A massive star-forming region in a very early stage of evolution

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**Abstract.** We present results from a study of two luminous IRAS sources thought to be young massive star-forming regions and which have no previously detected radio continuum emission: IRAS 15596-5301 and IRAS 16272-4837. Our study incorporates sensitive ATCA radio continuum data, SED 1.2-mm continuum (using the new SIMBA bolometer) and line data, as well as data taken from the MSX database. The results show that both sources are associated with dense molecular cores which appear to host recently formed massive stars. We argue that IRAS16272 is in a very early stage of evolution, prior to the formation of an ultra compact HII region and that IRAS15596 is in a more advanced stage and hosts a cluster of B-type stars.

1. Introduction

We are undertaking a multi-wavelength study of a sample of 20 luminous IRAS sources that are thought to be representative of young massive star-forming regions. The sources in our sample were chosen from the Galaxy-wide survey of CS(2–1) emission towards 843 IRAS sources with infrared colours typical of compact HII regions (Bronfman, Nyman, & May 1996). Each source selected for our sample showed line profiles indicative of either inward or outward motions and in some cases broad wings. Their IRAS luminosities were in the range $2 \times 10^4 - 4 \times 10^5 L_\odot$, implying that they all contain at least one embedded massive star ($> 8 M_\odot$).

Two sources in our sample, IRAS 15596-5301 and IRAS 16272-4837, were found to have no detectable radio emission (down to 2 mJy beam$^{-1}$) in the
survey by Walsh et al. (1998), making them candidates for massive stars in very early stages of evolution when dense material is still falling towards the protostar and quenching the development of an ultra compact (UC) HII region (e.g. Yorke 1984). Here we present the findings from our study towards these two exceptional sources.

Our study involves radio continuum observations using the Australia Telescope Compact Array (ATCA), 1.2-mm continuum observations using the new SIMBA 37-channel bolometer array installed at the SEST, as well as a series of SEST molecular-line observations between 85 and 250 GHz. We have also incorporated mid-infrared data obtained with the Midcourse Space Experiment (MSX) satellite. For IRAS15596 and IRAS16272, the ATCA radio continuum observations yielded a $1\sigma$ detection limit at 4.8-GHz of 0.08 mJy beam$^{-1}$. The synthesized beams of the resultant images (FWHM) were $\approx 2''$. At 1.2-mm (230 GHz) the FWHM beamsize of the SEST is 24$''$.

2. Results & Discussion

2.1. IRAS 15596-5301

The 1.2-mm continuum emission detected towards IRAS15596 is elongated over 42$''$ (0.6 pc at the distance of 4.6 kpc; Bronfman, private communication) and has a flux density of 5.8 Jy (see Fig. 1). Assuming a dust opacity at 1.2 mm
of 1 cm$^2$ g$^{-1}$ (Oseenkopf & Henning 1994) we derive a mass of 1.4 $\times$ 10$^3$ M$_\odot$. Results from the line observations indicate the presence of a molecular gas core with a rotational temperature of 27 $\pm$ 3 K (see Fig. 2), a molecular hydrogen column density N(H$_2$) of 2 $\times$ 10$^{24}$ cm$^{-2}$ and density n(H$_2$) of 4 $\times$ 10$^5$ cm$^{-3}$.

The 4.8-GHz continuum observations reveal three distinct compact sources with diameters of 0.06 to 0.2 pc. Their peak flux densities are in the range 1.1 – 2.8 mJy beam$^{-1}$, close to the sensitivity of the Walsh et al. (1998) survey. All three sources are located within a region of 30$''$ in diameter and are within the 1.2-mm continuum emission region (see Fig. 1). Assuming that the three sources are UCHII regions and excited by individual ZAMS stars, then their flux densities implies the presence of early B-type stars. The total radio luminosity emitted by this cluster is 4.1$\times$10$^4$ L$_\odot$, somewhat lower than the IRAS luminosity of 6.5 $\times$ 10$^4$ L$_\odot$. The presence of assorted masers in the vicinity of IRAS15596 is in accord with this being a massive star forming region.

From their observed sizes and assuming a sound speed in the ionized gas of 11.4 km s$^{-1}$ we estimate that the three UCHII regions have dynamical ages between 3 $\times$ 10$^3$ – 8 $\times$ 10$^3$ yr, which might suggest that they are very young. However, dynamical timescales may not provide realistic age estimates if the
IRAS 16272-4837: 1.2-mm continuum emission (contours) with levels 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 times 0.5 Jy beam$^{-1}$. In reverse grey scale are the MSX images at A-band (left) and E-band (right). Also shown are the maser positions (see caption in Fig. 1).

objects have already reached pressure equilibrium with the surrounding ambient medium. Using the equations given by Garay & Lizano (1999) we estimate that a molecular density of $5 \times 10^5$ cm$^{-3}$ is needed for the three UCHII regions to be currently pressure confined. This value is similar to that derived from the molecular line observations. The time needed for the HII regions to achieve such a pressure equilibrium is between $1 \times 10^5 - 2.5 \times 10^5$ yr, implying that massive star formation started within this molecular core more than $2.5 \times 10^5$ yr ago.

Although not illustrated here, IRAS15596 is also associated with a compact mid-infrared source as well as extended MSX A-Band emission (6.8 - 10.8 μm).

2.2. IRAS 16272-4837

The 1.2-mm continuum emission detected towards IRAS16272 is elongated over 41" (0.4 pc at the distance of 3.4 kpc; Bronfman private communication) and has a flux density of 13.8 Jy. Assuming the previously mentioned dust opacity, we derive a mass of $2 \times 10^3$ M$_\odot$. The line observations indicate the presence of a molecular gas core with a rotational temperature of 27 ± 4 K (see Fig. 2), N(H$_2$) of $1 \times 10^{24}$ cm$^{-2}$ and $n$(H$_2$) of $2 \times 10^6$ cm$^{-3}$, similar to IRAS15597. As evident in Fig. 3, the 1.2-mm continuum emission is associated with a mid-infrared dark cloud seen in absorption in the MSX A-Band against the emission from the galactic plane.

No 4.8-GHz continuum radio emission was detected to a 3σ upper limit of 0.2 mJy. A non-detection is somewhat surprising given that the IRAS luminosity of the source is $2.4 \times 10^4$ L$_\odot$. If a B0-type star were responsible for this high luminosity then we expect to measure a radio flux of $\approx 200$ mJy at optically thin frequencies if embedded in a uniform density medium. One explanation for the high luminosity and lack of detected radio emission could be that IRAS16272 is a dense massive molecular core which hosts a young massive protostar that is still undergoing an intense accretion phase. Adding support to this hypothesis
are the characteristics of the observed molecular line profiles. For instance, the behavior of the optically thick HCO\(^+\)(1–0) and optically thin H\(^{13}\)CO\(^+\)(1–0) lines shown in Fig. 4 are consistent with infalling motions. Furthermore, the broad wings evident in the SiO(2–1) spectrum suggest the presence of outflowing gas, a phenomenon thought to be closely related to accretion processes.

The notion that IRAS16272 hosts a young massive protostar is also supported by the presence of assorted maser emission and an emission source seen in the MSX E-Band (18.2 – 25.1 \(\mu\)m). It is tantalizing to note that this source appears slightly extended with the maser spots aligned along the major axis (see Fig. 3).

References

Yorke, H. W. 1984, Workshop on Star Formation, ed. R.D. Wolstencroft (Edinburgh: Royal Observatory), 63