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INFRARED STUDIES OF H II REGIONS AND OH SOURCES

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ABSTRACT

This paper presents the observational results of a high spatial-resolution mapping and photometric study in the wavelength range $1.65 \leq \lambda \leq 20\ \mu$ of four H II regions and seven OH sources. Infrared emission indicative of the presence of heated dust was found from the compact H II condensations in W51, DR 21, and NGC 7538. Infrared emission was also found from the positions of maser sources in NGC 7538, W75 (N), W75 (S) and Sharpless 269, but not from that in W51. An extended infrared source was found coincident with the peculiar OH source OH 0739−14.

Subject headings: infrared sources — molecules, interstellar — nebulae

I. INTRODUCTION

Although the connection between OH and infrared emission has become moderately clear in the case of late-type stars (Hyland *et al.* 1972; Wilson *et al.* 1972), the infrared emission from the vicinity of other maser sources, in particular those associated with H II regions, is less predictable. In this paper new observations at 1.65–20 μ of seven such contrasting OH sources are described.

Six of the OH sources, all detected at 1665 MHz, are associated with H II regions, although these H II regions form a very inhomogeneous sample. W51 is very powerful, distant, and totally obscured optically; W75, containing two widely separated OH sources, is also obscured and includes the compact H II region DR 21; NGC 7538 is smaller, partially visible, and contains an interesting group of very small, dense thermal radio sources as well as two OH sources; and Sharpless 269 is a small optical nebula with comparatively faint radio emission. The final OH source, OH 0739−14, is not associated with any distinctive optical or radio continuum feature. It has a unique OH spectrum, quite unlike that of an OH infrared star, with strong nonthermal 1667-MHz emission over the very wide velocity range -20 to $+90$ km s^{-1}. At one time this OH source was thought to be associated with the nearby planetary nebula NGC 2438 (Turner 1971).

Infrared studies are facilitated by the fact that the positions of most of the OH emission sources have recently been determined or redetermined at Caltech with a precision of 3″–5″ (Wynn-Williams, Werner, and Wilson 1974) and that W51 and NGC 7538 have recently been mapped at radio wavelengths with high spatial resolution (Martin 1972, 1973; Habing, Israel, and de Jong 1972). The present paper is a continuation of work which includes observations of W3 (Wynn-Williams, Becklin, and Neugebauer 1972) and W49 (Becklin, Neugebauer, and Wynn-Williams 1973).

II. OBSERVATIONS

Broad-band photometric observations were made between 1968 September and 1973 June on the Hooker 100-inch (2.5-m) and the Hale 200-inch (5.1-m) telescopes of the Hale Observatories, the 1-m telescope of the Carnegie Institution of Washington at Las Campanas, Chile and the 88-inch (2.2-m) telescope of the University of Hawaii at Mauna Kea. Observing techniques and wavelengths were essentially identical to those used by Wynn-Williams *et al.* (1972) with the addition that photometric measurements of several of the sources were made using filters at 8.7 μ (8.0–9.2 μ), 11.2 μ (10.4–11.9 μ), and 12.5 μ (11.8–13.1 μ). Photometry at these three wavelengths was used to search for strong 10-μ absorption features attributable to silicate particles, such as those found in the BN and KL sources in the Orion Nebula (Gillett and Forrest 1973) and W3–IRS 5 (Aitken and Jones 1973). All coordinates in this paper are for epoch 1950.0.

III. W51 (G49.5−0.5)

Figure 1 shows the center of the brightest component of W51 at 20-μ and 6-cm wavelengths. It can be seen that there are strong 20-μ infrared sources corresponding to each of the two main peaks of radio continuum emission, and that there is approximate

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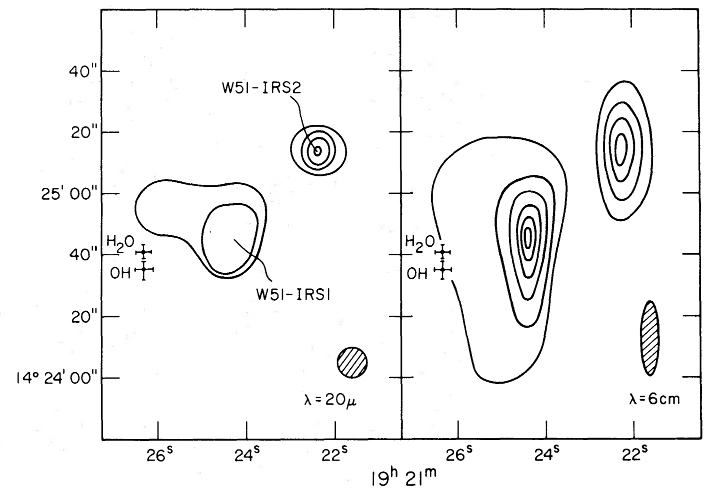

FIG. 1.—The central region of W51 at 20 μ and 5 GHz (adapted from Martin 1972). The infrared observations were made with a 10″ circular aperture and the radio observations with a 6″ × 24″ elliptical beam shown in the lower right-hand corner. Contour intervals are 7×10^{-16} and 14×10^{-16} W m^{-2} Hz^{-1} sterad^{-1} for W51–IRS 1 and W51–IRS 2, respectively, at 20 μ, and 400° K at 5 GHz. The crosses show the positions of the OH and H_2O maser sources (Wynn-Williams *et al.* 1974; Hills *et al.* 1972); Raimond and Eliasson's (1969) OH position lies between the crosses, but has been omitted for clarity.

agreement between their brightness distributions at radio and infrared wavelengths. Both infrared sources in figure 1 have been mentioned previously in the literature (Neugebauer, Hilgeman, and Becklin 1969) but most of the results given in this paper are derived from more extensive, recent observations. No other sources brighter than 100 f.u.[1] in an 18″ aperture at 20 μ were found in an area 5′ × 5′ centered on W51–IRS 2. There were, however, several sources at a level 50–70 f.u., including one which could be identified with Martin's (1972) radio component G49.5b.

Immediately apparent in figure 1 is the large separation of the OH and H_2O maser sources from the nearest radio or infrared source. The separation corresponds to 1 pc at an assumed distance to W51 of 7 kpc (Wilson *et al.* 1970). Although infrared sources have been found coincident with OH or H_2O masers in a significant number of H II regions (see, i.e., Becklin *et al.* 1973), no discrete source brighter than 25 f.u. at 20 μ, or 0.1 f.u. at 2.2 μ was found from the position of the W51 OH/H_2O source.

