ELSEVIER

Chinese Astronomy and Astrophysics 42 (2018) 213–238

CHINESE
ASTRONOMY
AND ASTROPHYSICS

The Gas to Dust Ratio in Three Star Forming Regions† ⋆

LV Zhang-pan JIANG Bi-wei△ LI Jun

Department of Astronomy, Beijing Normal University, Beijing 100875

Abstract Gas to Dust Ratio (GDR) indicates the mass ratio of interstellar gas to dust. It is widely adopted that the GDR in our Galaxy is 100∼150. We choose three typical star forming regions to study the GDR: the Orion molecular cloud — a massive star forming region, the Taurus molecular cloud — a low-mass star forming region, and the Polaris molecular cloud — a region with no or very few star formation activities. The mass of gas only takes account of the neutral gas, i.e. only the atomic and molecular hydrogen, because the amount of ionized gas is very small in a molecular cloud. The column density of atomic hydrogen is taken from the high-resolution and high-sensitivity all-sky survey EBHIS (Effelsberg-Bonn HI Survey). The CO J = 1 → 0 line is used to trace the molecular hydrogen, since the spectral lines of molecular hydrogen which can be detected are rare. The intensity of CO J = 1 → 0 line is taken from the Planck all-sky survey. The mass of dust is traced by the interstellar extinction based on the 2MASS (Two Micron All Sky Survey) photometric database in the direction of anti-Galactic center. Adopting a constant conversion coefficient from the integrated intensity of the CO line to the column density of molecular hydrogen, $X_{\rm CO} = 2.0\times10^{20}\,{\rm cm}^{-2}\cdot({\rm K\cdot km/s})^{-1}$, the gas to dust ratio $N({\rm H})/A_{\rm V}$ is calculated, which is 25, 38, and 55 (in units of $10^{20}\,{\rm cm}^{-2}\cdot{\rm mag}^{-1}$) for the Orion, Taurus, and Polaris molecular clouds, respectively. These values are significantly higher than the previously obtained average value of the Galaxy. Adopting the WD01 interstellar dust model (when the V-band selective extinction ratio is $R_{\rm V} = 3.1$), the derived GDRs are 160, 243, and 354 for the Orion, Taurus, and Polaris molecular clouds, respectively, which are apparently higher than 100∼150, the commonly accepted GDR of the diffuse interstellar medium. The high $N({\rm H})/A_{\rm V}$ values in the star forming regions may be explained by the growth of dust in the

† Supported by National Natural Science Foundation (11373015, 11533002), 973 Project (2014CB845702)

Received 2016–07–08; revised version 2016–09–28

⋆ A translation of *Acta Astron. Sin.* Vol. 58, No. 2, pp. 11.1–11.22, 2017

△ bjiang@bnu.edu.cn

doi:10.1016/j.chinastron.2018.04.004

molecular clouds because of either the particle collision or accretion, which can lead to the reduction of extinction efficiency per unit mass in the V band, rather than the increase of the GDR itself.

Key words stars: formation, ISM: clouds, ISM: molecules, submillimeter: ISM

1. BACKGROUND INTRODUCTION

1.1 Gas to Dust Ratio

Gas to Dust Ratio (GDR) means the mass ratio of interstellar gas to dust. The abundance and composition of dust in a galaxy represent the history of dust formation and destruction, hence the measurement of GDR will provide important information and constraint for the galaxy evolution[1].

The expression of GDR is not unique. According to the definition, for the GDR in a given interstellar environment (for example a molecular cloud), the mass ratio can be expressed by the density ratio, i.e.,

$$\mathrm{GDR} \equiv \frac{\rho_{\mathrm{gas}}}{\rho_{\mathrm{dust}}}\,, \tag{1}$$

in which ρ_{dust} and ρ_{gas} are the mass densities of gas and dust, respectively.

If the dimensions (l) of gas and dust are equivalent, the GDR can be expressed as:

$$\mathrm{GDR} = \frac{\mathrm{d}\sum_{\mathrm{gas}}/\mathrm{d}l}{\mathrm{d}\sum_{\mathrm{dust}}/\mathrm{d}l} = \frac{\mathrm{d}\sum_{\mathrm{gas}}}{\mathrm{d}\sum_{\mathrm{dust}}}\,, \tag{2}$$

in which $\sum_{\mathrm{gas}}$ and $\sum_{\mathrm{dust}}$ are the surface densities of gas and dust, respectively.

Besides, the GDR can also be calculated by means of column density:

$$\mathrm{GDR} = \frac{N(\mathrm{gas})}{N_{\mathrm{dust}}} \propto \frac{N(\mathrm{gas})}{A_{\mathrm{V}}}\,, \tag{3}$$

in which $N(\mathrm{gas})$ is the column density of all gaseous particles, i.e. the summation of the column densities of atoms, molecules, and ions; N_{dust} is the column density of dust particles, A_{V} is the total extinction at the visible light waveband V, as $A_{\mathrm{V}} = 1.086 \times N_{\mathrm{dust}} \times C_{\mathrm{ext}}(\mathrm{V})$ ($C_{\mathrm{ext}}(\mathrm{V})$ is the extinction cross-section of dust at the V band), it is positively proportional to N_{dust}, so the dust column density is often expressed by the extinction. This paper adopts $N(\mathrm{gas})/A_{\mathrm{V}}$ to express the GDR.

The commonly accepted GDR of the Galaxy is in the range of 100∼150, this is the range of average values, and for the diffuse interstellar medium it is also an acceptable range. The magnitude of GDR depends on not only the interstellar environment, but also the dust composition to be considered. The calculation of dust mass is generally based on the dust model fit with the infrared spectral energy distribution, if including only the hot dust ($T_{\mathrm{dust}} > 30\,\mathrm{K}$), then the mass of dust is underestimated, the value of GDR tends to be large; if including the cold dust ($T_{\mathrm{dust}} < 30\,\mathrm{K}$), the value of GDR will be relatively objective.