

## 40-350 MICRON OBSERVATIONS OF GALACTIC SOURCES

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### ABSTRACT

Broad-band 40-350  $\mu$  measurements are reported for 31 sources observed with a balloon-borne telescope. All but one of the sources have been identified with galactic H II regions, of which about one-third are optically visible. The objects include W3 (three components), W49, RCW 36, RCW 38, and 24 sources lying along the galactic plane between  $l^{\text{III}} = 327^\circ$  and  $349^\circ$ . Most of these sources have not previously been observed in the far-infrared. A contour map of the W3 region shows an emission arm extending from the main continuum component.

*Subject headings:* infrared sources — nebulae

### I. INTRODUCTION

A further three flights of the University College London balloon-borne telescope were made during 1973 April-May at the National Scientific Balloon Facility, Palestine, Texas. These flights continued the program of 40-350  $\mu$  observations of objects mainly along the galactic plane. This paper describes the observations made on one of the flights and includes a map of the W3 region, together with broad-band fluxes measured from RCW 36, RCW 38, W49, and 24 objects which lie along the galactic plane between  $l^{\text{III}} = 327^\circ$  and  $349^\circ$ . The identification of these sources with radio and optical nebulae is discussed and comparisons with other infrared observations made. More detailed discussion of these and other data with respect to dust-grain models appears elsewhere (Furniss *et al.* 1974).

Contour maps of the W51 and galactic center regions, also obtained on this flight, are being prepared separately for publication. Preliminary maps of these regions and a low-resolution spectrum of G49.5-0.4 in W51 obtained with a Michelson interferometer have already been presented (Alvarez *et al.* 1974).

### II. TELESCOPE AND 40-350 MICRON PHOTOMETER

The telescope and photometry systems used were essentially the same as described by Furniss *et al.*

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(1972), although several minor changes have resulted in improved guidance and flux sensitivity. One substantial change made prior to the 1973 flights was the replacement of the previously used "circular" sky chopping system by a conventional "linear" system achieved by magnetically driving the telescope secondary mirror to give a beam throw in cross elevation. This change was introduced primarily to aid the mapping and spectroscopic observations. Accurate phasing of this system was achieved by ground command during observation of Saturn. Signal and telescope-position information was recorded at the ground via telemetry in both analog and digital form on magnetic tape, and additionally on strip-chart recorders.

Table 1 lists the major instrumental parameters.

### III. OBSERVATIONAL PROCEDURE

The objects selected for observation on this flight were mostly H II regions which were either specifically searched for (e.g., W3, RCW 36, RCW 38, W49) or were identified later from raster scans in complex regions such as Norma. Typically 15 to 20 overlapping azimuth scans were made around each object to determine the position and magnitude of the peak flux. For each guide star, corrections were made during the data analysis to reduce any pointing bias, by allowing for any changes in balance of the gondola and for weaker stars in the star-tracker field of view, and by making use of the positions of any visible stars

TABLE 1  
 INSTRUMENTAL PARAMETERS

Telescope optics.....	40 cm aperture, f/5.5 Dall Kirkham
Guidance.....	Magnetometer and offset ( $\pm 5^\circ$ ) star-tracker
Pointing stability.....	Typically 30" rms ( $m \geq 4$ )
Pointing accuracy.....	$\sim 1.5$ rms
Sky chopping.....	5' beam throw in cross elevation
Half-power beam width.....	4'
Wavelength range.....	40-350 $\mu$
Noise equivalent flux.....	$\sim 10^{-10}$ W m $^{-2}$ under flight conditions

TABLE 2  
SUMMARY OF OBSERVATIONS

UCL NUMBER	INFRARED POSITION		RADIO IDENTIFICATION			40-350 MICRONS		
	$\alpha$ (1950)	$\delta$ (1950)	G Number	Name	$D$ (kpc)*	Peak Flux ( $10^{-10} \text{ W m}^{-2}$ )	$L/10^5 L_{\odot}$	Size (arcmin)
4.....	2 <sup>h</sup> 22 <sup>m</sup> 00 <sup>s</sup>	61°52'9"	133.7+1.2	W3	3.1 <sup>1</sup>	38.9	11.7	2
4a.....	2 23 18	61 39.2	133.9+1.1	W3(OH)	3.1 <sup>1</sup>	10.7	3.2	
4b.....	2 23 06	62 02.5	133.8+1.4	W3(N)	3.1 <sup>1</sup>	5.9	1.8	
18a.....	16 57 02	-40 32.1	345.2+1.0	IC 4628	1.2	17.5	0.8	2
19.....	16 37 29	-46 26.9	338.3-0.1		...	8.5	...	
20.....	16 37 31	-47 03.8	337.9-0.5		3.5	16.9	6.5	2
21.....	16 33 00	-47 22.7	337.1-0.2		5.7	7.4	7.5	
22.....	16 18 39	-49 55.9	333.6-0.2		3.7	48.5	20.8	2
23.....	16 18 06	-50 15.1	333.3-0.4		3.9	18.7	8.9	
24.....	16 17 38	-50 28.2	333.1-0.4		4.1 <sup>2</sup>	23.1	12.1	2
25.....	16 16 59	-50 30.7	333.0-0.4		4.2	20.1	11.1	
26.....	16 16 35	-50 45.8	332.8-0.6	RCW 106	4.3	14.7	8.5	2
27.....	16 16 15	-50 54.1	332.7-0.6	RCW 106	3.6	9.0	3.7	
28.....	16 12 55	-51 09.8	332.2-0.4		4.1 <sup>3</sup>	7.0	3.7	2
29.....	16 08 14	-51 20.0	331.5-0.1		6.5 <sup>3</sup>	15.8	20.9	
30.....	16 07 30	-51 22.1	331.4-0.0		5.8	11.3	11.9	2
31.....	16 05 44	-51 49.4	331.0-0.1		6.6	14.1	19.2	
32.....	16 06 21	-52 01.0	330.9-0.4		4.2	11.3	6.2	2
33.....	15 55 08	-53 37.6	328.6-0.5	RCW 99	...	12.5	...	
34.....	15 49 51	-54 26.8	327.3-0.5	RCW 97	3.5	28.8	11.0	2
34a.....	15 49 00	-54 25.2						
35.....	9 00 05	-47 31.7	268.4-0.8		...	12.5	...	3
36.....	8 57 21	-47 17.7	268.0-1.1	RCW 38	1.5 <sup>5</sup>	41.5	2.9	
37.....	8 57 42	-43 35.9	265.1+1.5	RCW 36	1.5 <sup>5</sup>	15.5	1.1	1.5
39.....	19 08 27	9 01.5	43.2-0.0	W49	13.9 <sup>4</sup>	37.2	224.7	
41.....	17 13 06	-37 54.9	349.1+0.0		...	6.2	...	1.5
42.....	17 08 45	-38 31.5	348.2+0.5	RCW 120	...	6.5	...	
43.....	17 08 18	-39 06.4	347.6+0.2		7.9	8.3	16.2	2
43a.....	17 07 54	-39 05.7						
44.....	17 02 54	-40 49.1	345.6-0.0		...	8.2	...	1.5
45.....	17 01 00	-40 43.1	345.5+0.3		...	19.2	...	

\* Distances are from Wilson *et al.* 1970 except where indicated. Superscripts refer as follows: (1) Reifenstein *et al.* 1970; (2) Goss *et al.* 1972; (3) Shaver and Goss 1970; (4) Schraml and Mezger 1969; (5) Radhakrishnan *et al.* 1972.

(>8 mag) seen by the focal-plane optical detector. The final estimated rms position error is around 1'.5.

Observations of both Saturn and Jupiter were used to determine the beam response, chopper throw, and flux sensitivity of the system. Saturn was observed at the beginning of the flight and Jupiter about halfway through. In each case more than 20 closely spaced scans were made. Jupiter was adopted for the actual flux calibration and has been assumed for this purpose to radiate as a blackbody at 135 K. The calibration procedure also uses the relative spectral response of the photometer measured with a Michelson interferometer, and assumes a color temperature of 80 K throughout for the sources. Varying the adopted Jupiter temperature by  $\pm 5$  K gives rise to a  $\pm 7$  percent change in the calculated fluxes, while changing the source color temperatures by  $\pm 20$  K changes the fluxes by  $-5$  percent and  $+8$  percent, respectively. Overall flux accuracy is estimated at  $\pm 20$  percent.