The infrared energy distributions of W51–IRS 1 and W51–IRS 2 are shown in figure 2, as well as the predicted free-free flux density calculated using the formula given by Willner, Becklin, and Visvanathan (1972). The latter is probably underestimated in the case of W51–IRS 2, since Balick's (1972) results indicate that at least part of the source may be still self-absorbed at 5 GHz. Nevertheless, it is clear from figure 2 that, as in W3 and W49, both W51–IRS 1 and W51–IRS 2 show excess emission at long wavelengths, and evidence for large amounts of interstellar or circumnebular extinction ($A_v \geq 40$ mag for W51–IRS 1, $A_v \geq 20$ mag for W51–IRS 2) at the shorter wavelengths. The excess emission is interpreted as arising from heated dust.

W51–IRS 2 has a sufficiently high surface brightness to make spatial scans across it with a small aperture and large signal-to-noise ratio. Figure 3 shows scans in declination through W51–IRS 2 using a 2″ wide slit at 20, 10, and 4.8 μ. It can be seen that the diameter of the source decreases significantly from about 5″ at 20 μ to < 2″ at 4.8 μ. Two possible causes of this effect are: first, that the mean dust temperature decreases with increasing distance from the center of the source, or, second, that W51–IRS 2 consists of two or more components with varied energy distributions. It should be noted that the Orion Nebula (Ney and Allen 1969) contains at least three different kinds of infrared sources separated by a distance which would correspond to only 4″ if the Orion Nebula were at the distance of W51. The 1- to 25-μ luminosity of W51–IRS 2 is, however, about 10 times greater than that of the three sources in the Orion Nebula.

Infrared emission of around 10^5 f.u. at a wavelength of about 100 μ has been found from W51 by Harper and Low (1971) and Hoffman, Frederick, and Emery (1971). The spatial resolution available to these observers was only about 10′ so it is not yet known how much of this far-infrared radiation has its origin in the compact sources W51–IRS 1 and W51–IRS 2.

IV. W75

W75 is part of the Cygnus X complex of radio sources. Two regions of it have been searched for infrared emission; the southern of the two includes the

[1] 1 f.u. = 10^{-26} W m^{-2} Hz^{-1}.

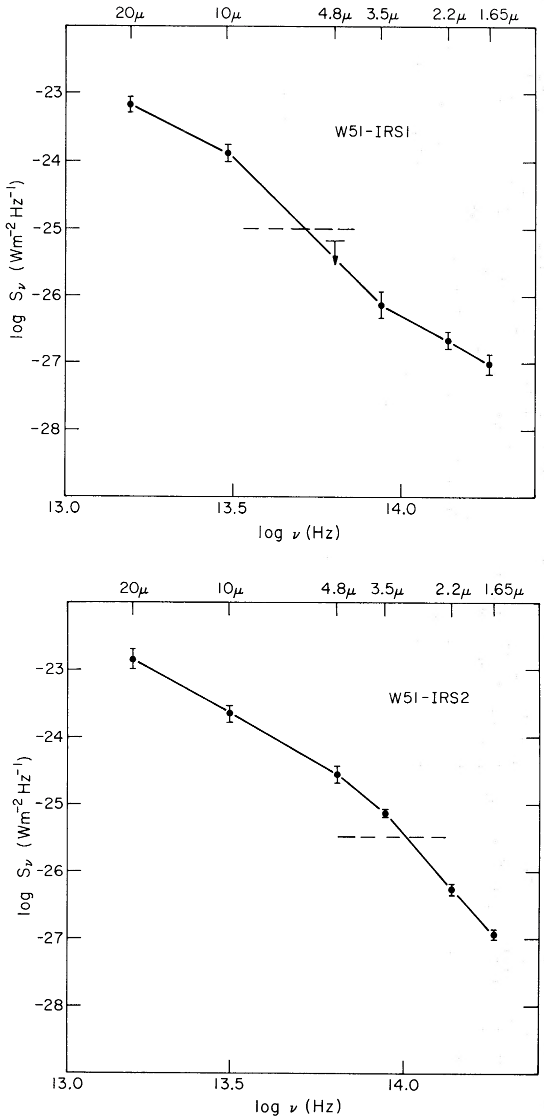

FIG. 2.—Infrared energy distributions of W51–IRS 1 and W51–IRS 2 measured with a 30″ aperture. The dashed lines are the flux densities expected from thermal emission from ionized hydrogen, based on Martin's (1972) 5-GHz data and the relationship given by Willner *et al.* (1972).

W75 (S)–OH source and the compact H II region DR 21, while the northern region surrounds the W75 (N)–OH emission source. In the south, infrared emission was found from two parts of DR 21, from the W75 (S)–OH source, and from two otherwise unidentified sources designated W75–IRS 1 and W75–IRS 2; see figure 4. In the north, a more limited search disclosed an extended region coincident with the W75 (N) source. The sources are discussed separately below; the observations of W75 are preliminary and less detailed than those of W51 and NGC 7538.

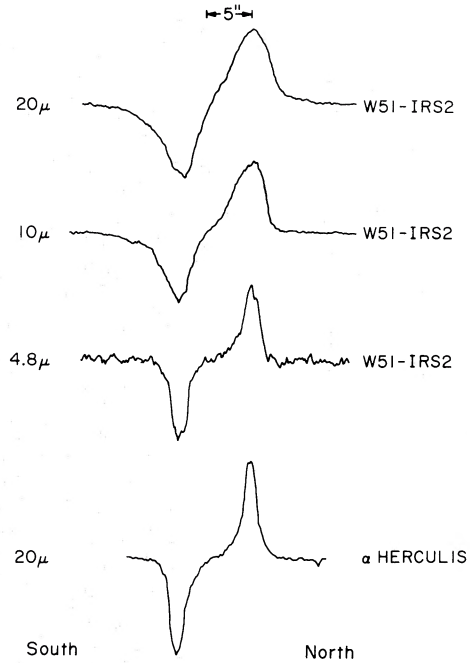

FIG. 3.—Declination scans of W51–IRS 2 using a 2″ wide, 5″ long slit on the 200-inch telescope. Scans of the comparison star, α Her, were essentially identical at 4.8, 10, and 20 μ. The vertical scale is arbitrary. The signal is the difference between two slits 7″.5 apart in a north-south direction.

a) *DR 21*

At radio wavelengths DR 21 has two components (Wynn-Williams 1971), which are indicated by the single contours in figure 4; the northern of these, DR 21 (N), is unresolved at 5 GHz with a 6″.5 beam, while the southern one, DR 21 (S), has a size of about 14″ × 22″. Infrared emission at 20 μ was detected from both sources, but despite the fact that at radio wavelengths DR 21 is one of the highest surface-brightness H II regions, neither source is very strong at 20 μ, and DR 21 overall is only a comparatively weak infrared source.

