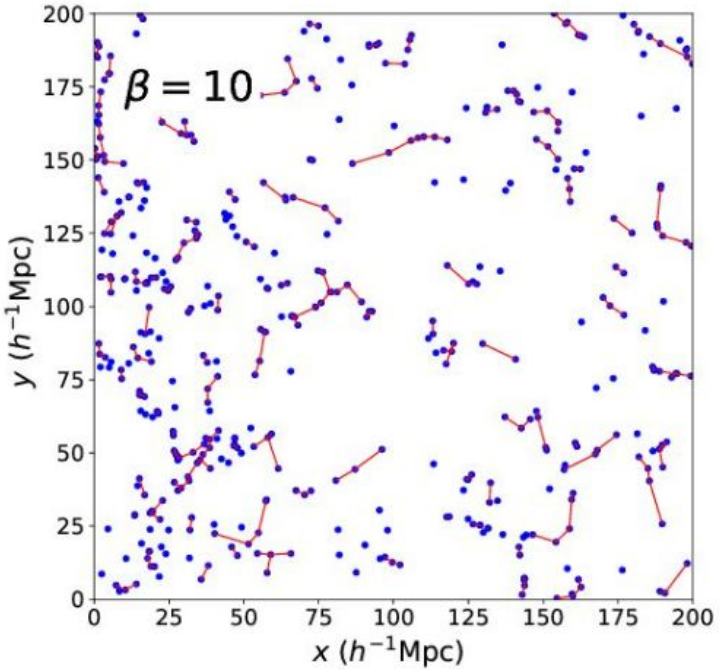


Figure 1. Empty region of the β-skeleton under the Lune-based definition. Left: $\beta < 1$, Middle: $\beta = 1$, Right: $\beta > 1$

Feng et al. (2019)

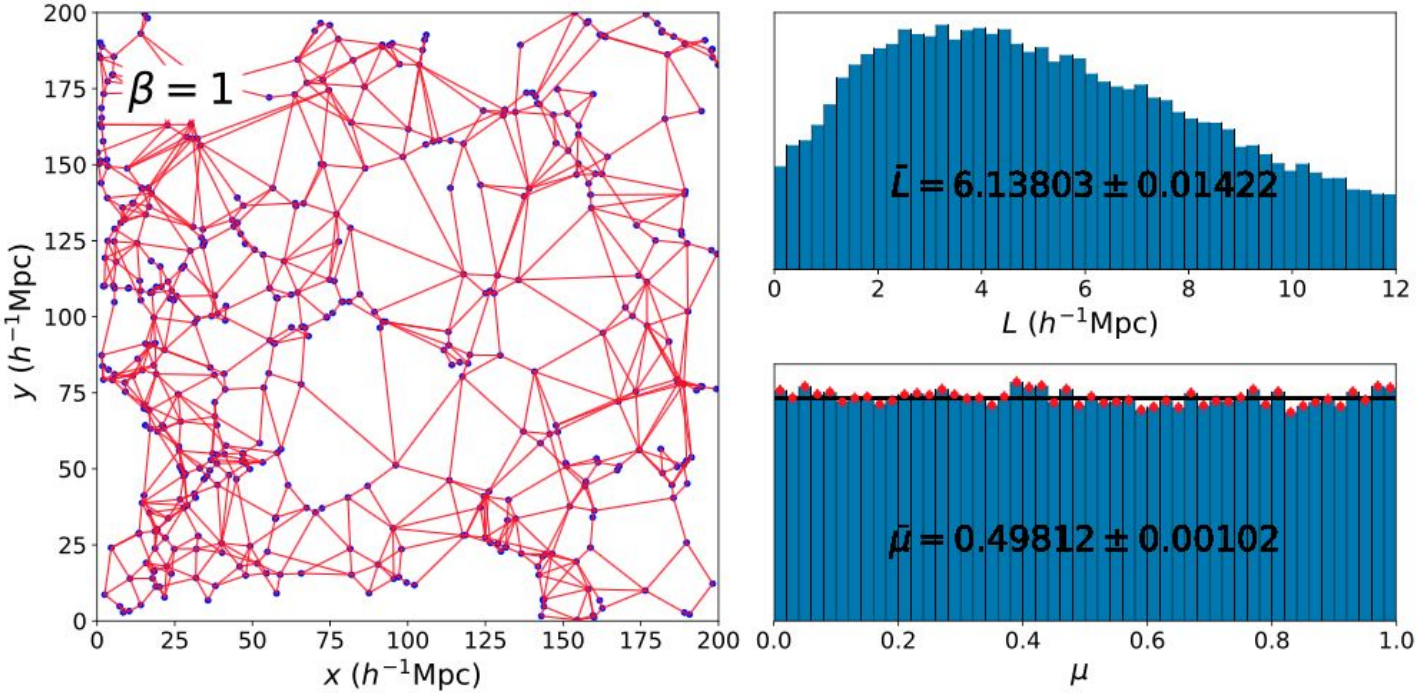
The detected cosmic web depends on the beta parameter





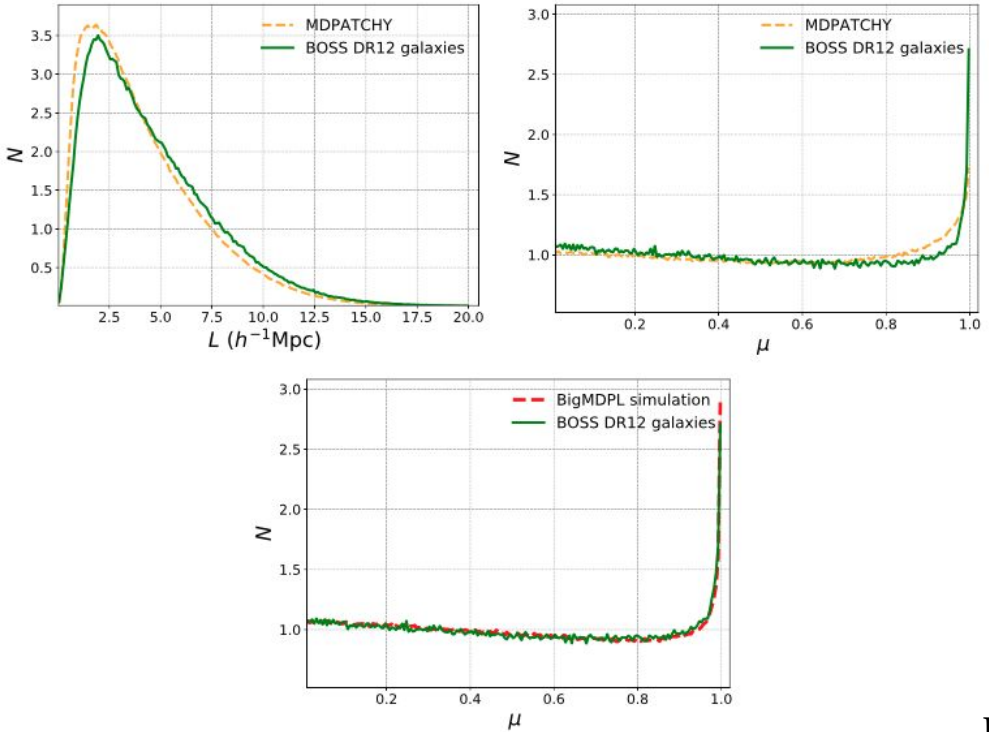
Feng et al. (2019)

