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The mid-infrared bubble Sh2-90: a possible case of triggered star formation?

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Abstract. We analyze the distribution of the young sources and interstellar matter in the environs of the mid-infrared (MIR) bubble coincides with the H II region Sh 2-90. Our study is based on the radio continuum mapping at 1280 MHz, along with *Spitzer*-IRAC and near-infrared (NIR) data. We performed the photometric analysis at NIR-MIR bands to assess the likely stellar candidates with disk and envelope using colour-colour (CC) diagrams. The morphology suggests a 8 μm void at the center of the H II region. However, we see roughly circular shell of 8 μm emission enclosing the ionized gas seen in 1280 MHz, indicating void is probably originated due to the energy input from a massive source. Our study shows that the massive star is possibly a O9-B0 type. From the photometric analyses, we find a group of young stellar objects (YSOs) at the border of the bubble. Our preliminary analysis suggets that Sh2-90 shows signature for a possible site of triggered star formation.

Keywords : stars – formation – pre-main-sequence: ISM – H II regions

1. Introduction

Interstellar bubbles appear as cavities and expanding shells in the neutral hydrogen (21cm) line emission distribution, and the emissions are generally external to their optical and radio continuum counterparts (Vasquez et al. 2005). Churchwell et al. (2006, 2007), using *Spitzer* GLIMPSE images, identified MIR bubbles around OB stars in the Galaxy. Since the mechanical energy released by these OB stars strongly modify the energetics, morphology and chemical abundances of the interstellar medium (ISM), they can therefore, regulate the star formation activity in the complex. Indeed, Watson et al. (2008) identified several sites of probable triggered star formation

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around these bubbles. It is still not clear how the bubbles interact with the surrounding medium, process local gas to form new stars. Therefore, the identification and characterization of such possible site of triggered star-forming environments around the bubbles are important. Here, we present preliminary results of a bubble N133 (l = 9.465°, b =-0.850°) identified by Churchwell et al. (2006), which coincidence with the H II region Sh2-90.

The Sh2-90 (α_{2000} = $19^h49^m11.7^s$, δ_{2000} = +26°51′36″) is a H II region situated at a distance of 2.4 kpc (Laflon et al. 1983) and possibly is a part of Vulpecula OB1 complex (Turner 1986). The observations in CO and HCO^+ suggest that Sh2-90 is a part of molecular cloud of mass $\sim 2 \times 10^5$ $M_\odot$ (Laflon et al. 1983). The region is also associated with an IRAS source (IRAS 19471+2641) at its northern side, whose FIR luminosity is of $\sim 3.9 \times 10^3$ $L_\odot$ and FIR colors consistent with being an ultracompact H II (UCH II) region. The association of Sh2-90 with a massive cloud and the presence of IRAS source of UCH II nature at its border indicates star formation is still going on. The stellar content and the star-formation activity in the vicinity of Sh2-90, has not been studied so far. Therefore, we employed deep NIR and *Spitzer*-IRAC observations to study the star formation activity in the region.

2. Observations

We retrieved the NIR images at J (1.25 μm), H (1.64 μm) and K (2.20 μm) filters from the WFCAM Science Archive (Hambly et al. 2008), taken with WFCAM instrument (Casali et al. 2007) at the United Kingdom Infrared Telescope (UKIRT). Photometry for the point sources in these images was performed using the PSF algorithm ALLSTAR in the DAOPHOT package of IRAF. The photometric calibration was done using isolated 2MASS point sources having error < 0.05 mag and using the color equations described in Dye et al. (2006). We consider only those WFCAM point sources for our analysis, whose photometric errors are less than 0.1 mag.

The Galactic Legacy Infrared Mid-Plane Survey Extraordinaire (GLIMPSE) survey using the infrared array camera (IRAC) on-board the *Spitzer* Space Telescope, survey has observed the Galaxy at 3.6, 4.5, 5.8 and 8.0 μm with a 1.2” pixel size between 10° < $|l|$ < 65° and $|b|$ < 1°. We retrieved point sources for the Sh2-90 region from the GLIMPSE Point Source Catalog archive and considered only those sources for our analysis peak signal-to-noise ratio as greater than 5.

The radio continuum observation at 1280 MHz band was carried out using the Giant Metrewave Radio Telescope (GMRT), India. NRAO Astronomical Image Processing System (AIPS) was used for the data reduction. The image of the field was formed by the fourier inversion and cleaning algorithm task IMAGR. The beam size of the resultant map is $\sim 24'' \times 27''$.

3. Results

In the optical Sh2-90 appears like a half shell structure with bright part of the shell is seen in the western direction, where as the eastern part appears dark. The radio morphology suggests a ionization-bounded zone in the eastern direction, with decreasing intensity distribution on the opposite side, which signifies the region could be density bounded in the eastern direction (the details of the result will be presented elsewhere). Assuming an electron temperature of 10^4 K and the region is optically thin at 1280 MHz, we estimated the number of Lyman continuum photons (log $N_{Nyc} \sim 47.90$), which suggests that the H II region is powered by an O9-B0 V star (Panagia 1973). The *Spitzer* color-composite image is shown in Fig. 1 ($left-panel$). The 8 μm emission displays ring like structure, with a central cavity. The ring of 8 μm emission, which traces the polycyclic aromatic hydrocarbons (PAHs), found beyond the ionized gas seen in 1280 MHz observation. The absence of 8 μm emission in the interior of the H II region is possibly due to destruction of PAH molecules by intense UV photons from the massive O9-B0 star. However, its emission at the periphery indicates an interaction of the H II region with the surrounding molecular cloud.