Of the two sources, the northern one is unresolved (≤ 3″ diameter) while the southern source is clearly extended. In contrast to almost all other compact H II regions, its shape at 20 μ is significantly different from that at radio wavelengths, with the ratio of 20 μ to 6 cm flux density a factor of at least 2 lower on the east side than the west side. The infrared emission from DR 21 is too faint to allow a test of whether the discrepancy appears at other infrared wavelengths.

Figure 5*a* shows the infrared energy distribution of the compact source DR 21 (N) measured with a 5″ aperture, and of the whole DR 21 source as measured with an 18″ aperture. The large aperture measurements include both DR 21 (N) and DR 21 (S) and some of the low surface-brightness envelope surrounding the

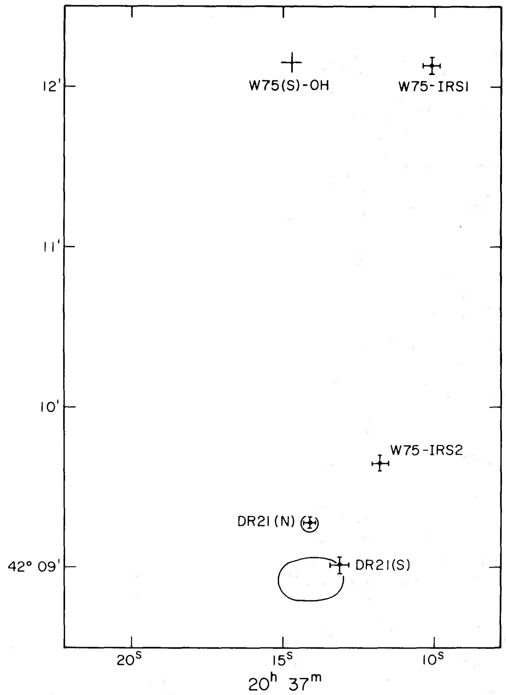

FIG. 4.—Infrared sources in the vicinity of DR 21 and the W75 (S)–OH source. The contours show the extent of the DR 21 radio continuum sources, while the crosses show the positions of peak brightness of the infrared sources. The extent of the barred crosses shows the uncertainties in the infrared position; the radio-line position was assumed in the case of W75 (S)–OH.

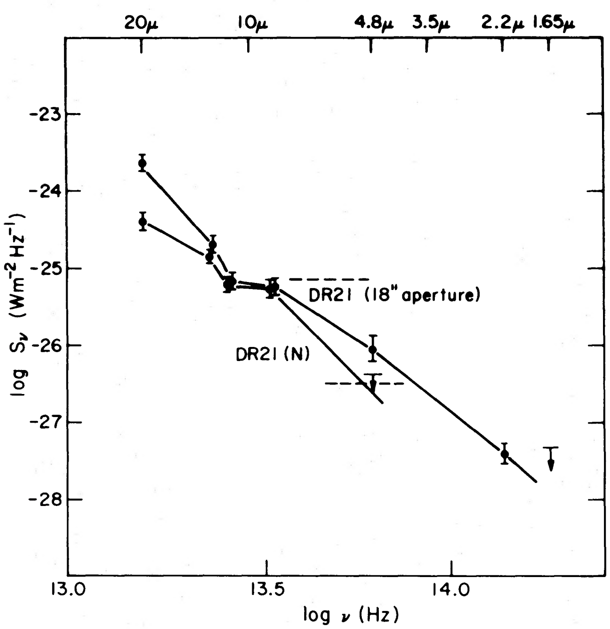

FIG. 5a

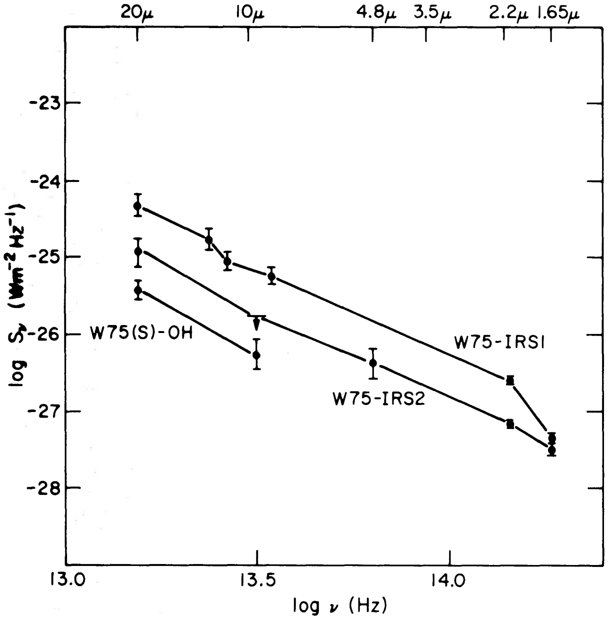

FIG. 5b

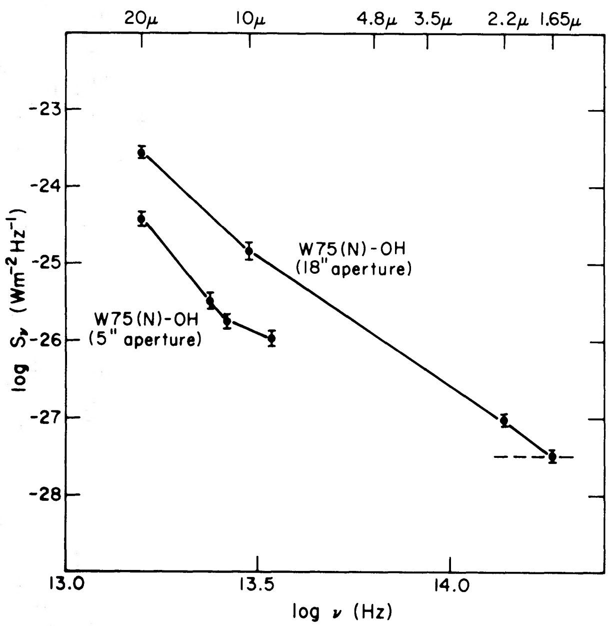

FIG. 5c

FIG. 5.—Infrared energy distributions of the W75 sources. Dashed lines indicate expected flux densities for thermal emission from ionized hydrogen.

source and observed on scans out to a distance of 20″ from the center of DR 21. The total flux density from this envelope is uncertain, but Lemke and Low (1972) measured 750 f.u. from DR 21 at 20 μ using a 1′ aperture, as compared to the value of 240 f.u. in an