The beta-skeleton provides new statistics to describe LSS



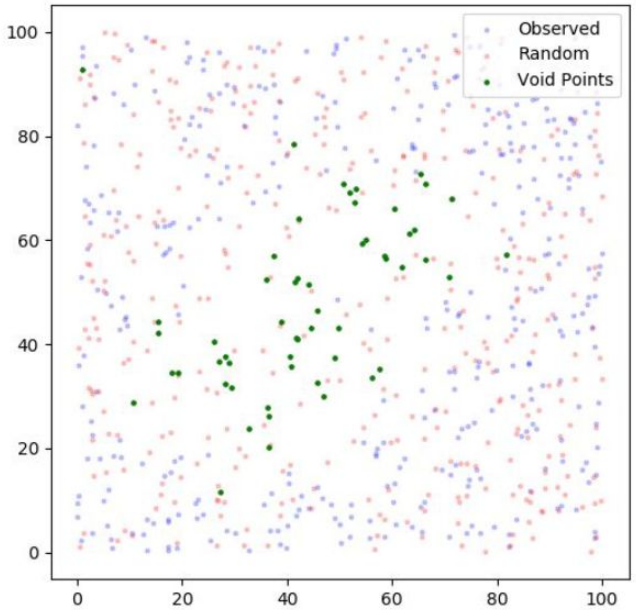
Feng et al. (2019)

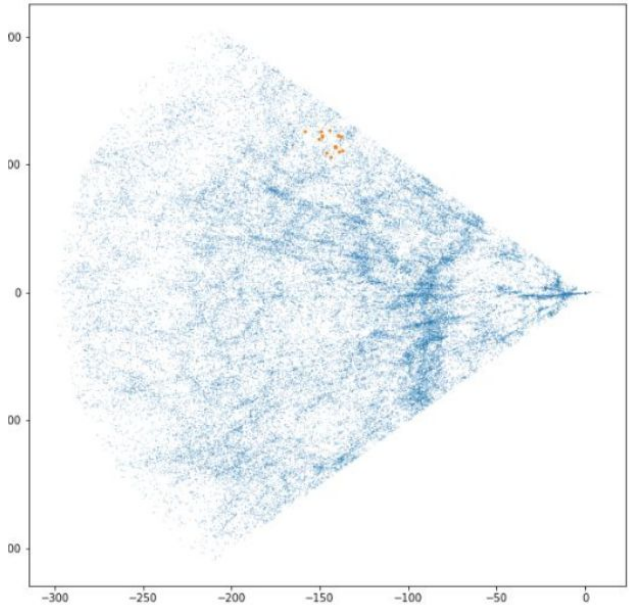
The beta-skeleton captures higher order correlations



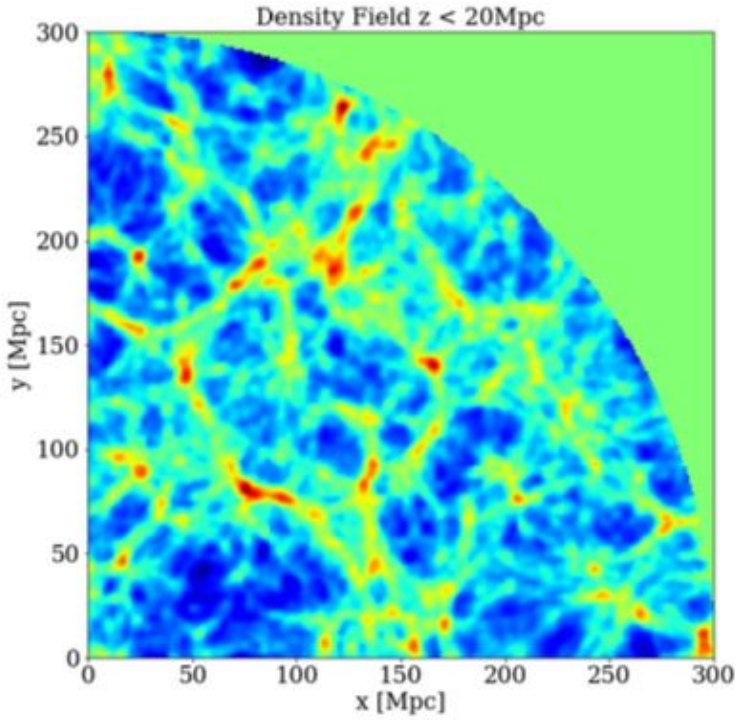
Feng et al. (2019)

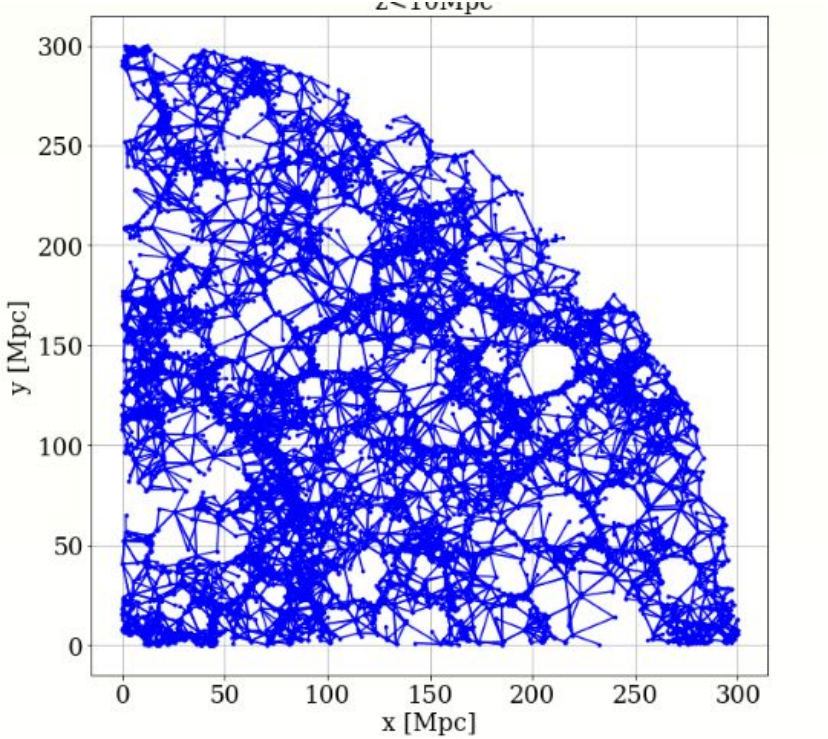
Finding voids with the beta-skeleton (Felipe)



