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Young stellar population in the star-forming complex Sh2-252

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Abstract. We present the preliminary results of our multi-wavelength analyses of the young stellar population associated with the star forming complex Sh2-252. The NIR and MIR data sets from 2MASS and *Spitzer*-IRAC, MIPS identified 131 Class I, 400 Class II sources and a slitless spectroscopic survey detected 61 $H\alpha$ emission line stars. The spatial distribution of these YSOs shows that majority of them are concentrated within the sub-regions Sh2-252 A, C and E. The optical CMD and SED analyses show that these YSOs show an age spread of ~ 5 Myr and a mass range of 0.3 $M_\odot$ - 2.5 $M_\odot$. The CMD and SED analyses as well as the Class I/Class II fraction show that the sub-regions have a median age of ~ 2-3 Myr, suggesting same evolutionary status for them. We report an enhanced concentration of Class I sources having a median age of ~ 0.5 Myr between the ionization fronts of Sh2-252 and Sh2-252A. We presume that the combined expansion process of these two H II regions in opposite directions has triggered the new star formation within the collected material between them.

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

1. Introduction

OB associations and young open clusters are important objects to study the profound influence of massive stars on their surroundings. As a continuation of our multi-wavelength analyses of star forming regions (SFRs) (Jose et al. 2008, 2011), an optically bright H II region Sh2-252, which is a member of the Gemini OB1 association,

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has been studied in this paper. The main source of ionization of Sh2-252 is the central star HD 42088 with a spectral type O6.5V (Conti & Alschular 1971). Two stellar clusters are present in this region; one is centered on the nebulosity (NGC 2175) and the other of smaller diameter (NGC 2175s) which is located at the north-east of the former. A new near-infrared (NIR) cluster Teutsch 136 has been identified towards the east of NGC 2175s by Koposov et al. (2008). The detailed ^{12}CO and ^{13}CO maps by Lada & Wooden (1979) show that the cloud complex is separated in two fragments by a long rift of little CO emission; these fragments are named as Western Cloud Fragment (WCF) and Eastern Cloud Fragment (ECF), respectively. Using the 5 GHz aperture synthesis observations, Felli et al. (1977) detected six extended radio sources towards Sh2-252 labeled as Sh2-252 A to F. They have identified four of these sources (Sh2-252 A, B, C and E) as compact H II regions, probably having a local source of ionization in each of them with a spectral type later than HD 42088. The most intense CO peak of the WCF is located very close to Sh2-252A having a water and methanol maser emission (Lada & Wooden 1979; Szymczak et al. 2000) within its proximity which shows recent star formation activity towards this region.

2. Data sets

The deep observations in V and I bands have been carried out using the 1-m Sampurnanand Telescope (ST) of ARIES, Nainital, India. The 2K × 2K CCD with a plate scale of 0.37 arcsec pixel^{-1} covers a field of $\sim 13 \times 13$ arcmin^2 and our observations covered a total area of ∼ 1 degree × 1 degree around Sh2-252. The standard star field SA 98 from Landolt (1992) was observed to calibrate the target field. A $H\alpha$ slitless spectroscopic survey of the region has been conducted using the HFOSC of the Himalayan Chandra Telescope (HCT). We obtained 61 $H\alpha$ emitting sources within our surveyed area. The NIR JHK_s data for point sources within a radius of 30 arcmin around Sh2-252 have been obtained from 2MASS PSC (Cutri et al. 2003). The *Spitzer*-IRAC observations in the 3.6, 4.5, 5.8 and 8.0 μm bands and *Spitzer*-MIPS observations in 24 μm have been obtained from the *Spitzer* space observatory archive program. The final mosaics were created using MOPEX pipeline (version 18.0.1) with an image scale of $1''.2$ per pixel for IRAC data and $2''.45$ per pixel for MIPS data. We applied the point response function (PRF) fitting method in the multi-frame mode using the tool APEX developed by *Spitzer* Science Center (SSC) on all the *Spitzer*-IRAC and MIPS images to extract the magnitudes. We have adopted the zero-points for conversion between the flux densities and magnitudes to be 280.9, 179.7, 115.0, 64.1 and 7.14 Jys in the 3.6, 4.5, 5.8, 8.0 and 24 μm bands, respectively, following the IRAC Data Handbook.

3. Results

The young stellar objects (YSOs) within Sh2-252 region have been identified and classified by using 2MASS and IRAC data sets based on the IR colour criteria given

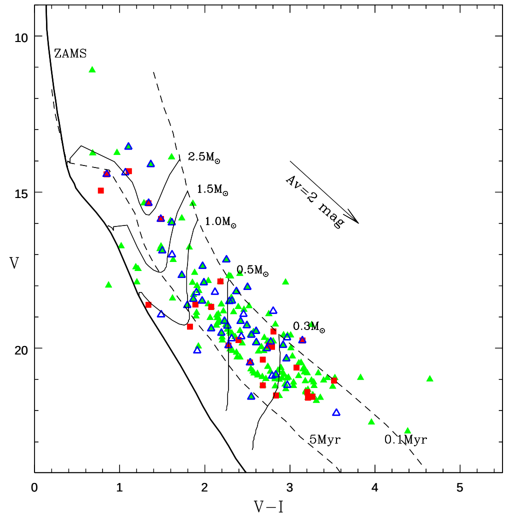

Figure 1. $V/(V-I)$ CMD of the candidate YSOs in Sh2-252. The Class I and Class II sources are shown by using red squares and green triangles, respectively, and the blue triangles are the $H\alpha$ emission line sources. The thick solid curve is the locus of ZAMS from Girardi et al. (2002), dashed curves are the PMS isochrones of age 0.1 and 5 Myr, respectively, and the thin continuous curves are the evolutionary tracks for various mass bins by Siess et al. (2000). All the isochrones and tracks are corrected for the distance and reddening.