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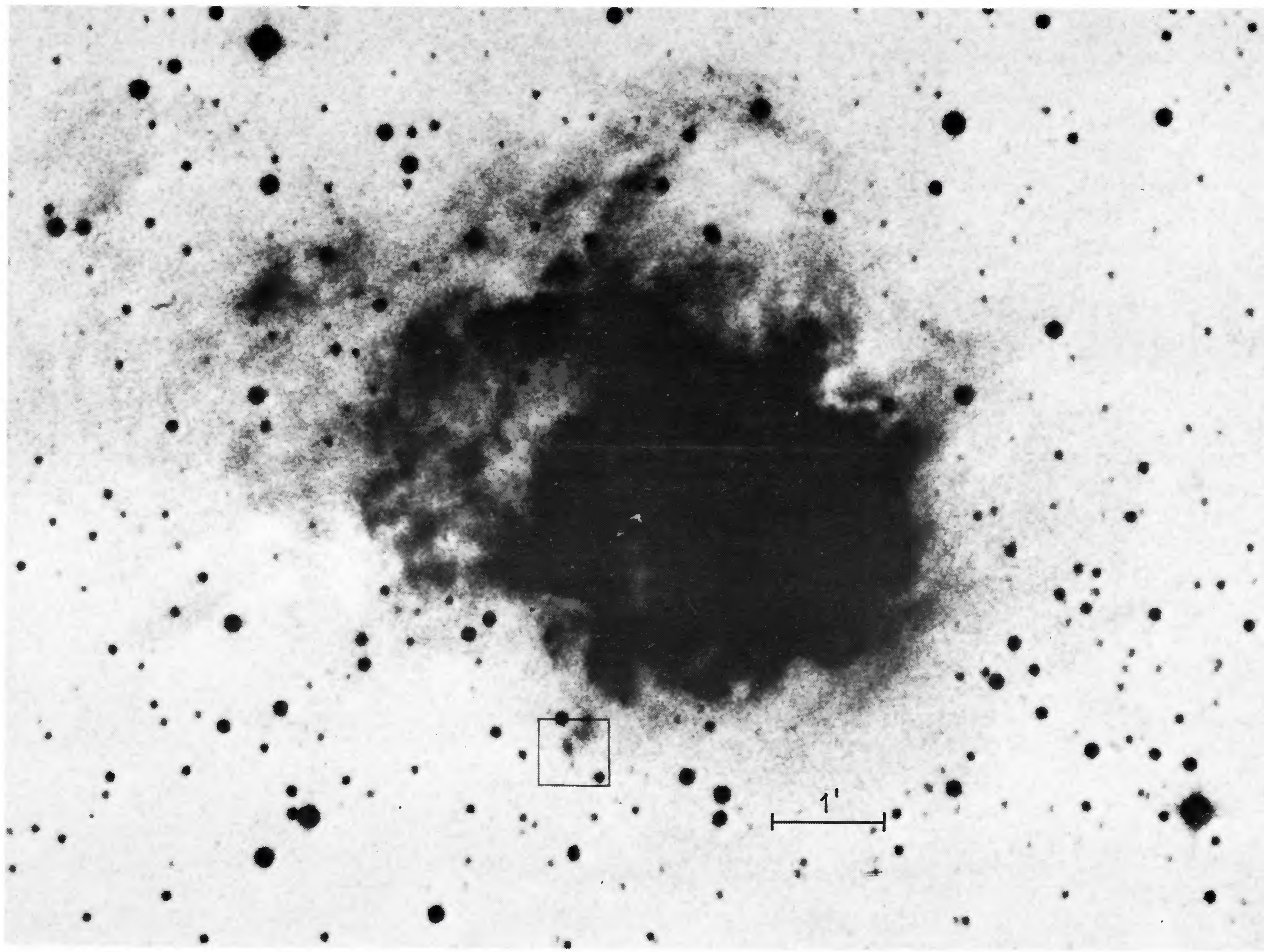


FIG. 6.—Reproduction of the red *Sky Survey* plate of NGC 7538. The rectangle shows the position of the maps in fig. 7. North is at the top, east is to the left.

TABLE 1

POSITIONS IN W75 (N)

Spectral Region	α	δ	Reference
Infrared............	$20^h36^m51^s.1 \pm 0^s.5$	$40°27'19'' \pm 5''$	This paper
Radio..............	20 36 51.3 ± 0.5	42 27 23 ± 5	Wynn-Williams (1971)
OH................	20 36 50.0 ± 0.5	42 26 58 ± 15	Hardebeck (1972)

18″ aperture measured here. The energy distribution of DR 21 (S) is not plotted on figure 5 because of the uncertainty in the shape and size of the component at wavelengths other than 20 μ.

The energy distributions in figure 5*a* show two particular features of interest. One is that, even at 5 μ, the measured infrared emission from DR 21 is less than that expected from recombination radiation in the H II region. Accurate estimation of the extinction is difficult because of the faintness of the source at 2 μ, but, following the method described by Wynn-Williams *et al.* (1972), a value in excess of 50 mag of extinction between DR 21 and the Sun seems to be indicated. The second point of interest is that DR 21 (N) apparently accounts for most of the flux from DR 21 at 10 μ and has a strong silicate absorption feature. DR 21 (N) therefore appears to have a hotter energy distribution than DR 21 (S), thereby resembling other unresolved infrared sources such as W3–IRS 5 and NGC 7538–IRS 1, (see § IV*a*).

b) *W75* (*S*)–OH, *W75–IRS 1*, *and W75–IRS 2*

The positions of these three sources are shown in figure 4. No other sources above a level of 70 f.u. at 20 μ were found in the area depicted. W75 (S)–OH is too weak in the infrared to allow a true determination of its position; the flux density shown in figure 5*b* is that for the source as measured through a 9″ aperture centered on Raimond and Eliasson's (1969) OH position. No radio continuum emission has been detected from the W75 (S)–OH position, or from anywhere else within the area shown in figure 4, to a level of about 0.1 f.u. at 21 cm (Wynn-Williams, private communication).

