RevMexAA (Serie de Conferencias), **3**, 77–80 (1995)

SELF-PROPAGATING STAR FORMATION IN THE SUPERGIANT SHELL LMC 2

Dominik J. Bomans[1], Sean Points[2], Kerstin Weis[3], and You-Hua Chu[2]
Univ. of Illinois, Astronomy Dept., 1002 W. Green Street, Urbana, IL 61801, USA

RESUMEN

Las cáscaras supergigantes son las estructuras más grandes en las galaxias y juegan un importante papel en la estructura global y la evolución del medio interestelar. La mayoría de estas cáscaras parecen estar formadas por la acción colectiva de vientos estelares rápidos y explosiones conjuntas de supernovas. La edad dinámica de una cáscara supergigante (varias veces 10^7 años) es mucho mayor que el tiempo de evolución de las estrellas masivas (unos pocos millones de años). Si las cáscaras supergigantes son creadas por vientos estelares y supernovas, se requiere una formación continua de estrellas masivas que proporcionen la energía necesaria, ésto implica que las cáscaras deben impulsar formación estelar secundaria. Nosotros hemos buscado el gradiente de edad que resultaría dentro de la burbuja LMC 2. Los resultados preliminares muestran que existe un cambio radial en la población estelar, lo que podría indicar formación estelar impulsada por LMC 2.

ABSTRACT

Supergiant shells are the largest interstellar structures in galaxies and play an important role in the global structure and evolution of the interstellar medium. Most supergiant shells seem to be formed by the collective action of fast stellar winds and clustered supernova explosions of massive stars. The dynamic age of a supergiant shell (several times 10^7 yr) is much larger than the evolution timescale of massive stars (a few times 10^6 yr). If supergiant shells are created by stellar winds and supernovae, massive stars must be formed continuously to supply the necessary energy, which implies that the shell triggers secondary star formation. We searched for the resulting stellar age gradient inside supergiant shell LMC 2. Preliminary analysis indicates a radial change of the stellar population, which may indicate triggered star formation from LMC 2.

Key words: **GALAXIES: STELLAR CONTENT — ISM: BUBBLES — MAGELLANIC CLOUDS**

1. INTRODUCTION

Supergiant shells with sizes approaching ~1000 pc are the largest interstellar structures in galaxies and are commonly seen in nearby galaxies. They play a very important role in the global structure and evolution of the interstellar medium because they occupy a significant fraction of the volume of the host galaxy and they provide the sites where energy and mass may be pumped to large distances from the galactic plane. It is believed that supergiant shells are formed collectively by fast stellar winds and supernova explosions from a large number of massive stars. In theory, this formation is similar to those of smaller interstellar shells (10–100 pc) around

[1]Feodor Lynen Fellow.

[2]Visiting Astronomer, CTIO, NOAO, operated by the AURA, Inc., under contract with the NFS.

[3]Also University of Heidelberg, Germany.

