Reanalysis of the LLS in QSO HS 1700+6416

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Abstract. We take advantage of the unique information provided by the recent HST observations of three Lyman limit systems toward QSO HS 1700+6416 by Reimers et al. (1992) to constrain photoionization models of the absorbing clouds. Constant density models are ruled out. However, the observed column densities (and in particular the large N(HeI)/N(HI) column density ratio) can be reproduced with a model in which the medium is considered inhomogeneous with two phases of different densities. The oxygen and nitrogen abundances are found to be about 0.1 solar, the carbon abundance may be slighly smaller. The presence of a break of a factor ten in the ionizing spectrum at the HeII edge is not ruled out by these observations. It is clear that the high ionization phase could be thermally ionized.

1 Constant density models

HST spectroscopic observations of QSO HS 1700+6416 are unique by the number and variety of the observed absorption lines from HI, HeI, CII to CIV, NIII to NV, and OIII to OVI, some of the latter ions being observed for the first time in a QSO spectrum. The data have been discussed by Vogel & Reimers (1993, 1994) in the framework of constant density photo-ionized clouds. They concluded that (i) the best solution for the ionizing spectrum is a power law of index $\alpha = -0.6$, (ii) a break in the ionizing spectrum at the HeII edge (54.4 eV) by more than a factor of five is excluded, and (iii) oxygen and nitrogen are enhanced relatively to carbon compared to solar with [C/H] = $-2.3, -1.9$; [O/C] = $0.9, 0.8$; [N/C] = $0.8, 0.8$ in the $z_{\rm abs}$ = 2.1678 and $z_{\rm abs}$ = 2.433 respectively. Reimers & Vogel (1993) discussed the N(HeI)/N(HI) ratio and found that photo-ionization models give values five times smaller than what is observed with no explanation.

However a break in the ionizing spectrum at 54.4 eV would help explain a high value of the N(HeI)/N(HI) ratio. This would lower somewhat the ionization rate of HeII into HeIII whereas the corresponding photons have small influence on the ionization level of hydrogen.

We have reanalysed the data taking into account all the constraints at the same time. We are led to different conclusions than previously found.

2 Models with inhomogeneity

When observed at high spectral resolution, metal lines split into several components spanning typically a few hundreds km s^{-1} (e.g. Petitjean & Bergeron 1994). The medium is inhomogeneous and several clouds of different ionization stages may be present along the line of sight. The HST data are of low resolution thus it is unclear whether absorptions from low and high ionization species, such as OIII and OVI, are produced in the same region. It is probable that they are not. To mimic this we have modified the code Nebula (Péquignot et al. 1978, Petitjean et al. 1990) to model the ionization state in an inhomogeneous photo-ionized cloud consisting of two phases of different densities and a smooth transition zone. The diffuse ionizing flux must be described in the detail since it can be as strong as the incident flux when the optical depth is of the order of unity and thus a careful description is of importance when modeling Lyman limit systems of small optical depth as those observed in QSO HS 1700+6416.
Assuming a typical ionizing flux of intensity at the Lyman limit $F_{\rm o} = 5\cdot10^{-22}$ erg s^{-1} cm^{-2} Hz^{-1} sr^{-1} and of spectral shape a power law $F_\nu \propto \nu^{-\alpha}$ with $\alpha = 0.6$ and a break of a factor ten at 54.4 eV, we find a typical solution for a cloud of total radial dimension 110 kpc and density $n_{\rm H} = 4\cdot10^{-4}$ cm^{-3} with an inhomogeneity in the centre of density 60 times larger and dimension about 1 kpc. Abundances are found to be $0.08\cdot Z_\odot$. The fraction of low excitation elements like HI, HeI and CII is highest in the central region of higher density while highly ionized ions like NV, OV and OVI are only produced in the extended low density region. All the column densities except N(CIV) are reproduced within the uncertainties. The observed CIV column density is too small, by up to a factor of 5, depending on the absorption system, compared to what can be reproduced by models with solar [C/O] abundance ratio. However new MMT data (M. Rauch private communication) show that the published CIV equivalent widths are in error by a factor three in some cases. In order to confirm that the [C/O] abundance ratio is smaller than the solar value, high spectral resolution observations of the CIV wavelength range are needed.

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