Structural Variation of Molecular Gas across the Galactic Spiral Arms

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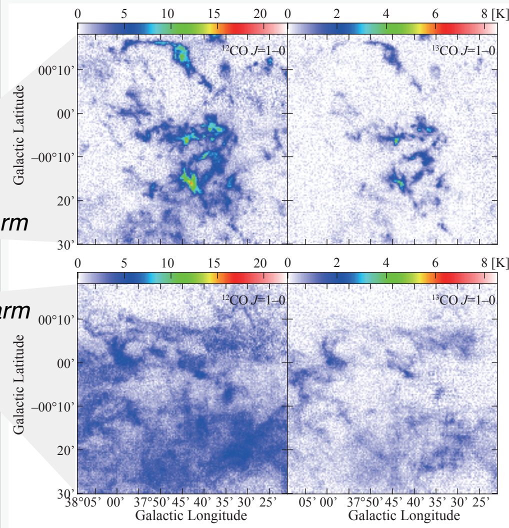
I. High-Resolution, Multi-Line Observations at *l* = 38° Sawada et al. 2012, ApJ, 752, 118

Spiral arms induce star formation (SF), and stars form in (sub-)pc-sized structures of molecular clouds (i.e., cores/clumps).

Is there any relationship between kpc-scale galactic dynamics and (sub-)pc-scale structures (~pc) of molecular gas which are directly relevant to SF?

We performed wide-field (0.8°x0.8° = 110x110 pc at 8 kpc), high-resolution (17” = 0.66 pc at 8 kpc), multi-line (^{12}CO and ^{13}CO *J*=1–0) observations toward the Galactic plane at *l* = 38° using the Nobeyama Radio Observatory 45-m telescope.

Figures below are velocity channel maps corresponding to the Sgr arm (top) and interarm (bottom). There is a remarkable arm/interarm difference in spatial structure of molecular gas, i.e., bright and compact structures in the Sgr arm; faint and diffuse emission in the interarm region.



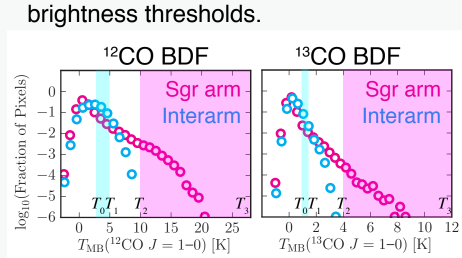
In order to express the spatial structure of the gas quantitatively, we introduce:

Brightness Distribution Function (BDF)
histogram of brightness temperature within a given *l*–*b*–*v* volume

Brightness Distribution Index (BDI)
flux ratio of the bright emission to faint emission (high BDI = dominance of bright and compact emission),

$$\mathrm{BDI} = \log_{10}\left(\int_{T_2}^{T_3} T\cdot B(T)dT \Big/ \int_{T_0}^{T_1} T\cdot B(T)dT\right)$$

where $B(T)$ is BDF; T_0, T_1, T_2, and T_3 are brightness thresholds.



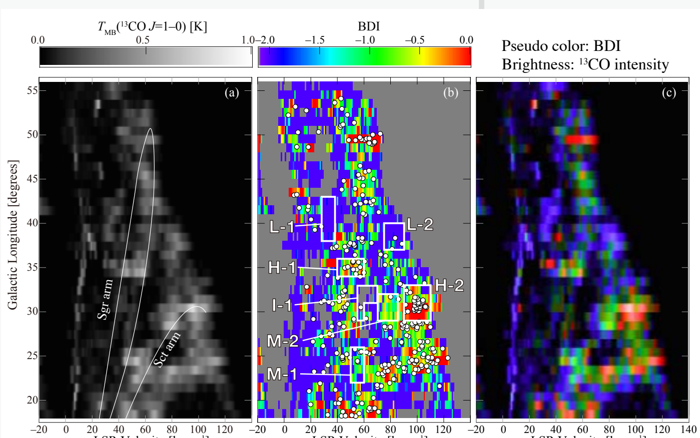
The bright and compact emission in the Sgr arm is represented by long tails toward high brightness in BDF, resulting in high BDI (–0.48 in ^{12}CO, –0.95 in ^{13}CO).

II. Analysis of Wide-Field ^{13}CO Data Sawada et al. 2012, ApJ, 759, L26

Is the difference in spatial structure of the gas between spiral arm and interarm regions generally seen in other areas of the Milky Way Galaxy? If the answer is yes, what is making the difference?

We apply the analysis described above to the Boston U.–FCRAO ^{13}CO *J*=1–0 Galactic Ring Survey (Jackson et al. 2006) data which cover the majority of the first Galactic quadrant.

Figures below present the *l*–*v* diagrams of (a) ^{13}CO *J*=1–0 intensity, (b) BDI (white circles indicate H II regions), and (c) the above two combined (i.e., brightness and color represent the ^{13}CO intensity and BDI, respectively).



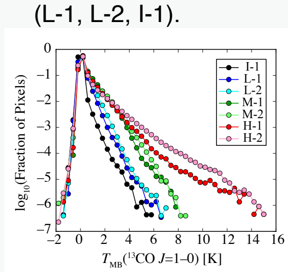
Findings from the *l*–*v* diagrams:

(1) Bands of high BDI are found along the bands of H II regions (i.e, Sgr and Sct arms) -- molecular gas in the spiral arms is *structured*, hosting relatively abundant compact concentrations.

(2) Although high BDI generally coincides with massive SF (H II regions), there also exists moderately high BDI gas which shows little/no signature of ongoing massive SF (M-1 and M-2 in the Figure) in spiral arms.

(3) BDI is low in interarm regions (i.e., lacking structures), even in massive (~$10^6 M_{sun}$) molecular gas complexes (L-1 and L-2 in the Figure).

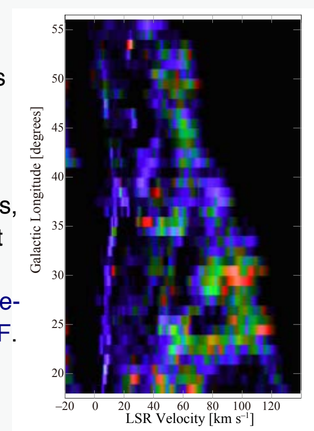
BDFs in individual regions: high BDI associated with H II regions (H-1, H-2); moderately high BDI without H II regions (M-1, M-2); interarm (L-1, L-2, I-1).



The aforementioned results indicate tight relation between high BDI (*structured molecular gas*), spiral arms, and SF. Is the high BDI a *result* of SF or the *cause*?

The *l*–*v* diagram of BDI is re-produced after excluding the gas under direct influence of massive SF (< 10 pc from ultra-compact and compact H II regions and < 25 pc from diffuse H II regions).

The result (right) shows that moderately high BDI persists in spiral arms, implying that high BDI is not the consequence of SF.



We suggest the structural evolution of molecular gas – Faint and extended gas in interarm develops bright and compact structures upon entering spiral arms. Stars form in the compact structures of the gas. The gas then becomes diffuse as it leaves the arms.