W75–IRS 1 and W75–IRS 2 have less red energy distributions between 20 μ and 2.2 μ than does DR 21. Neither is associated with any optical or radio feature. In this and in their energy distributions, the sources resemble W3–IRS 9, an infrared object close to W3 (OH) (Wynn-Williams *et al.* 1972) which was also discovered during searches at 2.2 μ.

c) *W75* (*N*)–OH

This OH source, discovered independently by Rydbeck, Elldér, and Kollberg (1969) and Zuckerman *et al.* (1969) lies 30″ ± 15″ from a small continuum radio source (Wynn-Williams 1971; Hardebeck 1972), which may be a compact H II region (see table 1). Strong emission at 20 μ was found from W75 (N); the source consists of a region approximately 20″ in diameter, coincident with the radio continuum source. The source is too faint for detailed mapping, but appears to be brighter toward the south. In figure 5*c* the energy distribution of W75 (N) is plotted as measured using 5″ and 18″ apertures. The flux through the 18″ aperture is about 8 times that through the 5″

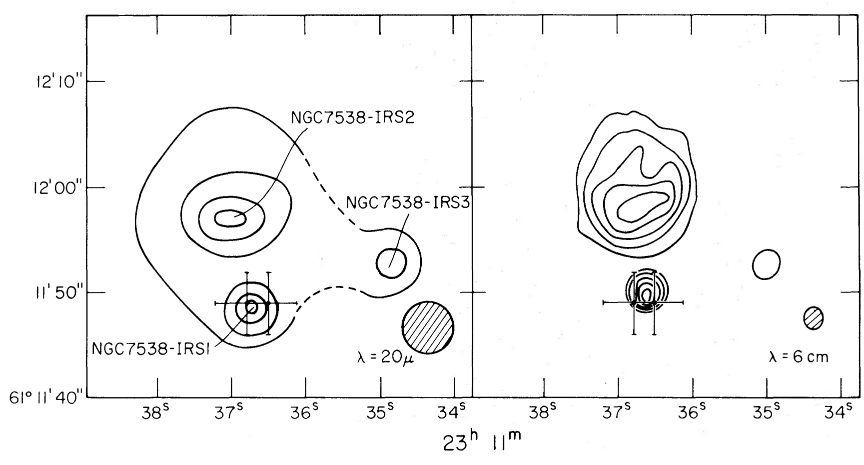
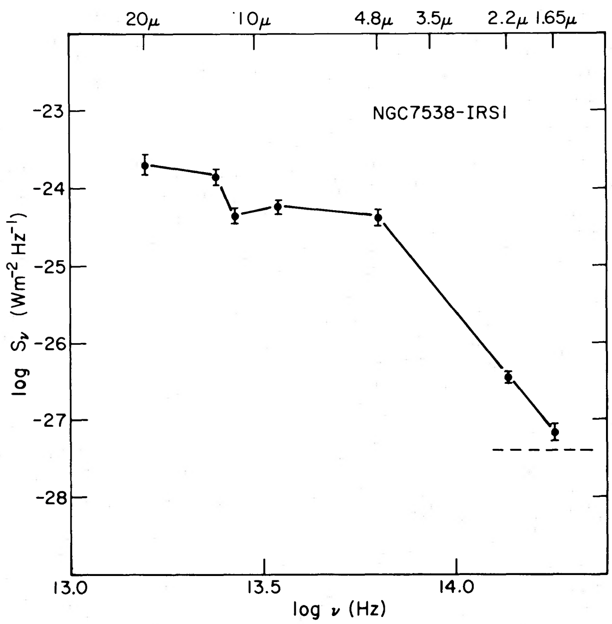
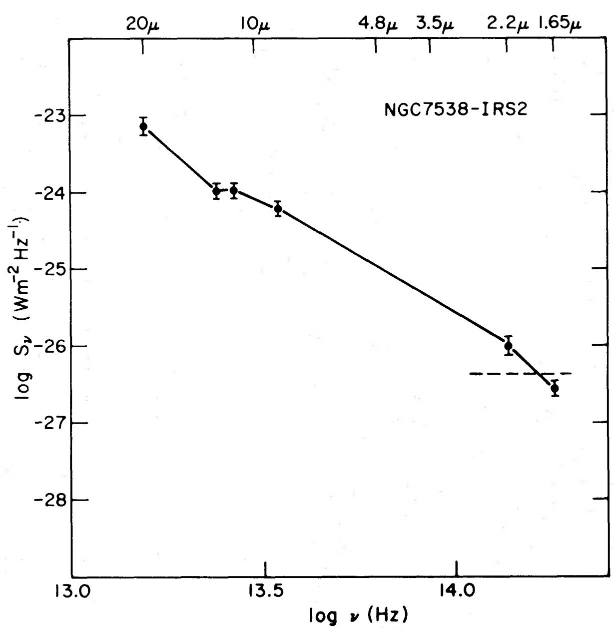


FIG. 7.—The radio and infrared emission from the vicinity of the NGC 7538 (N)–OH source. The infrared observations were made with a 5″ aperture, and the radio observations (Martin 1973) with a 2″ beam, as shown in the lower right-hand corner. Contour intervals are 1.2×10^{-15} W m^{-2} Hz^{-1} sterad^{-1} at 20 μ and 340° K at 5 GHz. The two crosses show the position of NGC 7538 (N)–OH as measured at 1720 and 1665 MHz (Wynn-Williams *et al.* 1974).

aperture; however, the latter flux density has probably been somewhat underestimated because of the effect of beamswitching on an extended source. Although detailed mapping was not attempted at 2 μ, a bright source was found about 5″ southwest of the 20-μ peak. This 2-μ source could possibly be stellar.

The radio source, being weak, has not been mapped with a resolution better than 14″ × 20″. Consequently it is not established whether radio emission is observed from the whole 20-μ source or only the brightest part of it. It is therefore difficult to make a quantitative comparison between the infrared emission and the extrapolated radio flux density, especially as the spectrum of the latter is unknown.





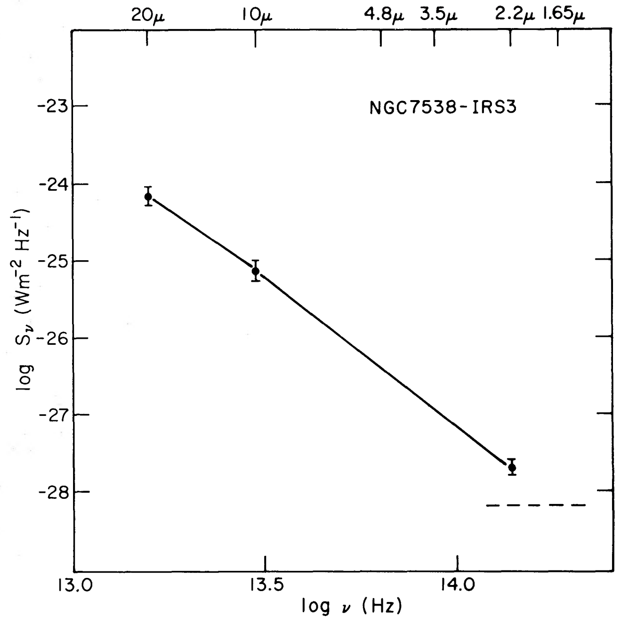


FIG. 8.—Infrared energy distributions for NGC 7538–IRS 1 to –IRS 3. The expected thermal emission from ionized hydrogen is shown as a dashed line.