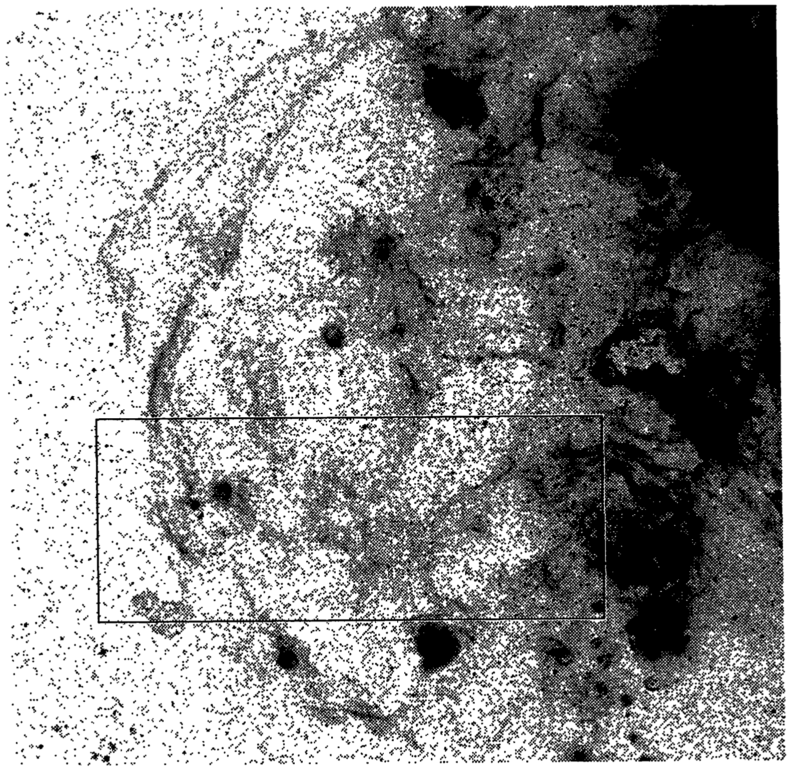

Fig. 1. Image of the supergiant shell LMC 2 taken in Hα with the Curtis-Schmidt telescope (Kennicutt & Hodge 1986). The area discussed in this paper is marked. East is left and north is up. 30 Dor is partly visible in the northwestern corner of the image.

isolated massive stars or OB associations, which have been successfully modeled by, e.g., Weaver et al. (1977) and Mac Low, Cray, & Norman (1989). In practice, the formation and evolution of a supergiant shell is much more complicated because the dynamical age of the shell (several times 10^7 yr) is much larger than the timescale of evolution of massive stars (a few times 10^6 yr). Therefore, a continuous formation or multiple formations of massive stars are needed. It has been suggested that the expansion of a supergiant shell may shock the ambient dense clouds and trigger star formation to provide a continuous supply of fast stellar winds and supernovae (Feitzinger et al. 1981). If this model is correct, one should see an age gradient from the center to the rim of a supergiant shell.

The Magellanic Clouds are the only galaxies in which supergiant shells and their enclosed stars can be resolved for detailed studies. Observational tests of the age gradient hypothesis gave conflicting results for the supergiant shell LMC 4 (Dopita, Mathewson, & Ford 1985; Reid, Mould, & Thompson 1987; Vallenari, Bomans, & de Boer 1993). We analyze here the stars inside LMC 2 (Figure 1), which is located east of 30 Dor. LMC 2 shows the brightest H II filaments and the largest diffuse X-ray emission of all LMC supergiant shells. Inside LMC 2 there is no large OB star "constellation", but rather a number of smaller associations. The same is found in the supergiant shells LMC 3 and LMC 4. LMC 2 appears to expand at 30 km s^{-1}, which implies an age of the order of 10 Myr (Caulet et al. 1982).

2. OBSERVATIONS AND REDUCTION

The data were taken in January, 1995 at the CTIO 36″ telescope by Dr. Michael Joner. A Tek 2k CCD was used giving a field of view of 13.′5 × 13.′5 sampled at 0.″4 per pixel. The data consist of short (45 to 60 s) and long (600 s) *B, V,* and *I* images, plus two 600 s Hα images. Three fields forming an east-west strip across the southern part of LMC 2 (see Figure 2) were observed during photometric conditions; seeing was 1.″5.

After basic reductions, we used DAOPHOT inside IRAF to perform photometry of stars in the fields. This paper is intended just to present preliminary results, so we did not refine the PSF to optimal quality and just

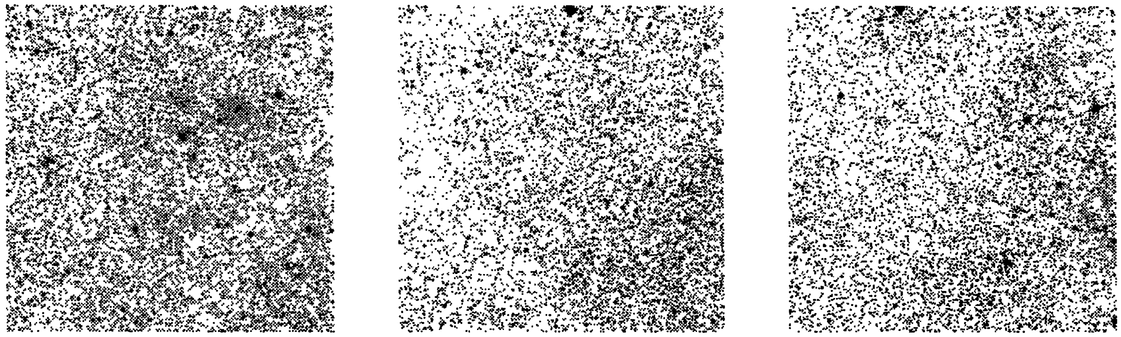

Fig. 2. V band images of the three fields. East is left and north is up, each field is 13.′5 × 13.′5. The fields are numbered 1, 2, and 3 from left to right.

