Abstract. Damped Lyα systems seen in the spectra of high-z QSOs arise in high-density neutral gas in which molecular hydrogen (H$_2$) should be conspicuous. Systematic searches to detect the H$_2$ lines redshifted into the Lyα forest at $< 3400$ Å are now possible thanks to the unique capabilities of UVES on the VLT. Here we summarise the present status of our ongoing programme to search for H$_2$ in DLAs, discuss the physical conditions in the systems where H$_2$ is detected and the implications of non-detections.

1 Introduction

Damped Lyman-α systems (DLAs) are characterized by high HI column densities. Such a gas, in a galactic environment in nearby universe, always harbours detectable amount of H$_2$. In our Galaxy, all clouds with $\log N$(HI) > 21, have $\log N$(H$_2$) > 19 [3]. The equilibrium formation of H$_2$ molecules is controlled by dust grains, kinetic temperature, particle density and ambient UV radiation field. Thus molecular content of HI gas that produces DLAs can give vital clues about the local physical conditions. More recently Ge & Bechtold [1] have searched, for H$_2$ in 8 DLAs, using the MMT moderate resolution spectrograph ($FWHM = 1$ Å). They have detected H$_2$ in two systems and found upper limits on the molecular faction, $f = 2N$(H$_2$)/($2N$(H$_2$)+$N$(HI)), ranging between $10^{-6}$ and $10^{-4}$ for non-detection. However as H$_2$ lines are prone to contamination by intergalactic Lyα absorption, reliable measurement of H$_2$ column densities can be achieved only using high spectral resolution data [7].

We use the blue sensitivity of UVES to perform H$_2$ searches at $z_{abs} \sim 2.0$ where the Lyα contamination is less.

Main objectives of our ongoing UVES programme are: (i) to perform systematic search for H$_2$ in DLAs with good detection limit and (ii) to extract physical conditions in the systems using spectra of wide wavelength coverage. Till date 19 DLAs were searched for H$_2$ using the spectra collected during our programme as well as from ESO public archive. Detail analysis of H$_2$ molecule is possible in 5 systems ($z_{abs} = 1.973$ toward 0013-004), ($z_{abs} = 3.025$ toward 0347-383), ($z_{abs} = 2.811$ toward 0528-250), ($z_{abs} = 2.338$ toward 0551-366), ($z_{abs} = 2.338$ toward 1232+082). We achieve de-
Figure 1: Few selected transitions from the J=0,1 and 2 rotational levels of the vibrational ground-state of H$_2$ at $z_{\text{abs}}=1.962$ toward 0551-366
detection limit of $10^{14}$ cm$^{-2}$ for H$_2$ and the derived upper limits on molecular fraction are in the range $10^{-5}$ to $10^{-7}$.

2 Physical conditions in individual systems:

2.1 $z_{\text{abs}}=1.962$ toward 0551-366:

We detect H$_2$ in two distinct components separated by 50 km s$^{-1}$ (see Fig. 1). We measure, $f=1.4\times10^{-4}$. C~i, C~i$^\ast$ are detected in 6 distinct velocity components spread over 150 km s$^{-1}$. The iron-peak elements are depleted compared to zinc, [X/Z]~ −0.8, probably because they are tied up onto dust grains. The depletion of heavy elements remains about the same in all the detected C~i components, irrespective of the presence or absence of H$_2$. Moreover the components in which H$_2$ is detected have large densities, $n_H \geq 60$ cm$^{-3}$, and low temperatures, $T_{\text{kin}} < 100$ K. This demonstrates that the presence of H$_2$ is not only related to the dust-to-metal ratio but is also highly dependent on the physical conditions of the gas. The photo-dissociation rate derived in the components where H$_2$ is detected suggests the presence of a local UV radiation field stronger than that in the Galaxy by at least an order of magnitude. Vigorous star formation therefore probably occurs near the H$_2$-bearing cloud.

2.2 $z_{\text{abs}}=1.973$ toward 0013-004:

H$_2$ is detected in four distinct components that are spread over $\sim700$ km s$^{-1}$. The overall molecular fraction is in the range $-2.7 < \log f < -0.6$, which is the
Figure 2: H$_2$ absorption profiles for transitions, $v = 1 - 0$ (left panels) and $2 - 0$ (right panels), plotted in relative velocity with respect to $z_{\text{abs}} = 1.97296$ toward 0013-004. The vertical dotted and dashed lines show the components with and without H$_2$ absorption.

The highest value found for DLA systems. The presence of H$_2$ among different components is closely related to the physical conditions: high particle density, low temperature. The excitation of high $J$ levels suggests that the UV radiation field is highly inhomogeneous through the system. The depletion, [Fe/Zn] = $-1.92$, [Fe/S] = $-1.86$, [Si/Zn] = $-1.01$, [Si/S] = $-0.95$, similar to what is observed in cold gas of the Galactic disk is seen in one of these components. H$_2$, with log $N$(H$_2$) $\sim$ 16.5, is detected in this metal rich ([Zn/H] $>$ $-0.54$) component. However dust extinction due to this component is negligible owing to small total HI column density, log $N$(HI) $\leq$ 19.6. The observed global metallicities are [P/H] = $-0.59$, [Zn/H] = $-0.70$ and [S/H] = $-0.71$ relative to solar. The clear correlation we notice between [Fe/S] and [Si/S] in different components indicates that the abundance pattern is due to dust-depletion.

2.3 $z_{\text{abs}} = 2.3377$ toward 1232+082:

We confirm the presence of H$_2$ in this system with $f = 3.8 \times 10^{-4}$. For the first time we detect HD molecular lines with N(HD) = $1 - 4 \times 10^{14}$ cm$^{-2}$[10]. The metallicity is $6.3 \pm 0.7 \times 10^{-2}$ solar with iron depleted by a factor of $\sim 3$. Absorption profiles corresponding to transitions from $J > 1$ rotational levels are consistent with a single component at the same redshift as C i absorption. The physical conditions within the cloud at $z_{\text{abs}} = 2.3377$ can be constrained directly from the observation of H$_2$, C i, C i*, C i** and C ii*. 
The kinetic temperature is defined by the $J = 0–1$ $\text{H}_2$ excitation temperature, $100 < T < 300$ K; the particle density is then constrained using the $N(\text{C} \, \text{ii}^+) / N(\text{C} \, \text{ii})$ column density ratio, $30 < n_\text{H} < 50 \text{ cm}^{-3}$; and UV pumping is estimated to be of the same order as in our Galaxy.

### 3 Global properties:

We notice a 3.1$\sigma$ correlation between molecular fraction and dust depletion\[3\]. However in the case of systems with $f \geq -4.0$, the level populations of $\text{C i}$ fine-structure lines suggest large densities ($n_\text{H} > 20 \text{ cm}^{-3}$) and low temperature ($T < 300$K). Also in the systems that show multiple components the presence/absence of $\text{H}_2$ in a given component is independent of the dust to gas ratio. Thus it is most likely that, even though dust is important for the formation of $\text{H}_2$, local physical conditions (gas density & temperature) play the vital role in governing the molecular fraction of a given cloud. The thermal pressure derived from the fine-structure excitation of $\text{C i}$ lines are much larger than that derived along the ISM sightlines. This difference can not be accounted for by the CMBR pumping alone. Lack of $\text{H}_2$ in systems with moderate dust depletion can be understood as the direct consequence of high kinetic temperature $\[5\]$. It is most likely that considerable percentage of the DLAs arise in diffuse and warm gas, typically $T > 3000$ K. This is consistent with the high spin temperature inferred in few systems\[2\].

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