CO-to-H$_2$ Abundance Ratio of the Foreground Gas of the Carina Nebula

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Abstract. We analyze CO and H$_2$ absorption lines of the foreground molecular cloud in the Carina nebula. We use HST-STIS (Hubble Space Telescope - Space Telescope Imaging Spectrograph) & IUE (International Ultraviolet Explorer) INES data to analyze the A-X (v=0→2) absorption band of CO for several hot stars toward the Carina nebula, while 9 stars of them have FUSE (Far Ultraviolet Spectroscopic Explorer) spectra to analyze the (v=0→4) vibrational band in the Lyman series of H$_2$. The column densities of CO and H$_2$ varies in the vicinity of N(CO) $\sim 10^{13}$ cm$^{-2}$ and N(H$_2$) $\sim 10^{19}$ cm$^{-2}$, respectively. The resultant CO-to-H$_2$ abundance ratio is about $10^{-6}$. We investigate the variation of the abundance ratio according to the relative position of the target stars to morphology the molecular cloud in the Carina nebula.

1. Introduction

The Carina nebula (NGC 3372) is a huge H II region which produces a large ultraviolet (UV) radiation field and strong stellar winds, spanning more than four square degrees at a distance of about 2.2 kpc (Tovmassian et al., 1995). This kind of environment causes not only systematic expansion of the giant H II region (Walborn et al., 1984), but also heavy interaction with the surrounding large molecular cloud which is left after star formation. Besides, Walborn and Hesser (1975), Laurent et al. (1982) and Walborn et al. (1998) assert the existence of a cold, low-velocity cloud near the Sun in the direction of the Carina nebula. We investigate the CO-to-H$_2$ abundance ratio of two such clouds — a foreground cloud and the Carina cloud.
2. Observation and Analysis

We use three kinds of data: HST-STIS & IUE INES data are used to analyze the CO A-X (0→2) band and FUSE data are used to analyze the H₂ Lyman (0→4) band. We coadd all available individual spectra to improve the S/N ratio except for the HST-STIS data which consists of only one spectrum. We obtain N(CO) and N(H₂) through $\chi^2$ minimization while fitting the line profile and via the curve of growth method. In the HST-STIS data and FUSE data, each rotational absorption line can be resolved so we use a $\chi^2$ minimization line profile fitting method. In contrast, in the IUE data the rotational absorption lines are unresolved so the curve of growth method was used. We use a Doppler parameter in the range 1–3 km s$^{-1}$ for the CO analysis and 4–5 km s$^{-1}$ for the H₂ analysis.

3. Results

Table 1 is our result. It shows that the CO-to-H₂ abundance ratio of the foreground gas is in the range of $10^{-6}$ and its value differs according to the position within the cloud. Walborn (1998) asserts that the existence of CO is evidence of foreground gas toward the Carina nebula. Therefore, we assume that CO lies in the foreground.

Table 1. CO-to-H₂ Abundance ratio & column density

<table>
<thead>
<tr>
<th>Star</th>
<th>N(CO)$_{fore}$</th>
<th>N(H₂)$_{fore}$</th>
<th>N(H₂)$_{carina}$</th>
<th>N(CO)</th>
<th>N(H₂)$_{fore}$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$\times 10^{13}$ cm$^{-2}$</td>
<td>$\times 10^{19}$ cm$^{-2}$</td>
<td>$\times 10^{19}$ cm$^{-2}$</td>
<td>$\times 10^{-6}$</td>
<td>$\times 10^{19}$ cm$^{-2}$</td>
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<tr>
<td>HD303308</td>
<td>5.879 ± 0.294</td>
<td>10.535 ± 2.635</td>
<td>6.795 ± 1.7</td>
<td>0.55804</td>
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<tr>
<td>HD92809</td>
<td>10.48 ± 0.1287</td>
<td>11.81 ± 1.673</td>
<td>11.81 ± 1.673</td>
<td>0.88738</td>
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<tr>
<td>HD93206</td>
<td>1.599 ± 0.078</td>
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<td>0.38419</td>
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</tr>
<tr>
<td>HD93222</td>
<td>2.029 ± 0.254</td>
<td>3.146 ± 0.356</td>
<td>5.033 ± 0.57</td>
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<tr>
<td>HD93249</td>
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<td>10.339 ± 0.913</td>
<td>10.339 ± 0.913</td>
<td>0.90637</td>
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<tr>
<td>HD93308</td>
<td>9.854 ± 0.1313</td>
<td>4.953 ± 0.93</td>
<td>9.907 ± 1.861</td>
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<tr>
<td>HD93403</td>
<td>10.63 ± 0.126</td>
<td>16.361 ± 2.588</td>
<td>16.361 ± 2.588</td>
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<tr>
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<td>-</td>
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<tr>
<td>HD94910</td>
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<td>-</td>
<td>0.60739</td>
<td></td>
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<tr>
<td>V* V572 Car</td>
<td>6.275 ± 0.361</td>
<td>7.454 ± 0.856</td>
<td>11.181 ± 1.283</td>
<td>0.84183</td>
<td></td>
</tr>
</tbody>
</table>

References