1.PUBLISHABLE SUMMARY

The main goal of this project is the characterization of the cosmological large-scale structure (LSS) on different scales from the measurement of quasar absorption spectra tracing the intergalactic medium (IGM) through the Lyα forest.

In the current cosmological picture structures in the Universe are believed to have grown from tiny fluctuations through gravitational clustering. Nonlinear processes of structure formation destroy the information about the origin of our Universe. This information is encoded in the large scales in which structures are close to the linear regime. Oscillations of the baryon-photon plasma in the early universe, known as Baryon Acoustic Oscillations (BAO), imprint a distinct signature on the clustering of matter. The BAOs set a characteristic scale that is measurable as an oscillatory pattern in the power spectrum of the LSS and can be used to extract cosmological parameters. The analysis of the LSS is thus one of the major tasks in cosmology.

As we look at the distribution of matter at large distances (redshifts 2-6) we are observing structures in the past light cone. This enables us to get a picture of the Universe at a particularly interesting epoch in which structures were younger remaining closer to the linear regime and galaxies were actively forming. Using the luminous distribution of galaxies as large-scale tracers becomes extremely expensive as larger volumes need to be surveyed. The neutral hydrogen of the IGM represents an appealing alternative. However, extremely luminous sources are required to radiate the IGM and make it visible to us. Such objects are called quasars and are believed to be galaxies with an active galactic nucleus. The ultraviolet radiation emitted by a quasar suffers resonant Lyα scattering as it propagates through the intergalactic neutral hydrogen. In this process, photons are removed from the line-of-sight resulting in an attenuation of the source flux, the so-called Gunn-Peterson effect. The measurement of multiple quasar absorption sight-line spectra traces the LSS. The explicit relationship between the underlying matter field and the observed flux of a quasar spectrum is very complex.

We have developed a novel 1D technique to recover the nonlinear density field from Lyα data which does not require the knowledge on the equation of state, the thermal history or the ionization level of the IGM (S.Gallerani, F.S.Kitaura & A.Ferrara 2010). The strong correlation we found between the flux and the matter density enabled us to establish a statistical one-to-one relation between the probability density of the flux and the one of matter. This approach reduces all the assumptions to the knowledge of the matter statistics which is well constrained by N-body simulations. It permits us to deal with strongly skewed matter PDFs which apply at small scales (~20 kpc). We could also show that the impact on the matter field reconstruction due to peculiar motions cancels out on scales larger than ~10 Mpc. In parallel we also developed a novel Bayesian 3D non-Gaussian reconstruction technique which permits us to accurately solve for incompleteness due to the sparse distribution of quasar spectra. In a first step the matter statistics from observations was investigated (F.S.Kitaura et al 2009) and the adequate statistical non-Gaussian model was worked out and compared against N-body simulations (F.S.Kitaura, J.Jasche and B.Metcalf 2010). Then the Hamiltonian Markov Chain Monte Carlo technique was developed to sample from such a non-Gaussian statistical model (J.Jasche & F.S.Kitaura 2010, F.S.Kitaura 2010). Moreover, we extended the Bayesian approach to extract the BAOs from the reconstructed LSS (F.S.Kitaura, S.Gallerani & A.Ferrara 2010). Our work provides a completely new state-of-the-art analysis of the intergalactic structure structure on small- and on large-scales.