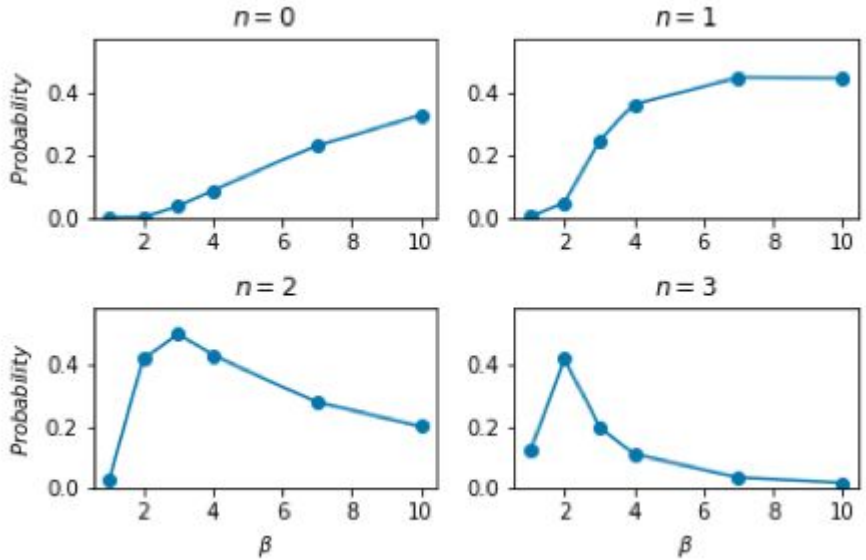


Linking the tidal web with the beta-skeleton web

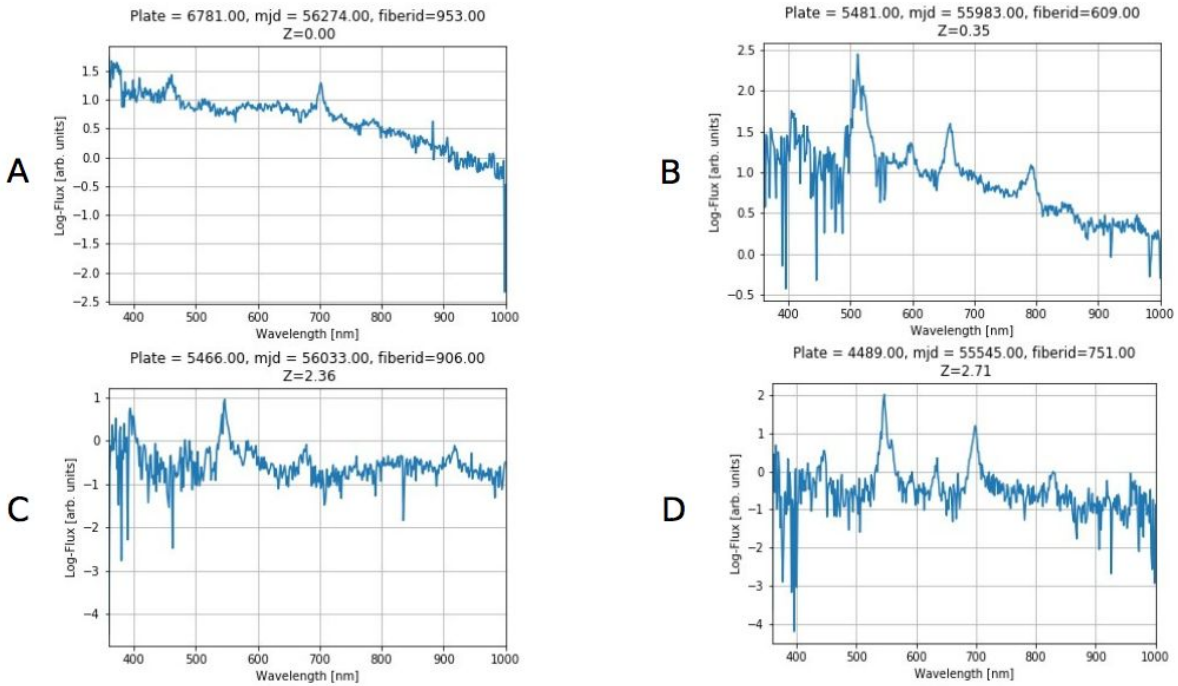




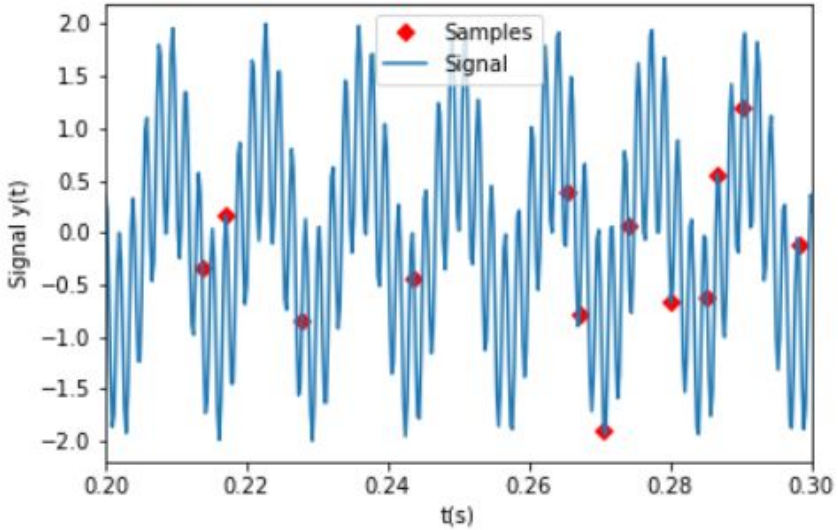
Using the beta-skeleton entropy as cosmological probe (Valentina)



