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Exploring molecular gas toward the Magellanic Bridge

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ABSTRACT

The Magellanic Bridge (MB) is a diffuse gas structure that connects the Large Magellanic Cloud with the Small Magellanic Cloud. The MB is the closest tidal interaction system between two galaxies to the Milky Way. Taking into account that young stellar objects are embedded in such gaseous structure, it is a unique laboratory to investigate gas dynamics and star formation processes in a very low metallicity environment. In this work we present a preview of the results obtained from observations made with the Atacama Pathfinder Experiment (APEX) telescope towards some regions of the MB. Through the emission of the ^{12}CO J=2–1 line we characterize the molecular gas of these regions.

Keywords: galaxies: ISM — (galaxies:) Magellanic Clouds — (galaxies:) intergalactic medium

1. INTRODUCTION

The Magellanic Bridge (MB), firstly identified through the emission of HI at 21 cm by Hindman et al. (1963), is the closest tidal interaction system between two galaxies to the Milky Way. The MB has an extension of about 20 kpc and it is believed that it was generated by a close interaction between the Large Magellanic Cloud (LMC) and the Small Magellanic Cloud (SMC) that occurred around 200 Myrs ago (Gardiner et al. 1994).

As well as atomic gas, molecular gas was first detected by Muller et al. (2003) from observations of the ^{12}CO J=1–0 line. Later, Mizuno et al. (2006), through single pointings of the same CO transition using NANTEN telescope (angular resolution of 2.6 arcmin), detected several gaseous condensations, likely molecular clumps, some of which hosting young stellar objects (Chen et al. 2014). Additionally, some regions (named MagBridge A and MagBridge C) of the MB were mapped with high-angular resolution in the ^{12}CO J=1–0 and J=2–1 lines using the Atacama Large Millimeter Array (ALMA) (Kalari et al. 2020 and Valdivia-Mena et al. 2020, respectively), achieving a detailed characterization of the molecular gas and its relationship with star formation. They are indeed very useful results that point to investigate the molecular gas and the star forming processes in regions of very low metallicity (Z$\sim$0.1 Z$_{\odot}$).

2. OBSERVATIONS

Observations of the ^{12}CO J=2–1 line were taken using the Atacama Pathfinder Experiment (APEX) telescope during the second semester of 2019. Three regions in the MB of approximately $5.5'\times5.5'$ were mapped in the on-the-fly mode. The achieved angular resolution was $27''$ ($\sim$8 pc at the distance of 60 kpc) and the spectral resolution of the data is 0.25 km s^{-1}. The data were reduced and handle using typical routines of CLASS and CASA softwares.

3. RESULTS

After inspecting the whole velocity range of the ^{12}CO J=2–1 data cubes we identified the positions and the velocity intervals in which emission appears above the noise in each region.

To appreciate the ^{12}CO emission distribution, in Figure 1 we present the SPIRE-Herschel far-infrared emission maps at 250, 350, and 500 μm (blue, green, and red, respectively) with the integrated ^{12}CO J=2–1 emission displayed in