To trace the star formation activity of the complex, we searched sources with disk and envelope (e.g Class I, Class II, Class III) using the NIR and MIR CC diagrams, along with its comparison with the CC diagrams of a near-by control field. Following the classification scheme by Allen et al. (2004) and Hartmann et al. (2005), we identified 36 Class0/I/II YSO candidates based on [3.6]-[4.5]/[4.5]-[5.8] and [3.6]-[4.5]/[5.8]-[8.0] diagrams. The search of YSOs based on IRAC 5.8 μm and 8.0 μm might have been affected by the lower sensitivity at these bands to detect faint sources and also by the bright background PAH emission. Therefore, we used our deep near-infrared and the sensitive IRAC 4.5 μm band to identify extra YSO candidates, which we termed as IR-excess sources. Using J-H/H-K and H-K/K-[4.5] diagrams (see, e.g Samal et al. 2010), we identified IR-excess sources. The spatial distribution of these sources is shown in Fig. 1(*right – panel*), which suggests that significant fractions of YSOs is distributed preferentially at the outskirts of 8 μm ring, however, we also see a group of YSOs inside the bubble.

4. Discussion and conclusions

We performed a NIR survey towards the Sh2-90 region to understand the star formation process in circumstances of the MIR bubble N133. We find significant number of YSOs are distributed preferentially at the outskirts of the bubble, similar to those found by Watson et al. (2008). The question is whether all the young sources were formed at the same time or they represent to different episode of star formation is difficult to conclude. Our radio continuum analysis suggests that the dynamical age of the bubble is ~2 Myr, for an ambient density of 10^5 cm^{-3} and constant sound speed ~11 km/s of the ionized gas (see e.g. Samal et al. 2007). If the massive star drove an ionization-shock front to the surrounding molecular cloud, then it can trigger new generation of star formation by the compression or sweeping of molecular

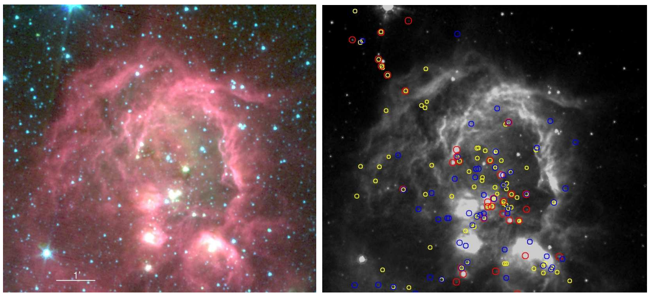

Figure 1. Left panel: The *Spitzer* color-composite image of Sh2-90 region (8.0 μm, red; 4.5 μm, green; and 3.6 μm, blue). The image has a filed of view $8'.0 \times 7'.4$, centered on α_{2000} = 297°.31646, δ_{2000} = 26°.85764. Right panel: Spatial distributions of Class I/II IRAC YSOs (red circles), H-K/K-[4.5] IR-excess (yellow circles) and J-H/H-K IR-excess (blue circles) overlaid on 5.8 μm image. In both the images north is up and east is to the left.

matter (Elmegreen & Lada 1977), where one would expect stars of younger age than the massive star. The main-sequence life time of an O9 star is ~8 Myr, whereas the dynamical age of the H II region is ~2 Myr. Majority of the YSOs distributed outside are Class II in nature, the typical life time of Class II sources is of the order of 2 Myr, which is comparable to the dynamical age of the H II region. Therefore, the present analysis, based on spatial distribution and morphology of the gas and dust, does not provide a decisive conclusion to say about triggered star formation. Perhaps a more compelling conclusion can be drawn with optical photometric observation and spectral-energy distribution modeling of the YSOs (see e.g Ojha et al. 2011). Therefore, this region deserves further investigation to unravel its star formation history.

References

Allen L. E., Calvet N., D'Alessio P., et al., 2004, ApJSS, 154, 363
Churchwell E., Povich M. S., Allen D., et al., 2007, ApJ, 670, 428
Churchwell E., Povich M. S., Allen D., et al., 2006, ApJ, 649, 759
Casali M. Adamson A., Alves de Oliveira C., et al., 2007, A&A, 467, 777
Dye S., Warren S. J., Hambly N. C., et al., 2006, MNRAS, 372, 1227
Elmegreen B. G., and Lada C. J., 1977, ApJ, 214, 725.
Hambly N. C. et al. 2008, MNRAS, 384,637
Hartmann L., Megeath T., Allen L., et al., 2005, ApJ, 629, 881
Lafon G., Deharveng L., Baudry A., et al., 1983, A&A, 124, 1
Panagia N., 1973, AJ, 78, 929
Samal M. R., Pandey A. K., Ojha D. K., et al., 2007, ApJ, 671, 555
Samal M. R., Pandey A. K., Ojha D. K., et al., 2010, ApJ, 714,1015
Ojha D. K., Samal M. R., Pandey A. K., et al., 2011 (arXiv:1106.1858)
Turner D. G., 1986, A&A, 167, 157
Vasquez J., Cappa C., McClure-Griffiths N. M., 2005, MNRAS, 362, 681
Watson C., Povich M. S., Churchwell E. B., et al. 2008, ApJ, 681, 1341