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DETERMINATION OF THE QUASAR CONTINUUM FOR HIGH REDSHIFT HIGHLY LUMINOUS QUASARS

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Abstract. Determination of the quasar continuum is important to study the absorption lines because the latter are characterized by flux-independet optical depths. This is not obvious specially at low spectral resolution and high redshift where there is little unabsorbed continuum remaining in the Lyman-alpha forest. There are different methods to normalize the quasar continuum. But no systematic comparison has been performed yet. We have made a qualitative comparison between the results obtained when applying the different methods and constrained its systematic errors.

1 Introduction

The IGM - which is believed to contain, at high redshift, most of the ordinary baryonic matter - and its physical properties can be studied using the imprint left in the spectra of background QSOs, the so-called Ly-α forest. Gas structures with masses as small as $1M_{\odot}$ can be detected if they are intercepted by the QSO line-of-sight.

We have observed 22 high redshift highly luminous QSOs (m $\leq$ 17.8 and 2.134 $\leq z_{em} \leq$ 4.697) at intermediate spectral resolution, with either EMMI (ESO Multi-Mode Instrument) on the ESO (European Southern Observatory) NTT (New Technology Telescope) telescope or CARELEC at the OHP (Observatoire de Haute-Provence) (see Aghaee et al. 2005, 2006). The reduction was performed using routines from the LONG MIDAS context.

2 Determination of QSO continuum

For each spectrum in our QSO sample, we have fitted the continuum using four different methods in order to compare the different results and constrain systematic errors induced by the method. One of the methods is to extrapolate in the Lyα forest the Power-Law (PL) continuum calculated over wavelengths redward of the Lyα emission line. The second method is the fully automatic Principal Component Spectra (PCS) method, in which the continuum of individual QSOs is predicted using the red side of its spectrum (see Suzuki et al. 2005). The Iterative Estimating (IE) method is another automatic method. The continuum is produced by minimising the sum of a regularisation term and a χ^2 term, which is computed from the difference between the quasar spectrum and the continuum estimated during a previous iteration (see Aracil et al. 2004). The Smooth Local (SL) method fits the continuum of a spectrum to regions of the Lyα forest deemed 'free of absorption lines' *as judged by eye*. This is done by attempting to identify unabsorbed regions within the forest and to connect them by smoothing splines.

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3 Flux decrement determination

We define DA $= \langle 1 - f_i/c_i \rangle$ where f_i is the flux in pixel i and c_i is the continuum level in the same pixel. We used up to five different continua for each QSO. We averaged DA over intervals of redshift path 0.1 in the observed frame. To calculate DA in the IGM, we masked the strong DLA Lyα lines. In Figure 1 we show DA from the IGM alone as a function of redshift for different continua. The IE1 and IE2 are respectively the lowest and highest continuum obtained by changing the parameters when using the IE method. The curves are the best fit power-law DA(z) $= A(1+z)^{\alpha}$.