by Gutermuth et al. (2009). A total of 131 Class I and 400 Class II YSOs are identified within this complex. We obtained V and I counterparts for 25 Class I, 172 Class II, 50 $H\alpha$ emission line sources. The distribution of these candidate YSOs on the $V/(V-I)$ CMD is shown in Fig.1 using red squares, green triangles and blue triangles, respectively. The distance to Sh2-252 is adopted as 2.4 kpc based on our spectroscopic analysis of the massive members of the region. In Fig.1, ZAMS locus by Girardi et al. (2002) (thick solid curve) and PMS isochrones by Siess et al. (2000) for age 0.1 and 5 Myr (dashed curves) are also shown. The isochrones are shifted for the distance of 2.4 kpc and reddening $E(B-V) = 0.35$ mag. The distribution of YSOs on the $V/(V-I)$ CMD is an ideal tool to estimate the approximate ages of YSOs. It is evident from this figure that a majority of the YSOs in Sh2-252 are distributed between the PMS isochrones of age 0.1 and 5 Myr showing that the region Sh2-252 is significantly comprised of young sources. In Fig.1 we have also shown the PMS evolutionary tracks by Siess et al. (2000) (thin continouous curves) for various mass bins which indicate that majority of the YSOs have masses in the range between 0.3 $M_{\odot}$ - 2.5 $M_{\odot}$.

We constructed the spectral energy distributions (SEDs) in the wavelength range from 0.36 μm to 24 μm using the grid of models and fitting tools of Robitaille et al. (2007) for characterizing and understanding the nature of YSOs in the Sh2-252

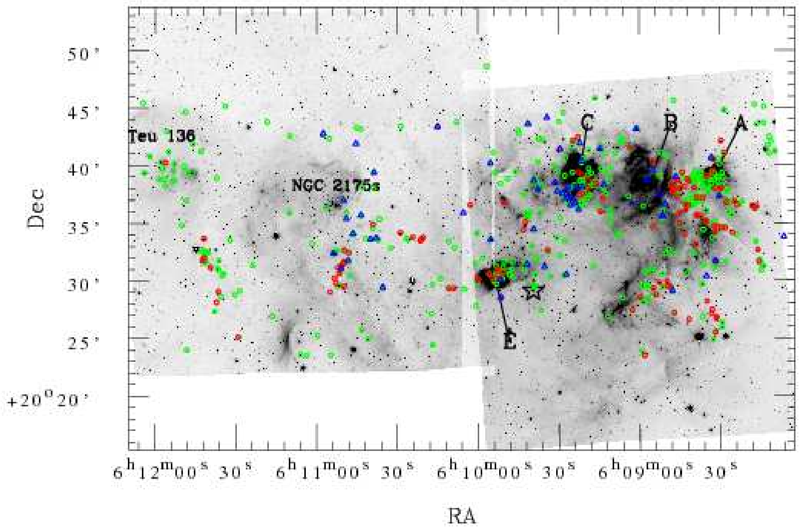

Figure 2. Spatial distribution of candidate YSOs in Sh2-252 overplotted on the 4.5 μm mosaic image. Class I and Class II sources are represented in red, green, respectively, and the blue triangles are the $H\alpha$ emission line sources. Star symbol represents the location of HD 42088 and the sub-regions are also marked in the figure.

complex. SED analysis shows that ~ 90% of the YSOs have an age range between 0.1 to 5 Myr which is in agreement with that of Fig.1. Similarly, a majority of the YSOs are distributed in a mass range between 0.5 to 3.0 $M_\odot$. A majority of the Class II YSOs have the disk accretion rates of the order of ~ 10^{-7} - 10^{-8} $M_\odot$ yr^{-1}. The envelope infall rates of most of the Class I YSOs are > 10^{-6} $M_\odot$ yr^{-1}, which are more or less higher than that of the Class II YSOs, confirming their Class I nature.

In Fig.2, we have shown the spatial distribution of all the identified candidate YSOs in Sh2-252 (i.e., red: Class I; green: Class II; blue: $H\alpha$ emission line sources) overlaid on the IRAC 4.5 μm mosaic image. A majority of the identified YSOs in Sh2-252 are concentrated around the compact H II regions Sh2-252 A, C and E, respectively. There are a smaller number of sources scattered towards the west of HD 42088. There seems to be a small clustering of Class II YSOs towards Teu 136. We attempted to constrain the evolutionary status of the candidate YSOs within the sub-regions of Sh2-252 using SED fitting models. The median ages of the YSOs lying within Sh2-252 A, B, C and E are obtained as ~ 2-3 Myr, suggesting a rather similar evolutionary status for these regions. The optical CMD analysis also shows similar median age for these regions. The Class I/II fractions again show roughly the same values for these regions. All these observational evidences suggest that the sub-regions in Sh-252 should be of same age. A close look at the spatial distribution of YSOs around Sh2-252A shows that there is a significant enhancement of Class I YSOs towards the east of Sh2-252A. The SED analysis shows that they are of age ∼ 0.5 Myr, much younger than the regions A, B, C and E. This younger population seems to be aligned parallel to the ionization fronts of Sh2-252A (Tej et al. 2006) and Sh2-252. Hence, we presume that the combined expansion activities of the H II regions Sh2-252 and Sh2-252 A might have triggered the star formation in the collected material between them.

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