Probing weak NeVIII absorption with ‘agnostic stacking’ of COS data

Stephan Frank (OSU), Matthew Pieri (LAM), Charles Danforth (Colorado), and Smita Mathur (OSU)

Abstract

Utilising the largest available high-quality COS dataset towards quasars at redshifts z>0.7, we probe weak NeVIII absorbers to an unprecedented low column density limit (log N > 12.3) via a new method (‘agnostic stacking’). The total pathlength for NeVIII detection (Δz = 9.3), and high S/N of the data in conjunction with this new statistical method allow us to place tight constraints for the slope and normalisation of the column density distribution function over a range of column densities not accessible to direct searches. We find that this method (with modelling of the absorber population and noise characteristics) is a powerful tool for measuring doublet absorption at the noise limit.

1. The importance of searching for weak NeVIII absorption signals

Seven-times ionised Neon (the 7th most abundant element in the universe, ionization potential of 207 eV) is a good tracer of warm, collisionally ionized gas, although at densities n_e < 10^{20} cm^{-3} photoinization may also play a significant role in its creation (e.g. Oppenheimer 2011). Exploiting even the best available UV-spectra has thus far only been a handful of direct detections of NeVIII absorbers (Savage et al. 2005, 2011a; Narayanan et al. 2009, 2011, 2012; Tripp et al. 2011; Meiring et al. 2013, Hussain et al. 2015), all of which require column densities log N > 13.0. Simulations predict the bulk of the NeVIII absorber population to lie between 12.0 < log N < 12.7 (Tepper-Garcia 2013, Oppenheimer 2013). Hence, we have developed a new technique to probe weak absorption distributed amongst the data with a statistical approach. This releases the requirement that absorbers be detected individually, opening a more numerous population hidden to traditional line searches, and circumventing potential subjectivity of identifications.

We are able to exploit the largest high-quality dataset of sightlines towards UV-bright QSOs observed with COS, analysed in coherent fashion. For details see Danforth (2014). The total pathlength suitable for NeVIII detection summed over the 25 sightlines is Δz = 9.3.

2. Introducing the ‘agnostic’ stack

We construct composite spectra following a new procedure: we identify all pixels in our dataset exhibiting a normalised flux between f_σ = 0.88 (corresponding roughly to the flux limit associated with log N = 13.0) and an optimised maximum in the absorption profile (the assumed absorber population) regardless of our knowledge of their nature as absorbers (hence ‘agnostic’). We then treat each of these as if they were the strong members of the NeVIII 7767/780 Å doublet, and shift the COS spectrum into the thus assumed absorber refsmre. By generating the arithmetic mean of all these absorber spectra, we arrive at our ‘NeVIII composite spectrum’.

Figure 1 shows our experimental result: a non-detection. If there were significant NeVIII absorption in that sample, we would expect a signal at the location of the weaker doublet member (NeVIIIb at 780 Å, indicated by the arrow in Fig. 1). Most of the many selected pixels are likely to arise due to noise and absorption other than NeVIIIb, hence the NeVIIIb signal is expected to be diminished by the same large factor. The apparent strength of the NeVIII feature combined with the deterministic doublet line strength ratio provides a direct measurement of this dilution, allowing the population to be explored with modelling.

3. Modelling to infer the significance of (non-)detection

We create model spectra matching the size of our data set, and populate them first with a set of NeVIII absorbers as follows: we generate a NeVIII absorbing population in line with our pathlength, and a normalisation and slope (β) of the column density distribution function (CDDF). We then assign them β parameters randomly between 20 < β < 40 km/s, and place them at random redshifts in our spectra, assuming them to be represented by Voigt profiles. To these pure NeVIII spectra, we then add both additional absorption following a purely heuristic model (essentially an exponential distribution in optical depth), and noise replicating characteristics of each pixel in the real data. We adjust the parameters of the heuristic absorption model such that a best fit for the pixel flux distribution with all three components (NeVIII absorbers, additional non-NevIII absorption, and noise) is achieved when compared to the best dataset (illustrated in Fig 2 for an example CDDF).

After the construction of mock sets of spectra, we run exactly the same pixel selection mechanism as for real data, and hence can assess which of the NeVIII absorbers end up in the composite. Thus, we can predict the expected signal strength at NeVIIIb, and using the error estimate measured in the real composite – its significance.

4. The meaning of the non-detection of NeVIIIb

Our main result is a non-detection of the weak NeVIII absorber population (12.0 < log N < 13.0). Our statistical analysis allows us to place tight limits on the slope and normalisation of the CDDF for such absorbers. For example, extending the observed div/dz for higher column density systems with slopes higher than β >-2.2 is ruled out at a significance >3 by our approach (cf. Fig. 3). We propose to use the same method to probe the weak absorber populations for different ionic transitions in similar fashion (e.g. OVI, MgX and SiXII).

References: