Bulletin de la Société Royale des Sciences de Liège, Vol. 88, Actes de Colloques, 2019, p. 270 - 274

Characterization of pre-main sequence population in H II region Sh2-242

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Abstract: We present here preliminary results of the young stellar population associated with an active star-forming region Sh2-242 using multi-wavelength observational data. The cluster radius of the region is estimated as 11 arcmin from the radial density profile, using Wide-field InfraRed Camera deep K-band photometric data. Using a deep infrared photometric survey, we have classified more than 150 young stellar objects, distributed within the cluster region. A total of 36 Hα emission line objects were detected using slitless spectroscopic observations and INT Photometric Hα Survey of the Northern Galactic Plane photometric data. The optical spectroscopic study confirms that the cluster member BD+26 980 is a massive early-type star (B0.5 V). From the spectrophotometric analysis, the distance to the massive star is estimated as 1769 $\pm$ 193 pc, confirming earlier estimations.

Keywords: stars: formation – stars: pre-main-sequence – infrared; interstellar medium – H II regions

1 Introduction

Young stellar objects (YSOs) are formed in the star-forming regions (SFRs) in clusters within giant molecular clouds (Lada & Lada 2003). The presence of massive stars of spectral type O or early B in the young clusters plays a profound role in creating a birthplace of stars by shaping the surrounding medium. H II regions are zones of ionized gases surrounding massive O- or B-type stars created by the stellar far-ultraviolet radiation from the massive stars (Anderson et al. 2014). Galactic H II regions are the active sites of massive star formation and tracers of Galactic spiral structures. From observational studies, it is well known that young SFRs often show elongated and clumpy structures in the presence of massive stars. YSOs could be probed efficiently from their infrared excess due to circumstellar disk emissions.

In this paper, we present a multiwavelength analysis of YSOs associated with the SFR Sh2-242 (S242; RA_{2000} = $05^h52^m13^s$; DEC_{2000} = +26°59′33″). S242 is a faint SFR showing a red nebulosity. It is found at a distance of 2.1 kpc in the direction of the Taurus constellation (Blitz et al. 1982; Stark 1984; Lada & Lada 2003). It is moderately populated with low-to-high mass ranges of pre-main sequence sources and distributed in a high extinction region. The S242 region contains at least 96 members based on magnitude-limited observations (Lada & Lada 2003). Previous observations show that the region is excited by the B0 V star- BD+26 980, having an extinction 2.4 mag (Crampton & Fisher 1974; Lahulla 1987; Snell et al. 1990; Sepulveda et al. 2011). We study here the YSOs population and cluster properties both from observations in deep optical ($V \sim 19.4$ mag) and infrared wavelength and from spectroscopic studies of few bright member candidates.

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2 Data sets

Multiwavelength datasets (optical and infrared) were used to study the S242 region. New optical photometric and spectroscopic data were acquired from Indian national facility telescopes. These observations were complemented with archival data from the Wide-field InfraRed Camera (WIRCam) on 3.6-m Canada-France-Hawaii Telescope, the 2-Micron All Sky Survey (2MASS), the *Spitzer* space telescope, and the INT Photometric Hα Survey (IPHAS) on the 2.5-m Isaac Newton Telescope (INT).

2.1 New observations

Optical photometric data in the Bessell B, V, R, and I broad-band filters were obtained with the 1.3-m Devasthal Fast Optical Telescope (DFOT), operated by the Aryabhatta Research Institute of Observational Sciences (ARIES, Nainital, India). Different sets of exposure times were used for each filter. The 2K$\times$2K Andor CCD camera with a field of view of $18' \times 18'$ was used for this purpose. Observations of the standard field SA 95 (Landolt 1992) at different airmasses were taken for photometric calibrations.

Few bright sources ($V < 14.5$ mag, $J < 10.5$ mag) within the region were selected for optical slit spectroscopic observations. Low-resolution spectroscopic observations were carried out using the Himalaya Faint Object Spectrograph and Camera of the 2-m Himalayan Chandra Telescope (HCT) with Grism 7 (380 - 684 nm). Optical standard stars were observed for flux calibrations and FeAr arc lamp observations were taken for wavelength calibrations. Slitless spectroscopic data were obtained from HCT using the broad-band Hα filter (630 - 674 nm) in combination with Grism 5 (520 - 1030 nm) to detect Hα emission line sources. Photometric and spectroscopic data were reduced using standard tasks of the IRAF[1] software package.