#### IV. RESULTS

Positions and 40-350  $\mu$  fluxes for the objects detected are given in Table 2. The new observations of the W3 region are listed first, and a map of this region constructed from the scans is shown in Figure 1. The

UCL source numbers assigned to the remaining sources follow on in order of galactic longitude from our previous observations (Emerson *et al.* 1973, hereafter EJM). Column (4) gives the G numbers of the radio sources with which the infrared sources have been identified, and column (5) the radio name or optical identification. Assuming the estimated infrared rms pointing accuracy of 1'.5 and taking the rms radio position errors as typically 0'.5, 28 of the 31 infrared sources listed are within  $3\sigma$  of the radio positions. In general, however, several objects were observed from the same guide star, and overlays of the infrared position on radio maps of the regions reveal a residual systematic displacement between the positions. The identifications made, therefore, are rather more positive than indicated by a straight statistical comparison of the positions. The largest differences are for source 31, which is 9' from G331.0-0.1, and source 39, which is 8'.5 from G43.2-0.0(W49). In the case of W49, which was specifically searched for, only a small region of sky was scanned, with no visual stars being seen by the focal-plane optical detector.

The infrared fluxes given in column (7) correspond to the peak signals recorded, and the far-infrared luminosities in column (8) refer to the radio-source distances given in column (6).

