WARM DUST AROUND HOT STARS IN THE TRIFID NEBULA

B. Lefloch[1], J. Cernicharo[2], D. Cesarsky[3], K. Demyk[4], L.F. Rodriguez[5], and M.A. Miville-Deschênes[6]

[1]LAOG, Observatoire de Grenoble, B.P. 53, 38041 Grenoble, France
[2]CSIC, IEM, C. /Serrano, 121, 28006 Madrid, Spain
[3]MPIfEP, 86741 Garching, Germany
[4]IAS, Université Paris XI, 91450 Orsay Cedex France
[5]UNAM, Campus Morelia, A.P. 3-72, Morelia, Mexico
[6]LRA, ENS, 75231 Paris, France

Abstract

We report on mid-infrared observations of the central region in the Trifid nebula, carried out with ISOCAM in several broad-band filters and in the low-resolution spectroscopic mode provided by the Circular Variable Filter. Analysis of the emission indicates the presence of a hot dust component (500-1000 K) and a warm dust component at lower temperatures (150-200 K) around several members of the cluster exciting the HII region and other stars undetected at optical wavelengths. Complementary VLA observations suggest that the mid-IR emission could arise from the a dust cocoon or a circumstellar disk, evaporated under the ionization of the central source and the exciting star of the nebula. In several sources the 9.7μm silicate band is seen in emission. Around one young stellar source we found the presence of crystalline silicates in the circumstellar dust.

Key words: Stars: formation – Stars: early-type – ISM: HII regions – ISM: dust, extinction

1. Introduction

The Trifid nebula is a nice example of a small HII region in an early stage of evolution, It is located at a distance of 1.68kpc and has an estimated age of $0.3 - 0.4$ Myr. The nebula is excited by the O7 V star HD 164492A. In the optical, five other stars of various masses, components B to F, are found within $20''$ (0.16 pc) of HD 164492A, suggesting that the formation of a cluster accompanied the birth of the ionizing star.

The Trifid is an ideal object to study the early stages of high-mass star forming regions, such as Orion. For this reason, we carried out a comprehensive study of the nebula with the instruments on ISO. Previous observations in the FIR and at millimeter wavelengths have revealed the presence of young massive protostars in the nebula (Cernicharo et al. 1998; Lefloch & Cernicharo 2000). Here we report on the detection of more evolved sources surrounded by large amounts of dust, in the center of the nebula.

2. The Mid-Infrared Emission

Several images of the Trifid were taken in the LW4 filter ($\lambda = 6.2\mu m$; $\Delta\lambda = 1.0\mu m$) at $6''$ resolution, in the LW7 filter ($\lambda = 10\mu m$; $\Delta\lambda = 3\mu m$) at $6''$ resolution, and in the LW10 filter ($\lambda = 11.5\mu m$; $\Delta\lambda = 7\mu m$) at $3''$ resolution (Fig. 1).

The maps show some extended emission which closely follow the dust absorption lanes observed in the optical Hα line. We detected several point-like sources near the stellar cluster (sources IRS 1 to IRS 5) and two more remote sources (IRS 6 and IRS 7). The point-like sources appear with the highest contrast in the LW4 filter; by comparison, LW7 and LW10 are hardly visible in the LW7 and LW10 bands. Except for the bright sources IRS 1-2 and IRS 6, the individual sources in the LW7 filter can hardly be separated from the extended emission of the dust lane.

The spectra of IRS 1-2, IRS 3 and IRS 6 between 5 and 17μm (Fig. 2) were obtained after subtracting the emission of a nearby reference position. The observed emission was fitted with a gaussian function convolved with the Point Spread Function of the instrument. The silicate band at 9.7μm is detected in *emission* towards these sources whereas it is seen in absorption in the dust lanes.

The continuum emission towards IRS 1-2 is satisfactorily fitted by two black-body components modified by a dust opacity law $\tau_\nu \propto \nu$ at temperatures T $\sim$ 500 K and $\sim$ 200 K (Fig. 3). We adopted a size of $0.2''$ for the "cold" component (see Sect. 3). We find a a typical hydrogen column density N(H) $\sim 10^{21}$ cm^{-2} of the component at 200 K. Similar results are found for IRS 3 and IRS 6, with temperatures at $700 - 1000$ K and $150 - 300$ K. The short wavelength part of the silicate band ($8 - 11\mu$m) is closely reproduced by amorphous pyroxenes containing or mixed with inclusions of FeO. The broad shoulder at longer wavelengths is probably due to crystalline silicates and is well reproduced with pure forsterite grains (Fig. 3).

