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PHYSICAL PROPERTIES OF MOLECULAR GAS IN THE MILKY WAY DISK

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The physical properties of the equatorial "subcentral vicinity" of quadrant IV of the Milky Way disk are investigated using a multi-line analysis of the observed ratios $R_{13/12}={}^{13}CO(J=1\to0)/{}^{12}CO(J=1\to0)$ and $R_{21/10}={}^{12}CO(J=2\to1)/{}^{12}CO(J=1\to0)$, and models with one and two components. Comparison with kinematical stability parameters reinforces our view of galactic structure and suggests a "Smith Law" like relationship for the massive star formation on galactic scales (i.e. kpc scale).

Introduction

The physical properties of the interstellar medium, kinetic temperature, gas density, optical depth, and magnetic and velocity fields control the nature of star formation. These parameters can be obtained from infrared and analysis of microwave molecular line radiation (Evans 1999). We will focus on an analysis of emission from the $^{12}CO(J=2\to1)$, $^{12}CO(J=1\to0)$ lines, and from the isotopic line $^{13}CO(J=1\to0)$. In the analysis of the kinematics and high-mass star formation (Luna et al. 2002) we focussed on the vicinity of the subcentral points. We will continue to use that region to obtain the physical conditions there and compare this with our previous results. The main reason for choosing this region is that there is no ambiguity in the distances to these points.

Data and Observations

We use three sets of data at 115.27 GHz, 110.20 GHz and 230.54 GHz ($CO(J=1\to0)$, $^{13}CO(J=1\to0)$ and $CO(J=2\to1)$, respectively) on $b=0^\circ.0$, with a beam FWHM of 8.8 arcmin approximately, and $\Delta v=2\,km\,s^{-1}$. These data sets are directly comparable because the instruments used (see for description, Bronfman et al. 1989, 1988; Luna et al. 2001) had compatible spatial and velocity resolution, and used the same observational technique and reference positions (ON-OFF positions in position switching) at the different frequencies.

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TABLE 1

WARM COMPONENT USED[a]
$T_K=50$, $N(H_2)=10^{4.5}$, $N/\Delta V=10^{16.6}$

Three possible cool components	variable	%	η
$T_K=10$, $n(H_2)=10^{2.3}$	$N/\Delta v$	94	<1
$T_K=10$, $N/\Delta v=10^{18}$	$n(H_2)$	97	<1.2
$n(H_2)=10^{2.3}$, $N/\Delta v=10^{18}$	T_K	94	<1

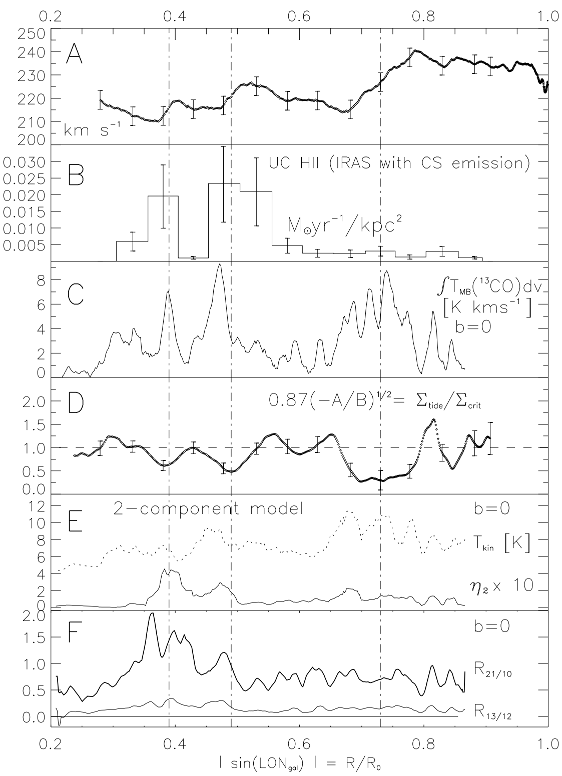
[a]Units are: T_K in [K], $n(H_2)$ in [cm^{-3}], and $N/\Delta v$ in [$cm^{-2}/(kms^{-1})$]

Analysis

• 1. Under the LTE approximation ratio $R_{21/10}$ depends on τ and T_K (optical depth and kinetic temperature, respectively). Using a one-component model, the selection of τ and T_K gives us the filling factor ($\eta=T_{obs}/T_{mod}$). The observations are not completely matched by one component model or the η values do not make physical sense (>1). For example, in the case with $\tau=2$, values of $R_{21/10}$ under 1.2 were matched (70%), but values for their filling factors were larger than 1 in almost all these cases.

• 2. For non-LTE conditions and a one-component model, we use a large velocity gradient model, depends on three variables: T_K, $n(H_2)$ and $N/\Delta v$ (kinetic temperature, volume density and column density per velocity interval, respectively). Matching our observed ratios, also in this case we can not match all the observations (matches was under 50%).

• 3. We explore two component models in both cases, LTE and non-LTE (e.g. Wall et al. 1993). Results for our best cases (non-LTE and two-components model) are summarized in TABLE 1. In these cases, T_K shows little variation near to 10 K. The filling factor of the hot component is important, because it suggest the presence of warm molecular gas in the beam.



Comparison with Kinematics:

We plot our results on the kinematics and star formation rate for the subcentral vicinity (Luna et al. 2002). Figure A at right shows the smoothed rotation curve, B shows the star formation rate per square kpc, C shows the integrated intensity for $^{13}CO(J=1 \rightarrow 0)$ at b=0°.0. In plot D we show the ratio -A/B which is related to the amount of shear (Luna et al. 2002); in plot E we show the kinetic temperature (variable) for the cool component and the filling factor for warm component (dimensionless). Finally in plot F we show the smoothed observed ratios $R_{13/12}$ and $R_{21/10}$ from the subcentral vicinity at b=0°.0 used to characterize the molecular gas. In plot E a factor of 10 was applied in order to use the same y-scale. Galactocentric distances related with arms regions are marked in vertical lines. We can see that star formation and warm gas component filling factor are correlated with a confidence level of better than 90% (rank correlation of 0.48 with 0.079 significance, in Spearman test). Also we observed anticorrelation between warm gas component filling factor and shear influence parameter (in Figure D), with a confidence level of better than 90% (-0.67 and 0.008, in Spearman test).

Conclusion

A two-temperature gas component model is needed to explain the multi-line observations. One-component models do not work for the full range of observed ratios. We find at least a factor of 3 for the ratio in kinetic temperature between cold and warm components, and a factor 10 for the volume and column densities. Using the locus and kinematics for the spiral arms regions we conclude that the warm and dense gas component is more likely found in the directions of the spiral arms. These results shows a qualitative agreement with a modified Schmidt law. A possible scenario could be that transient molecular clouds are destroyed by shear in inter-arm regions producing low or not star formation. On the other hand, in arm regions molecular clouds could pile up, reach a critical mass and increase the star formation rate and temperature of gas, as is inferred here.

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