2.2 Archival data

Deep near-infrared (NIR) observations in the J (1.25 μm), H (1.63 μm), and K (2.14 μm) bands[2] were collected from WIRCam (Puget et al. 2004). The raw images were reduced using the Interactive Data Language based interface SIMPLE Imaging and Mosaicking Pipeline (SIMPLE; Wang et al. 2010). We used 2MASS Point Source Catalog (Skrutskie et al. 2006) photometry to replace the saturated sources in WIRCam. *Spitzer* Infrared Array Camera (IRAC; Fazio et al. 2004) [3.6] and [4.5] μm data were collected from Glimpse360[3] catalog. Mid-infrared (MIR) data are limited to only this two bands, as the region S242 was covered during the *Spitzer* Warm Mission (Hora et al. 2012) survey. To detect the Hα emission line objects, we used r, i and Hα photometry from the IPHAS data release 2 (Barentsen et al. 2014) catalog. To obtain good quality photometry, the photometric datasets were restricted to a photometric uncertainty in each band < 0.1 mag for the NIR observations and the IPHAS catalog and to a photometric uncertainty in each band < 0.2 mag for the MIR catalog.

3 Results

The cluster extension of the S242 region is estimated using the radial density profile, which is generated from WIRCam K-band photometric data for the sources having an uncertainty < 0.1 mag. The cluster radius is estimated as 11 arcmin as shown in Fig. 1. The vertical dashed line at 11 arcmin marks the cluster radius, where the cluster density blends towards the background density level, represented by the horizontal dashed line.

We used the infrared color-color space to identify and characterize the YSOs within S242. YSOs can be probed from their excess infrared emission due to the presence of a circumstellar envelope (Lada & Adams 1992). We used IRAC [3.6] and [4.5] μm along with WIRCam J, H, and K photometry, taking the dereddened

[1] Image Reduction and Analysis Facility (IRAF) (http://iraf.noao.edu/)
[2] http://www.cfht.hawaii.edu/Instruments/Filters/wircam.html
[3] http://www.astro.wisc.edu/sirtf/glimpse360/

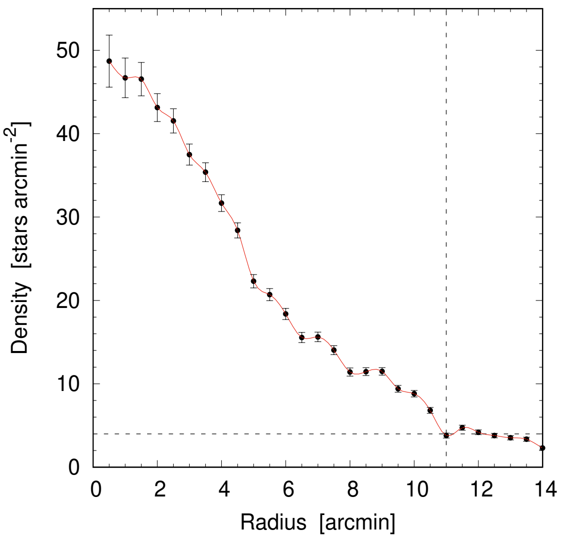

Figure 1: Radial density distribution of stars towards S242 from WIRCam K-band observations with a photometric uncertainty < 0.1 mag.

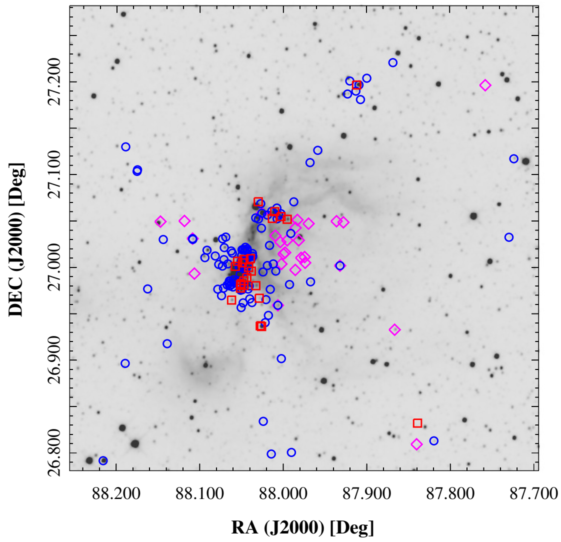

Figure 2: Spatial distribution of Class I (red square), Class II (blue circle) and H_α emitters (tilted magenta box) overplotted on the *Wide-Field Infrared Survey Explorer* (*WISE*; Wright et al. 2010) 4.6 μm image for the S242 region.

color ($[K-[3.6]]_0$ and $[[3.6]-[4.5]]_0$) conditions from Gutermuth et al. (2008, 2009). The dereddened colors were calculated using the color excess ratios listed in Flaherty et al. (2007). Several non-stellar field contaminations (Gutermuth et al. 2008) were removed to generate a proper YSO sample. Using the infrared colors, we have identified 33 Class I and 134 Class II (Lada & Adams 1992; Greene et al. 1994) sources within the region S242. From the slitless spectroscopy and IPHAS photometry, a total of 36 Hα emitting sources were detected. The majority of the Hα emitters shows accretion phenomena of circumstellar material onto the central star and are therefore considered as Classical T Tauri (Meyer & Calvet 1997) stars. The spatial distribution of Class I (red square), Class II (blue circle) and Hα emitting sources (tilted magenta box) are shown in Fig. 2 to study the morphological structure of the region. It was noticed that a majority of Class I and Class II sources are clustered towards the arc-like filamentary structures. The Hα emitting sources are concentrated within the central region and few sources show a scattered distribution. The spatial distribution of YSOs infers ongoing star formation activity within the region.

The flux calibrated normalized spectra of the bright source BD+26 980 towards S242, observed with the 2-m HCT using Grism 7, is shown in Fig. 3. Spectroscopic classification was performed by comparison with the spectral indices and spectral library (Jacoby et al. 1984, Lundquist et al. 2014) available in the literature. Spectral line features and their equivalent widths were compared with those from literature spectra.

The optical spectroscopic result of BD+26 980 confirms it to be a massive early-type star (B0.5 V). This massive star, classified as the main ionizing source of the region, was previously known as a B0 V star. From spectrophotometric analysis, the intrinsic distance modulus of the star is estimated as 11.24 ± 0.05 mag, corresponding to a distance of 1769 $\pm$ 193 pc, which confirms the star as a member of the cluster. The $Gaia$ parallax ($Gaia$ Data Release 2; Brown et al. 2018) provides the distance to the source 2079 $\pm$ 192 pc, which agrees well with the spectrophotometric distance.

4 Conclusions

In this work, we report preliminary results of a multi-wavelength study of the young cluster S242, a compact H II region. The cluster radius is estimated as 11 arcmin using WIRCam deep K-band photometric data. From a deep infrared photometric survey, we have classified more than 150 young objects, distributed within the

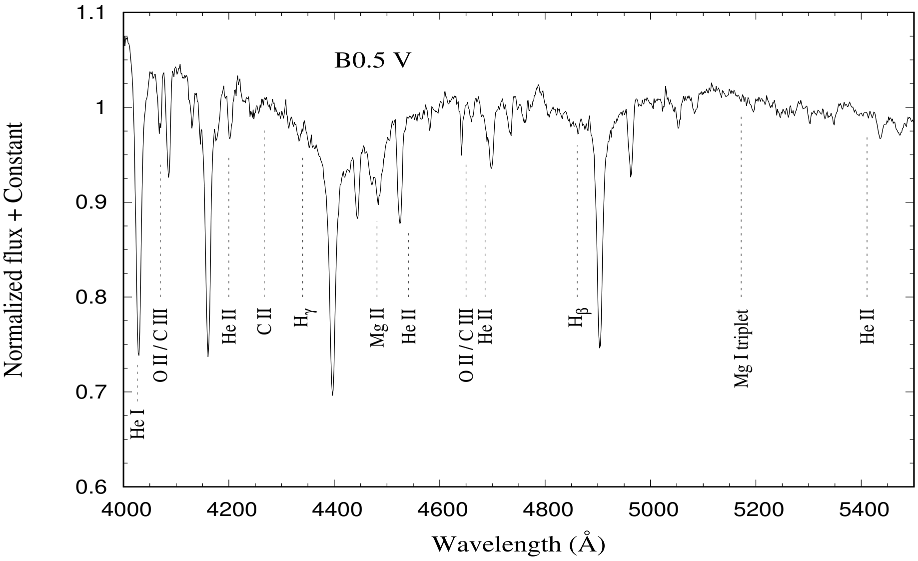

Figure 3: The flux calibrated normalized spectra of the bright star BD+26 980, as observed with the 2-m HCT.

cluster region. A total of 36 Hα emission line objects were detected using IPHAS photometry. They are all bonafide members of the cluster. From the optical spectroscopic study, BD+26 980 is confirmed to be a massive early-type star (B0.5 V), which is a member of the cluster. From the spectrophotometric analysis, the intrinsic distance modulus of the star is estimated as 11.24 ± 0.05 mag, corresponding to a distance of 1769 ± 193 pc.

Acknowledgements

We thank the anonymous reviewer, whose constructive suggestions and comments greatly improved the quality of the paper. This research work is financially supported by S. N. Bose National Centre for Basic Sciences under the Department of Science and Technology, Govt. of India. This work makes use of the data from IPHAS, WIRCam, 2MASS and *Spitzer*. We are thankful to the time allocation committee members and the staff of HCT, operated by the Indian Institute of Astrophysics, Bangalore. The authors acknowledge the observational facility from 1.3-m DFOT, operated by ARIES, Nainital.

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