Recycling Intergalactic and Interstellar Matter
IAU Symposium Series, Vol. 217, 2004
Pierre-Alain Duc, Jonathan Braine and Elias Brinks, eds.

Molecules in Damped Lyα Systems: Spatial Distribution

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Abstract. To interpret H_2 quasar absorption line observations in DLAs (damped Lyα clouds), we model the H_2 spatial distribution within a DLA. Based on numerical simulations of disk structures with parameters similar to those derived for such absorbers, we calculate the H_2 distribution as a function of ultraviolet background (UVB) intensity and dust-to-gas ratio. For typical values of these two quantities we find that the area in which the H_2 fraction exceeds 10^{-6} (typical observational detection limit) only covers $< 10\%$ of the disk surface, i.e., H_2 has a very inhomogeneous, clumpy distribution even at these low abundance levels. This explains the relative paucity of H_2 detections in DLAs. We also show the dependence of the covering fraction of H_2 on dust-to-gas ratio and UVB intensity and we comment on the physics governing the H_2 chemical network at high redshift. We finally comment on our implication on the statistics of the H_2 column density distribution.

1. Introduction

The important role of dust on the enhancement of the H_2 (hydrogen molecule) abundance in damped Lyα clouds (DLAs; QSO absorption line systems whose neutral hydrogen column density is > 1–2×10^{20} cm^{-2}) has been suggested by various observations (e.g., Ledoux et al. 2003). For the H_2 fraction (mass ratio of H_2 to all the hydrogen nuclei), stringent upper limits are laid on a significant fraction of DLAs in the range $\sim 10^{-7}$–10^{-5}. We should keep in mind that if the covering fraction of H_2-rich regions on a galactic surface is extremely small, it is natural that H_2 is not detected in DLAs. Therefore, the argument on the H_2 abundance in DLAs is strongly dependent on the geometry of H_2 distribution within those systems.

https://doi.org/10.1017/S0074180900197712 Published online by Cambridge University Press

2. Molecular fraction map

In order to get a better understanding of the spatial distribution of H_2, we present our study based on high-resolution numerical simulations. We calculate the spatial structure of H_2 distribution in galactic disks under various conditions for the UVB intensity and dust-to-gas ratios (see Hirashita et al. 2003 for the details). A 50 pc $\times$ 50 pc zoom of the distribution of molecular fraction ($f_{\mathrm{H_2}}$) is shown in Fig. 1 (left).

We plot the data of Ledoux et al. (2003) in Fig. 1 (right; crosses), where we adopt clouds those with $\log N(\mathrm{H\ I}) > 20.5$. The squares in the figure represent our theoretical prediction (the UVB intensity is assumed to be $J_{21} = 0.1$), where we have selected randomly five lines of sight on the simulated disk for each value of dust-to-gas ratio $\mathcal{D}$. In addition to the rough trend between the two quantities, we find the increase of $f_{\mathrm{H_2}}$ spread towards higher dust-to-gas ratios. This is caused by the inhomogeneous H_2 distribution.

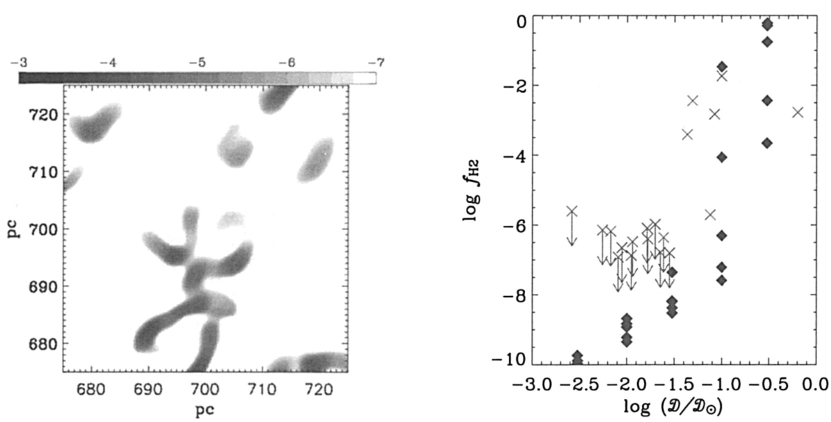

Figure 1. *Left*: Distribution of molecular fraction ($\log f_{\mathrm{H_2}}$) zoomed on a region in a simulated "DLA". The UVB intensity and dust-to-gas ratio are assumed to be $J_{21} = 0.1$ and $\mathcal{D} = 0.001$, respectively. The grey scale bar show the levels of $\log f_{\mathrm{H_2}}$. *Right*: Molecular fraction ($f_{\mathrm{H_2}}$) and dust-to-gas ratio ($\mathcal{D}$). The dust-to-gas ratio in the solar neighborhood is assumed to be $\mathcal{D}_{\odot} = 0.01$. The crosses are from Ledoux et al. (2003), while the squares are our theoretical prediction.

Acknowledgments. H. H. was supported by the Research Fellowship of the Japan Society of the Promotion of Science for Young Scientists.

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