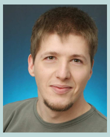
The Transverse Proximity Effect in Spectral Hardness



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We report on the detection of a systematically harder intergalactic UV radiation field in the vicinity of QSOs at $2.2<z<3.2$. By comparing the intergalactic He II absorption to the corresponding H I absorption, we recovered the fluctuating spectral shape of the UV background towards Q 0302–003 (z=3.285) and HE 2347–4342 (z=2.885). We correlated the spectral shape variations with foreground QSOs discovered in a dedicated survey near the these two lines of sight. We find a hard radiation field near the background QSOs and in the projected vicinity of all seven known foreground QSOs. We interpret this as the proximity effect in spectral hardness acting on distances of several Mpc across the sky. The spectral hardness breaks the overdensity degeneracy that is responsible for the frequent non-detections of the transverse proximity effect in the H I forest. From the transverse proximity effect of the foreground QSOs we infer minimum QSO lifetimes of 10–30 Myr.

The Transverse Proximity Effect

In the vicinity of QSOs the intergalactic medium is statistically more highly ionized due to the local enhancement of the UV flux by the local sources. This is observable as a statistically reduced H I absorption, i.e. a radiation-induced void. While this so-called proximity effect has been found on lines of sight towards QSOs (e.g. Bajtlik et al. 1988; Scott et al. 2000, Dall'Aglio et al. 2008), a transverse proximity effect, created by foreground QSOs nearby a background line of sight, has not been clearly detected in the H I forest at $z\sim3$ (e.g. Schirber et al. 2004, Croft 2004). On the other hand, two voids in the Gunn-Peterson troughs of He II and H I are likely caused by nearby foreground QSOs (Jakobsen et al. 2003, Gallerani et al. 2008).

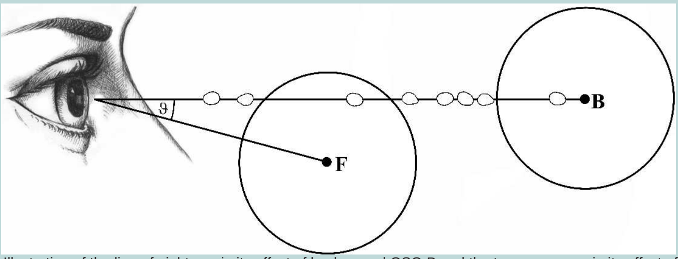


Illustration of the line-of-sight proximity effect of background QSO B and the transverse proximity effect of QSO F, observed as a reduced number density of Lyα absorbers.

Intergalactic He II Absorption

On clear lines of sight far-UV spectroscopy with HST and FUSE revealed intergalactic He II Lyα absorption (e.g. Heap et al. 2000, Kriss et al. 2001, Fechner et al. 2006). Although the transverse proximity effect has been found as a void in the He II Gunn-Peterson trough near a foreground QSO towards Q 0302–003 (Jakobsen et al. 2003), we do not detect additional significant underdensities towards Q 0302–003 and HE 2347–4342 near the other foreground QSOs. This is not surprising, since the weak transverse proximity effect can be easily masked by intrinsic overdensities hosting the QSOs.

The Transverse Proximity Effect in Spectral Hardness

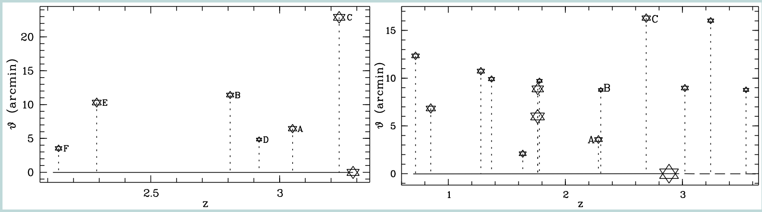
Due to the different ionization potentials of H I and He II, the column density ratio $\eta=N_{\mathrm{HeII}}/N_{\mathrm{HI}}$ indicates the spectral shape of the UV radiation field. By comparing the H I and the He II absorption we are able to distinguish hard quasar radiation ($\eta\lesssim100$) from soft radiation by star-forming galaxies ($\eta\gtrsim100$) along the line of sight.

Although the He II forest towards Q 0302–003 remains unresolved at the low STIS resolution, we inferred η by comparing the data with simulated He II absorption generated from the H I line list as a function of η. The FUSE spectrum of HE 2347–4342 resolves the He II forest and η was directly estimated by line fitting.

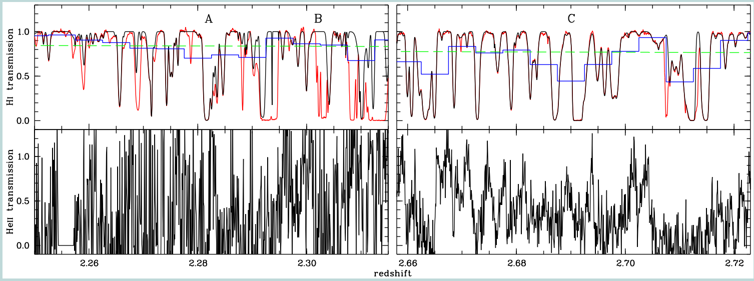
We find that the radiation field is systematically harder than on average near all seven foreground QSOs on both lines of sight. This hardening is also visible near the central QSOs. Due to the intrinsically hard spectral energy distribution of QSOs we interpret this as a signature of the transverse proximity effect in the fluctuating UV spectral shape. The remaining local spectral shape variations in the *on average* harder radiation field could be due to radiative transfer in the intergalactic medium between the foreground QSO and the background line of sight.

