FAR-INFRARED STUDY OF IRAS 00494+5617 AND IRAS 05327−0457

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ABSTRACT

High angular resolution far-infrared observations at 143 and 185 μm, using the Tata Institute of Fundamental Research 1 m balloon-borne telescope, are presented for two Galactic star-forming complexes associated with IRAS 00494 + 5617 and IRAS 05327−0457. The latter map also reveals the cold dust in OMC-3. Both these regions are illuminated at the edges by high-mass stars with substantial UV flux. The HIRES (High-Resolution processing using Maximum Correlation Method) processed IRAS maps at 12, 25, 60, and 100 μm have also been presented for comparison. The present study is aimed at quantifying the role of the nearby stars vis-à-vis embedded young stellar objects in the overall heating of these sources. Based on the FIR observations at 143 and 185 μm carried out simultaneously with almost identical angular resolution, reliable dust temperature and optical depth maps have been generated for the brighter regions of these sources. Radiative transfer modeling in spherical geometry has been carried out to extract physical parameters of these sources by considering the observational constraints, such as spectral energy distribution, angular size at different wavelengths, dust temperature distribution, etc. It is concluded that for both IRAS 00494 + 5617 and IRAS 05327−0457, the embedded energy sources play the major role in heating them with finite contribution from the nearby stars. The best-fit model for IRAS 00494 + 5617 is consistent with a simple two-phase clump-interclump picture with ~5% volume filling factor (of clumps) and a density contrast of ≈80.

Subject headings: infrared: ISM: continuum — ISM: clouds —
ISM: individual (IRAS 00494 + 5617, IRAS 05327−0457) —
radiative transfer

1. INTRODUCTION

A long-term program of studying the distribution of cold dust (down to ~15 K) in and around Galactic star-forming regions is in progress using the 1 m Tata Institute of Fundamental Research (TIFR) balloon-borne far-infrared (FIR) telescope. Under this program, high angular resolution (~1′) mapping is carried out simultaneously in two trans-IRAS FIR wave bands (Ghosh et al. 1996; Mookerjea et al. 1998, 1999; Verma et al. 1999). In this paper we present FIR mapping of the sources IRAS 00494 + 5617 and IRAS 05327−0457 in wave bands centered around 143 and 185 μm. These are similar in that each is heated by a luminous external source in addition to one or more possible embedded sources. The simultaneity of observations in the two wave bands with nearly identical beams is useful in deriving reliable temperature distributions of the interstellar dust in these regions.

The source IRAS 00494 + 5617 is part of the western fragment of the molecular cloud NGC 281, located in the Perseus arm at a distance of 2.2 kpc (Cesaroni, Felli, & Walmsley 1999). A compact star cluster containing the multiple star HD 5005 as the brightest star excites an ionization front at the edge of NGC 281W. HD 5005 is an O6 V type star, and the cluster is at an angular distance of ~5′ from IRAS 00494 + 5617. Observational evidences in the form of detection of C^{34}S (3 → 2) (Megeath & Wilson 1997), NH_3 (Henning et al. 1994), 22 GHz H_2 O masers (Tofani et al. 1995), CO emission (Carpenter, Snell, & Schoelkopf 1990), and molecular outflows (Snell, Dickman, & Huang 1990) together with FIR and millimeter continuum emission strongly suggest ongoing star formation activity in this region. Existing literature on this source suggests that the ongoing star formation activity has been induced by the compression due to the propagation of the ionization front (energized by HD 5005) into the molecular cloud (Elmegreen & Lada 1978; Megeath & Wilson 1997). The gas emission features from this source are reasonably well studied. There are not as many high angular resolution observations of the emission from the dust component. Longward of IRAS wavelengths, the only available observations are the high-resolution maps at 1.3 mm (Henning et al. 1994).

The source IRAS 05327−0457 is associated with the nebulosity NGC 1977, located near the northern star in the sword of Orion. It is bounded on the south by the northern end of the Orion molecular cloud (Kutner, Evans, & Tucker 1976) and is at a distance of 450 pc. The exciting star for the H II region is the B1 V star HD 37018, also known as 42 Ori, and is at an angular distance of ~5′ from IRAS 05327−0457. Earlier observations of the NGC 1977 region include FIR (~160 μm), near-infrared, and radio continuum mapping together with extensive molecular line observations (Makinen et al. 1985; Kutner et al. 1985). High-resolution molecular line maps (Kutner et al. 1985) indicate an increase in radial velocity from south to north, implying an expansion of the H II region into the molecular cloud, with a velocity of a few kilometers per second.

In the present study the structural details and dust temperature distributions obtained from FIR observations have been used to quantify the relative contributions of the external and internal sources toward heating these regions. In §§ 2 and 3, the observations and the results are described. A discussion of radiation transfer modeling of these sources is presented in § 4.

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2. OBSERVATIONS

2.1. The 143 and 185 μm Maps

The Galactic star-forming regions associated with the sources IRAS 00494 + 5617 and IRAS 05327−0457 were observed using a two-band FIR photometer system at the Cassegrain focus of the TIFR 1 m (f/8) balloon-borne telescope. The FIR telescope was flown from the TIFR Balloon Facility, Hyderabad, in central India (latitude N17·47, longitude E78·57) on 1995 November 12. Details of the telescope and the observational procedure have been given by Ghosh et al. (1988). Additional information specific to this balloon flight has been presented by Mookerjea et al. (1999). The photometer consists of 12 composite silicon bolometers, each having a field of view of 1·6 and arranged in a 3 × 2 array for each band. The sky was chopped at 10 Hz by wobbling the secondary mirror. The chopper throw was 42 along the cross-elevation axis. The same region of the sky was viewed simultaneously in two bands. The effective wavelengths for the two bands are 143 and 185 μm for a graybody spectrum with a temperature of 36 K and λ−1 emissivity. All flux densities presented in this paper also use the same assumptions regarding temperature and emissivity. Saturn was observed for absolute flux calibration as well as for the determination of the instrumental point-spread (PSF) including the effect of sky chopping. The absolute flux calibration was done following the method described by Ghosh et al. (1988).

The regions (refer to Figs. 1 and 3) around IRAS 00494 + 5617 and IRAS 05327−0457 were mapped by scanning the sky in cross-elevation with steps in elevation at the end of each scan line. The chopped FIR signals were gridded in a two-dimensional sky matrix (elevation and cross-elevation) with a cell size of 0·3 × 0·3. The observed chopped signal matrix was deconvolved using an independently developed procedure based on the maximum entropy method similar to that of Gull & Daniell (1978) (see Ghosh et al. 1988 for details). The FWHM sizes of the deconvolved maps of the pointlike source (Saturn) are 1·6 × 1·9 and 1·6 × 1·8 in the 143 and 185 μm bands, respectively. An optical photometer at the Cassegrain focal plane was used to improve the absolute positional accuracy of the telescope to ≈0·5 (Mookerjea et al. 1999).

2.2. The HIRES-Processed IRAS Maps

To supplement our balloon-borne observations, we used the IRAS survey data for all four (12, 25, 60, and 100 μm) bands for the regions of the sky around IRAS 00494 + 5617 and IRAS 05327−0457. These data were HIRES (High-Resolution processing using Maximum Correlation Method; Aumann, Fowler, & Melnyk 1990) processed in the Infrared Processing and Analysis Center (IPAC3, Caltech) to improve the angular resolutions of the raw maps. These maps have been used to obtain flux densities and angular sizes in the four IRAS bands.

3. RESULTS

3.1. IRAS 00494 + 5617

Figure 1 shows the intensity maps of the region around IRAS 00494 + 5617 in the two TIFR and the four IRAS bands. Table 1 presents the coordinates and flux densities (in a circle of 5′ in diameter) at all six wavelengths. The main peak at 185 μm is shifted by ≈1′ compared to the peaks detected at all other wavelengths. The brightest source at 12 μm (IRAS 00492 + 5614) is too faint in the FIR maps and is not the main source of interest.

