IRAS observations of two early-type pre-main-sequence stars in the association Chamaeleon I

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IRAS[1] OBSERVATIONS OF TWO EARLY-TYPE PRE–MAIN-SEQUENCE STARS IN THE ASSOCIATION CHAMAELEON I

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ABSTRACT

The most massive stars in the Chamaeleon I dark cloud, HD 97048 (A0 pe) and HD 97300 (A0 V), both associated with prominent reflection nebulae, were observed by *IRAS* at 50 and 100 μm, with 1'.2 resolution. Both stars show large far-infrared fluxes from circumstellar dust and material in the reflection nebulae. At least one other source is embedded within the Cha I cloud close to HD 97300.

Subject headings: infrared: sources — stars: circumstellar shells — stars: early-type — stars: massive

I. INTRODUCTION

HD 97048 and HD 97300 are the most massive stars of the Cha I star formation region. HD 97300 is thought to belong to the Cha I association because it illuminates the reflection nebula Cederblad 112, and it is classified as a zero-age main-sequence (ZAMS) A0 V star by Grasdalen *et al.* (1975). Its visual magnitude is 9.05 mag. HD 97048 ($V = 8.45$ mag) is a spectrum variable of type A0 pe (Irvine and Houk 1977). It is a Herbig Ae/Be star having no line emission in the blue spectral region, but with Hα in emission.

Both stars were observed with the chopped photometric channel (CPC) at 50 and 100 μm in order to obtain maps with the highest spatial resolution that *IRAS* offers. For HD 97048, *IRAS* survey data are available (Neugebauer *et al.* 1984, hereafter Paper I), providing photometry down to 12 μm.

II. CPC OBSERVATIONS

The observations consist of a series of parallel scans fully covering a rectangular area of sky. In the maps presented here, the scans are separated by 30″, and the integration interval translates into a motion of 12″.

The observations are listed in Table 1. Figures 1 and 2 show single observations of both stars. The maps are oriented with the scan direction running vertically. The preliminary photometric calibration is accurate to 30%; the positional accuracy of the maps is 20″.

Some very narrow peaks, attributed to detector spiking, were deleted from the maps. The remaining features were all confirmed by comparing repeated observations. In addition, comparison with preliminary results from *IRAS* observations using the smallest survey detectors (Paper I) qualitatively confirmed all detected features.

The maps of HD 97048 prominently show emission from the star near the field center. Three other features can be readily identified with stars visible on the photograph published by Glass (1979). The features at map positions $(-1, 4.5)$ and $(-0.5, -1)$ correspond to the emission-line stars VW Cha and CD $-76°486$ (Henize and Mendoza 1973). The source at $(4, -4)$ corresponds to star I of Glass, a "field star" with a pronounced near-infrared excess.

The maps of HD 97300 show extended structure, much larger at 100 μm than at 50 μm. The (1, 0.5) peak at 50 μm is close to the position of HD 97300 as given by Hyland, Jones, and Mitchell (1982). Probably the CSI (Ochsenbein 1979) position ($\alpha = 11^h08^m18^s$, $\delta = -76°21'00''$) is wrong. (The position from Hyland *et al.* appears in Table 1.) The second 50 μm peak coincides with two pre–main-sequence (PMS) stars studied by Hyland *et al.*, H23 and H24. The infrared flux suggests that at least one of these stars has a luminosity comparable to HD 97300. Alternatively, yet another source, not observable shortward of 2 μm, could be embedded in Cederblad 112. The feature at $(-3, 0)$ was seen in both 100 μm observations.

Half-widths for both sources, corrected for instrumental broadening, are listed in Table 2. Clearly, the half-widths do not account for the low-level extents seen in the maps. This is particularly true for the weak 100 μm emission around HD 97300, which extends over an area of $5' \times 7'$, comparable to the size of Cederblad 112.

III. RESULTS

The CPC flux densities given in Table 2 were obtained by integrating above the lowest brightness contour clearly delineating the source. For HD 97048, for which survey data are available, flux densities in the four survey bands (Paper I) are also listed. The agreement between CPC and survey results is

TABLE 1

CPC OBSERVATIONS

Star	α (1950)	δ (1950)	Observing Dates (1983)
HD 97048 ...	$11^h06^m39\overset{s}{.}6$	$-77°23'01''$	Feb 15 (2x)
			May 2 (2x)
HD 97300 ...	11 08 16.6	−76 20 33	Feb 22 (1x)
			Mar 17 (1x)

[1]The *Infrared Astronomical Satellite* was developed and is operated by the Netherlands Agency for Aerospace Programs (NIVR), the US National Aeronautics and Space Administration (NASA), and the UK Science and Engineering Research Council (SERC).

