The VLT-UVES Survey for H_2 Molecules and Dust in high-Redshift galactic Halos

C. Ledoux[1], P. Petitjean[2], R. Srianand[3]

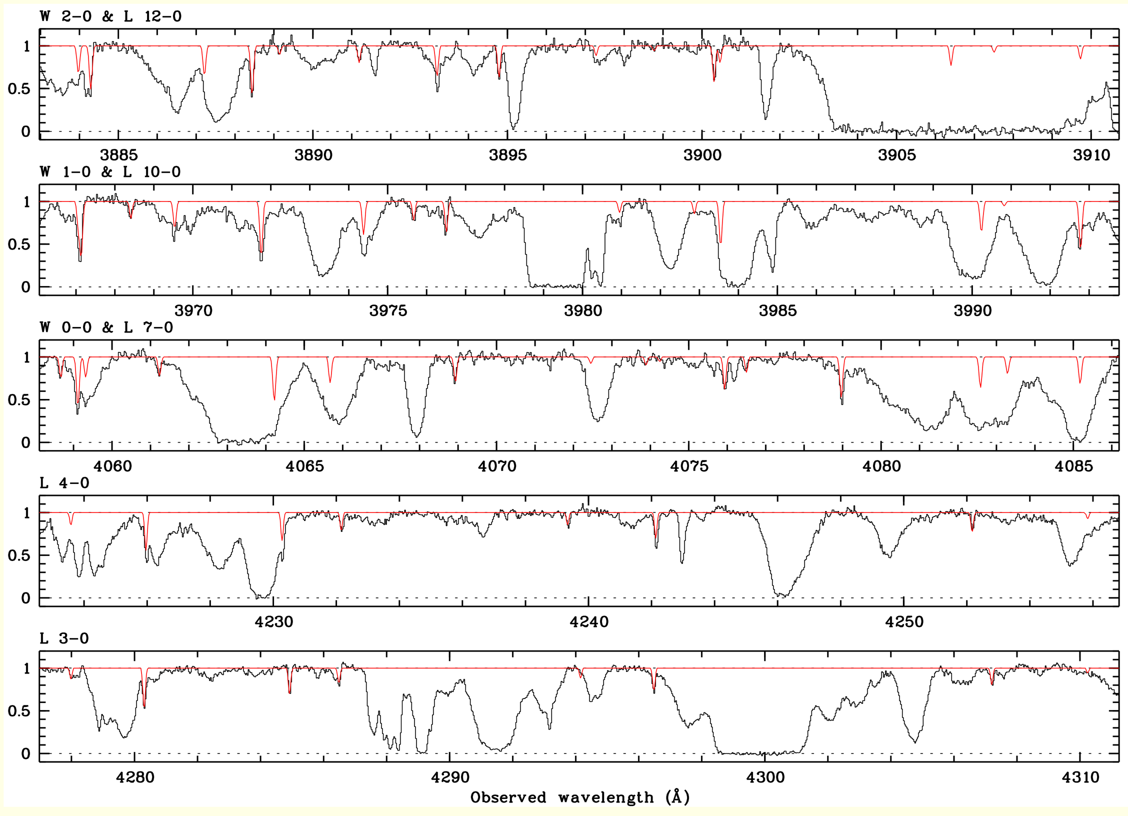
(1) European Southern Observatory, Santiago, Chile, (2) Institut d'Astrophysique de Paris, France, (3) Inter-University Center for A&A, Pune, India

Abstract

We have searched for molecular hydrogen in damped Lyman-α (DLA) and sub-DLA systems at high redshift ($z_{\rm abs} > 1.8$) using UVES at the VLT down to a detection limit of typically $N(\mathbf{H}_2) \sim 2 \times 10^{14}$ cm^{-2}. This represents 10 observing nights spread over the first two years of operations of UVES. Some of our most important results are summarized below (see refs.):