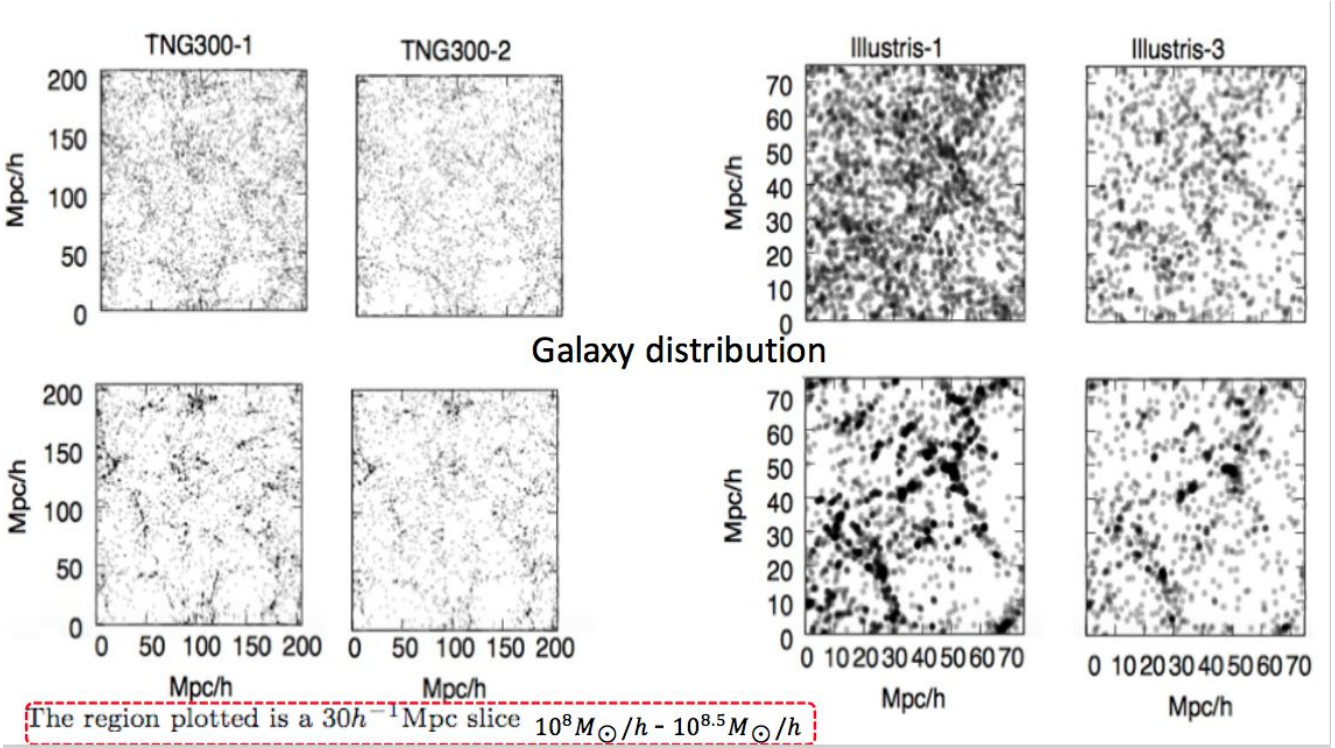
Using machine learning to build better galaxy maps (Jairo)



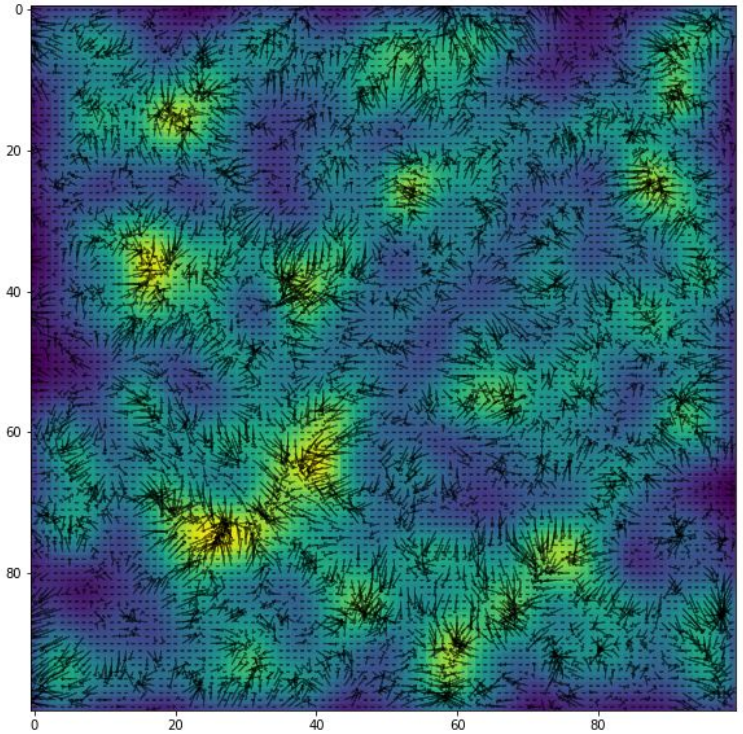
Using compressed sensing to build better galaxy maps (Diego)



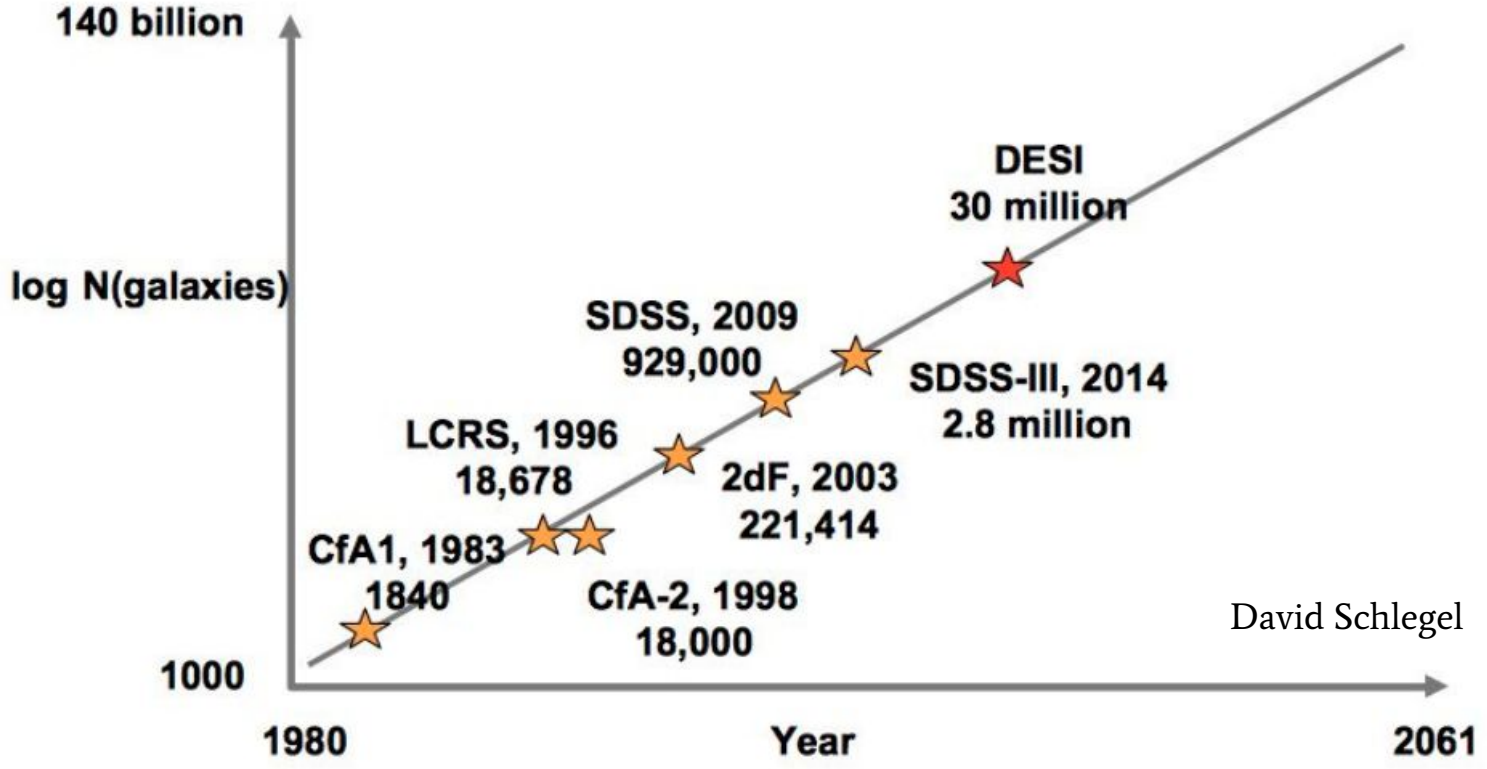
Measuring the cosmic web influence in building up galaxies (Yeimy)