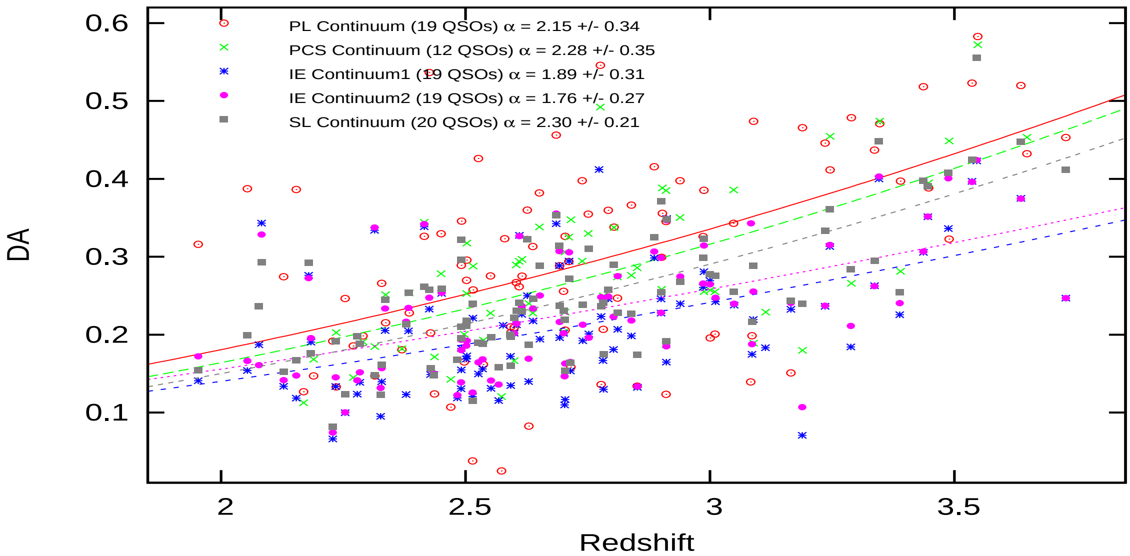

Fig. 1. DA vs. redshift, each point shows the mean DA in $\Delta z = 0.1$ for each QSO.

4 DA from high and intermediate spectral resolution spectra

In Figure 2 we show as example the reduced spectra for the same quasar observed at intermediate resolution ($R \simeq 2300$) with EMMI at the NTT and at high spectral resolution ($R \simeq 45000$) and high S/N ratio ($\sim$100 at 6000 Å) with UVES at the VLT. The QSO continua at intermediate and high spectral resolution have been obtained using the SL and IE methods, respectively.

In Figure 3 we compare DA using different methods, for the same quasars observed at both high and intermediate spectral resolution, in wavelength bins of 200Å.

5 Result

As shown in Figs 2 and 3, DA values are similar in both high and intermediate spectral resolution spectra, if we use the SL method, at least up to $z \sim 3.5$. This method should therefore be recommended. But the SL method is not an automatic method and depends on subjective decision. This problem can be overcome to a first approximation, if we make a *correction* according to the result of DA measured in Fig. 1. This correction factor should be applied to the results of an automatic method (in this paper the IE method) for data at intermediate resolution, instead of using the SL method. This correction factor is shown in Figure 4.

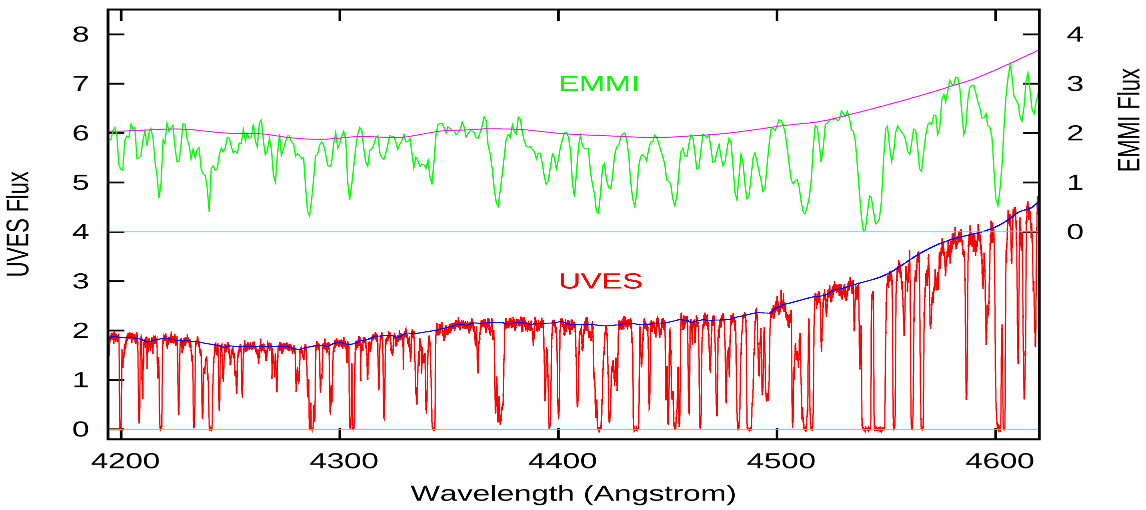

Fig. 2. HE 2347−4342 spectra at intermediate (top) and high (bottom) spectral resolution. The upper smooth curves correspond to the continua.