provided a rough calibration. Because we are looking for differential effects among the fields, these uncertainties do not affect our conclusions. In total, about 4 000, 8 000, and 13 000 stars in fields 1, 2, 3 are used for this analysis. It is clear from Figures 1 and 2 that the long Hα filaments which define LMC 2 bisect field 1 into two parts: the eastern rim of field 1 samples the stars outside LMC 2, while the western part of field 1 samples the interior. Field 2 is completely inside LMC 2. Field 3 has bright Hα filaments at its extreme western edge, which belong to the outskirts of the large H II complex N 160.

3. RESULTS

Color–magnitude diagrams (CMD) of the three fields are presented in Figure 3. CMD of field 1 shows only few young massive stars, which produce the few small classical H II regions in the field. The main sequence turn-off in field 1 is as low as $V = 16.8$ mag. In field 2 the main sequence is populated up to about 15.2 mag, and in field 3 up to about 14.5 to 14.0 mag. In addition, the number of main-sequence stars is much larger in field 3 compared to field 2, and again in field 2 compared to field 1. These CMD morphologies have immediate implications for the age structure of the stellar populations inside LMC 2.

Field 2 and especially field 3 clearly show a population of massive stars. The difference in turn-off magnitude visible in the two CMDs implies an age difference of the youngest populations in the two fields of 5 Myr. The approximate youngest ages in fields 2 and 3 are about 15 and 10 Myr respectively, both in rough agreement with the dynamic age estimate for LMC 2.

We cannot immediately conclude from this age difference, that self propagating star formation (SPSF) has occured in the surveyed area of LMC 2, because of the uncertain 3-D shape and expansion pattern of this shell. We always sample the total population of stars in a column through the LMC. Assuming the presence of SPSF, we may show one, two or even three ages from independent OB associations in a given column just depending on the structure of LMC 2. Nevertheless, in the most probable case of LMC 2 being a shell expanding away from the LMC main body, our age difference between field 2 and 3 can be interpreted as sign of SPSF. A second effect of projection is the change of volume inside the shell we are sampling. A normalization to the sampled volume is therefore needed when comparing numbers of young stars inside LMC 2.

The absence of young, massive stars in field 1 implies that in this region of the LMC no sizeable star formation has taken place during the last 10^8 yr. Scaling the sampled volume makes the effect somewhat less dramatic, but does not change the result. The CMD morphology strongly resembles the "quiet" fields analyzed by Bertelli et al. (1992). This means that no (or only very little) star formation has been triggered by the expanding shell of LMC 2 during its latest phase of growth. If we accept that the shockwave of a supergiant shell triggers new star formation by compressing existing dense clouds (e.g., Elmegreen 1987) then we must conclude that no such clouds were present in the volume sampled by field 1. This is consistent with the hypothesis that LMC 2 is already expanding into the lower density region above or below the LMC main body. In this case we expect the rapid growth of Rayleigh-Taylor instabilities in the supergiant shell (e.g., Mac Low et al. 1989). These turbulent structures should be seen in deep high resolution Hα and [S II] images, but neither our nor Hunter (1994) images of LMC 2 filaments show obvious signs of such turbulences. This may favor another