The 143 and 185 μm maps show more structural details of the region as compared to the 100 μm HIRES map. These maps show extended features (diffuse component) along the east-west direction at low contour levels. The

![Fig. 1](image-url)

Fig. 1.—Intensity maps for the region around IRAS 00494 + 5617 at (a) 185 μm, with peak = 644 Jy arcmin−2 with contour levels at 95, 90, 80, 70, 60, 50, 40, 30, 20, 10, and 7·5 percent of the peak and (b) 143 μm with peak = 341 Jy arcmin−2. Contour levels are the same as in (a), but up to 20% of the peak. The asterisk shows the position of HD 5005. The lowest contour for each map is ≈5 times the noise level. The insets show deconvolved images of Saturn in the respective bands, aligned to the instrumental axes for meaningful comparison. The contours for Saturn denote 90, 70, and 50 percent of respective peaks. Also shown are HIRES-processed IRAS maps at (c) 100 μm, (d) 60 μm, (e) 25 μm, and (f) 12 μm, with contours at levels the same as in (a) but up to 10% of the respective peaks. The peak values in these bands are 302, 173, 209, and 5·6 Jy arcmin−2, respectively. The resolutions at 12, 25, 60, and 100 μm are 0′9 × 0′45, 0′7 × 0′45, 1′3 × 0′8, and 2′0 × 1′6, respectively.

3 IPAC is funded by NASA as part of the part of the IRAS extended mission program under contract to JPL.
In addition to the diffuse component, the 143 μm map shows a secondary peak (S2) toward the west; this is not seen in the maps of other bands. The position and flux density (after correcting for the diffuse emission) of S2 at 143 μm are also presented in Table 1. The limits in the other bands refer to the flux densities measured in a circle (2' in diameter) centered at the position of S2 at 143 μm. Although the HIRES maps do not detect S2, the HIRES map at 60 μm processed with the Groningen IRAS Software Telescope (Henning et al. 1994) with better angular resolution indicates the presence of the same.

Figure 2 presents the contour maps of the temperature \(T(143/185)\) and optical depth (\(\tau_{150}\)) for this region, generated using the method described by Mookerjea et al. (1999). For these maps a dust emissivity \(\epsilon_j \propto \lambda^{-1}\) has been assumed. The temperatures determined are accurate to within \(\pm 2\) K between 20 and 50 K and within \(\pm 5\) K between 50 and 75 K. The structural details in these maps are highly reliable as a result of (1) the simultaneity of observations and (2) conservative processing, e.g., 3 × 3 pixel smoothing of the flux densities done prior to the determination of the temperature. The temperature and optical depth maps have been restricted to the regions where the intensities in both the wave bands are substantially higher (>10 times) than the measured noise level. From the temperature map it is seen that there are two regions of enhancement close to the boundary, the highest temperature being close to the boundary facing HD 5005. Furthermore, the temperature distribution seems to be featureless over most of the central region and shows a minimum near the center. In contrast, the peak of the \(\tau_{150}\) map coincides with the peak at 185 μm, and the contours decrease smoothly outward, as in the intensity map.

### 3.2. IRAS 05327–0457

Figure 3 presents the intensity maps of the region surrounding IRAS 05327–0457 in the six wave bands considered in this paper. The positions of the global peak in the 143 and 185 μm maps agree with the IRAS Point Source Catalog (PSC) coordinates within the achieved absolute positional accuracy in the maps. The source is extended along a direction approximately perpendicular to the line joining the cloud to the star 42 Ori. The basic features of the intensity distributions at 143 and 185 μm are similar to the 60 and 100 μm HIRES maps as well as the 158 μm [C II] map by Howe et al. (1991). The emission due to 42 Ori

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**TABLE 1**

**Positions and Flux Densities of the Detected Sources in the Region around IRAS 00494 + 5617**

| Source | \(\lambda\) (μm) | \(\alpha_{1950}\) | \(\delta_{1950}\) | Flux Density* (Jy) |
|--------|-----------------|----------------|----------------|-----------------|
| S1..... | 12 0 49 24.8 | +56 17 42 | 35 |
|        | 25 0 49 28.4 | +56 17 27 | 70 |
|        | 60 0 49 30.2 | +56 17 42 | 733 |
|        | 100 0 49 26.6 | +56 17 27 | 1762 |
|        | 143 0 49 29.9 | +56 17 22 | 2460 |
|        | 185 0 49 27.8 | +56 16 31 | 28220 |
| S2..... | 143 0 48 44.6 | +56 16 39 | 115* |
|        | 60 0 48 44.6 | +56 16 39 | <25* |
|        | 100 0 48 44.6 | +56 16 39 | <60* |
|        | 185 0 48 44.6 | +56 16 39 | <110* |

*Flux density in 5' diameter circle.