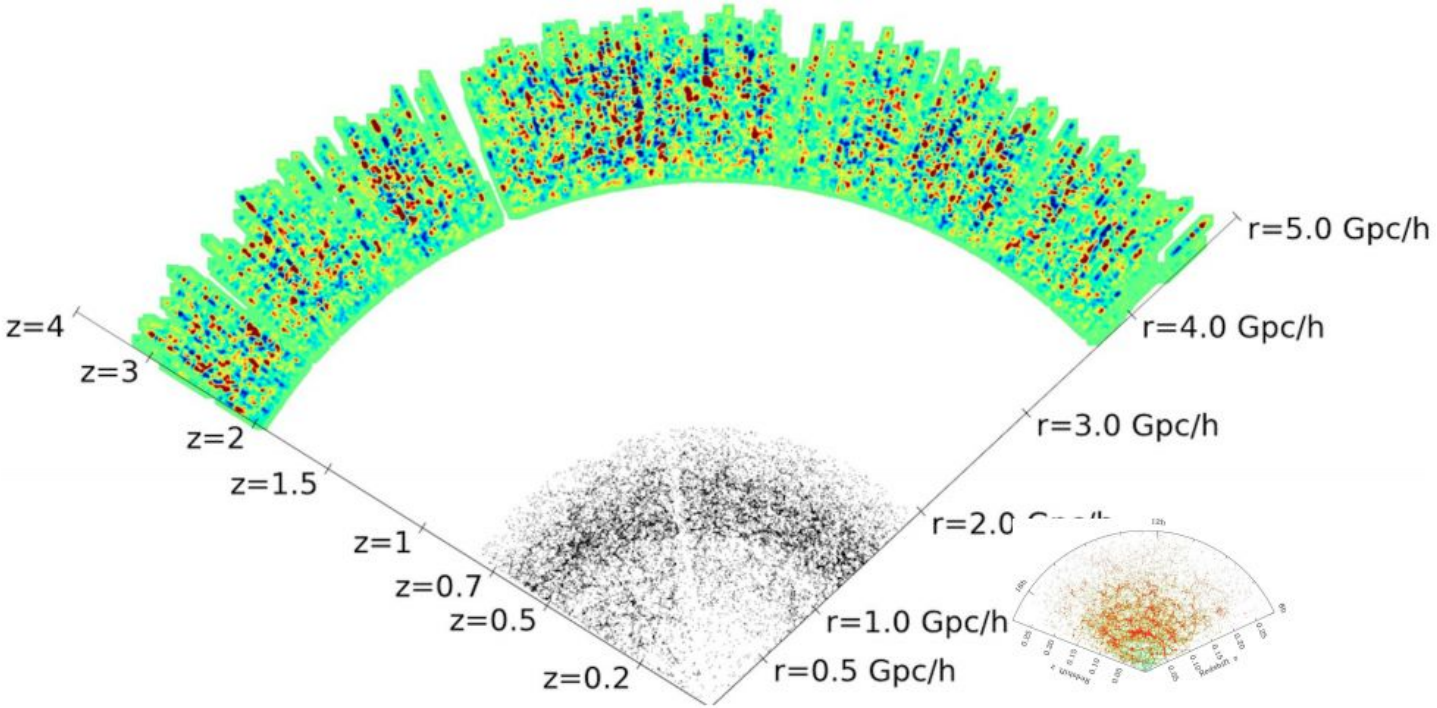
Splitting the cosmic web into superclusters (David)