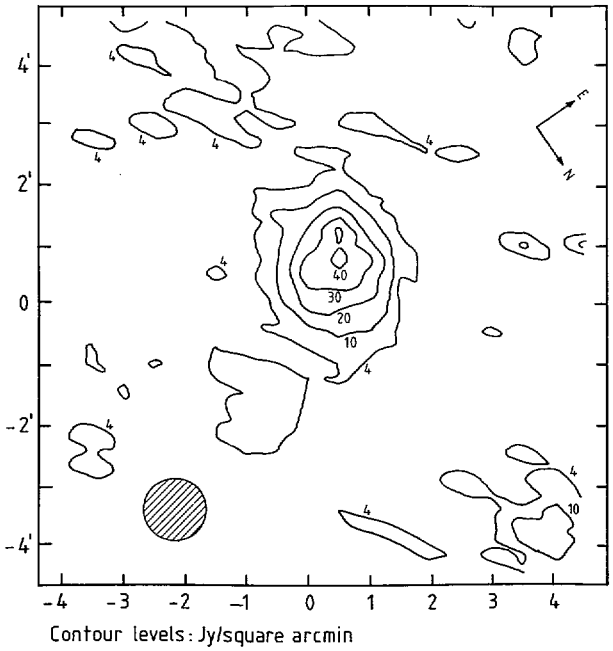

FIG. 1a

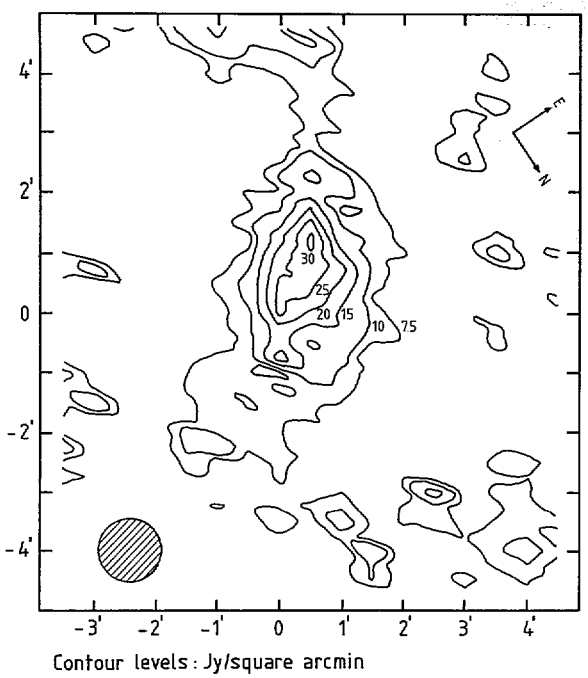

FIG. 1b

FIG. 1.—CPC maps of HD 97048 at (*a*) 50 and (*b*) 100 μm observed on 1983 May 2. The origin of the maps is at $\alpha = 11^h06^m25^s$, $\delta = -77°22'13''$. Arrows define the orientation. The hatched circles indicate the beam size.