V. NGC 7538

NGC 7538 is an optical H II region which also has associated with it several compact radio sources and two OH sources. Searches were made at 2.2 μ over an area ±1′.5 from the center of the optical nebula, and also in the immediate vicinity of the compact radio sources associated with the northern OH source (see fig. 6). Six sources were found which had flux densities in a 27″ aperture greater than 0.15 f.u. ([2.2 μ] = 9.0 mag). One of these, coincident with the OH source, was shown on more detailed examination to consist of three sources which are all powerful at 20 μ; these have been labeled NGC 7538–IRS 1 to –IRS 3 (fig. 7). Of the other five, labeled NGC 7538–IRS 4 to –IRS 8, at least two are almost certainly ordinary stars, and not all are necessarily physically associated with NGC 7538 (see table 2).

Searches were also made at 20 μ of areas ±1′ centered on the optical nebula and ±40″ centered on NGC 7538–IRS 1 to look for additional sources not detected at 2.2 μ. No sources with flux densities greater than 300 f.u. at 20 μ in a 10″ aperture were detected apart from those shown in figure 7. It is also possible to put a similar upper limit at 20 μ on

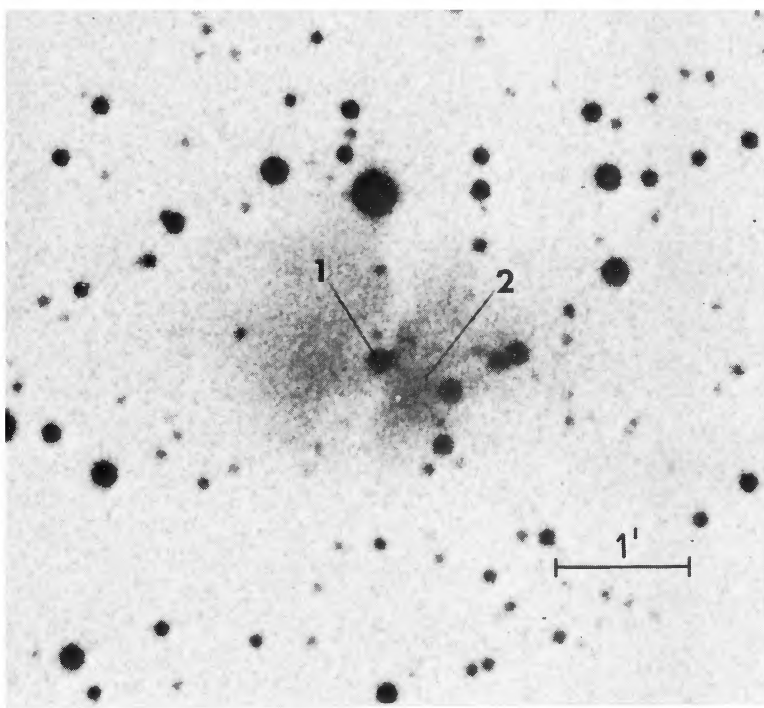


FIG. 9.—Blue *Sky Survey* photograph of Sh 269, showing the positions of Sh 269–IRS 1 and Sh 269–IRS 2. North is at the top, east to the left.

TABLE 2

SOURCES ASSOCIATED WITH NGC 7538 (excluding those shown in fig. 7)

Position (1950)			[2.2] and log ($S_{2.2\mu}$)	[1.65] and log ($S_{1.65\mu}$)	Aperture	Notes
NGC 7538–IRS 4.......	$23^h11^m24\overset{s}{.}1$	+61°12′43″	7.91 ± 0.10 (−26.37)	9.23 ± 0.10 (−26.70)	27″	H II condensation (log ($S_{20\mu}$) = −24.35 ± 0.15)
NGC 7538–IRS 5.......	23 11 21.7	+61 13 50	8.72 ± 0.15 (−26.72)	9.27 ± 0.15 (−26.72)	15″	Nebula Center
NGC 7538–IRS 6.......	23 11 25.8	+61 13 54	7.87 ± 0.10 (−26.36)	8.03 ± 0.15 (−26.22)	15″	O7 Star
NGC 7538–IRS 7.......	23 11 28.2	+61 14 19	7.32 ± 0.15 (−26.14)	7.47 ± 0.07 (−26.00)	13″	K Star
NGC 7538–IRS 8.......	23 11 18.8	+61 14 29	8.90 ± 0.15 (−26.77)	9.68 ± 0.15 (−26.88)	15″	...

NOTE.—Positions are accurate to about ±4″, and flux densities through a given aperture are in units of $\log_{10}$ (W m^{-2} Hz^{-1}).

the emission from the southern OH source ($\alpha = 23^h11^m36\overset{s}{.}1$, $\delta = +61°10'29''$) whose position was measured by Wynn-Williams *et al.* (1974).

a) *NGC 7538–IRS 1, NGC 7538–IRS 2, and NGC 7538–IRS 3*

This cluster of sources lies close to the OH emission source and a group of compact radio sources. It can be seen in figure 7 that there is a very close correspondence between the infrared and radio brightness distributions (Martin 1973). At both wavelengths there are three sources: NGC 7538–IRS 1 and NGC 7538–IRS 3 which are unresolved (< 3″ at 20 μ) and NGC 7538–IRS 2 which is extended by 5″ to 10″. The northern OH source is coincident with NGC 7538–IRS 1, the brighter of the unresolved sources. Comparison of figure 7 with the red *Sky Survey* plate (fig. 6) indicates that NGC 7538–IRS 2, is probably associated with the knot of optical nebulosity pointed out by Habing *et al.* (1972).

The infrared energy distributions of the three sources between 1.65 and 20 μ are shown in figure 8. The total flux density for NGC 7538–IRS 2 was determined only at 20 and 2.2 μ; the flux densities at other wavelengths are extrapolated from the flux measured in the central 7″ of the source, and may be subject to a small systematic error in addition to the errors shown in figure 8*b*. It may be seen that NGC 7538–IRS 1 has a strong 10-μ absorption feature which is almost certainly attributable to dust particles containing silicate-type materials; the neighboring extended source NGC 7538–IRS 2 shows no signs of this absorption feature.