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**TABLE 2**

**Positions and Flux Densities of the Detected Sources in the Region around IRAS 05327–0457**

| Source | \(\lambda\) (μm) | \(\alpha_{1950}\) | \(\delta_{1950}\) | Flux Density* (Jy) |
|--------|-----------------|----------------|----------------|-----------------|
| P1      | 12 5 32 46.9 | -56 57 28 | 191 |
|        | 25 5 32 45.9 | -56 57 43 | 383 |
|        | 60 5 32 45.9 | -56 56 58 | 5401 |
|        | 100 5 32 45.9 | -56 56 58 | 7896 |
|        | 143 5 32 45.4 | -56 57 47 | 5350 |
|        | 185 5 32 46.4 | -56 37 38 | 3810 |
| P2      | 143 5 32 56.6 | -56 30 50 | 580* |
|        | 185 5 32 57.0 | -56 25 | 1820* |

*Flux density in 2' diameter circle.

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**Fig. 2.** (a) Dust temperature \(T(143/185)\) and (b) optical depth \(\tau_{150}\) maps, respectively, for the region near IRAS 00494 + 5617 for \(\epsilon_j \propto \lambda^{-1}\) emissivity law. The contours in (a) are at 70, 60, 50, 45, 40, 35, 30, 25, 20, and 16 K. The contours in (b) are at 95, 90, 80, 70, 60, 50, 40, 30, 20, 10, 5, 2.5, and 1 percent of the peak (0.15).
(located to the north of IRAS 05327—0457) is clearly seen in the 12 and 25 μm maps. Table 2 presents the position and flux densities in a circle of 5' diameter centered on the global peak in each of the six wave bands.

In both the 143 and 185 μm maps, a fainter source (P2) is detected toward the south of IRAS 05327—0457. Positionally this matches very well with the coldest submillimeter source (CSO 10) detected at 350 μm by Lis et al.
(1998). This is associated with OMC-3 and has also been detected at 1.3 mm by Chini et al. (1997). The dust temperature, $T(143/185)$, for P2 has been estimated to be $\sim 19$ K assuming $\varepsilon_\lambda \propto \lambda^{-2}$, the choice of the dust emissivity index being guided by Lis et al. (1998). This low-temperature source is not detected in any of the HIRES maps. Table 2 presents the position and flux densities of P2.

Figure 4 shows the maps of the dust temperature [$T(143/185)$] and optical depth ($\tau_{150}$) for IRAS 05327$-$0457, generated using the same methods as for IRAS 00494$+5617$. In the $\tau_{150}$ map, the peak has a value of 0.02 and is shifted northeast toward the direction of the ionizing star. The optical depth decreases monotonically toward the southwest. Higher temperatures are seen toward the southeastern and western edges; the rest of the region is seen to have smoothly varying temperatures between 25 and 35 K. There is no increase in the dust temperature near the edge facing 42 Ori. The $T(143/185)$ and the $\tau_{150}$ map together suggest the presence of (1) embedded sources of heating at the positions of temperature enhancements and (2) a high-density shell facing 42 Ori.

