RevMexAA (Serie de Conferencias), **40**, 173–174 (2011)

THE MOLECULAR INTERSTELLAR MEDIUM ASSOCIATED WITH THE YOUNG COMPACT STELLAR CLUSTER WESTERLUND 1

A. Luna,[1] Y. D. Mayya,[1] L. Carrasco,[1] and L. Bronfman[2]

RESUMEN

Analizamos el medio interestelar molecular en torno a Westerlund 1, el cúmulo estelar joven más masivo conocido en la Vía Láctea. Descubrimos una región molecular central evacuada entre dos complejos moleculares con corrimientos al rojo y azul con respecto al cúmulo. Nuestra definición de nube está basada en la cinemática del gas molecular y en un modelo de estructura espiral Galáctica. Estas regiones moleculares están asociadas con formación estelar activa posiblemente relacionada con la presencia de Westerlund 1.

ABSTRACT

We analyze the molecular interstellar medium around Westerlund 1, the most massive young stellar cluster known in the Milky Way. We have discovered an evacuated central region surrounded by two molecular complexes blue and red shifted with respect to the cluster. Our definition of the cloud is based on the gas kinematics and a model of Galactic spiral structure. These molecular regions are associated with ongoing star formation likely related to the presence of Westerlund 1.

Key Words: open clusters and associations: individual (Westerlund 1) — ISM: clouds

1. INTRODUCTION

Westerlund 1 (Wd1) is the most massive known young stellar cluster in the Milky Way. In order to study its molecular environment and explore its possible star formation feedback and fate of the residual parental molecular cloud, we have explored the large scale (∼200 pc) molecular environment of Wd1 from ^{12}CO observations. A strong interaction is expected between the young cluster and its surroundings, given the large concentration of Wolf-Rayet stars (Negueruela et al. 2010). It also has an associated magnetar (Muno et al. 2006). The line of sight (LOS) at $l = 339.75°$ crosses at least through three spiral structures: the 3 kpc arm, the Norma arm, and the Scutum-Crux (SCX) arm. An initial result in the "dissection" of the galactic plane components at this LOS was discussed by Luna et al. (2010, hereafter Luna10). In that paper the diffuse γ-ray emission detected by H.E.S.S. towards Wd1 (Ohm et al. 2010) was discussed and this feature is associated with a molecular cavity structure in the Norma arm. It is not related with Wd1 which is located in the SCX arm, at a distance of 4.3 kpc (Luna10), i.e. closer to us by 1 kpc as compared to the H.E.S.S. source. This placement of Wd1 is supported by stellar radial velocities measurements and the kinematical distance estimated from a spiral structure model (Figure 1). The spectral analysis of post main sequence stars (Negueruela et al. 2010) derive an age of 5 Myr.

2. THE MOLECULAR ISM

We explore the molecular environment of Wd1 using the Columbia-Calan CO survey data (Bronfman et al. 1989) which has a beam of 8.8 arcmin. In Figure 1 (top) we show the velocity integrated CO emission and overplotted the adopted Galactic model. The expected velocity gradient due to Galactic rotation in this velocity and longitude range, only accounts for 5 km s^{-1}. In Figure 2 we show the longitude-latitude-velocity maps. We suggest that the molecular gas within 2° radius around the cluster has an additional velocity component due to the interaction with Wd1 feedback activity. We identify three distinct molecular regions: a blueshifted one (−59 km s^{-1}) containing 1×10^6 $M_\odot$, and a redshifted (−45 km s^{-1}) of 2×10^6 $M_\odot$. The molecular gas at rest with respect to the cluster contains only a mass of 4×10^3 $M_\odot$, over a diameter of 80 pc, i.e., almost evacuated. The cavity is most likely created by the mechanical energy deposition from the massive stars in the cluster. The two molecular clouds might be parts of the massive parental cloud that formed Wd1. Masses are estimated using the borders shown in Figure 2 and the ratio $N(H_2)/W_{^{12}CO} = 1.56 \times 10^{20}$ cm^{-2} K^{-1} km s^{-1} (Hunter et al. 1997).

[1]Instituto Nacional de Astrofísica Óptica y Electrónica, Tonantzintla, Puebla, Mexico (aluna@inaoep.mx).
[2]Departamento de Astronomía, Universidad de Chile, Chile.