The three energy distributions shown in figure 8 behave in a similar fashion to those of other H II components, such as those in W3, W49, and W51, in having 20-μ flux densities several orders of magnitude more intense than those expected from thermal emission from the ionized gas. This result is again interpreted as indicating heated dust coexisting with the ionized gas in these regions.

Assuming a distance of 3.5 kpc to NGC 7538 (Israel, Habing, and de Jong 1973), we find 1- to 25-μ luminosities for these sources in the range 3×10^3–$3 \times 10^4\ L_\odot$, comparable to the sources in W3. The three sources, however, differ from W3, W49, and W51 in that their 2.2-μ flux densities are above the extrapolated radio emission. This result, together with the absence of silicate absorption and possible identification with an Hα knot, implies that there is no evidence for large amounts of extinction in front of NGC 7538–IRS 2, as there is in the case of, say, W3, where the extinction is in the range 15–50 magnitudes. The case of NGC 7538–IRS 1 is more complicated, since it is quite likely that the radio source is self absorbed at 5 GHz and since the presence of the 10-μ silicate absorption suggests that there is a localized shell of cold dust around the source. It is of special interest that NGC 7538–IRS 1, which is more compact than NGC 7538–IRS 2, has a "hotter" energy distribution (fig. 8*a*), and is identified with the OH source.

b) *NGC 7538–IRS 4 to –IRS 8*

Five other sources, of lesser interest, were also found in the 2.2-μ search. Their positions and flux densities at 2.2 and 1.6 μ are given in table 2. NGC 7538–IRS 4 coincides with a minor peak on Martin's (1973) 2.7-GHz map and in view of its significant 20-μ flux density (table 2) is probably a source of the same type as NGC 7538–IRS 1 to –IRS 3. NGC 7538–IRS 5 coincides with the center of the optical nebula, and has flux densities agreeing with those predicted from Martin's (1973) radio data for thermal emission from ionized hydrogen. NGC 7538–IRS 6 and –IRS 7 coincide with, and have flux densities appropriate to the reddened O7 and K stars studied by Chopinet, Georgelin, and Lortet-Zuckermann (1973). NGC 7538–IRS 8 does not coincide with any optical or radio feature and is possibly a distant obscured star unrelated to the nebula.

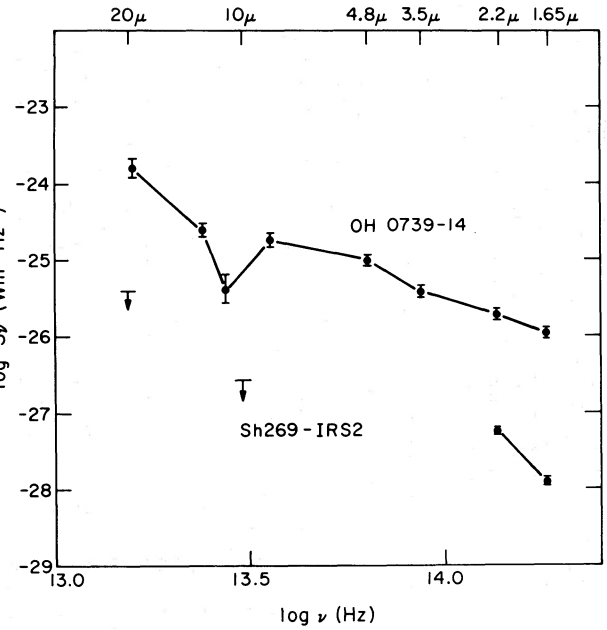


FIG. 10.—Infrared energy distributions of Sh 269–IRS 2, and OH 0739 − 14. The upper limits at 20 and 10 μ both refer to Sh 269–IRS 2. Measurements for Sh 269–IRS 2 pertain to a 7″.5 aperture, those for OH 0739 − 14 pertain to a 13″.5 aperture for $\lambda < 4$ μ, and a 10″ aperture for $\lambda > 4$ μ.

VI. SHARPLESS 269

Sharpless 269 is a bright, compact optical nebula, about 2′ in diameter (fig. 9) with a flux density in the range 0.3–2.7 GHz of about 1 f.u. (Terzian and Pankonin 1972). As a result of a search at 2.2 μ over an area approximately 1′.5 × 2′.5 around the nebula two faint infrared sources above a level of 0.05 f.u. in a 15″ aperture were found. Their positions are shown in figure 9. One, Sh 269–IRS 1, coincides with a star near the geometric center of the nebula, and has infrared colors appropriate to a reddened star ([2.2 μ] = 9.9, [1.65 μ] = 10.3). The second source, Sh 269–IRS 2, has the position

$$\alpha = 06^{h}11^{m}47^{s}.0 \pm 0.2^{s} ,$$

$$\delta = +13°50'32'' \pm 3'' .$$

Sh 269–IRS 2 has no visible counterpart, but coincides instead with the probable position of the OH maser source (Wynn-Williams *et al.* 1974).[2] The source is too faint for detailed mapping, but it is clearly extended on a scale of 5″–10″, giving a diameter of the order of 1 pc if Turner's (1971) rather uncertain distance estimate of 2 kpc is adopted. Its energy distribution is shown in figure 10; the source is clearly unlike most other extended infrared sources in H II regions, in that it is so weak at 10 and 20 μ.

[2] No infrared emission was found from the alternative position for the OH emission source mentioned by Wynn-Williams *et al.* (1974).

VII. OH 0739 − 14

The area around Hardebeck's (1972) position for the unusual OH source OH 0739 − 14 was searched at 2.2 μ resulting in the discovery of an extended infrared source. Its 2.2-μ diameter is of the order of 5″ and its position, determined with a 5″ aperture at the 200-inch telescope, is

$$\alpha = 07^{h}39^{m}58^{s}.9 \pm 0^{s}.1 ,$$

$$\delta = -14°35'44'' \pm 2'' .$$

No other source with a flux density above 0.2 f.u. through a 15″ aperture was found within 40″ of the above position. Subsequent remeasurement of the OH position (Wynn-Williams *et al.* 1974) established that the OH and infrared positions coincide to 1″ ± 4″. A very faint star is visible on the red and blue *Sky Survey* plates within 3″ of the infrared object, but the field is very crowded and the association is probably fortuitous, particularly as the infrared source is extended.

The energy distribution from 1.65–20 μ is shown in figure 10. In common with other galactic infrared sources described in this paper and elsewhere, the flux density of OH 0739 − 14 increases with decreasing frequency out to 20 μ, though less steeply than in most H II regions.

