Thermal Evolution in the IGM during the Peak of Galaxy Formation

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The line-of-sight power spectrum $P_F(k)$ of the Lyα forest has proven to be a valuable tool for doing cosmological observations. It also not only allows to constrain cosmological parameters, but enables us to measure the thermal state of the IGM at redshifts $z \gtrsim 1.8$.

While at large scales ($k < 0.02\,\mathrm{s\,km^{-1}}$) $P_F(k)$ has been precisely measured using the large number (10^3–10^5) of SDSS/BOSS quasar sightlines, there are much less spectra available at smaller scales (larger k). Prior power spectrum measurements at these redshifts from high-resolution data, however, only used ~ 10 quasar spectra. We performed a new measurement of this statistics using 75 HIRES/UVES quasar sightlines with $1.8 < z < 3.4$ significantly improving the precision of the small-scale $P_F(k)$ compared to older datasets.

Using this additional precision on small scales combined with the BOSS power spectrum on large scales and the measurements by Viel et al (2013) and the XQ-100 project at higher redshifts enables us to accurately constrain the thermal cutoff scale of the IGM set by a combination of temperature broadening of Lyα forest lines (with $T = T_0(\rho/\bar{\rho})^{\gamma-1}$), and 'Jeans' smoothing (with scale λ_P) due to baryonic pressure support.

We apply Gaussian process based techniques for power spectrum interpolation between a grid of 35 hydrodynamical simulations (covering a larger volume in parameter space than grids used by other groups with similar resolution) generated to have different combinations of thermal parameters T_0, γ, λ_P using the NYX code ($N = 1024^3$, $L = 20\,h^{-1}$ Mpc) and mean Lyα forest transmissions $\bar{F}$ generated in post-processing.

Performing an MCMC analysis on each power spectrum measurement (from our own data as well as archival measurements) allows us to jointly constrain thermal parameters and set tight constraints on thermal evolution of the IGM during the end phase of He II-reionization and the peak of Galaxy formation (see Figure). Fitting a simplified thermal evolution to the power spectrum data we can clearly see a preference towards a maximum in T_0 at $z \sim 3.3$ which agrees with a He II reionization context and a predicted cooldown afterwards that has never been unambiguously measured.

These constraints will help solving the existing discrepancies in the IGM thermal evolution between different works using different techniques as existing degeneracies between different thermal parameters in the existing measurements can be broken in our analysis and can be used to place limits on possible exotic sources of heating. Additionally a better knowledge of thermal evolution will also lead to better constraints of e.g. the nature of dark matter or neutrino masses and thereby improve our knowledge of the underlying cosmology. In the future, we will also extend our dataset to both higher and lower redshifts.

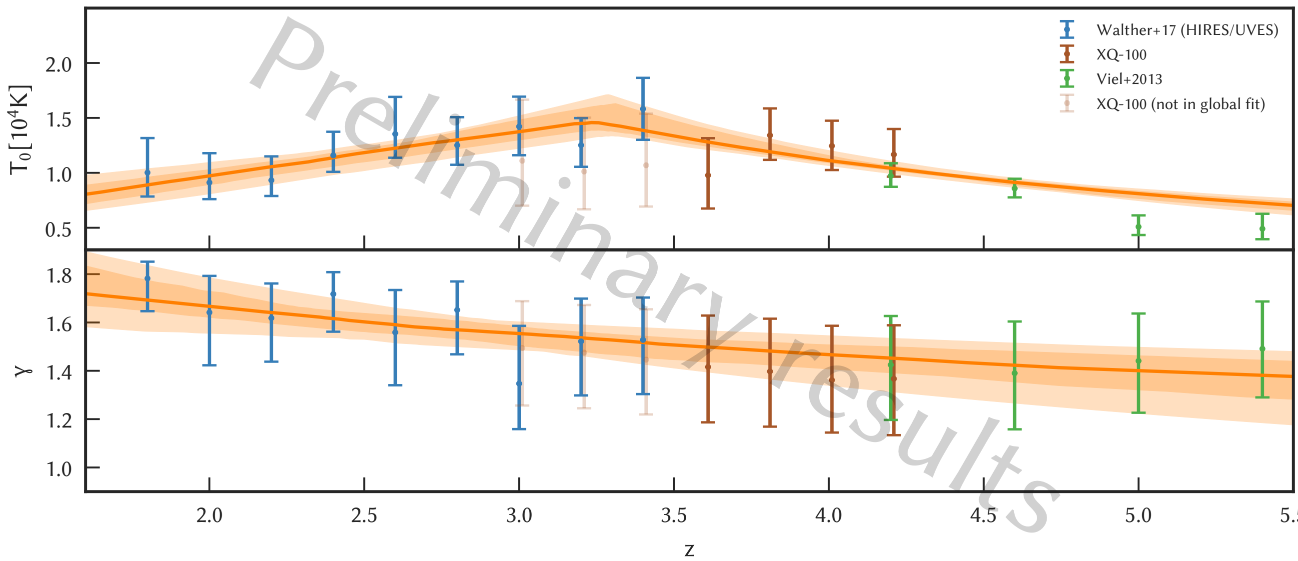

Figure: Preliminary evolution of T_0 and γ measured by fitting the power spectra at each individual redshift for different datasets (colored points). Additionally a global fit of all the different redshifts in our HIRES/UVES dataset, Viel+ (2013) and the VIS data of XQ-100 is shown as a yellow line (with bands showing 1σ and 2σ regions) assuming a broken power law for the redshift evolution of T_0 and power laws for γ, λ_P and $\bar{F}$.

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