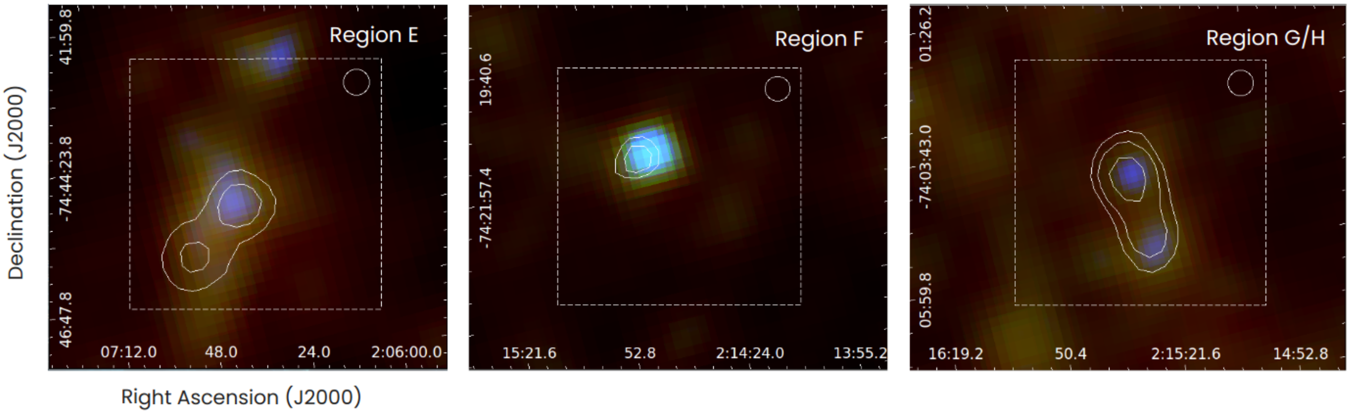

Figure 1. Contours of the integrated ^{12}CO J=2–1 emission superimposed over SPIRE-Herschel maps (250, 350, and 500 μm in blue, green, and red, respectively). Region E: integrated between 175 and 179 km s^{-1}, contour levels: 0.66 and 0.12 K km s^{-1}, rms noise level (σ)=0.02 K km s^{-1}. Region F: integrated between 177 and 181 km s^{-1}, contour levels: 0.03 and 0.04 K km s^{-1}, σ=0.021 K km s^{-1}. Region G/H: integrated between 175 and 179 km s^{-1}, contour levels: 0.05, 0.10, and 0.20 K km s^{-1}, σ=0.015 K km s^{-1}. The beam of the molecular observations is included at the top right corner in each region.

contours. It is worth noting that the molecular peaks coincide, in general, with the far-IR maxima, which trace dust condensations.

A gas mass (M[H$_2$]) was obtained from the CO luminosity for each region, yielding (8.2, 10.3 and 34.3) $\times 10^3$ M$_\odot$ for the Regions E, F, and G/H, respectively. To calculate this mass, the H$_2$ column density was derived from N(H$_2$) $= X\ I_{\rm CO}$, where $I_{\rm CO}$ is the integrated line, and as done by Mizuno et al. (2006), we use the conversion factor $X = 1.4 \times 10^{21}$ cm^{-2} (K km s^{-1}). This factor was derived for the SMC (Mizuno et al. 2001), hence it would represent a lower limit since the metallicity in the MB seems to be somewhat smaller than in the SMC (Muller et al. 2003).

Virial masses were obtained from $\rm M_{vir} = 1040\ \sigma_v^2\ R_{eff}$, where σ_v is the velocity dispersion obtained from the measured line width $\Delta \rm V_{FWHM}$, and R$_{\rm eff}$ is the beam deconvolved effective radius. This equation considers a density profile $\rho(r) \propto r^{-1}$. We obtained (5.2, 11.3, and 52.5) $\times 10^3$ M$_\odot$, for Regions E, F, and G/H, respectively.

The ratios $\frac{M_{vir}}{\rm M[H_2]}$ are 0.64, 1.10, and 1.53, respectively for each region. This ratio, gives us at least, some hints about the gravitational stability of the molecular clumps.

4. DISCUSSION

Taking into account previous results towards the analyzed region presented by Mizuno et al. (2006) based on observations of ^{12}CO(1-0) using the NANTEN telescope, the analysis presented here represents significant progress in the research of these particular molecular clumps in the MB.

For instance, it was found, within the 27″ resolution, that Region E is composed by two molecular clumps (the northern one completely resolved, the southern one approximately the size of the beam). It was observed that Region F only has one clump, and Region G/H has a well-defined clump and a molecular structure that extends toward the south. In all cases there is a good correlation with the far infrared emission that traces the presence of dust.

We find that the mass of the studied molecular clumps in the MB is (0.8–4)$\times 10^4$ M$_\odot$. The ratios $\frac{\rm M_{vir}}{\rm M[H_2]}$, close to unity, suggest that the clumps are gravitationally bound (Bertoldi & McKee 1992). This is under the assumption that M[H$_2$] faithfully traces the clump mass. However, as mention above, this value should be taken with care because it could represent a lower limit for the mass. In that sense, depending on the actual gas mass, it could be that the $\frac{\rm M_{vir}}{\rm M[H_2]}$ ratio is $\ll 1$, and then, the studied clumps should be under collapse.

The used X factor can be justified by assuming that we are probing gas in similar conditions to that in the SMC. Additionally, it was assumed that such a factor applies also for the ^{12}CO J=2–1 transition. Under these assumptions, we conclude that it is likely that the studied clumps are indeed gravitationally bound.

More single dish and interferometric observations are needed to map different regions in the MB to obtain information about their physical and chemical conditions. This is indeed very important for our knowledge about the formation of stars in regions of very low metallicities.

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