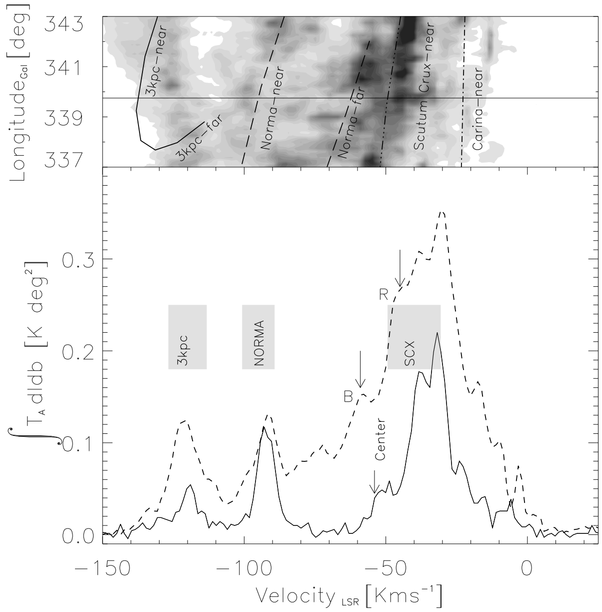

Fig. 1. Top: The longitude-velocity diagram indicating the position of spiral arms. Bottom: The ^{12}CO emission profiles in the direction of Wd1 in a narrow ($15' \times 15'$; solid line), and wide ($2^\circ \times 2^\circ$; dashed line, intensity scaled by a factor of 1/30) beams at $l = 339.75^\circ$ (horizontal line in the top panel). The range of radial velocities for 3 of the arms are indicated by the shaded boxes. The arrows point to the radial velocities obtained by fitting Gaussian profiles to the CO emission peaks relevant to this study (marked B, and R) and the average radial velocity of the stellar component of Wd1 (marked center).

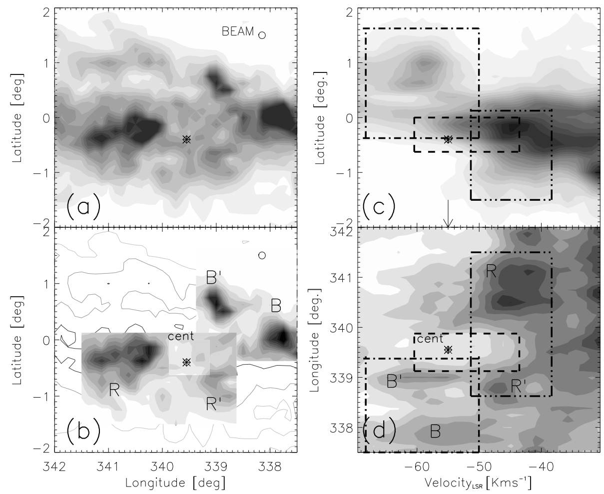

Fig. 2. Two-dimensional projections of the ^{12}CO data cube ascribed to the Scutum-Crux arm ($-70 < V_{\rm rad} < -30$ km s^{-1}). (a) Velocity integrated intensity map. The lowest gray-scale level corresponds to 7σ above the background, with successive levels increasing in steps of 7σ. (b) Contour maps showing the receding (R and R') and approaching (B and B') gas with respect to that at rest ($-60 < V_{\rm rad} < -43$ km s^{-1}; central). The position of Wd1 is indicated by an asterisk. (c) Latitude-velocity map, and (d) longitude-velocity map. An area of $3^\circ \times 3^\circ$ is integrated in the projected spatial axis in the last two panels, where we also identify the slices of receding, approaching, and rest gas.

3. ASSOCIATED RECENT STAR FORMATION

The three molecular complexes described above have several Ultracompact H II (UCH II) regions associated. These regions are associated by their projected position and by their velocity emission of detected CS(2-1) line (Bronfman et al. 1996). The redshifted giant molecular cloud is the most massive and has four detected UCH II regions, it has the highest far infrared (FIR) integrated flux. While the blueshifted giant molecular cloud has one detected UCH II region with lower FIR integrated flux. The central region contains the young compact cluster Wd1, and does not have associated UCH II regions. A zone of 200 pc analyzed here has a high concentration of molecular gas. A scenario to be tested is whether the central molecular gas region collapsed 5 Myr ago creating the compact star cluster Wd1. It is likely that the star formation in the surrounding molecular clouds is triggered by the feedback from the massive stellar population due to winds an supernova events.

REFERENCES

Bronfman, L., Alvarez, H., Cohen, R., & Thaddeus, P. 1989, ApJS, 71, 481

Bronfman, L. Nyman, L., & May, J. 1996, A&AS, 115, 81

Hunter, S., et al. 1997, ApJ, 481, 205

Luna, A., Mayya, Y. D., Carrasco, L., & Bronfman, L. 2010, ApJ, 713, L49

Muno, M. P., et al. 2006, ApJ, 636, L41

Negueruela, I., Clark, J. S., & Ritchie, B. W. 2010, A&A, 516, A78

Ohm, S., et al. 2010, in ASP Conf. Ser. 422, High Energy Phenomena in Massive Stars, ed. J. Martí, P. L. Luque-Escamilla, & J. A. Combi (San Francisco: ASP), 265