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MASSIVE STAR FORMATION IN THE MAGELLANIC CLOUDS

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RESUMEN

Estudios de las regiones de formación estelar masivas en la LMC y SMC revelan la presencia de nuevas generaciones de estrellas formadas en las zonas densas de las nubes moleculares cercanas. Estas regiones moleculares densas han logrado sobrevivir la acción de la radiación UV y los fuertes vientos de las estrellas masivas que se formaron anteriormente. Ellas aparecen como grumos compactos y densos de H_2 asociados a regiones de emision de CO débil. Presentamos resultados de observaciones en varias longitudes de onda obtenidas en las Nubes de Magallanes e investigamos sus implicancias en la formación estelar del universo primigenio.

ABSTRACT

Multiwavelenghts studies of massive star formation regions in the LMC and SMC reveal that a second generation of stars is being formed in dense molecular clouds located in the surroundings of the massive clusters. These dense molecular clouds have survive the action of massive star UV radiation fields and winds and they appear as compact dense H_2 knots in regions of weak CO emission. We present results of observations obtained towards massive star forming regions in the low metallicity molecular clouds in the Magellanic Clouds and investigate its implication on star formation in the early universe.

Key Words: H II regions — ISM: clouds — stars: early-type

1. GENERAL

The Magellanic Clouds are the nearest (50kpc) galaxies. They provide an excellent laboratory to invetigate the ISM in galaxies. These studies can be used to address several topics. The consequence of low metallicity (1/4 and 1/10 for the LMC and SMC) on molecular cloud structure and chemistry. The dense insterstellar matter and the star formation from large to small scales. The dynamic and radiative impact of massive star formation on the ISM. Giant star forming regions as templates for the studies of star bursts galaxies.

We have been conducting a multiwavelength study of the massive star forming regions in the Magellanica Clouds We have gathered a large set of obervations done with different telescopes and wavelenghts (VLT, NTT, LCO, CTIO, ISO, SEST, SIMBA, HST) and we have find evidence of a second generation of massive stars in several of the massive star forming regions in the LMC and SMC. We have investigated their embedded stellar content in the molecular regions by deep NIR imaging, and we are currently doing an spectroscopic follow up of the brightest embedded IR sources detected. In addition, we are doing studies using the millimeter continuum emission obtained with the SIMBA bolometer as an alternative way to determine the amount of the molecular gas. We are combiming these data with SPITZER images (Bolatto et al. 2007) to undertake a study of the dust properties in the low mettallicity ISM around these massive star forming regions. In this contribution we concentrate mainly on results obtained towards 30 Doradus in the LMC.

2. RESULTS

30 Doradus is the brightest HII region in the LMC and has no counterpart in the Local Group. It is a giant HII region containing the nearest super star cluster (SSC) R136. The central cluster R136 has more than 65 O stars with several Wolf Rayet stars concentrated in about 0.5 pc. This massive star forming region has two large giant molecular cloud in its surrounding with masses of several 10^6 $M_\odot$ (Johansson et al. 1998). We have detected weak CO emission coming from several dense clumps in CO(2-1) between the two GMC's (Figure 1). These dense clumps have masses of 10^4 $M_\odot$ and they show a velocity gradient of several tens of km s^{-1}, consistent with expansion due to the kinetic energy of the winds from the massive stars in R136. Figure 1 shows the distribution of the molecular H_2 gas as seen in 2.12 μm images obtained with the 1.5 m CTIO telescope and the IR cameram (CIRIM). In

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the figure we have superimposed to the 2.12 μm H_2 image the CO(2-1) emission line contours. The cold molecular gas and the excited molecular H_2 gas show a similar spatial distribution i.e., H_2 is seen in the same regions as the CO(2-1) emission, but the H_2 gas is clumpy and knotty as opposed to the ionized gas which shows arcs and shells.

Near Infrared studies of 30 Doradus revealed a second generation of massive stars (Rubio et al. 1998). These sources, with magnitudes brighter than Ks=13 and IR colors with H-Ks $>$ 1.6 have IR properties consistent with massive embedded sources (MYSO's) from their positions in the color-color and color-magnitude IR diagrams.