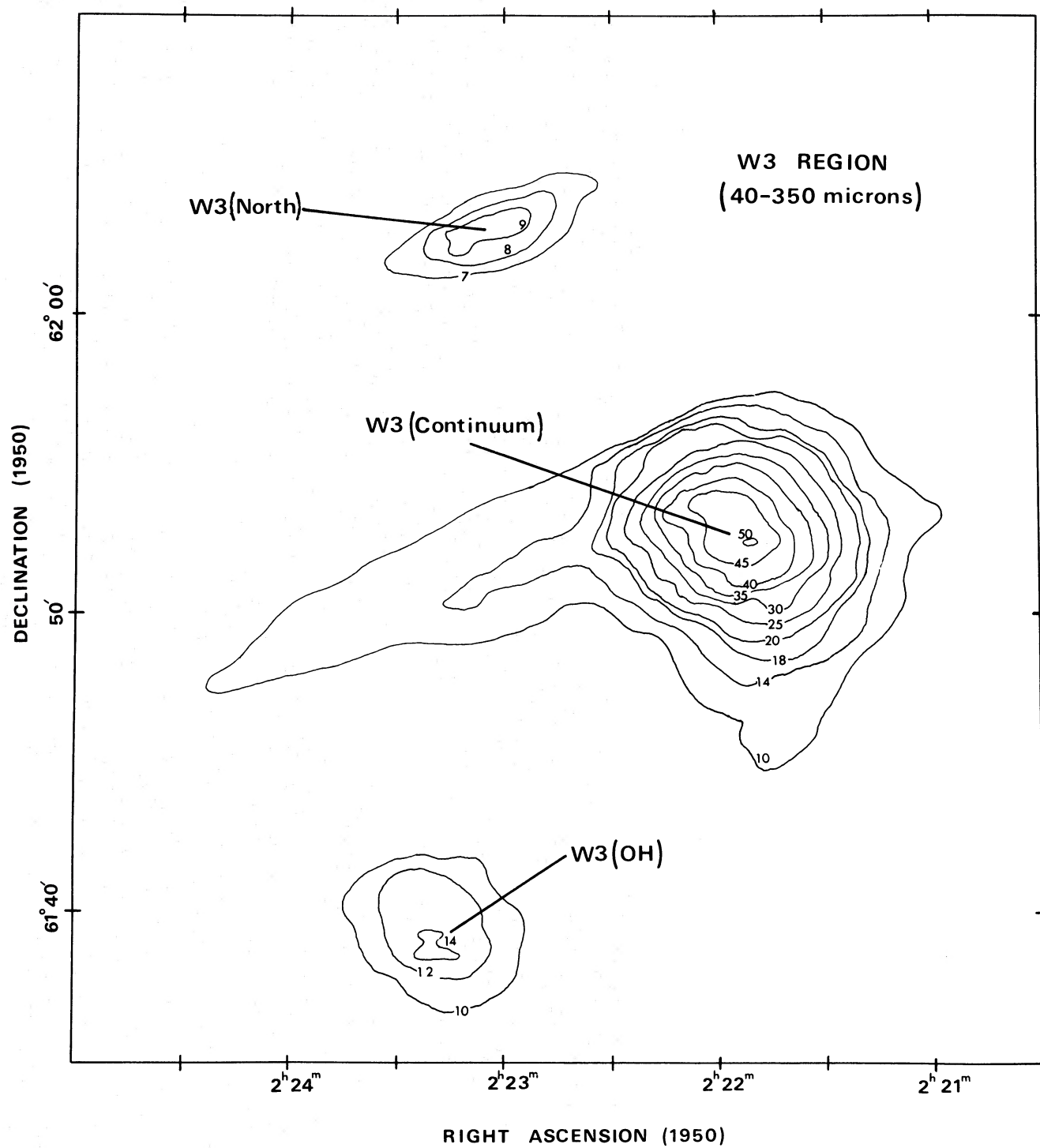


FIG. 1.—40–350  $\mu$  map of the W3 region. The effective beam size is  $5.5 \times 5.5$  ( $\alpha \times \delta$ ). Contours normalized to 50 for peak value of W3 continuum.

TABLE 3  
BRIGHTEST RADIO SOURCES NOT DETECTED TO A  
LEVEL OF  $3 \times 10^{-10} \text{ W m}^{-2}$

G Number	5 GHz Flux (Jy)	Remarks
338.1-0.2.....	6.3	
338.1+0.0.....	7.3	
338.0-0.1.....	11.1	
337.8-0.1.....	7.2	
337.5-0.3.....	5.7	
336.5-0.2.....	14.2	
336.4-0.2.....	7.6	RCW 107
333.2-0.1.....	12.3	
332.4-0.4.....	13	RCW 103, non thermal
49.1-0.4.....	15	

For a few sources, approximate sizes have been estimated by assuming Gaussian distributions for the source and beam shape (i.e.,  $\theta_s^2 = \theta_M^2 - \theta_B^2$ ). These are given in the last column.

Table 3 lists the brightest of the radio sources which were included in the scans but not detected.

#### V. DISCUSSION AND INDIVIDUAL SOURCES

##### a) W3/IC 1795

The 40-350  $\mu$  map constructed from scans of this region is shown in Figure 1.<sup>1</sup> Effects of sky chopping have been removed along the scanning direction by deconvoluting the scans with the system response determined on Jupiter. The effective beam size ( $\alpha \times \delta = 5'.5 \times 5'.5$ ) is larger than the actual 4' beam used on the sky due to the averaging procedure used in correlating the results from adjacent scans. For W3 (continuum), the flux quoted is within 15 percent of both our previous measurement (EJM) and that of Harper (1974).

The three distinct emission regions observed agree in position, to within 1', with the centers of the radio components on the 2-cm map of Schraml and Mezger (1969). One feature which does not appear either on the 2-cm map or on a recent 69  $\mu$  map obtained by Fazio *et al.* (1974) is the pronounced extension to the main continuum component, which coincides with the optically visible nebula IC 1795. We intend to re-scan this region in greater detail to determine whether this extension is real. Comparison with a map of W3 in brightness-temperature contours for CO emission (Wilson 1974) indicates emission from the CO cloud in this region, but there is also a trend for the CO contours to extend up toward the northern component G133.8+1.4 (UCL source 4b). In addition, recent measurements reported at the Mittelberg Symposium on H II Regions and Related Topics (January 1975) also show a radio-continuum extension from W3 in the same direction as that in the far-infrared.

Within the main continuum component, Wynn-Williams *et al.* (1972) observed seven sources radiating in the 1.6-20  $\mu$  range, and deduced the existence of locally obscuring dust external to the ionized gas. Their

<sup>1</sup> This map differs slightly from the preliminary map presented at the 8th ESLAB Symposium.

identification of one of the sources as a heavily reddened O5 star has recently been confirmed by Beetz *et al.* (1974), who also found a second O5 star nearby. Scaling the far-infrared flux to the size of 2' and adopting an 80 K distribution to allow for the energy radiated below 40  $\mu$  gives the total infrared luminosity as  $\sim 2 \times 10^6 L_\odot$ , which exceeds the combined luminosity  $\sim 1.35 \times 10^6 L_\odot$  of two O5 stars (Panagia 1973). If Aitken and Jones (1973) are correct, however, in their conclusion that IRS-5 is a dust-embedded protostar radiating  $\sim 5 \times 10^5 L_\odot$ , then the observed total luminosity can almost be accounted for. As the Lyman continuum output of two O5 stars is double that required to account for the separated 2-cm flux measured by Schraml and Mezger, there could be absorption of Ly $\alpha$  photons by dust within the ionized region.

W3(OH) is a weaker continuum source but the strongest center of OH emission in the region, and it contains an H<sub>2</sub>O maser. The far-infrared flux reported here is slightly larger than that measured by Harper, and the ratio of far-infrared to 2-cm radio flux is a factor 3.3 higher than for W3 (continuum). The relatively weak radio flux coupled with the high infrared luminosity ( $> 3 \times 10^5 L_\odot$ ) is consistent with this being a young region surrounding a recently contracted massive star (see, for example, Mathews 1969). Wynn-Williams *et al.*, however, observed two infrared sources in this object, and recent high-spatial-resolution radio observations (Harten 1974) have revealed at least four continuum sources embedded in a faint extended component. The OH sources appear to be associated with the main cluster of continuum sources, while the H<sub>2</sub>O source is not correlated with any.

The remaining source W3(N) has not previously been measured in the infrared. There appears to be less visible obscuration in the central region of the source, and the ratio of far-infrared to 2-cm flux is only about half that of W3 (continuum).

##### b) IC 4628

G345.2+1.0 (source 18a) is a visibly obscured region of the CTB 35 complex which in turn is associated with the young optical nebula IC 4628 (Laval 1972). Far-infrared emission from G345.4+1.4, also in IC 4628, has already been reported by EJM.

##### c) The Norma Region

Sources 19 through 34a all lie along 11° of the galactic plane in the direction of the constellation Norma. The extended complex of thermal and non-thermal radio sources in this region has been surveyed at 2.65 GHz by Beard (1966) and Thomas and Day (1969), at 2.7 GHz by Day *et al.* (1969), at 408 MHz by Shaver and Goss (1970a), and at 5 GHz by Goss and Shaver (1970). All of these surveys were used to identify possible radio counterparts to the infrared sources, but the G numbers used for identification in Table 2 are those appearing in the 5 GHz catalog, except for source 33. This has been identified with G328-6-0.5 (Day *et al.* 1969) and with the optical

nebula RCW 99 (Rodgers *et al.* 1960). No distance to this source is available.

Source 19 lies within 1' of G338.3-0.1, which has been classified as nonthermal by Shaver and Goss (1970*b*) and also by Dulk and Slee (1972). There is no obvious thermal source with which to identify the infrared source, but this is a confused region and, without further observations, we cannot exclude the possibility that the signal observed is due either to G338.4-0.2 or to the edge of the extended emission region centered at G338.4+0.0. We remark also that no infrared emission was detected at the position of G332.4-0.4, which is a brighter nonthermal source than G338.3-0.1.

Sources 26 and 27 correspond to thermal peaks associated with the optically identified nebula RCW 106.

In the case of another optically identified nebula, however, RCW 97, we find two infrared peaks (sources 34 and 34a), whereas Shaver and Goss report only a single peak in the radio. This source has recently been observed from the ground in the 1-25  $\mu$  region by Frogel and Persson (1974), who found considerable structure at 10  $\mu$ , but over a much smaller area. Obviously, higher-spatial-resolution observations of this region in the far-infrared are required.

The nearest thermal radio source to source 31 is G331.0-0.2, 9' away. However, Caswell *et al.* (1974) report both H<sub>2</sub>O and OH maser sources at  $\alpha = 16^{\text{h}}06^{\text{m}}02^{\text{s}}.2$ ,  $\delta = -51^{\circ}47'30''$  and  $\alpha = 16^{\text{h}}06^{\text{m}}08^{\text{s}}.0$ ,  $\delta = -51^{\circ}47'02''$ , respectively, which only differ from our source position by approximately 3'. It is possible that source 31 should be identified with these maser sources and might be similar in nature to the northern OH emission center in NGC 6334 which has been observed at 10 and 100  $\mu$  and has very little radio continuum emission.