Galaxy redshift surveys have been growing exponentially

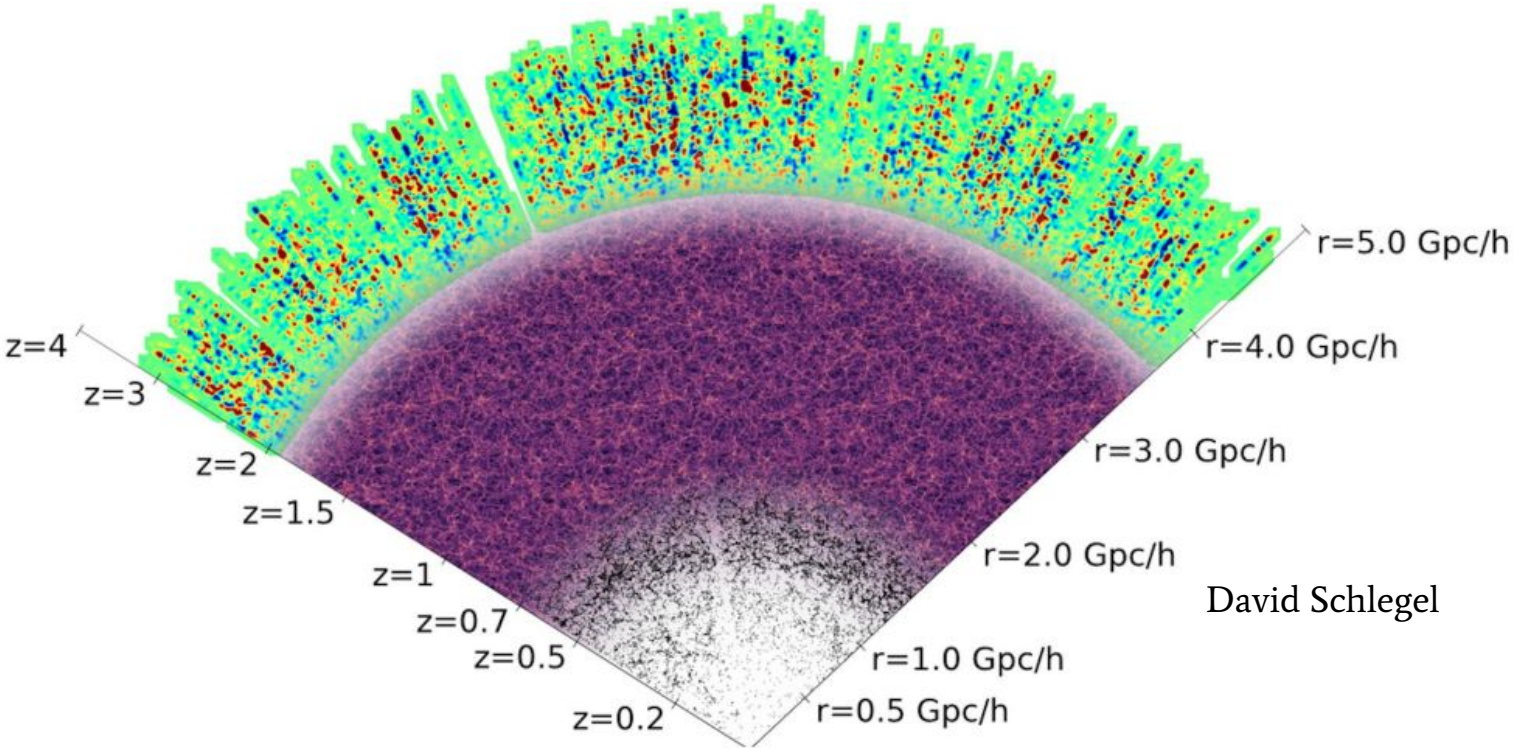


Vast volumes remain to be mapped out in detail



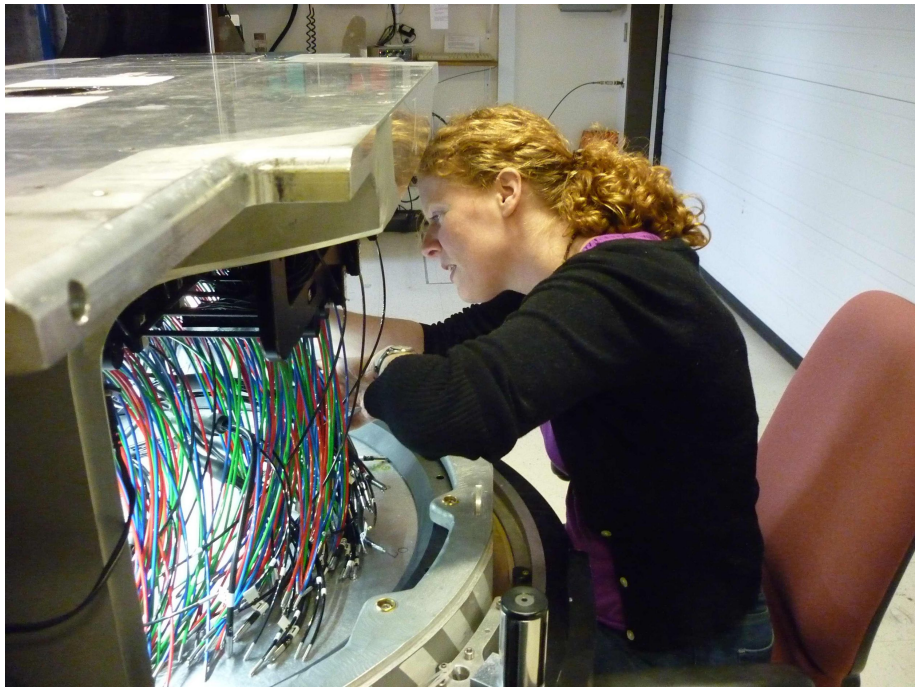
David Schlegel

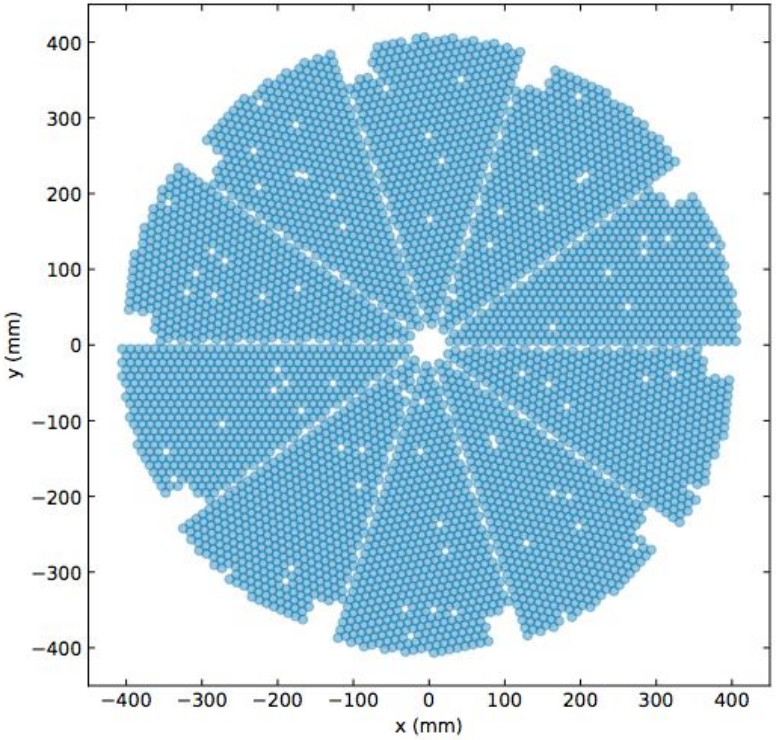
The DESI project will fill the gap



David Schlegel

The key to success: 5000 robotic positioners

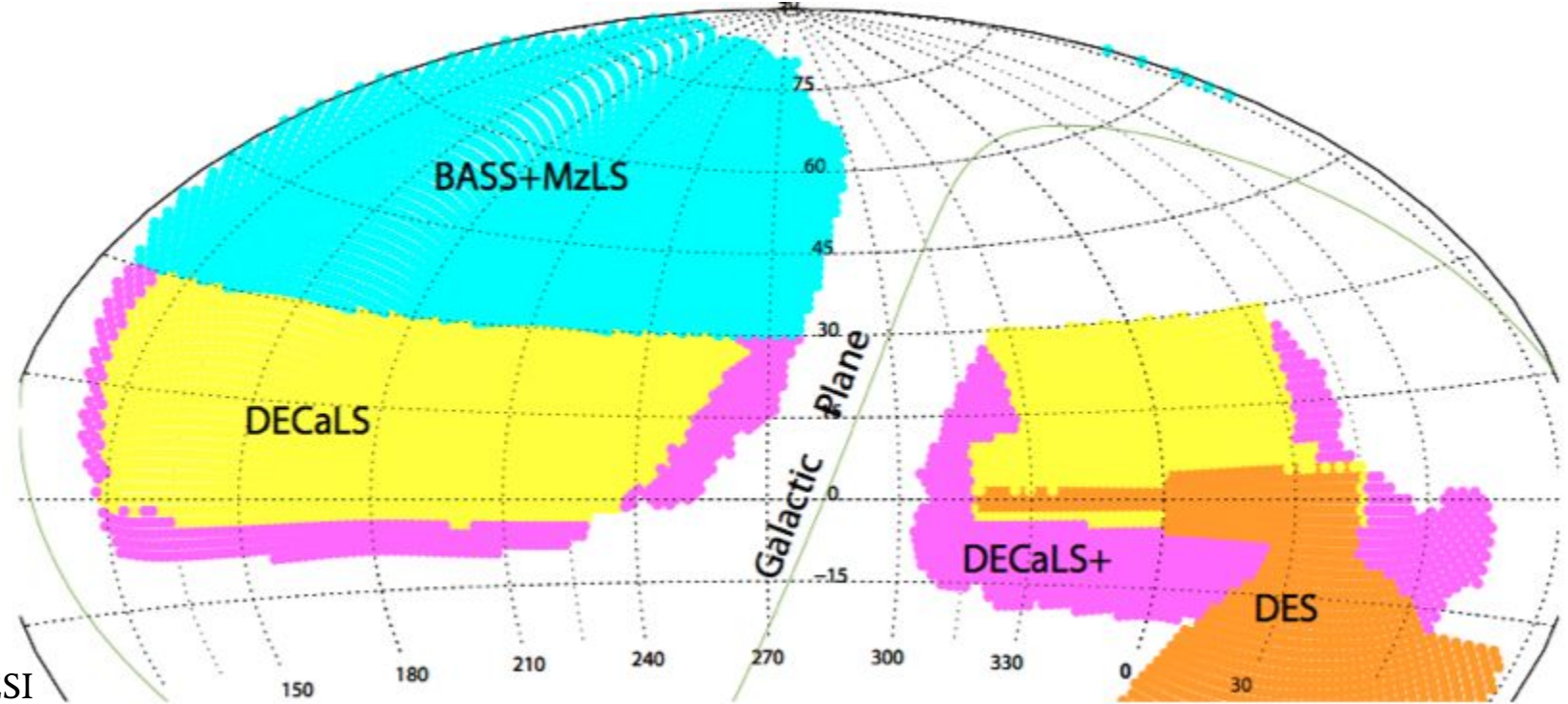




The key to success: a larger telescope

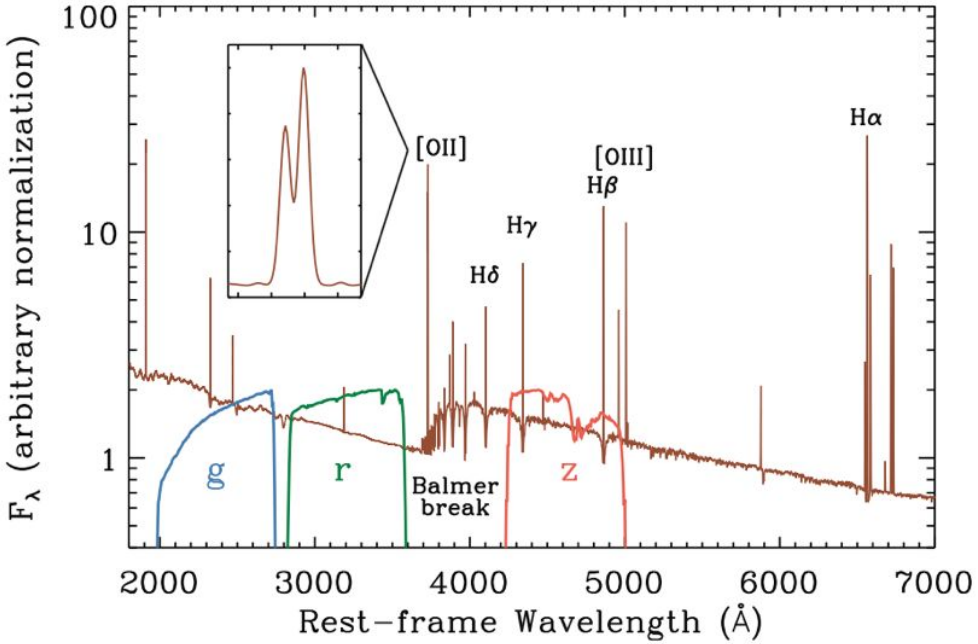
