A Molecular Dark Cloud in the Low-Metallicity Environment *

Yi-nan Chin[1], C. Henkel[2], J.B. Whiteoak[3], M. Blondiau[4]

[1]Department of Physics, Tamkang University, 251-37 Tamsui, Taipei Hsien, Taiwan
[2]Max-Planck-Institut für Radiostronomie, Auf dem Hügel 69, D-53121 Bonn, Germany
[3]Australia Telescope National Facility, CSIRO Radiophysics Labs.
P.O. Box 76, Epping, NSW 2121, Australia
[4]Radioastronomisches Institut der Universität Bonn, Auf dem Hügel 71, D-53121 Bonn, Germany

Abstract

A queiscent molecular core in the Large Magellanic Cloud was found. This molecular cloud provides us for the first time an opportunity to investigate the dark cloud chemistry in a low-metallicity environment. 26 rotational transitions of 12 molecules, including their isotopic species, were observed by SEST. Some preliminary results are presented.

1 Introduction: Chemical Evolution

Temperature, density, metallicity, and radiation field are the most important parameters to characterize molecular clouds. In order to understand the physics and chemistry of molecular clouds, it is therefore necessary to observe and analyse molecular clouds with different properties and compare the observational results with model calculations. Observationally, it is possible to vary the first two parameters (temperature and density) within our Milky Way by observing clouds in different locations. The metallicity, however, remains very similar across our Galaxy.

The Magellanic Clouds, being two of the closest galaxies to the Milky Way, provide the unique environment with metallicities which are factors of 3 and 10 lower, respectively, to the Galaxy (Westerlund 1991). If we treat our Galaxy as a "chemically" evolved system, the Magellanic System is without doubt still in an early stage of "chemical" evolution. In addition, the radiation field is also stronger than in our own. As a consequence of low metallicities and strong UV radiation field, the low dust-to-gas ratios have been found in the Magellanic Clouds. They are thus a "laboratory" where we can find molecular clouds with different properties to ours and with which we can verify our model of molecular clouds, especially the dependence of metallicity.

2 This Experiment and Results

As presented before, the Magellanic Clouds are unique targets to study astrophysical processes in an environment that differs drastically from that of the Milky Way. Although searches for a variety of molecules in the LMC and SMC have been made (e.g. Johansson et al. 1994; Chin et al. 1997, 1998), all these studies have so far concentrated on molecular cores associated with prominent

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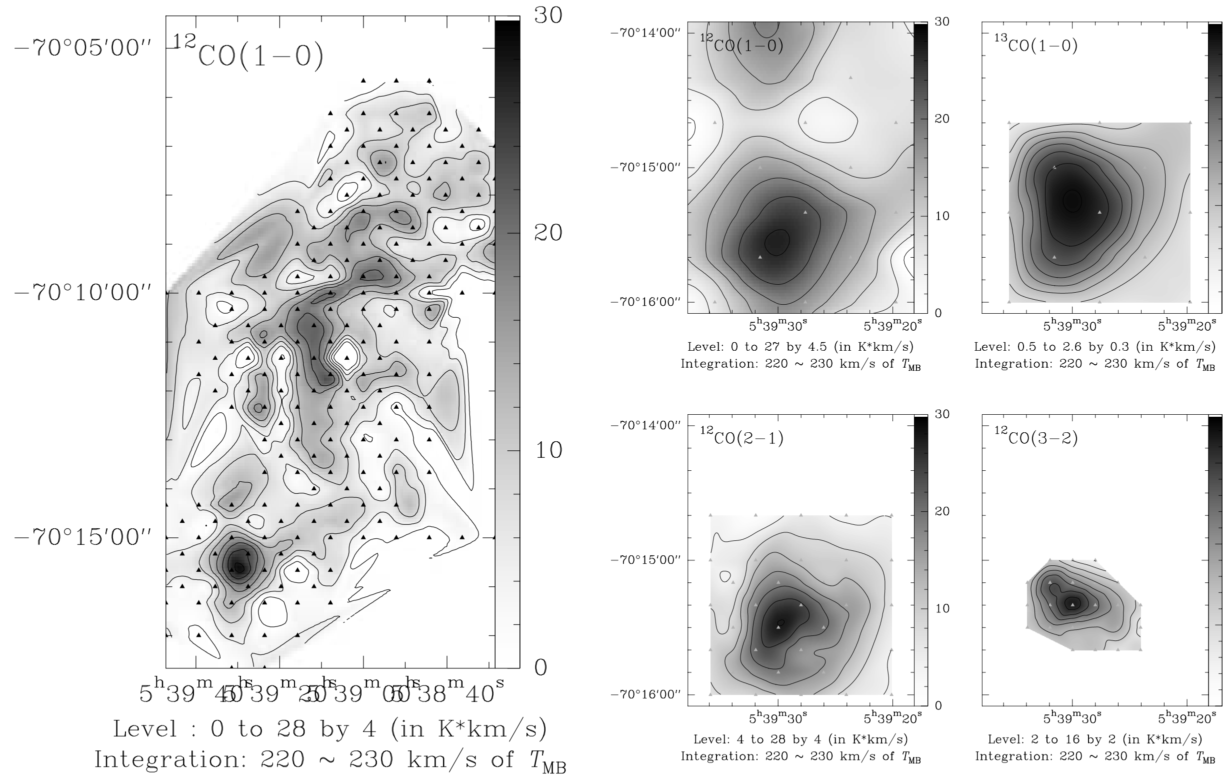

Figure 1: CO contour map of the dense molecular core in the X-ray shadow

H II regions. This does not cover, however, the entire range of physical and chemical properties. Extending our studies to dark clouds would introduce a second molecular environment and would make a systematic comparison between the Magellanic System and our own more meaningful.

