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The First Sample of Sub-Damped Lyα Systems and their Chemical Properties

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Abstract. We took advantage of the ESO UVES/VLT archive of quasar spectra to build a homogeneous sample of 'sub-DLAs', absorption line systems with H I column densities between 10^{19} and 2×10^{20} cm^{-2}. According to Péroux et al. (2002), these systems should contain a major fraction of the neutral hydrogen mass at $z > 3.5$ and may thus play an important role at high redshift. Twelve sub-DLAs have been identified. We performed a detailed chemical analysis, and addressed the issues of photoionization corrections. We obtained the first sub-DLA chemical abundance data base ideal for the study of a number of interesting properties of these systems. The implication of sub-DLAs in the cosmic metallicity evolution was our main concern. We also undertook a detailed comparison of the sub-DLA chemical properties with the well studied DLAs to see whether the sub-DLAs are associated with a different class of objects.

Construction of the Sub-DLA Sample

To construct the sub-DLA sample, we used all of the quasar spectra available to us in July 2001 in the ESO UVES/VLT archives and suitable for a sub-DLA search. This led to a set of 22 quasars. We proceeded to a rigorous identification of all of the intervening sub-DLAs with the help of an automated selection algorithm and visual criteria, like the presence of damping wings in the Lyα absorption lines, clearly observed in the sub-DLA H I column density regime. We identified 12 sub-DLAs in the redshift interval $z = 1.8 - 4.3$.

Ionization Corrections and Chemical Abundances of Sub-DLAs

A comprehensive abundance analysis was carried out for each of the 12 sub-DLAs. Sixteen ions and 11 elements – O, C, Si, N, S, Mg, Al, Fe, Ni, Zn and Cr – were detected. To derive the ionization corrections in these systems with lower H I column densities than the DLAs, we computed the photoionization models

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for each sub-DLA, using the CLOUDY software package. We constrained the ionization parameter with the Al^{++}/Al^{+} and Fe^{++}/Fe^{+} ratios for 9 sub-DLAs, and found that the corrections are almost negligible, being lower than 0.2 dex.

Metallicity Evolution
Until now only the DLAs have been used to trace the evolution of the metal content of the Universe, but they do not shown any evolution (e.g. Pettini et al. 1999; Vladilo et al. 2000; Prochaska & Wolfe 2002). Given the expected sub-DLA high neutral hydrogen content in the high redshift Universe, we explored their contribution to the metal content of the Universe. When comparing the evolution of the H I weighted-mean metallicity of the sub-DLA and DLA samples, we noted that the sub-DLAs clearly show a more pronounced evolution than the DLAs. Starting from a metallicity 1/100 solar at $z \sim 4.5$, the sub-DLA metallicity increases up to 1/3 solar at $z \sim 0.5$. However, this evolution is not any more observed when at once the sub-DLAs and DLAs are considered. This is not surprising, since in our sample the number of DLAs (72, found in the literature) is much larger than the number of sub-DLAs. On the contrary, in the Universe we expect the number of sub-DLAs to be up to 3 times the number of DLAs at $z \sim 4$ (Péroux et al. 2002). It is thus important to enlarge the sub-DLA sample, and mainly at $z > 3.5$, to better probe the H I weighted-mean metallicity which is a good tracer of the metal content of the Universe.

Chemical Abundance Patterns
The study of the chemical abundance patterns of absorption line systems provides insight into their nature and star formation history. Hence, to determine whether the sub-DLAs sample a different class of objects than the DLAs, a comparison of their abundance patterns is very instructive. We compared their [Si/Fe] and [O/Fe] versus [Fe/H] patterns, and found no outstanding differences. The question related to the nature of the sub-DLAs then remains fully open. We also considered the [C/Fe] versus [Fe/H] pattern, since we obtained the first set of C II measurements in high H I column density absorbers. The C/Fe ratio is a good dust indicator. The non-solar [C/Fe] ratios observed in some sub-DLAs are suggestive of the presence of dust in these systems.

More information on the different results we have obtained on the sub-DLAs can be found in Dessauges-Zavadsky et al. (2003) and Péroux et al. (2003).

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