4. DISCUSSION

4.1. Radiation Transfer Scheme and Models Explored

We have explored the major sources of dust heating based on radiation transfer modeling of the sources. The radiation transfer equations have been solved assuming a two-point boundary condition for a spherically symmetric cloud of dust and gas. Based on the boundary conditions, we have constructed three types of models. In model A the cloud is heated by centrally embedded sources and by an external radiation field due to the average Galactic interstellar radiation field (ISRF) and nearby stars. In model B the cloud is heated by internal sources and the ISRF only. In model C there is no embedded source; the cloud is heated only externally by the ISRF and radiation due to nearby stars. The contribution of the nearby star in models A and C has been calculated in the following way. The geometrically diluted stellar radiation intercepted by the cloud surface is estimated and then smeared out uniformly over the entire surface of the cloud. This calculated contribution could be a slight overestimate since the absorption in the intervening medium has been neglected. For modeling the observed spectral energy distribution (SED), two types of dust have been considered. The dust properties have been taken from two sources, viz., Draine & Lee (1984, hereafter DL) and Mezger, Mathis, & Panagia (1982, hereafter MMP). The dust compositions include mixtures of astronomical silicate and graphite. For the DL type of dust grains, size-averaged properties are used, taking a size distribution of $n(a) \sim a^{-3.5}da$ (Mathis, Rumpl, & Nordsieck 1977), with $a$ ranging between 0.01 and 0.25 $\mu$m. The average Galactic ISRF used for this problem has been taken from Mathis, Mezger, & Panagia (1983). The cloud is parameterized by the following physical quantities: $R_{\text{max}}$, the outer size of the cloud; $R_{\text{rad}}$, the radius of the inner dust cavity; $\tau_{100}$, the total radial optical depth at 100 $\mu$m; and the radial dust (hence gas) density distribution ($r^\beta$, $\beta = 0$, $-1$, $-2$). The contributions of ISRF and the external source (if any) are kept fixed, while the luminosity of the embedded source, the dust composition, the value of $\tau_{100}$, the radial distribution of the dust density, and the physical sizes of the cloud are varied to obtain a good match to observations. The gas-to-dust ratio has been assumed to be 100:1 by mass. Using this scheme, a best-fit model matching the observed SEDs, radial profiles at selected wavelengths, and the radio continuum flux are obtained. These radiation transfer calculations have been done using a modified version of the code CSDUST3 (Egan, Leung, & Spagna 1988), which is capable of treating gas and dust in a self-consistent manner (Mookerjea et al. 1999; Mookerjea & Ghosh 1999).

In the following subsections we explore the tenability of the models A, B, and C in the light of available observational constraints for individual sources.

4.2. IRAS 00494$+5617$

4.2.1. The Main Source

The observed SED for the source IRAS 00494$+5617$ has been constructed using the flux densities presented in Table 1 along with flux densities at 1.3 mm (Henning et al. 1994) and 2.9 mm (Walker, Adams, & Lada 1990). The total observed luminosity is $2.4 \times 10^4 L_\odot$ (Carpenter, Snell, & Schloerb 1990), and no radio continuum emission is detected at 8.4 GHz (Tofani et al. 1995) from this cloud. The $T(143/185)$ map shows enhanced temperature toward the boundary closer to HD 5005. In order to explain this, the embedded source in radiation transfer models A and B is assumed to be a cluster of stars. In models A and C, an intercepted luminosity of $6.9 \times 10^3 L_\odot$ from HD 5005 has been considered. For each type of model, it is found that the best fit is obtained for the case of uniform density and grains of DL type. Figure 5 shows the observed and the best-fit SEDs. Model A fits the SED at all wavelengths very well, while model B shows some mid-infrared excess. Model C fails to reproduce any of the observed flux densities. The predicted radial profiles (as obtained by convolving the model profiles with instrumental PSFs) for models A and B are almost similar. Table 3 compares the FWHMs predicted by model A with those observed at 25, 60, 100, 143, and 185 $\mu$m. The observed FWHMs presented here refer to the FWHMs for the source along its major and minor axes. We
find that model A not only fits the observed SED better than model B but also achieves an overall consistency by supporting the role of HD 5005 in heating the cloud and fitting the observed FWHMs reasonably well. Table 4 presents the parameters of the best-fit model A for this source along with the uncertainties in \( \tau_{100} \) and the embedded luminosity. These uncertainties have been estimated using only the SED fit and keeping the other parameters fixed. From this radiation transfer modeling and the \( T(143/185) \) map, we conclude that the source IRAS 00494+5617 is primarily heated by one or more embedded sources with non-negligible contribution from HD 5005.

We compare the FWHM predicted from the best-fit spherically symmetric model with the observed FWHM along the minor axis. For IRAS 00494+5617 we find that at 100, 143, and 185 \( \mu \text{m} \), model predictions for FWHMs match the observed FWHMs (along the minor axis) fairly well. However, at 25 \( \mu \text{m} \) (which traces much hotter dust) the observed FWHM is substantially larger than the model prediction. This trend is also seen at 60 \( \mu \text{m} \), although not to the same extent as at 25 \( \mu \text{m} \). This can be explained by invoking spatially distributed heating sources embedded in clumps. It may be noted that our dust temperature maps also show the presence of two temperature enhancements. This clumpiness is also substantiated by high-resolution C\(^{18}\)O observations by Megeath & Wilson (1997), which have revealed that this western fragment of NGC 281 is composed of three clumps. The best-fit model A obtained above corresponds to a gas density of 2.2 \( \times \) \( 10^4 \) \( \text{cm}^{-3} \) (for a gas-to-dust density ratio of 100:1 by mass) and a total mass of 1890 \( M_\odot \). Megeath & Wilson (1997) obtain 1080 \( M_\odot \) as the lower limit for the total mass in the three clumps. The residual mass (810 \( M_\odot \)) as predicted by the model can be present in the form of the interclump medium.