G333.6-0.2 (source 22) is one of the brightest radio sources (84 Jy) measured at 5 GHz by Goss and Shaver and is associated with OH and H<sub>2</sub>O line emission (Goss *et al.* 1970; Johnston *et al.* 1972). Both the radio flux and the far-infrared luminosity reported here ( $2 \times 10^6 L_{\odot}$ ) imply the presence of more than one early-type star in the region. Observations at 1-25  $\mu$  by Becklin *et al.* (1973*a*), however, reveal only a single component with a diameter of 11", compared with the 1:1 (5 GHz) and 3:1 (408 MHz) radio sizes. The 8-13  $\mu$  spectrum measured by Aitken and Jones (1974) shows clearly the Ne II line at 12.8  $\mu$ , but is otherwise featureless. They argue that the emission is due to optically thin dust containing silicates, with extinction amounting to  $\sim 1.5$  mag at 10.4  $\mu$  in a cold dust envelope which cancels the silicate emission feature. The observations of Becklin *et al.* also suggest the presence of locally obscuring dust external to the H II region. A recent optical photograph (Churms *et al.* 1974) shows optical nebulosity coincident in position and approximately the same size as the infrared (1-25  $\mu$ ) source, and a near-infrared photograph shows several starlike objects within the nebulosity.

Allowing for the energy radiated below 40  $\mu$ , the total infrared luminosity is  $\sim 3 \times 10^6 L_{\odot}$ . As the H II

region is surrounded by locally obscuring dust, this probably approximates closely the total stellar luminosity. A cluster of average spectral type O6 with this luminosity provides  $\sim 14 \times 10^{49}$  Ly<sub>c</sub> photons s<sup>-1</sup> (Panagia 1973), while, using Rubin's (1968) formula, approximately  $12 \times 10^{49}$  Ly<sub>c</sub> photons s<sup>-1</sup> are required to account for the measured radio continuum flux. In this object, therefore, it is likely that heating of grains within the H II region by direct absorption of Ly<sub>c</sub> photons is relatively unimportant, and that the bulk of the far-infrared emission originates in a shell outside the ionized gas.

G333.3-0.4 (source 23) has been measured in the range 1-25  $\mu$  by Frogel and Persson (1974), and is similar to G333.6-0.2 in consisting of a single component embedded in a region of lower surface brightness. In this case, however, the luminosity and radio continuum flux could be provided by a single O4 star.

#### d) RCW 38 and RCW 36

Three sources (35-37) were detected in the region containing the optically identified and extended nebulosities RCW 38 and RCW 36. G268.4-0.8 (Manchester and Goss 1969) is obscured in the visible, and the components G268.0-1.1 and G265.1+1.5 (Goss and Shaver 1970) are partially obscured.

Frogel and Persson (1974) have measured G268.0-1.1 in the range 1-25  $\mu$  and give  $L_{1-25} = 0.95 \times 10^5 L_{\odot}$ . Their map of the region at 10  $\mu$  shows a number of components, with a main peak 9" in diameter and with an estimated 10-20  $\mu$  color temperature of 175 K. Close to this peak they find an unresolved 2.2  $\mu$  source which they conclude could be an O4 star or cluster of later-type stars.

Scaling the peak far-infrared flux to our estimated size of 3' increases the 40-350  $\mu$  luminosity given in Table 2 to  $4.6 \times 10^5 L_{\odot}$ . Addition of the 1-25  $\mu$  luminosity as given by Frogel and Persson and making a suitable allowance for the 25-40  $\mu$  band brings the total luminosity to  $\sim 7 \times 10^5 L_{\odot}$ .

The O4 star in this complex will have a luminosity of  $1.3 \times 10^6 L_{\odot}$  (Panagia 1973). This is more than sufficient to supply the total infrared luminosity and to emit sufficient Ly<sub>c</sub> photons to give twice the radio flux actually observed. This suggests that a significant absorption of Ly<sub>c</sub> photons is taking place in the H II region or that the region is density-bounded. The 1-25  $\mu$  luminosity is supplied by the L $\alpha$  flux absorbed by dust in the H II region. Alternatively, the known parameters can be fitted with an O5 star and little or no dust absorption of the continuum photons in the ionized region; in any case, the region is complex and a simple spherical model is a poor approximation.

#### e) W49 (G43.2-0.0)

The thermal source W49 A is completely obscured in the visible and contains a large number of dense condensations ( $N_e$  up to  $10^5$  cm<sup>-3</sup>) embedded in a low-density gas (Gordon and Wallace 1971). It is a rich region for molecular emissions, and most of the total mass is probably in the form of molecular clouds

rather than in the H II regions (Scoville and Solomon 1973). Becklin *et al.* (1973b) have observed infrared sources in the 1–20  $\mu$  range coincident with both the powerful OH/H<sub>2</sub>O maser sources.

