Probing the OVI forest

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Abstract. Recent FUSE and STIS observations of O\textsuperscript{vi} absorption at low redshift along the sightline to distant quasars have been interpreted as the signature of a warm-hot diffuse component of the intergalactic medium (IGM). In these proceedings we show that the predicted numbers of such absorbers in numerical simulations agree with the observed characteristics, lending support to this idea. We find that collisionally ionized lines tend to be stronger and wider, while photo-ionized absorbers are weaker and narrower. We also find that a comparison of the predicted distribution of line widths to that observed is marginally too low.

1 Introduction

The Ly\textsubscript{a} transition of five-times ionized Oxygen is an important tracer of diffuse matter in the universe, both at high redshift where the transition falls in the optical and now — thanks to new high-resolution spaced-based UV-spectroscopy — at low and moderate redshift as well. Absorption lines due to intervening gas in high-redshift quasars are an indispensable way to detect low density material because the signal is proportional to the integrated column density of the element. In contrast, X-ray emission grows as the second power of the local density. This means that the low-density, hot filaments predicted in numerical simulations \cite{2,4} are much more accessible to absorption line studies than to direct X-ray detection.

2 Predicting the number of O\textsuperscript{vi} lines

In these proceedings, we use numerical simulations of a cosmological-constant dominated universe ($\Omega_\Lambda = 0.7, \Omega_b = 0.04, h = 0.67$) to make predictions of O\textsuperscript{vi} absorption line statistics. We use an adaptive mesh refinement code \cite{1} to model a 20 $h^{-1}$ Mpc box with up to 10 kpc resolution (in small regions). A drawback of this simulation is that while it includes hydrodynamic shock-heating, it does not model star formation and stellar feedback. Therefore, it does not self-consistently pollute the IGM with metals. In order to make predictions for the O\textsuperscript{vi} distribution, we must assume a distribution of metals. We do this by parameterizing the results of \cite{2}, who found in their simulations a strong correlation between local density and metal abundance. We have also experimented with a spatially constant metal fraction of 10\%, which does not substantially change the results described below.

In Figure \ref{fig:1}, we plot the predicted number of O\textsuperscript{vi} absorption lines as a function of equivalent width. In order to investigate the relative effects of
collisional and photoionization, we plot the results with and without a uniform ionizing background (as predicted in [6]). The collisional ionization-only model marginally matches the observations, while the combined version provides excellent agreement with observations. In either case, lines with equivalent widths larger than about 70 mÅ arise only in collisionally ionized gas.

3 The distribution of line widths

If the raw number of absorption lines agree with observations, what about the distribution of their widths? In Figure 2, we plot the prediction for this distribution, assuming minimum cutoffs of 30 mÅ and 60 mÅ. Clearly these two distributions are quite different, with the higher cutoff curve coming mostly from collisionally ionized regions, while the lower cutoff includes contributions from both ionization mechanisms. This plot confirms previous speculation ([3, 5]) indicating that collisionally ionized lines are hotter and hence have larger Doppler parameters than photo-ionized regions.

While it is difficult to compare this to observations due to the differing resolutions and analysis techniques, a recent compilation of low-redshift O vi lines provides a useful point of comparison [9]. This sample, which includes a diverse set of systems, has a median b parameter of 22 km/s. The two distributions in Figure 2 have medians of 13 km/s (for the 30 mÅ cutoff) and

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Figure 1: The predicted cumulative number of O vi absorption lines. The solid line (Model B) includes both photo- and collisional ionization, while the dashed line (Model A) is computed assuming only collisional ionization. Two observation points are plotted with 1σ error bars from [7, 8].
Figure 2: The predicted distribution of Doppler line widths for two different minimum cutoffs in the line strength.

18 km/s (for 60 mA).

4 Discussion

There is a reasonably strong case that the O vi absorption lines are tracing the filaments of hot gas long predicted by numerical simulations of structure formation. Here we show — in agreement with a recent preprint [3] — that the predicted number of absorbers roughly agrees with the number observed.

Most of the absorbers are found in systems with densities typically 5-100 times the mean density (see [5] for a more complete discussion of this point). These are not primarily galactic systems, but are the web of filaments that link collapsed objects.

While the total numbers are in good agreement with observations, the line widths (as measured by the Doppler b distribution) are somewhat low. Although it is not clear what the appropriate lower cutoff is for the observational sample discussed above, it seems likely that the simulations predict median b parameters that are lower than that seen in FUSE and STIS samples.

If this disagreement persists, there are a number of possible explanations. The first is that the numerics are incorrect. Certainly the filaments are marginally resolved, and it is possible that improved simulations will refine the predicted value (as occurred for the Lyα forest results at high redshift). The second is that energy ejected from galactic systems increases the mean temperature of the IGM, which would boost the b parameters in Figure 2.

A final possibility is that this is telling us something about the strength of either the ionizing background or the value of the mean baryon density (or
the metallicity. Varying either of these could decrease the number of photo-ionized systems which make it above the 30 or 60 mÅ cutoff and so increase the proportion of lines which are collisionally ionized. Since these hotter systems have higher $b$ values in general, this would boost the median $b$ value. In Figure 3, we have used various line-strength cutoffs and then fit the resulting $b$ distribution to a log-normal profile. For the model which includes photo-ionization, increasing the cutoff leads to an increase in $b_{\text{ln}}$ (which is nearly equal to the median). It is clear that the distribution of line widths (and absorption line studies in general) will tell us important information about the physical condition of the IGM.

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