### Table 3

**Comparison of Model Predictions of FWHMs with Observations**

| Source                     | \( \lambda \) (\( \mu \text{m} \)) | Model (arcmin) | Observations (Major × Minor) (arcmin) |
|----------------------------|---------------------------------|---------------|-------------------------------------|
| IRAS 00494+5617……          | 25                             | 0.6           | 1.8 \times 1.6                      |
|                            | 60                             | 1.0           | 2.6 \times 1.8                      |
|                            | 100                            | 2.2           | 2.3 \times 2.0                      |
|                            | 143                            | 2.3           | 3.4 \times 2.3                      |
|                            | 185                            | 2.5           | 2.3 \times 1.8                      |
| IRAS 05327−0457……          | 60                             | 1.5           | 5.5 \times 2.2                      |
|                            | 100                            | 2.8           | 7.3 \times 3.1                      |
|                            | 143                            | 2.7           | 5.0 \times 1.8                      |
|                            | 185                            | 3.0           | 3.2 \times 1.9                      |

ed radii (taking the distance to the source to be 2.9 kpc) of the clumps were given by Megeath & Wilson (1997), assuming the clumps to be spherical. We assume that all three clumps are spherical and are confined within the boundary of the spherical model A above. After scaling the clump sizes to our assumed distance of 2.2 kpc, we find that the volume filling factor is 4.5%. Using the total mass from our model A and assuming an interclump medium of uniform density, we obtain a value of 4.5 \( \times \) \( 10^3 \) \( \text{cm}^{-3} \) for the number density of the interclump medium. We also calculate the clump-interclump density contrast to be \( \sim 80 \). The resultant clump density of 3 \( \times \) \( 10^5 \) \( \text{cm}^{-3} \) is consistent with the detection of C\(^{34}\)S. Although the estimates presented here are based on crude approximations, the values for filling factors of clumps and clump-interclump density contrast obtained here can be called very typical when compared with the measured values of such parameters for other clumped sources (Howe et al. 1991).

#### 4.2.2. Diffuse Emission

The 143 \( \mu \text{m} \) map of this region shows a considerable amount of diffuse emission, particularly toward the west. This emission is to a certain extent positionally coincident and structurally similar to that in the 185 \( \mu \text{m} \) map. We have looked into the possible energy sources for this emission. The flux densities (in an aperture of 2' diameter centered at 049°09', +56°17'30" [1950]) at 143 and 185 \( \mu \text{m} \) are 236 and 265 Jy, respectively. The bolometric luminosity of the diffuse emission over a diameter of 2' has been estimated to be \( \sim 870 \, L_\odot \). This luminosity cannot be explained by heating by either the average ISRF or the star cluster HD 5005. We explore the possibility of radiation actually leaking from the main source (around IRAS 00494+5617) and heating the dust in the neighborhood. Under this assumption, we obtain that about 8% of the total luminosity of the embedded source would have to be intercepted by the region where diffuse emission is detected. The separation between the region of diffuse emission and IRAS 00494+5617 is such that the solid angle covered by the diffuse region is adequate to intercept the requisite amount of radiation. This evidence of luminosity leakage further supports the presence of clumpiness discussed in §4.2.1.

### Table 4

**Parameters for the Best-Fit Radiation Transfer Model**

| Source                     | \( \beta \) (pc) | \( R_{\text{max}} \) (pc) | \( R_{\text{min}} \) (pc) | Dust Type | \( \tau_{100} \) (\( 10^3 \) \( L_\odot \)) | Silicate : Graphite Dust Composition (%) |
|----------------------------|-----------------|------------------|-----------------|-----------|-----------------|----------------------------------------|
| IRAS 00494+5617……        | 0.0             | 1.2              | 0.0001          | DL*       | 0.1 \( \pm \) 0.01 | 12 \( \pm \) 2                           | 32:68                                  |
| IRAS 05327−0457……        | 0.0             | 0.35             | 0.0001          | MMPab     | 0.03 \( \pm \) 0.005 | 2.8 \( \pm \) 0.2                       | 11:89                                  |

* Draine & Lee 1984.

b Mezger, Mathis, & Panagia 1982.
to be a zero-age main-sequence B2.5 or later type star. Based on their observations, Kutner et al. (1985) have suggested that 42 Ori plays the most significant role in fueling the FIR emission from this source. However, the $T(143/185)$ map presented here shows no temperature enhancement toward the boundary illuminated by the star 42 Ori. It rather shows an increase from the boundary toward the position of IRAS 05327$-4047$.