Whatever the nature of the object, the slope of its intrinsic flux density versus frequency curve at wavelengths near 2 μ is unlikely to be steeper than that of the Rayleigh-Jeans relation. The measured 2.2- to 1.65-μ color can therefore be used to place an upper limit to the dust extinction in the line of sight to the object. If a standard interstellar extinction law is assumed, this upper limit is 15 mag. This value is in apparent conflict with the presence of the very deep silicate absorption feature seen at 10 μ.

The fact that no unique velocity can be ascribed to the OH source means that no kinematic distance can be calculated, although the comparatively high galactic latitude of the source ($b^{II} = +4°.2$) would suggest it is not more than a few hundred parsecs from the Sun and consequently that most of the extinction is physically related to the object. The lack of knowledge of either the intrinsic luminosity or energy distribution of the source, together with the lack of precedent for the OH spectrum, makes speculation about the nature of the source rather dangerous. The fact that the infrared source is so extended, however, makes it quite unlike late type OH/infrared stars such as VY CMa. Observations of other molecular lines, which may yield less ambiguous velocities, of infrared emission at wavelengths greater than 20 μ and less than 1.6 μ, and of radio continuum emission, would obviously be very desirable.

VIII. SUMMARY OF OBSERVATIONS

a) *W51*

Two very luminous sources were found at 20 μ, one with a diameter of about 20″, the other with a diameter of about 5″ at 20 μ, but smaller at 5 μ. The infrared emission is strongly correlated with the radio continuum emission, but *not* with the OH or H_2O emission.

b) *W75*

DR 21 is a comparatively weak infrared source, with the unusual property that radio and infrared isophotes do not coincide. Infrared emission is associated with both W75 OH sources. Two additional infrared objects, unidentifiable with any optical or radio feature, were also found near DR 21.

c) *NGC 7538*

A compact group of three 20-μ infrared sources coincides with a similar group of compact radio sources and, possibly, some visible nebulosity. One of the sources, that associated with the OH emission, is particularly interesting in having a hotter energy distribution than most H II regions and having a strong silicate absorption.

d) *Sh 269*

This small optical H II region contains an optically unidentified, extended 2.2-μ source which coincides with an OH emission source. It is relatively weak at 20 μ.

e) OH *0739−14*

An extended infrared object which has a strong silicate absorption is associated with this OH source. It is not an OH/infrared star, and may not be an H II region.

IX. CONCLUSIONS

A full discussion of the properties of these sources as they relate to other H II regions is deferred to a forthcoming review article by the authors (Wynn-Williams and Becklin 1973). Nevertheless the following conclusions may be drawn at this stage:

At infrared wavelengths the H II regions with strong radio emission, W51, DR 21, and NGC 7538 have much in common with other H II regions such as W3 and W49, in that they contain 20-μ sources, smaller than 1 pc in diameter, coincident with compact radio continuum sources. Except for the case of DR 21 (S), the shapes and sizes of the individual sources agree well at radio and infrared wavelengths, indicative of the coexistence of gas and heated dust, though, as has been pointed out previously (Becklin *et al.* 1973), there is a wide range in the ratio of 20 μ to radio flux density among the different sources.

In almost all the cases studied in this paper infrared sources were discovered coincident with sources of OH maser emission.

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REFERENCES

Aitken, D. K., and Jones B. 1973, *Ap. J.*, **184**, 127.
Balick, B. 1972, *Ap. J.*, **176**, 353.
Becklin, E. E., Neugebauer, G., and Wynn-Williams, C. G. 1973, *Ap. Letters*, **13**, 147.
Chopinet, M., Georgelin, Y. M., and Lortet-Zuckermann, M. C. 1973, in preparation.
Gillett, F. C., and Forrest, W. J. 1973, *Ap. J.*, **179**, 483.
Habing, H. J., Israel, F. P., and de Jong, T. 1972, *Astr. and Ap.*, **17**, 329.
Hardebeck, E. G. 1972, *Ap. J.*, **172**, 583.
Harper, D. A., and Low, F. J. 1971, *Ap. J.* (*Letters*), **165**, L9.
Hills, R., Janssen, M. A., Thornton, D. D., and Welch, W. J. 1972, *Ap. J.* (*Letters*), **175**, L59.
Hoffmann, W. F., Frederick, C. L., and Emery, R. J. 1971, *Ap. J.* (*Letters*), **170**, L89.
Hyland, A. R., Becklin, E. E., Frogel, J. A., and Neugebauer, G. 1972, *Astr. and Ap.*, **16**, 204.
Israel, F. P., Habing, H. J., and de Jong, T. 1973, *Astr. and Ap.*, **27**, 143.
Lemke, D., and Low, F. J. 1972, *Ap. J.* (*Letters*), **177**, L53.
Martin, A. H. M. 1972, *M.N.R.A.S.*, **157**, 31.
———. 1973, *ibid.*, **163**, 141.
Neugebauer, G., Hilgeman, T., and Becklin, E. E. 1969, *Bull. A.A.S.*, **1**, 201.
Ney, E. P., and Allen, D. A. 1969, *Ap. J.* (*Letters*), **155**, L193.
Raimond, E., and Eliasson, B. 1969, *Ap. J.*, **155**, 817.
Rydbeck, O. E. H., Elldér, J., and Kollberg, E. 1969, *Ap. J.* (*Letters*), **156**, L141.
Terzian, Y., and Pankonin, V. 1972, *A.J.*, **77**, 115.
Turner, B. E. 1971, *Ap. Letters*, **8**, 73.
Willner, S. P., Becklin, E. E., and Visvanathan, N. 1972, *Ap. J.*, **175**, 699.
Wilson, T. L., Mezger, P. G., Gardner, F. F., and Milne, D. K. 1970, *Ap. Letters*, **5**, 99.
Wilson, W. J., Schwartz, P. R., Neugebauer, G., Harvey, P. M., and Becklin, E. E. 1972, *Ap. J.*, **177**, 523.
Wynn-Williams, C. G. 1971, *M.N.R.A.S.*, **151**, 397.
Wynn-Williams, C. G., and Becklin, E. E. 1973, *P.A.S.P.*, in press.
Wynn-Williams, C. G., Becklin, E. E., and Neugebauer, G. 1972, *M.N.R.A.S.*, **160**, 1.
Wynn-Williams, C. G., Werner, M. W., and Wilson, W. J. 1974, *Ap. J.*, **187**, 41.
Zuckerman, B., Ball, J. A., Dickinson, C. F., and Penfield, H. 1969, *Ap. Letters*, **3**, 97.