The far-infrared flux reported here is larger, but within 20 percent of that measured by Harper and Low (1971), and the size of 1.5 estimated for the far-infrared emitting region is close to the 2-cm radio size (1'  $\times$  2') measured by Schraml and Mezger (1969). If the distance of 14 kpc is correct, this is the most luminous far-infrared source known outside the galactic center region.

#### f) The Scorpius Region

The group of sources 41–45 which lie along the galactic plane in the direction of the Scorpius constellation have been identified with radio sources in the surveys of Beard *et al.* (1969) and Altenhoff *et al.* (1970). One of them, source 42, is RCW 120. Two sources, 43 and 43a, appear to be associated with the single radio peak G347.6–0.2, which is the only one of the group for which a distance is available (Wilson *et al.* 1970).

### VI. SUMMARY AND CONCLUSIONS

All but one of the 31 objects discussed here have been identified with galactic H II regions. The remaining source (19) is coincident with a supernova remnant but is situated in a confused region, and it is possible in this case that the observed emission is also associated with nearby thermal sources.

Approximately one-third of the sources are optically visible. The emission is generally patchy, indicating variable extinction across the regions, and in some cases there is evidence from near-infrared measurements that part of the extinction is local to the source. The objects also vary widely in size, luminosity, presence of OH/H<sub>2</sub>O masers, association with molecular clouds, etc.

Due to the limited spatial resolution of these and other far-infrared measurements, uncertainty still exists as to the precise location of the far-infrared emitting regions. In W3 the far-infrared sources are coincident, within our pointing accuracy, with the centers of radio continuum emission, and the appearance of the infrared and radio maps is similar, with an additional infrared feature which extends into the region of brightest optical emission and into the extended CO cloud. Far-infrared maps of other H II regions (EJM; Harper 1974; Alvarez *et al.* 1974; Fazio *et al.* 1974) are also similar to the radio continuum maps, and where any sizes have been measured these are close to the radio continuum sizes, but larger than those measured below 25  $\mu$ . At longer wavelengths there is evidence that cooler dust within the more extended molecular clouds becomes important. The 1-mm map of the Orion Nebula (Harvey *et al.* 1974), for example, exhibits more similarities to the H<sub>2</sub>CO emission than to the radio continuum distribution. It

seems reasonable on the basis of the available evidence however, to assume that most of the 40–350  $\mu$  emission is associated with the H II regions.

The ionizing stars in these regions, which are the ultimate source of most of the reradiated energy, cannot in general be observed directly. Where stars have been identified optically or in the near infrared, there is essentially no conflict between the energy available and the total infrared luminosity. In the majority of cases, however, it is necessary to infer the nature of the exciting stars on the basis of the measured infrared and radio continuum fluxes.

For several of the sources discussed above, it is possible that primary stellar photons as well as L $\alpha$  photons are responsible for heating dust within the ionized region. This is a somewhat controversial point, and opinions expressed in the literature are divided. We have considered this question separately (Furniss *et al.* 1974) in an attempt to assess the relative importance of dust inside and outside the H II region with regard to the far-infrared emission. Some 40 far-infrared sources were analyzed in terms of a simplified spherical model similar to that discussed by Panagia (1974). The average dust-absorption optical depth for Ly $\alpha$  photons within the H II regions was found to be close to unity, and the average dust-to-gas ratio  $\approx 2.5 \times 10^{-3}$ . As the infrared fluxes were not integrated over the source sizes, the optical depths calculated were essentially lower limits.

In general, therefore, we conclude that a considerable fraction of the 40–350  $\mu$  energy could originate in the outer regions of the ionized gas where the dust temperature should be a factor  $\sim 2$  lower than in the central cores which are responsible for the 1–25  $\mu$  emission. The balance of the far-infrared emission is provided by dust grains external to the H II region which absorb escaping stellar and nebular photons. The expected intensity distribution, therefore, lies somewhere between the extreme cases considered by Wright (1973)—that is, between the “peaked” distribution corresponding to a normal dust-to-gas ratio within the H II region and the “shell” structure expected if the dust is heavily depleted within the ionized gas but optically thick outside.

Spatial resolution achieved so far in the far-infrared is probably not sufficient to distinguish among these various possibilities.

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