PHYSICAL CONDITIONS OF MOLECULAR GAS IN THE GALAXY

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1. The Tokyo-NRO Survey of the Galaxy in CO (J=2–1)

Physical conditions of molecular gas are key parameters to the formation rate and initial mass function of stars formed in molecular clouds. The ongoing Tokyo-NRO survey has been observing the Galactic CO (J=2–1) emission with a beamsize matched to the Columbia CO (J=1–0) survey. Intensities of the two lines should reflect physical conditions of the CO-emitting gas. An out-of-plane survey of the inner Galaxy which covers from 20° to 60° in galactic longitude and from −1° to +1° in galactic latitude with grid spacings of 0.25° has already been made (Sakamoto et al. 1994). Its coverage is large enough to draw conclusions on global properties of molecular gas in the inner Galaxy.

2. Meaning of the CO (J=2–1)/CO (J=1–0) Intensity Ratio

Through a numerical calculation based on a large velocity gradient approximation, the CO (J=2–1)/CO (J=1–0) intensity ratio ($\equiv R_{2-1/1-0}$) was found to be a useful tracer of physical conditions of molecular gas. Molecular gas can be classified into four classes in terms of the $R_{2-1/1-0}$ value; very high ratio gas (VHRG; $R_{2-1/1-0} \gg 1$), high ratio gas (HRG; $R_{2-1/1-0} \sim 0.8$), low ratio gas (LRG; $R_{2-1/1-0} \sim 0.5$), and very low ratio gas (VLRG; $R_{2-1/1-0} < 0.4$). The VHRG is optically thin, dense, and warm gas. The

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HRG is opaque and dense enough for low-J transitions of CO to be excited to local thermodynamical equilibrium through collisions, while the LRG is less dense and these low-J transitions are not thermalized. The VLRG is faint and usually not detected in quick surveys. For usual molecular gas, i.e., the HRG and the LRG, the $R_{2-1/1-0}$ value is sensitive to gas density rather than to gas kinetic temperature.

3. Distribution of Dense Molecular Gas in The Galaxy

Through comparison of the CO (J=2–1) data with the CO (J=1–0) data of Cohen, Dame, & Thaddeus (1986), we found a systematic variation of the $R_{2-1/1-0}$ value across the Galactic plane. The ratio varies from ~0.75 at 4 kpc to ~0.6 at 8 kpc in galactocentric distance, which implies large-scale variation in gas density across the Galactic disk by the factor of 2. This trend agrees quantitatively with that obtained with the pilot in-plane survey by Handa et al. (1993). There is little, if any, evidence for the difference of physical conditions between the in-plane gas and the out-of-plane gas.

Concentration of the HRG is found predominantly along arm-like structures called the Sagittarius arm and the Scutum arm in the inner Galaxy. This supports an idea that strong arms in the inner Galaxy compress molecular gas to contain much of the HRG. This, as well as the deficiency of atomic gas in the inner Galaxy, indicates that the predominance of dense molecular gas traced by the HRG is caused by compression processes such as shock compression by density waves followed by gravitational collapse, and not by dissociative stripping of low-density molecular gas due to UV photons.

4. Smaller Scale Height of Molecular Gas in Spiral Arms

Thickness of molecular gas in a disk galaxy reflects midplane total mass density and velocity dispersion of molecular gas. The Galaxy is a unique target to date for exact measurements of vertical extent of molecular gas. Analysis of the CO (J=1–0) data of Cohen, Dame, & Thaddeus (1986) and Bronfman et al. (1988) and of our CO (J=2–1) data at tangential points gives consistent results which indicate that the scale height of molecular gas layer in interarm regions is larger by a factor of 1.2 than in the arms. This fact requires either (1) that the arm-interarm contrast of midplane total mass density is larger than 1.5 or (2) that the velocity dispersion of molecular gas is smaller in arms.

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