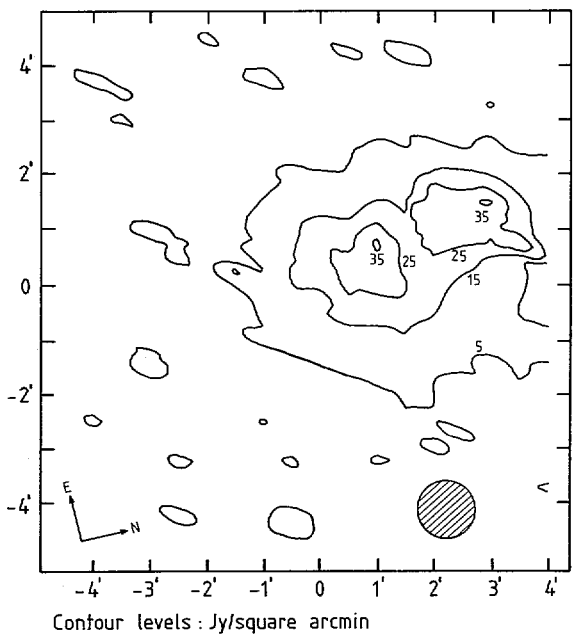

FIG. 2a

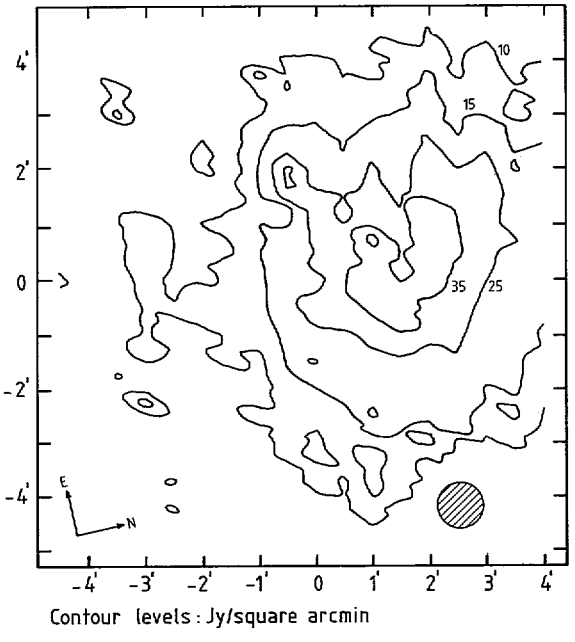

FIG. 2b

FIG. 2.—CPC maps of HD 97300 at (*a*) 50 and (*b*) 100 μm observed on 1983 February 22. The origin of the maps is at $\alpha = 11^h08^m11^s$, $\delta = -76°21'35''$. Arrows define the orientation. The hatched circles indicate the beam size.

TABLE 2

FLUX DENSITIES AND SPATIAL EXTENT

Star	Band (μm)	Flux Density (Jy)	Half-Widths[a] (arcmin)	
HD 97048 ...	12	14	...	...
	25	44	...	...
	CPC 50	100	0.8	< 0.5
	60	82	...	...
	CPC 100	130	0.9	< 0.5
	100	98	...	...
HD 97300 ...	CPC 50	260	2.0	3.5
	CPC 100	640	2.2	2.3

[a]Half-widths are measured parallel and perpendicular to the scan direction.

TABLE 3

BAND-TO-BAND TEMPERATURES

Star	Band (μm)	T_0	T_1	T_2
HD 97048 ...	12–25	195	165	140
	25–60	110	90	70
	CPC 50–100	65	48	39
	60–100	65	47	38
HD 97300 ...	CPC 50–100	49	39	33

NOTE.—T_n is the temperature obtained assuming emissivity to be proportional to ν^n.

good, considering that the point-source templates used in the survey data analysis do not accommodate all of the extent present in the CPC maps.

Table 3 characterizes the spectra in terms of dust temperatures derived from band-to-band flux ratios, assuming grain emissivities proportional to ν^0, ν^1, and ν^2. Clearly, temperatures vary appreciably within the cloud around HD 97048, as indeed they should, with the spatial distribution so dependent on wavelength. (The 12 μm and 25 μm sizes must be less than about 1′ for the source to be accepted as a point source.) The outer parts of the emitting regions in both maps, with 100 μm emission dominating, must be cooler than 40 K.

In order to obtain far-infrared luminosities, we assume a distance of 215 pc to the Cha I dark cloud. Combining survey and CPC data, the far-infrared flux of HD 97048 adds up to 18 $L_\odot$. The emission around HD 97300 within the CPC bands amounts to 25 $L_\odot$. If its infrared spectrum is as broad as observed for other PMS stars, its total far-infrared luminosity should be at least 50 $L_\odot$. Depending on the relative contribution of the second embedded source, the far-infrared output from HD 97300 should be 25 $L_\odot$ or more. (The 50 μm map of HD 97300 suggests about equal contributions from the two different sources.)

The far-infrared luminosities constitute more than 20% of the total luminosities of HD 97048 and HD 97300, which we estimate to be 80 $L_\odot$, the luminosity of an A0 V star (Allen 1973). These two stars are on, or very close to, the ZAMS and, therefore, are certainly not superluminous as younger PMS stars would be. Baud *et al.* (1984) find lower fractions (5%–20%) for the lower mass A and K PMS stars in Cha I.

IV. CONCLUSION

The CPC observations show that HD 97048 and HD 97300 are embedded in large dust complexes that absorb and reemit 20% or more of the stellar radiation. The dust around HD 97048 emits at temperatures ranging from 1500 K close to the star to less than 40 K at a distance of 0.1 pc. The emission around HD 97300 is very extended, reaching out at 100 μm to a distance of 0.2 pc. An unknown fraction of that emission is due to a second embedded source close to HD 97300.

These two stars were presumably formed out of the massive concentration of gas and dust in the Cha I complex. After their formation, a large fraction of the material in the original concentration was left over. In contrast, the G and K type PMS stars are surrounded by relatively little dust (Baud *et al.* 1984). This might imply that the formation of massive stars is less efficient than that of lower mass stars.

We thank Dr. P. S. The for his advice and interest in this study, and the members of the CPC processing team for their efforts to produce these maps. For the analysis of the CPC maps, we used the Groningen Image Processing System developed by the radio astronomy group of the Kapteyn Institute.

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