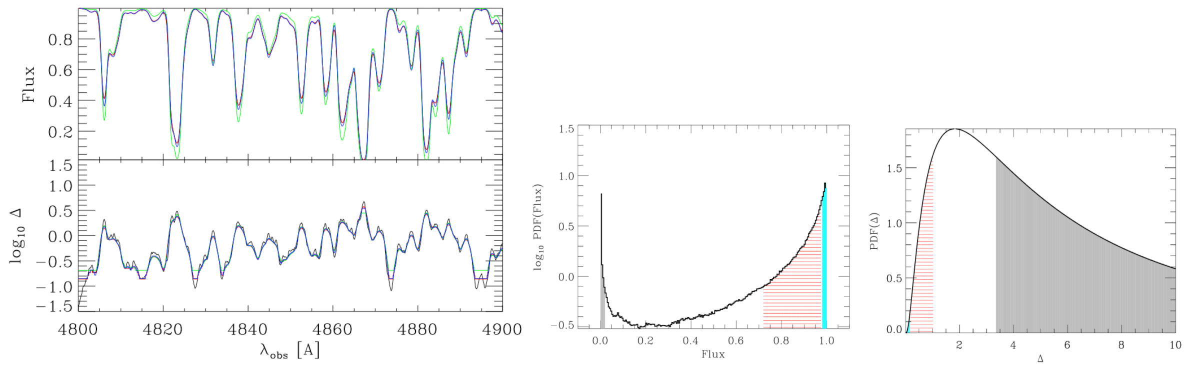

Fig1. On the left: top: mock quasar spectra assuming different equations of state, thermal histories and ionization levels of the IGM. **bottom:** reconstruction of the IGM matter overdensity field applying our 1D reconstruction technique. **On the right:** flux and matter PDFs. The flux PDF is extracted from a set of mock flux spectra. The matter PDF is assumed to be known. The corresponding shaded areas in the PDFs are set to be equal giving a one-to-one relation between the flux and the matter overdensity.

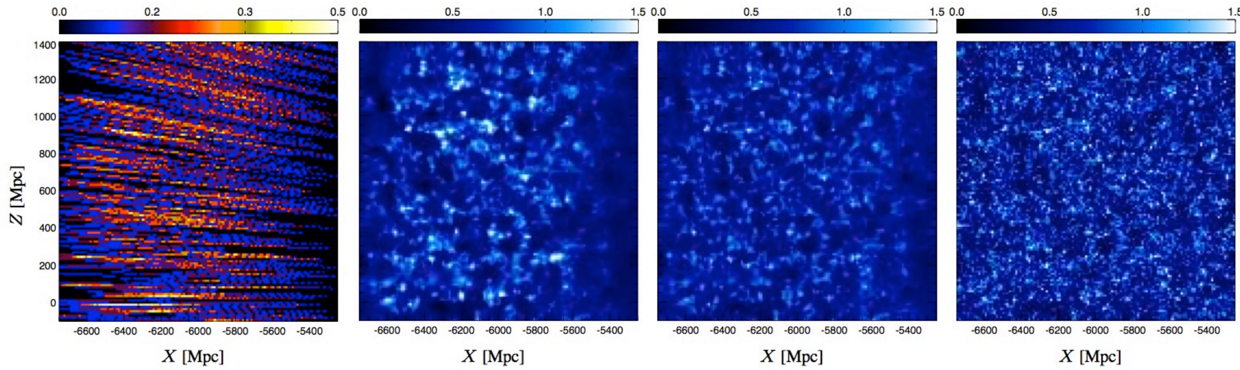

Fig2. Left panel: slice through a 1.5 Gpc box showing the distribution of ~70000 mock quasar spectra. **Right panels:** different Hamiltonian samples obtained with our 3D reconstruction code: after 1, 3 and 4000 MCMC iterations.

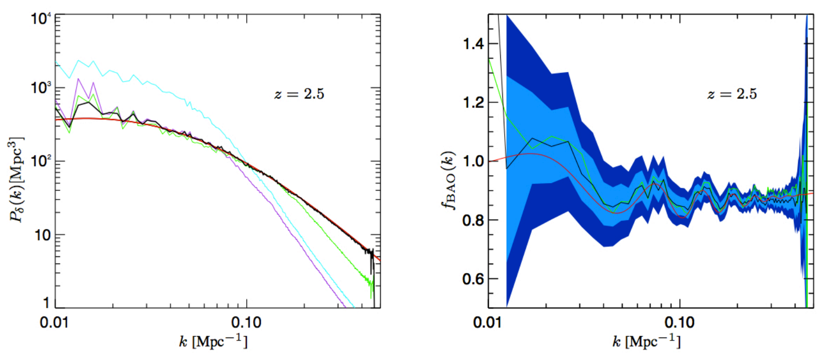

Fig3. Left panel: the red curve represents the assumed power spectrum (no BAOs). The cyan, purple, green and black curves show the evolution of power spectra corresponding to the 1st, 3rd, 5th and 4000th sample. **Right panel:** BAO signal extracted from ~5000 reconstruction samples. The light and dark blue regions correspond to the 1 and 2 sigma confidence levels, respectively. The green curve stands for the particular matter realization. The red curve is the theoretical prediction. The black curve is the mean over the reconstruction samples.