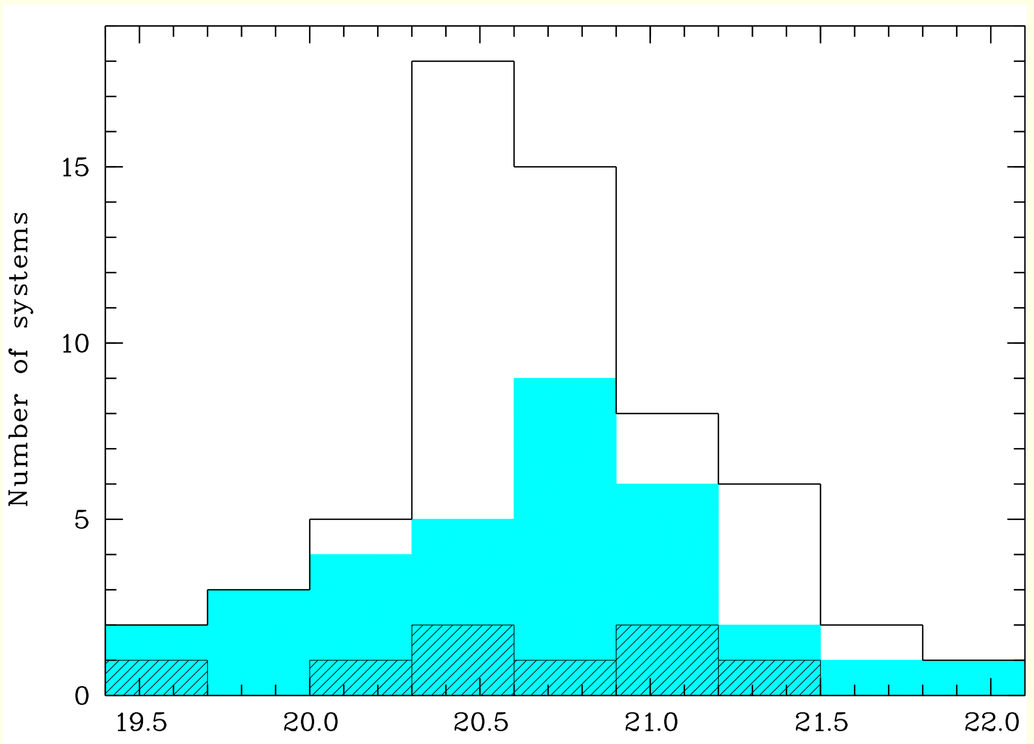
- Out of 33 absorbers in our sample, 8 have firm and 2 have tentative detections of associated H_2 molecular lines. Considering that 3 detections were already known from past searches using lower resolution data, H_2 molecules are detected in 13 to 20 percent of the newly surveyed systems.
- We find that there is a correlation between metallicities and depletion factors in both our sample and also the global population of DLA systems. Although H_2 molecules are detected in systems with [Zn/Fe] as small as 0.3, the systems where H_2 is detected are usually amongst those with the highest metallicities and the largest depletion factors. This clearly demonstrates the presence of dust in a significant fraction of the DLA systems.
- The mean H_2 molecular fraction, $f = 2N(\mathrm{H}_2)/[2N(\mathrm{H}_2) + N(\mathrm{H\,I})]$, is generally small in DLA systems (typically $\log f < -1$) and similar to what is observed in the Magellanic Clouds. Approximately 50 percent of the systems have $\log f < -6$. This can be explained if the formation rate of H_2 onto dust grains is reduced, probably because the gas is warm ($T > 1000$ K) and/or the ionizing flux is enhanced relative to what is observed in our Galaxy.

Detecting H_2 molecules with UVES



Some of the transition lines from the J = 0, 1, 2, 3 and 4 rotational levels of the vibrational ground-state Lyman and Werner bands of H_2 detected at $z_{\rm abs} \approx 3$. Molecules are detected on this particular line of sight in a single gas cloud.