We have applied the radiation transfer models A, B, and C (see § 4.1) to IRAS 05327$-4047$. The embedded source for models of type A and B is taken to be a star of type B2. In models of types A and C the intercepted contribution of 600 $L_\odot$ from 42 Ori is considered. Figure 6 presents the SEDs predicted from models A, B, and C in comparison with the observations. The model outputs shown are the best fits for each type. As in the case of IRAS 00494$+5617$, uniform density gives the best fit for all three models. Furthermore, the MMP type grains lead to better fit than the DL type grains. While the predicted SED from model A matches the observations at all wavelengths reasonably well, model B predicts fluxes less than the observed values longward of 60 $\mu$m. Predictions from model C do not fit the observations at all. The predicted FWHMs (postconvolution) are similar for models of type A and B. Table 3 presents the comparison of FWHM sizes from model A at different wavelengths with observations. From model A, the predicted radio continuum emission at 5 GHz is $\sim 14$ mJy, which is well above the sensitivity of the VLA observations by Kutner et al. (1985). There are several possible reasons for this nondetection. (1) The embedded source is a cluster of stars (with masses less than that of a B2 star) with combined luminosity equal to that of a B2 star. This is supported by the detection of multiple stars in the near-infrared (Makinen et al. 1985). They have detected seven stars having a total luminosity of $2.3 \times 10^3 L_\odot$ (model A total luminosity $= 2.8 \times 10^3 L_\odot$). Our temperature map also indicates the presence of two sources, again close to the boundary. (2) Since the radio continuum emission has a strong $n_e^2$ dependence, a smaller gas-to-dust ratio could explain the reduced emission. (3) The radio emission could largely be attenuated by free-free absorption. The third possibility proposed would arise if the gas density distribution very close to the star ($r \approx R_{\text{min}}$) is $r^{-2}$, a typical situation for ionized wind.

Of the models presented here, model A explains the observed SED, the radial profile, the $T(143/185)$ map, and the role of 42 Ori in heating the cloud most satisfactorily. Table 4 presents the parameters of this model and the estimated uncertainties in the embedded luminosity and $\tau_{100}$. From radiation transfer modeling we conclude that it is absolutely necessary to have an embedded source to explain the total emission from IRAS 05327$-4047$. Clearly, 42 Ori cannot be the only heating source, since the luminosity intercepted by IRAS 05327$-4047$ is $\lesssim 20\%$ of the observed luminosity. Furthermore, we have verified that the temperature profile from radiation transfer calculation using a slab geometry and 42 Ori as the source does not fit observations.

The observed angular sizes for IRAS 05327$-4047$ at 100 $\mu$m and more prominently at 60 $\mu$m are larger than the model values. As in IRAS 00494$+5617$, this is again consistent with a distribution of embedded hot sources, as suggested by the $T(143/185)$ map (Fig. 4). The apparent reduction in the observed FWHMs at 143 and 185 $\mu$m as compared to the FWHM at 100 $\mu$m could be due to the effect of sky chopping.

5. SUMMARY

This paper presents simultaneous FIR mapping observations at 143 and 185 $\mu$m of the regions around IRAS 00494$+5617$ and IRAS 05327$-4047$. Both sources have been well resolved at these wavelengths. The cold dust source CSO 10 located in OMC-3 (Lis et al. 1998) has also been detected in our map of IRAS 05327$-4047$. HIRES-processed $IRAS$ maps in all four bands have been used for comparison. Reliable dust temperature [$T(143/185)$] and optical depth ($\tau_{150}$) maps for these sources are presented. Radiation transfer models have been constructed to explain the observed SEDs, the radial profile, and the influence of external heating agencies for both these sources. These models provide useful physical parameters for the star-forming clouds associated with these sources. For both IRAS 00494$+5617$ and IRAS 05327$-4047$ it has been demonstrated that, although HD 5005 and 42 Ori contribute to their heating, respectively, to explain the observed SEDs the dominant contribution must come from embedded sources. Comparison of predicted radial profiles from models with observations suggest the presence of a distribution of embedded clumps in both sources. This is corroborated by spatially resolved peaks in the maps of dust temperature. A simplistic model for the clumpiness of IRAS 00494$+5617$ has been proposed based on parameters derived from radiation transfer models and previous molecular line observations.