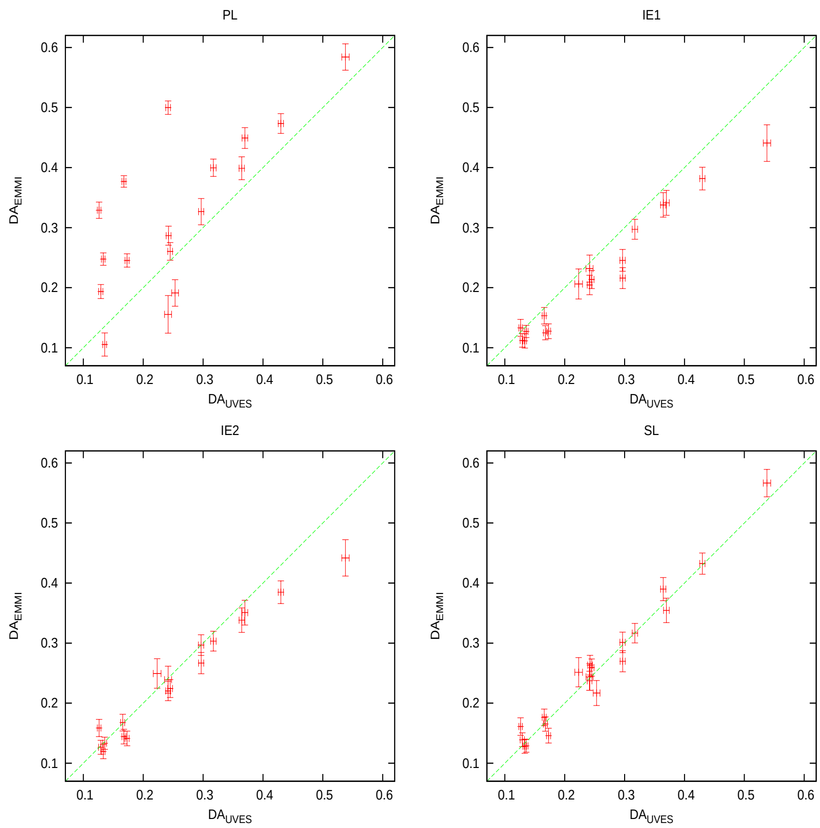

Fig. 3. DA measured from EMMI spectra and for different methods versus DA measured from UVES spectra for the same objects.

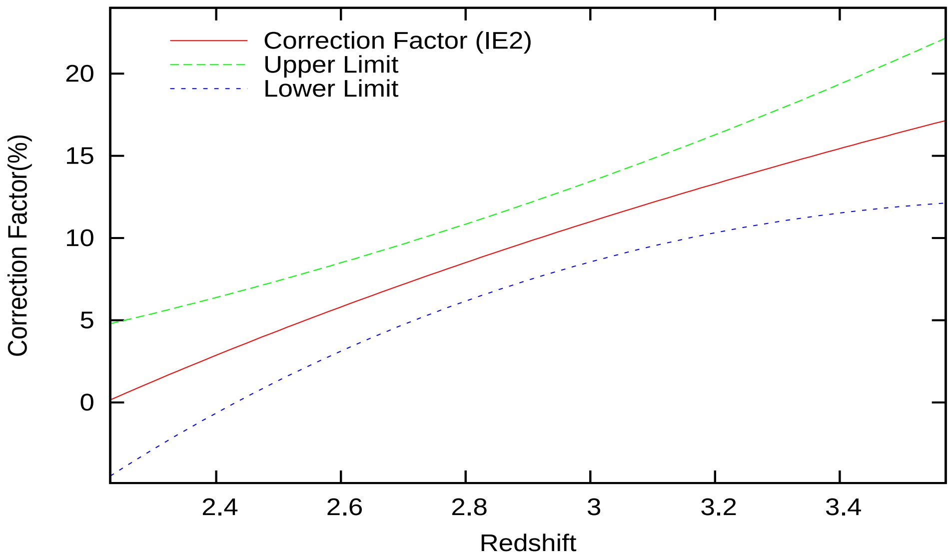

Fig. 4. The correction factor to correct the measered DA value when we use the automatic IE2 for data at intermediate spectral resolution.

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