In Figure 1 we have included the position of these IR sources. They are concentrated towards the peak of the molecular CO(2-1) gas and towards bright H_2 gas concentrations in the NE CO Cloud. In the SW CO Cloud, the IR sources are located in the border of the molecular cloud which faces the R136 cluster and where the CO(2-1) emission shows a steep density gradient. Also, an IR source is seen associated to an H_2 knots and CO clumps in the region between the NE and SW clouds. We believe that the 2.12 μm H_2 emission is arising from PDRs around the dense molecular clumps produced by the interaction of the UV photons or winds reaching the dense molecular clumps or in some cases, by the intercaction of newly formed massive star or a massive compact cluster at the interior of the dense molecular clump. NICMOS/HST images towards some of these IR sources did reveal that they are multiple sources in compact groups with several bright IR stars (Walborn et al. 1999).

Boulanger & Rubio (2006), by combining the 2.12 μm image, a 2.16 Brγ image,the ISO CVF data, and the SPITZER data, have related the spatial and spectral distribution of the mid-infrared emission to the radiative and dynamical impact of the super star cluster R136 on the ISM structure and dust composition of the region. They suggest that the spatial/clumpiness of the ionized and molecular gas is a key to understand the mid-IR emission of massive star forming rergions. The surface filling factor of the molecular gas fixes the fraction of the stellar radiation which is absorbed in the PDRs. The density and the dust abundance in the HII gas fixes the fraction of Lyman continumm absorbed by dust rather than by H and He atoms. In 30 Doradus, the CO is arising from shielded interiors of dense clumps with a small surface filling factor (Poglitsch et al. 1995). In a clumpy medium, the ionizing photons are not expected to propagate ahead of the wind swept shell

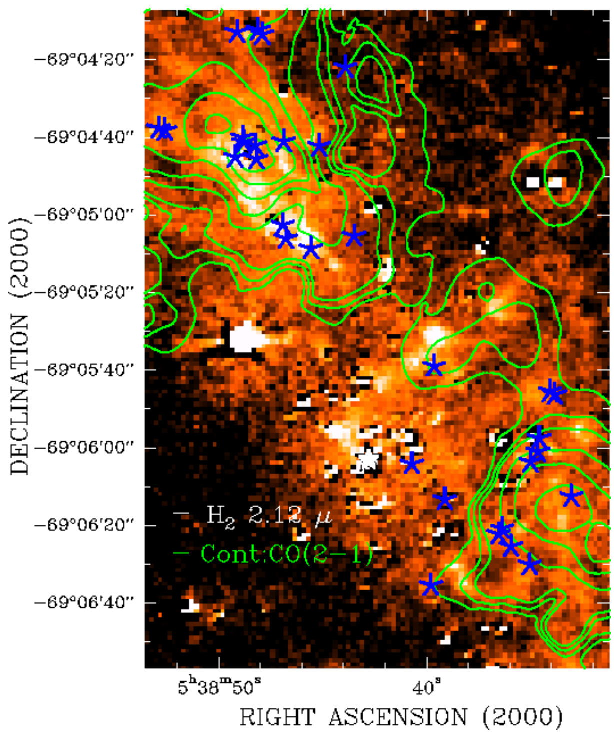

Fig. 1. The 2.12 μm H_2 emission of 30 Doradus. The CO(2-1)emission contours are superimposed. Note the molecular emission between the SW and NE CO clouds. The IR sources with characteristics of massive YSO's are indicated by stars. These concentrate on H_2 knots and regions of CO maxima. The central cluster R136 is indicated by a white star with black borders.

in the lower density gas and thus they could ionize the inter-clump medium. If so, then the ionization could increase the pressure at the surface of the dense clumps and may be produce infall, creating the conditions for a new burst of star formation.

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REFERENCES

Bolatto, A., et al. 2007, ApJ, 655, 212
Boulanger, F., & Rubio, M. 2006, RevMexAA (SC), 26, 5
Johansson, L. E. B., et al. 1998, A&A, 331, 857
Poglitsch, A., et al. 1995, ApJ, 454, 293
Rubio, M., Barbá, R., Walborn, N., Probst, R. G., García, J., & Roth, M. 1998, AJ, 116, 1708
Walborn, N. R., et al. 1999, AJ, 117, 225