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REFERENCES

Aumann, H. H., Fowler, J. W., & Melnyk, M. 1990, AJ, 99, 1674
Carpenter, J. M., Snell, R. L., & Schloerb, F. P. 1990, ApJ, 362, 147
Cesaroni, R., Felli, M., & Walmsley, C. M. 1999, A&AS, 136, 333
Chen, P. S., Gao, H., & Xiong, G. Z. 1995, ApJS, 100, 389
Chini, R., Reipurth, B., Ward-Thompson, D., Bally, J., Nyman, L.-A.,
Sievers, A., & Billawala, V. 1997, ApJ, 474, L135
Draine, B. T., & Lee, H. M. 1984, ApJ, 285, 89
Egan, M. P., Leung, C. M., & Spagna, G. F. 1988, Comput. Phys.
Commun., 48, 271
Elmegreen, B. G., & Lada, C. J. 1978, ApJ, 219, 467
Ghosh, S. K., Iyengar, K. V. K., Rengarajan, T. N., Tandon, S. N., Verma,
R. P., & Daniel, R. R. 1988, ApJ, 330, 928
Ghosh, S. K., Rengarajan, T. N., Verma, R. P., & Karnik, A. D. 1996, Proc.
11th IAP Astrophysics Meeting, Interplay between Massive Star For-
mation, the ISM and Galaxy Evolution, ed. D. Kunth, B. Guiderdoni,
M. Heydari-Malayeri, & T. X. Thuan (Gif-sur-Yvette: Editions
Frontieres), 499
Gull, S. F., & Daniell, G. J. 1978, Nature, 272, 686
Henning, Th., Martin, K., Reimann, H.-G., Launhardt, R., Leisawitz, D., &
Zinnecker, H. 1994, A&A, 288, 282
Howe, J. E., Jaffe, D. T., Genzel, R., & Stacey, G. J. 1991, ApJ, 373, 158
Kutner, M. L., Evans, N. J., & Tucker, K. D. 1976, ApJ, 209, 452
Kutner, M. L., Machnik, D. E., Mead, K. N., & Evans, N. J. 1985, ApJ, 299,
351
Lis, D. C., Serabyn, E., Keene, J., Dowell, C. D., Benford, D. J., Phillips,
T. G., Hunter, T. R., & Wang, N. 1998, ApJ, 509, 299
Makinen, P., Harvey, P. M., Wilking, B. A., & Evans, N. J. 1985, ApJ, 299,
341
Mathis, J. S., Mezger, P. G., & Panagia, N. 1983, A&A, 128, 212
Mathis, J. S., Rumph, W., & Nordseeck, K. H. 1977, ApJ, 217, 425
Megeath, S. T., & Wilson, T. L. 1997, AJ, 114, 1106
Megeath, P. G., Mathis, J. S., & Panagia, N. 1982, A&A, 105, 372
Mookerjea, B., & Ghosh, S. K. 1999, J. Astrophys. Astron., 20, 1
Mookerjea, B., Ghosh, S. K., Karnik, A. D., Rengarajan, T. N., Tandon,
S. N., & Verma, R. P. 1998, Bull. Astron. Soc. India, 27, 155
———. 1999, ApJ, 522, 285
Snell, R. L., Dickman, R. L., & Huang, Y.-L. 1990, ApJ, 352, 139
Tofani, G., Felli, M., Taylor, G. B., & Hunter, T. R. 1995, A&AS, 112, 299
Verma, R. P., Ghosh, S. K., Karnik, A. D., Mookerjea, B., & Rengarajan,
T. N. 1999, The Universe as Seen by ISO, ed. P. Cox & M. F. Kessler
(ESA SP-427; Noordwijk : ESA), 775
Walker, C. K., Adams, F. C., & Lada, C. J. 1990, ApJ, 349, 515