3. VLA Observations

We observed the 3.6cm continuum radiation using the VLA in its highest angular resolution configuration in 1998 March 13 (see Fig. 2). All the infrared sources but IRS 6 lie within the field. The rms noise in the map is 20μJy beam^{-1}; the beam size (HPFW) is $0.38'' \times 0.19''$ and the position angle is 11°. Two radio sources are de-

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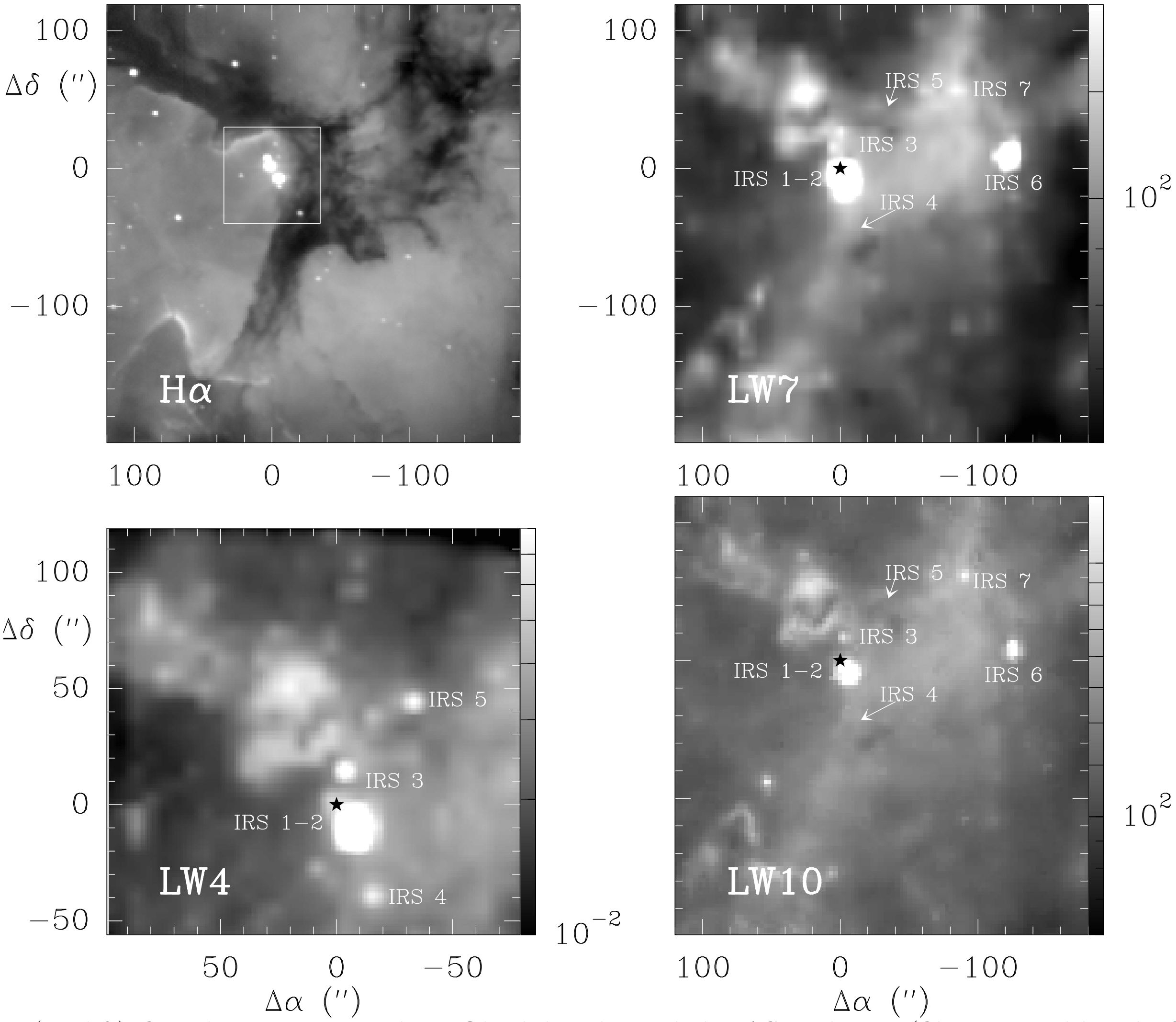

Figure 1. (top left) *Optical Hα emission in the Trifid nebula, taken with the IAC80 telescope (Observatorio del Teide, Spain). Coordinates are in arcsec offsets with respect to the exciting star of the nebula HD 164492A.* (top right) *Infrared emission in the* $8.5-11.5\mu$m *band (LW7). The black star marks the position of HD 164492A.* (bottom) *Infrared emission in the* 5.5μm *band (LW4) and* $8-15\mu$m *band (LW10).*

tected, that coincide with components C and D of the stellar cluster. We do not detect any emission from any other ISOCAM source. The flux densities at 3.6cm were 1.64 ± 0.02 mJy (C) and 1.48 ± 0.02 mJy (D). Both sources appear unresolved with an angular size smaller than $\sim 0.2''$. No linear or circular polarization was found in the sources to an upper limit of $\sim$4% for the degree of polarization. Additional VLA observations at 2-cm were in the C configuration were carried out. The spectral indices we derive are 0.0 ± 0.2 and -0.2 ± 0.2, for C and D, respectively. These flat spectral indices are characteristic of optically thin free-free emission, in agreement with the lack of polarization.