During the last years, the hot interstellar medium of the LMC has been investigated by satellites in more and more detail. For instance, a hot diffuse X-ray emitting component seems to be widely distributed (e.g. Wang et al. 1991). One of the regions with enhanced X-ray emission is a wedge-shaped structure south of 30 Dor. At the western side of this feature a large X-ray shadow was observed by *ROSAT* (Snowden & Petre 1994). The shadow is caused by a total absorbing column density of $N_{\rm H} \approx 1.0 \times 10^{22}\,{\rm cm}^{-2}$, the characteristic column density of local molecular clouds (Larson 1981). A comparison with H I data of Luks & Rohlfs (1992) suggests the existence of dense molecular clouds, since H I column densities are smaller and large amounts of diffuse gas are not observed. Furthermore, no H II emission has been seen toward the X-ray shadow, either. This result encouraged us to look for dense molecular gas in this area which might show different properties to the other regions.

The observation was carried out in different periods between 1997 and 1999 using the 15-m Swedish-ESO Submillimetre Telescope (SEST) at La Silla, Chile. Fig. 1 shows part of the X-ray shadow which we investigated. In addition to the diffuse CO gas detected in this area, several molecular cores were found. A follow-up millimeter line survey of one particular dense core has been carried out and the results are shown in Fig. 2.

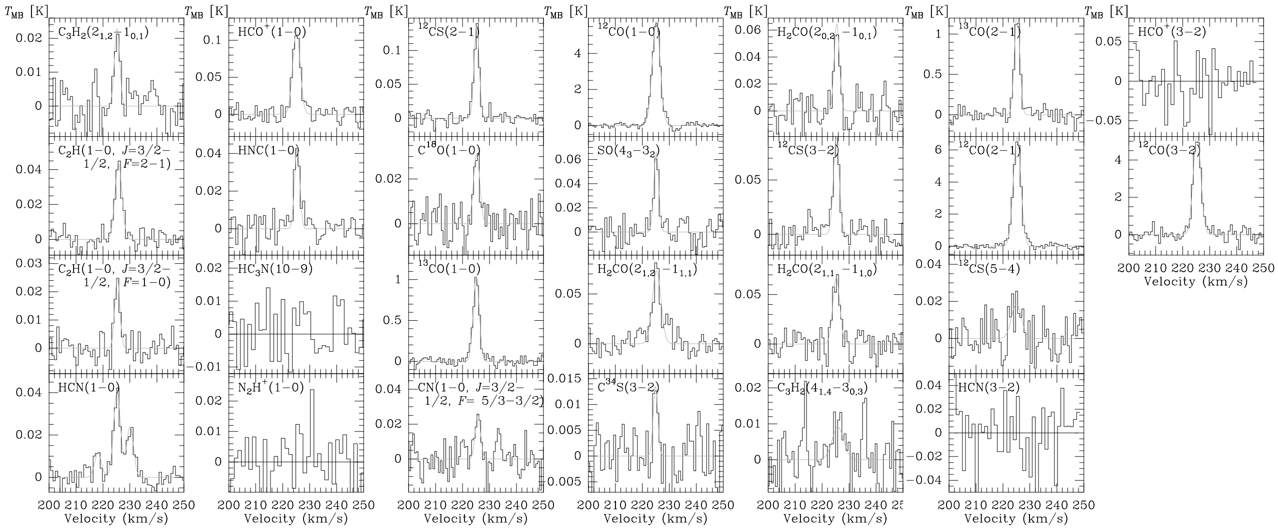

Figure 2: Spectra of the dense molecular core in the X-ray shadow

3 Short Discussion

For this molecular dense core, which lies near the leading edge of the LMC, some preliminary results can be derived directly:

3.1 X-factor

Assuming that the interstellar medium is in virial equilibrium at all linear scales and that the line width is representing the cloud's velocity distribution, we can deduce the conversion factor $X = N_{\mathrm{H}_2}/I_{\mathrm{CO}}$ from $M_{\mathrm{vir}} = M_{\mathrm{gas}}$:

$$X_{\text{dark cloud}} = 1.9 \times 10^{20}\ \mathrm{cm}^{-2}/(\mathrm{K\,km\,s^{-1}})$$

This value is identical to the ratio determined in the Milky Way.

3.2 Gas density

This estimated gas mass leads to a H_2 column density (averaged over the map) of $N_{\mathrm{H}} \approx 4.2 \times 10^{21}\,\mathrm{cm}^{-2}$, which is similar to the column density of nearby Galactic molecular clouds (e.g. Larson 1981). The average number density becomes $n_{\mathrm{H}} \approx 300\,\mathrm{cm}^{-3}$.

By applying the LVG model to different molecular species of which several transitions have been measured, we can estimate the gas temperature to be $10 \sim 15\,\mathrm{K}$, with a particle density of $n_{\mathrm{H}} \approx 10^7 \sim 10^9\,\mathrm{cm}^{-3}$ in the center. Currently we are working on modeling the chemical processes in order to try to better understand the chemistry of the dark cloud in this low-metallicity environment.

References

Chin, Y.-N., Henkel, C., Whiteoak, J.B., et. al. 1997, A&A 317, 548

Chin, Y.-N., Henkel, C., Millar, T.J., et al., 1998, A&A 330, 901

Johansson, L.E.B., Olofsson, H., Hjalmarson, A, et. al. 1994, A&A 291, 89

Larson R.B. 1981, MNRAS 194, 809
Luks, Th., & Rohlfs, K., 1992, A&A 263, 41
Snowden, S.L. & Petre, R. 1994, ApJ 436, L123
Wang, Q., et al., 1991, ApJ 374, 475
Westerlund, B.E., 1991, A&AR 2, 29