Observed $\log N(\mathrm{H\,I})$ distribution

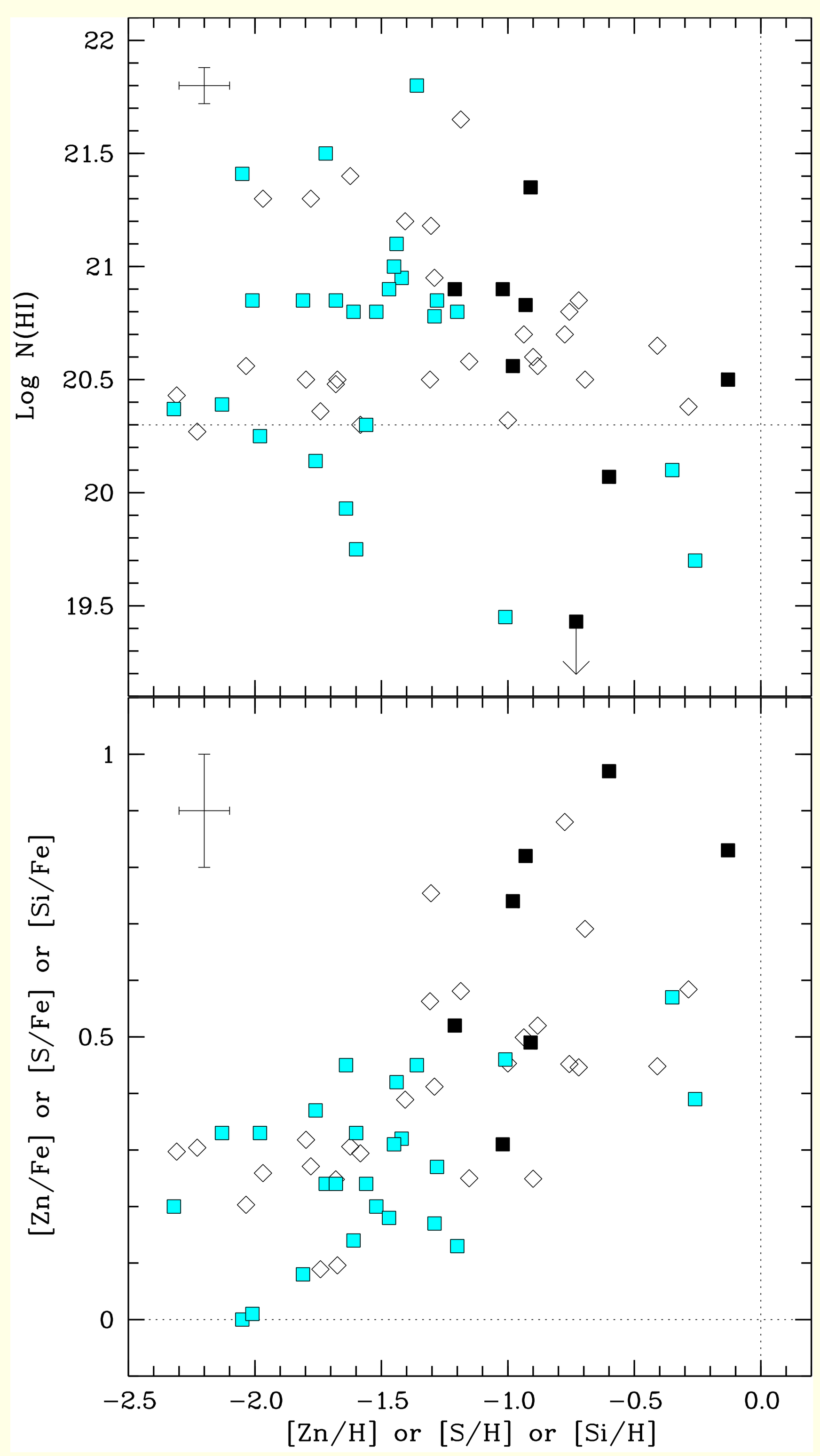


Distributions of neutral hydrogen column densities in, respectively, the global population of DLA/sub-DLA systems (continuous line), the H_2 survey sample (blue-shaded histogram) and the sub-sample of H_2-detected systems (hashed histogram).

References

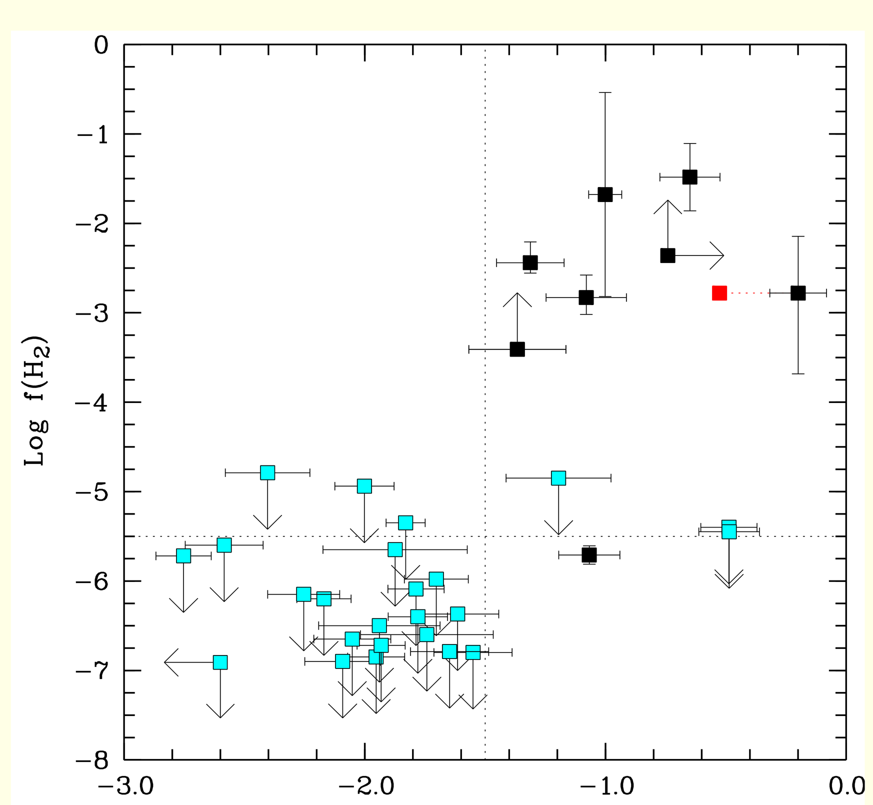
Ledoux C., Petitjean P., Srianand R., 2003, MNRAS, accepted
Ledoux C., Srianand R., Petitjean P., 2002, A&A **392**, 781
Petitjean P., Srianand R., Ledoux C., 2000, A&A **364**, L26
Petitjean P., Srianand R., Ledoux C., 2002, MNRAS **332**, 383
Srianand R., Petitjean P., Ledoux C., 2000, Nature **408**, 931