Adopting a transverse size of $0.2''$ for the emitting region, the emissivities imply a density of $\approx 10^5$ cm^{-3} and a total mass of 6.0×10^{-6} $M_\odot$ for the ionized gas around C and D.

4. Discussion

There is no large-scale gas reservoir which can slow down the expansion of the ionized gas around components C and D of the cluster. The expansion timescale of the ionized gas ($\sim$ 80 yr) is so short that the free-free emission has to be sustained through the ionization of some "fresh" neutral material. The mid-infrared data provide some direct evidence for the presence of neutral material around components C and D. We propose that the emission observed at the VLA and in the mid-infrared originates from a reservoir of dense circumstellar material exposed to the ionizing radiation of HD 164492A, similar to

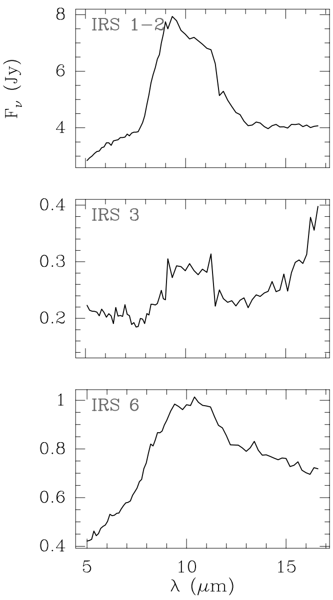

Figure 2. Spectral emission observed with the Circular Variable Filter towards some bright point-like sources.

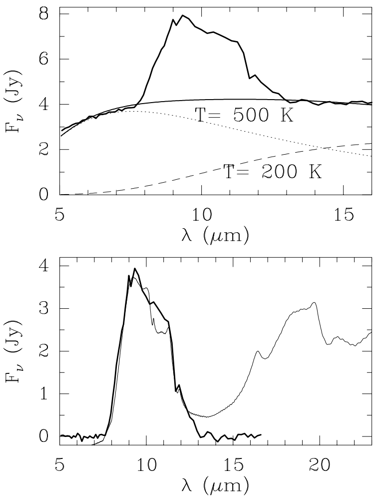

Figure 3. (top) Fit to the IRS 1-2 continuum emission in the range $5 - 17\mu$m. *(bottom) Silicate emission band after subtracting the continuum (thick) and fit to the emission (thin) assuming a mix of pure forsterite with amorphous pyroxenes with inclusions of FeO.*

the photo-evaporated disks detected in Orion (Churchwell et al. 1987; O'Dell, Wen & Hu 1993).

Based on the mass-loss rate ($\sim 4 \times 10^{-8}$ M$_\odot$yr^{-1}), the warm material detected ($\sim 2-3 \times 10^{-5}$ M$_\odot$) should evaporate on a timescale of 400 yr. The total circumstellar mass is probably much higher than the mass of material detected here, and the bulk of disk material corresponds to a colder component which at longer wavelengths. The column density of warm gas derived from the CVF data is

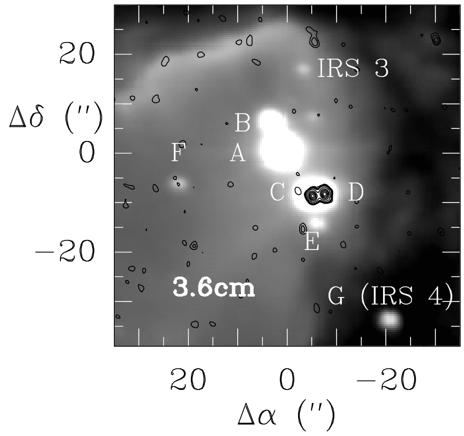

Figure 4. magnified view of the Hα emission. We have superposed (contours) the 3.6cm free-free emission observed at the VLA. The contours range from 0.1 to 1 mJy beam^{-1}.

in good agreement with the model of Johnstone, Hollenbach & Bally (1998) for the warm PDR gas at the surface of a photo-evaporated disk. It suggests that we are detecting the emission of the PDR at the surface of the disk. The cold disk component should be more easily detectable at longer wavelengths with PACS in its imaging mode.

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