DESI

DESI will be based on a 14k squared degrees imaging survey



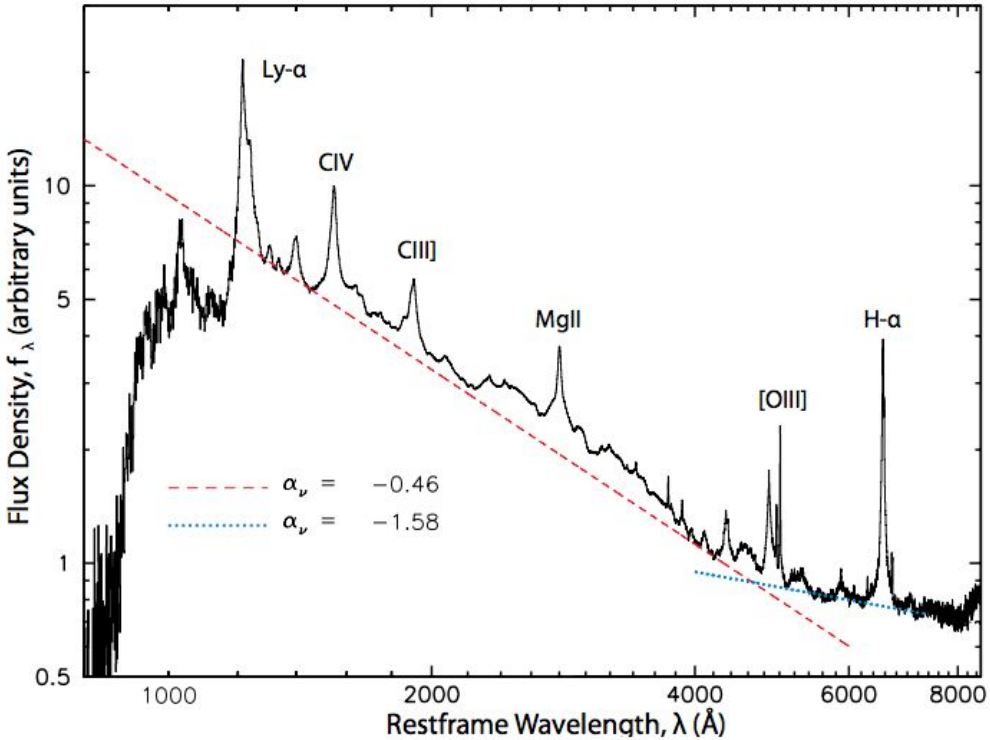
DESI

Emission Line Galaxies will be the bulk of the survey



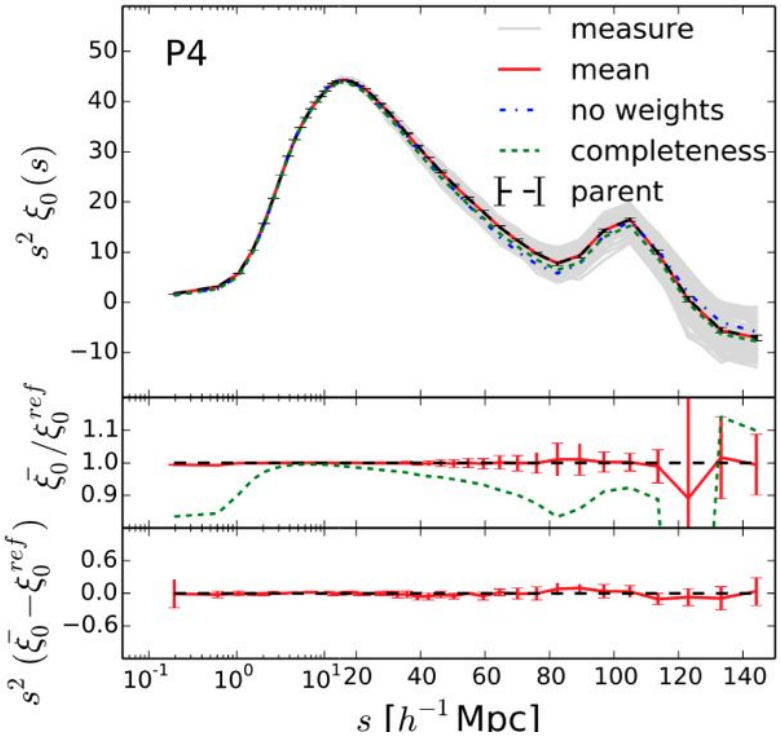
DESI

Distant quasars will allow deeper maps



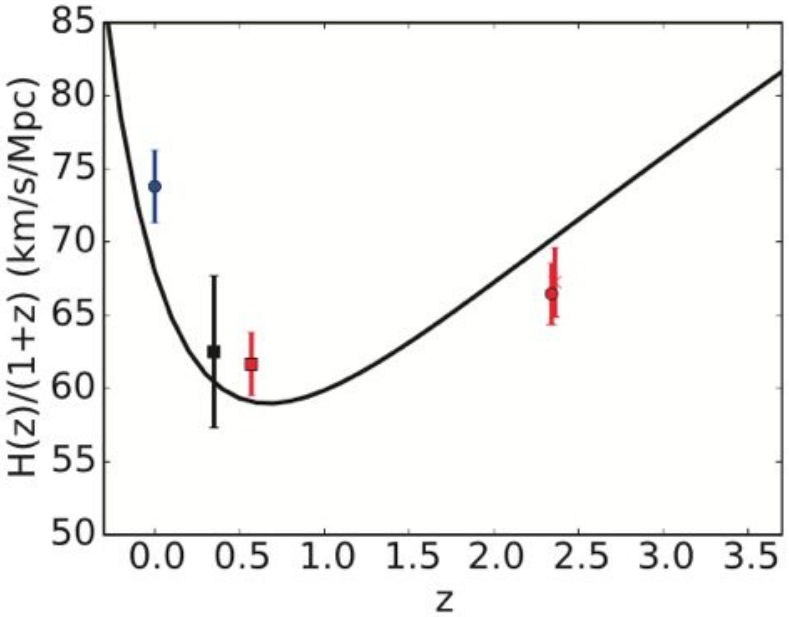
DESI

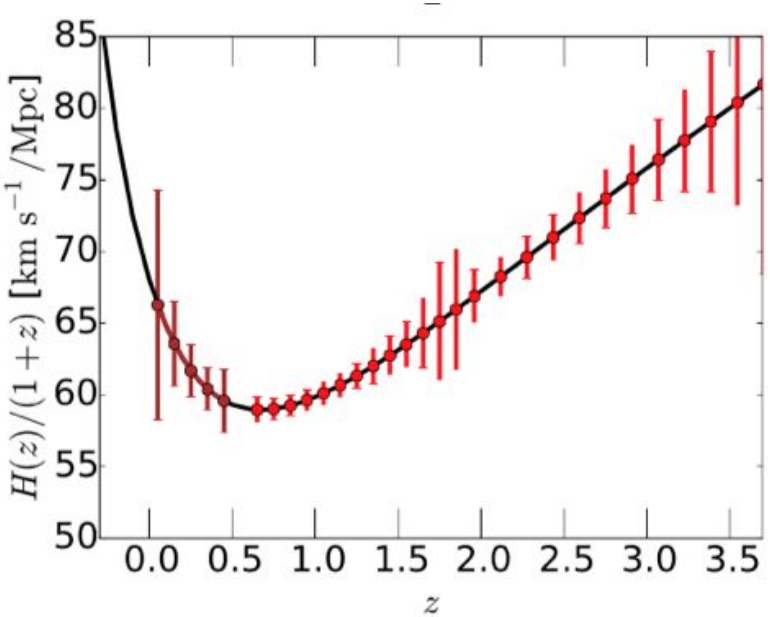
DESI will measure the correlation function with high precision



Bianchi et al. (2018)

The future with the Dark Energy Spectroscopic Instrument





DESI

Summary

- At Uniandes our research is placed on the interface between large scale structure observations, simulations and machine learning.
- The cosmic web is our primary tool to study both galaxies and cosmology.
- The beta-skeleton opens up new possibilities to study the cosmic web directly on observational data.
- DESI will provide exquisite data to constrain the expansion history of the Universe.