Our Survey for Quasars near Quasars

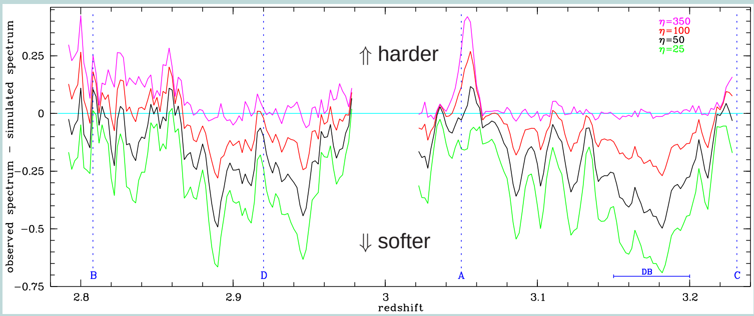
We performed a slitless spectroscopic survey for faint QSOs at $1.7\lesssim z\lesssim3.6$ around 16 luminous high-redshift QSOs with the ESO Wide Field Imager (Worseck et al. 2008). Follow-up spectroscopy confirmed 80 of 81 targeted candidates as QSOs. 64 of them are at z>1.7. Our survey significantly increases the number of high-redshift QSO groups on the southern hemisphere. Together with known QSOs from the literature, we searched for the transverse proximity effect of foreground QSOs on the lines of sight towards Q 0302–003 (z=3.285) and HE 2347–4342 (z=2.885).



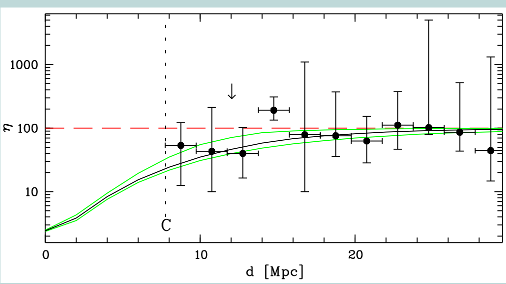
Angular distance ϑ vs. redshift z of the QSOs in the vicinity of Q 0302–003 (left) and HE 2347–4342 (right), always with respect to the central QSO in the field. Four of the six foreground QSOs to Q 0302–003 can be used to search for the transverse proximity effect. Near HE 2347–4342 we discovered in total 14 QSOs. We study the transverse proximity effect of the three foreground QSOs A, B and C (z_A=2.282, z_B=2.302, z_C=2.690).



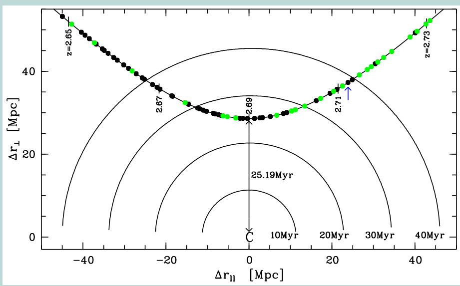
The Lyα forest of HE 2347–4342 in the vicinity of three foreground QSOs A, B and C. The upper panels show the observed optical spectrum (red), the H I transmission (black), the mean transmission towards HE 2347–4342 (binned line) and expected mean transmission (dashed line). The lower panels display the corresponding He II transmission.



Observed vs. predicted He II Lyα absorption towards Q 0302–003 in differential representation (observed minus predicted) for different η values. Positive (negative) deviations from zero indicate that η has to be smaller (higher) than the assumed η of the curve, corresponding to harder (softer) radiation. The radiation field near the foreground QSOs A–D is harder ($25\lesssim\eta\lesssim100$) than far away from them ($\eta\sim350$).



Column density ratio η in bins of Δd=2 Mpc vs. proper distance d between the line of sight to HE 2347–4342 and foreground QSO C (filled circles). The minimum separation is 7.75 Mpc. Hard radiation corresponds to small η. The black line shows the modelled decrease of η approaching QSO C with respect to the ambient soft UV background with $\eta\sim100$ (dashed line). Near the quasar the radiation field is harder than on average despite large small-scale fluctuations.



Transverse comoving separation $\Delta r_\perp$ vs. line-of-sight comoving separation $\Delta r_\parallel$ with respect to QSO C near HE 2347–4342. Black (green) points denote absorbers with $\eta<100$ ($\eta\geq100$) on the line of sight towards HE 2347–4342 (curved line) with indicated redshifts. The half circles show the distance traveled by light emitted at the indicated times prior to our observation.

Conclusions

The spectral hardness breaks the density degeneracy that is responsible for the frequent non-detections of the transverse proximity effect. It is a sensitive physical measure to reveal the transverse proximity effect even in intrinsically overdense regions or in cases where the local QSO radiation only marginally exceeds the UV background. Via the light travel times between the foreground QSOs and the background sightlines we obtain lower limits on the QSO lifetime of 10–30 Myr.

Publications

Worseck & Wisotzki 2006, A&A, 450, 495
Worseck et al. 2007, A&A, 473, 805
Worseck et al. 2008, A&A, in press, arXiv:0806.2532