Evidence for dust in DLA systems



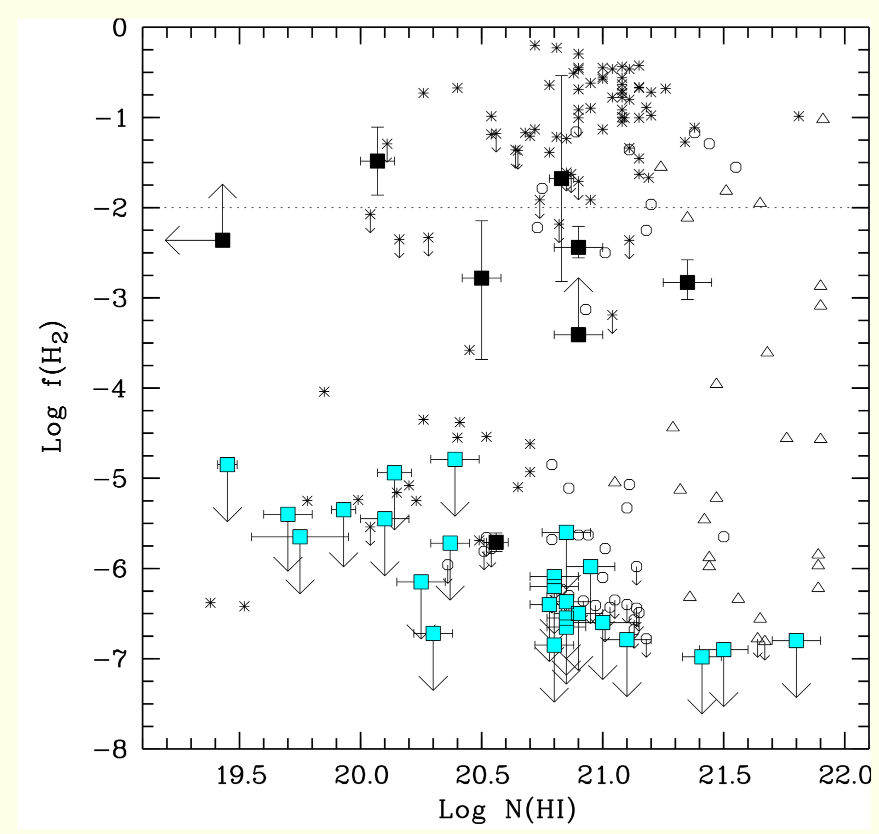
Neutral hydrogen column density *(upper plot)* and depletion factor *(lower plot)* versus metallicity in, resp., the global population of DLA/sub-DLA systems (all symbols), the H_2 survey sample (all squares) and the sub-sample of H_2-detected systems (black squares).

