Molecular Cloud Structure in the Magellanic Clouds: II. CO-to-H_2 Conversion Factor

Soojong Pak

Astronomy Department, Seoul National University, Kwanak-Gu, Seoul 151-742, Republic of Korea

D. T. Jaffe

Astronomy Department, University of Texas at Austin, Austin, TX 78712, U.S.A.

1. Introduction

In the Milky Way, the ^{12}CO $J = 1 \rightarrow 0$ line traces the molecular gas content. The conversion factor, X^{GAL}, between the H_2 column density, $N(H_2)$, and the velocity integrated intensity of CO, $I(CO)$, has been measured via the virial theorem or via γ-ray emission (Solomon et al. 1987, Bloemen et al. 1986, Digel et al. 1997, and references therein).

How can we apply X^{GAL} to other galaxies where the metallicities are different from that of our Galaxy? The metallicity dependence of the conversion factor has been an issue. Cohen et al. (1988), Wilson (1995), and Arimoto, Sofue, & Tsujimoto (1996) argued that the value of X increases as the metallicity of the individual galaxy decreases. By contrast, Taylor, Kobulnicky, & Skillman (1996) showed that some low abundance galaxies have lower X.

2. The Cloud Size versus Metallicity

In our previous work (Pak et al. 1998), we examined the chemical structure of neutral clouds in low-metallicity environments by comparing the observed emission lines (i.e., far-IR, ^{12}CO $J = 1 \rightarrow 0$, [CII] 158 μm, and H_2 $(1,0)S(1)$) from photo-dissociation regions (PDRs) and the simulated results from numerical codes (i.e., a PDR code and a radiative transfer code). The column density of the cloud increases as the metallicity decreases. Figure 1 shows that the typical cloud size in the LMC is 4 times bigger than that of the Galaxy. Our result also agrees with the photoionization-regulated star formation theory of McKee (1989).

3. The CO-to-H_2 Conversion Factor in the Magellanic Clouds

Neglecting the micro-turbulent width of the CO line, the CO-to-H_2 conversion factor, X, can be expressed by the radius of the neutral cloud, R_{cloud}:

$$X = \frac{N(H_2)}{I(CO)} \propto \frac{M_{cloud}}{L(CO)} \propto \frac{R^3_{cloud}}{R^2_{cloud}} \propto R_{cloud} \ ,$$

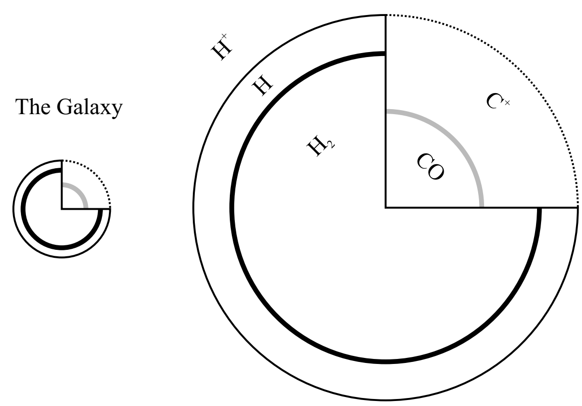

Figure 1. Schematic of chemical structures and sizes of typical clouds in the Galaxy and the LMC. The size of the star-forming clouds is inversely proportional to the metallicity of the galaxy. We assumed that the far-UV field and the gas density are same in both clouds.

where M_{cloud} is the mass of the neutral cloud, and $L(CO)$ is the luminosity of the CO line emission from the cloud. From our previous results (Pak et al. 1998), we deduced that $R_{cloud} \propto Z^{-1}$, where Z is the metallicity. Therefore, the conversion factor is inversely proportional to the metallicity:

$$X \propto Z^{-1} ,$$

which agrees with the results of Wilson (1995) and Arimoto, Sofue, & Tsujimoto (1996).

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