Title: 3D reconstruction of the Intergalactic Medium

1 Introduction and Scientific Background:

The gas in the Intergalactic Medium (IGM) is revealed by the numerous absorption lines that are seen in the spectra of quasars bluewards of the Lyman-α emission line from the quasar. It has been shown that the IGM at high redshift contains most of the baryons in the Universe. The IGM is therefore the reservoir of baryons for galaxy formation. In turn galaxies emit ionizing photons and expell metals and energy through powerful winds which determine the physical state of the gas in the IGM. The interplay of galaxy and the gas in the IGM is therefore central in the field of galaxy formation. This happens on scales of the order of 1 Mpc or less, or about 2 armin at $z \sim 2.5$ using standard cosmological parameters. At larger scales, the gas is in the linear regime and probes large scale structures.
The main goal of this programme is to reconstruct the 3D density field of the IGM at $z \sim 2.5$ to study the topology of the IGM and to correlate the position of the galaxies with the density peaks.

2 Tomography of the IGM:

The Lyman-α forest seen in QSO spectra arises from moderate density fluctuations in a warm photo-ionized IGM. The spatial distribution of the IGM is related to the distribution of dark matter in a simple manner and it is possible to reconstruct the full density field using a grid of spatially close lines of sight (Pichon et al. 2001, MNRAS, 326, 597; Caucci et al. 2008, MNRAS, 386, 211). A bayesian inversion method interpolates the structures revealed by the absorptions in the spectra. Fig. 1 shows to which level the matter distribution could be recovered. Hundred lines of sight are drawn through a 50×50×50 Mpc N-body simulation box parallel to one dimension of the box. Artificial spectra are generated with similar characteristics as the data we propose to obtain. It can be seen that the structures with scales of the order of or larger than the mean separation of the LOSs are recovered.
About 500 randomly distributed targets per square degree would be required to recover the matter distribution with a resolution of 1–2 arcmin at $z \sim 2.$. Once the density field is recovered, topological tests can be applied to recover the true characteristics of the density field (see Fig. 2).

3 Outline of a ”representative observing program”:

To reach the above goals, we need to target LBGs in addition to high redshift quasars, at $z > 2.5$ around $\lambda_{\rm obs}$~420 nm. We forsee 500 sources per square degree. We would need a spectral resolution of $R \sim 2000$ although $R = 5000$ could be helpful to avoid metal lines. A combination of both resolutions at different luminosities would be ideal. If we want to reach a minimum SNR of 4 at $r = 23.8$, considering the background sources as point-sources, we would need to expose about 20 hours per field. The amount of time for this project is inversely proportional to the field of the instrument. The program would be interesting if at least 20 sq degrees are observed, amounting to a total of 300 to 500 hours.
The wavelength range should cover the Lyman-α forest which will imply that the reconstruction will be performed at different redshifts using the same lines of sight which is one of the main advantage of the method. In addition, observing the objects redwards the Lyman-α emission would allow to study the LBGs themselves, the metal in the IGM in the case of quasars and the quasars themselves in case the near IR is accessible.

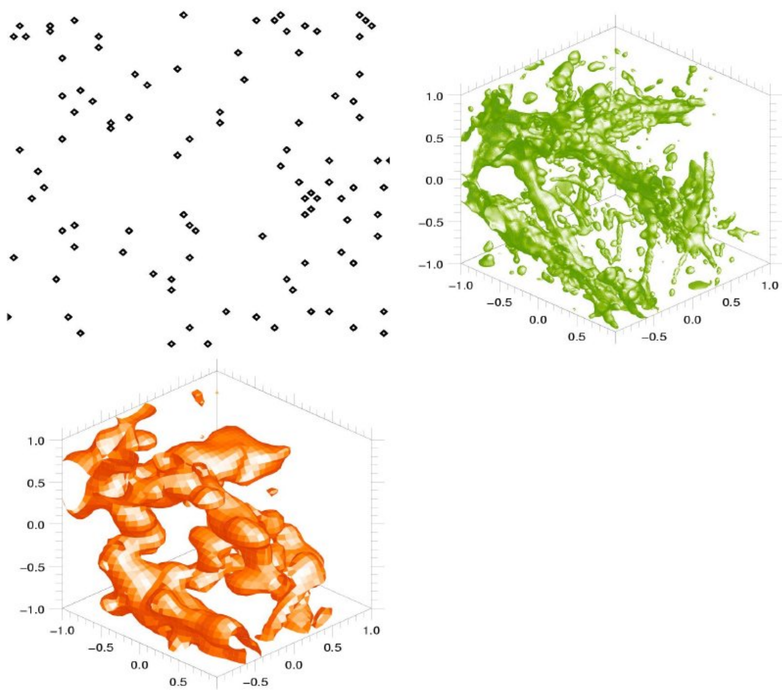

Figure 1: The 3D density field in the simulation is shown in the right-handside box. Hundred lines of sight randomly spaced are drawn through this simulation box. The position of the background sources in the sky are shown in the left-handside panel. The corresponding absorption spectra are considered as the input data for the reconstruction. The reconstruction density field is shown in the bottom box.

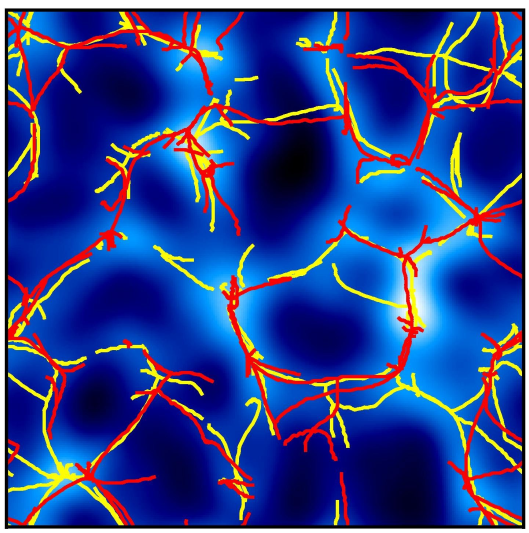

Figure 2: Comparison between the skeletons of the original field *(light lines)* and its recovered counterpart *(darker lines)* (the skeletons represented here are the true ones, and not their local approximations). The original field was recovered by inverting 500 los per square degree, corresponding to a separation $< d >\sim 2$ Mpc. Both skeletons are computed on fields smoothed over a scale $L_s = 3.2$ Mpc, in logarithmic space. For clarity, only a 4 Mpc slice is shown, the background contour representing the original smoothed density field (lighter colors corresponding to higher densities).