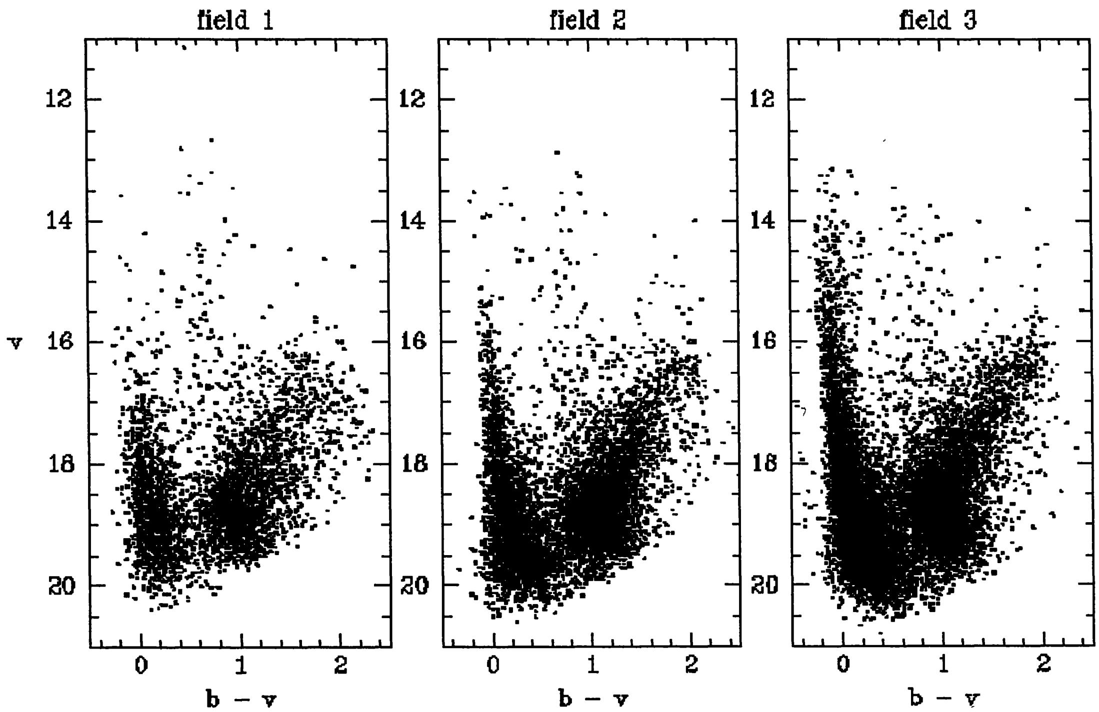

Fig. 3. Color-magnitude diagrams of the three fields.

speculation, that LMC 2 is currently expanding into a very smooth ISM, which is consistent with the absence of massive star formation for more than 10^8 yr.

The well-known clump of intermediate age He burning stars and the red giant branch are well populated in all three fields. When checking number counts, again a gradient is visible. Field 1 shows a smaller number of old, evolved stars than field 2 and field 2 is less populated by these stars than field 3. Because the seeing of the images was comparable, and crowding increases toward field 3, completeness problems would work in the opposite direction. The number counts of these stars have not to be corrected for sampled volume, because these stars are much older than LMC 2 and their distribution is therefore unrelated to the actual morphology of the supergiant shell.

The difference in the number counts of the red giant stars and clump stars may reflect the decrease of stellar density of intermediate and old stars radially from the LMC bar, or a spatial gradient in the star formation rate in our sampled area 5 to 2 Gyr ago. A more detailed analysis is needed to distinguish between these possibilities.

REFERENCES

Bertelli, G., Mateo, M., Chiosi, C., & Bressan, A. 1992, ApJ, 388, 400

Caulet, A., Deharveng, L., Georgelin, Y. M., & Georgelin, Y. P. 1982, A&A, 110, 185

Dopita, M. A., Mathewson, D. S., & Ford, V. L. 1985, ApJ, 297, 599

Elmegreen, B. G. 1987, in IAU Symp. 115, Star Forming Regions, ed. M. Peimbert & J. Jugaku (Dordrecht: Reidel), 457

Feitzinger, J. V., Glassgold, A. E., Gerola, H., & Seiden, P. E. 1981, A&A 98, 371

Hunter, D. A. 1994, AJ, 107, 565

Kennicutt, R. C., & Hodge, P. W. 1986, ApJ, 306, 130

Mac Low, M.-M., McCray, R., & Norman, M. L. 1989, ApJ, 337, 141

Reid, N., Mould, J., & Thompson, I. 1987, ApJ, 323, 433

Vallenari, A., Bomans, D. J., & de Boer, K. S. 1993, A&A, 268, 137

Weaver, R., McCray, R. A., Castor, J., Shapiro, P., & Moore, R. 1977, ApJ, 218, 377