Link between H_2 and dust contents



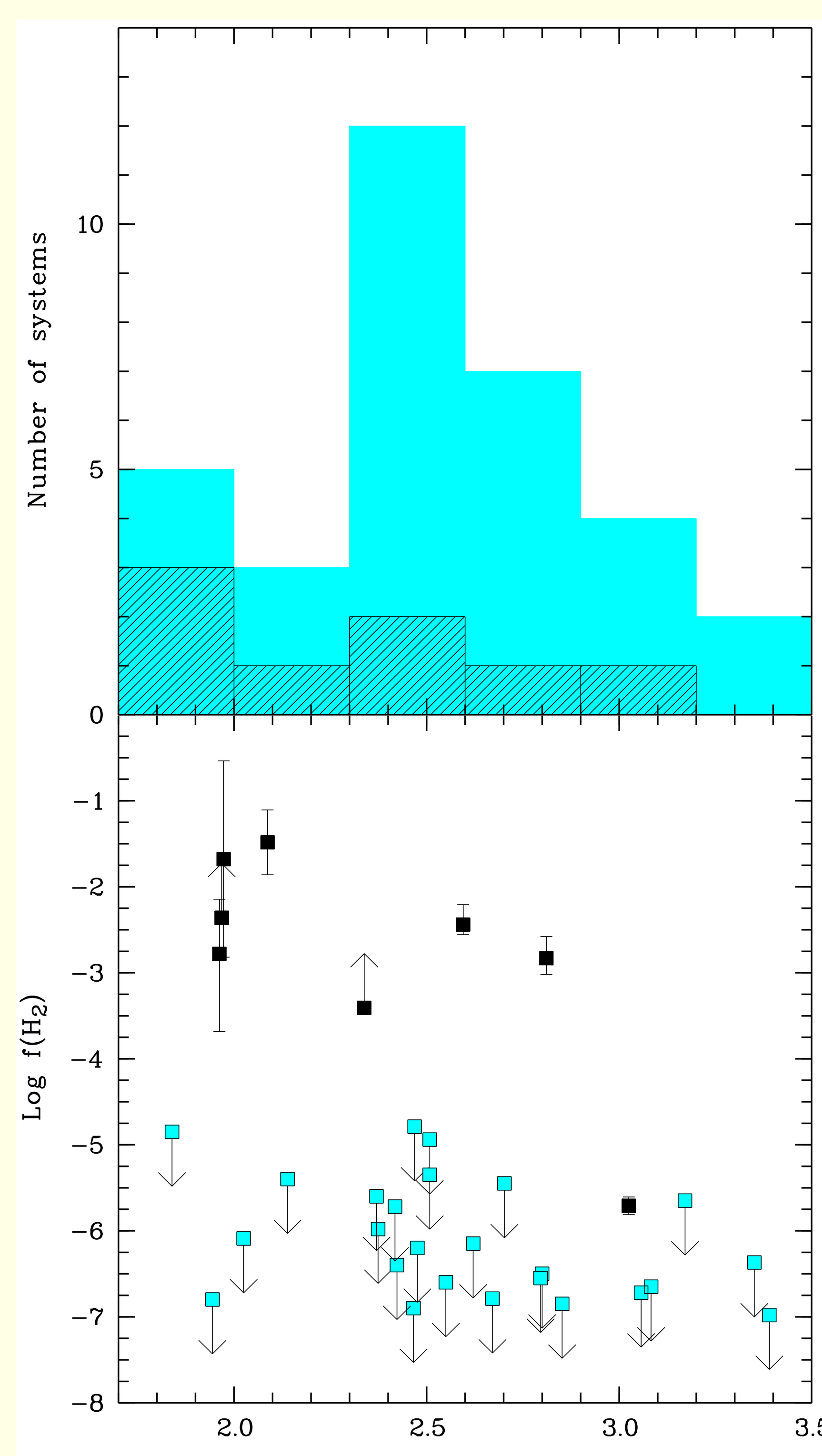
H_2 molecular fraction versus dust-to-gas ratio, i.e. the amount of dust. A weak trend between the two quantities is apparent; however, several orders of magnitude spread in $f(\mathrm{H}_2)$ for a given dust content, among the detected cases, suggests that, in addition to the amount of dust, **the physical conditions of the gas** (density, temperature, UV flux) **play an important role** in governing the formation of molecules in DLA systems.

Comparison to the Galaxy and MCs



H_2 molecular fraction versus neutral hydrogen column density. Measurements in DLA/sub-DLA systems are indicated by black squares for H_2 detections and blue ones for upper limits. Observations along lines of sight in the Galaxy, LMC and SMC are indicated by, resp., asterisks, circles and triangles.

Evolution with redshift



Upper panel: Number of systems versus redshift. The H_2-detected subsample is indicated by the hashed histogram. *Lower panel:* H_2 molecular fraction versus redshift. Detections are shown by black squares. Although the statistics are based on small numbers, the probability of finding molecules at $z_{\rm abs} \sim 2$ is highest. This probably reveals that the amount of dust in DLA systems increases with time.