Luminous Radio-Quiet Sources in the W3(Main) Cloud Core

E. F. Ladd, J. R. Deane, D. B. Sanders, and C. G. Wynn-Williams
Institute for Astronomy, University of Hawaii, 2680 Woodlawn Dr., Honolulu, HI 96822

ABSTRACT

We have resolved the 450–800 μm emission from the W3(Main) star forming region into three major peaks, using an 8″ beam on the James Clerk Maxwell Telescope (JCMT). One of the submillimeter sources is identified with W3-IRS 5, a well-known candidate protostar. However, to our surprise, we find that none of the submillimeter peaks coincides with any of the prominent compact HII regions in the area. We estimate that the three submillimeter sources together contribute 35–50% of the total bolometric luminosity of the region and speculate that the contribution of luminous radio-quiet sources to the total luminosity of HII region/molecular cloud complexes may be larger than is often assumed.

The spectral energy distributions of HII region/molecular cloud complexes indicate that the bulk of their luminosity is emitted in the far infrared and that this far infrared and submillimeter emission is generated by cool (T = 30–60 K) dust (see, e.g. [1),2)]). Because of the large beam sizes typically used for far-infrared and submillimeter continuum observations, it has been difficult to determine whether the OB stars ionizing the HII regions are the sources of the luminosity, or whether this luminosity is generated independently within the nearby molecular material.

Submillimeter observations of the W3(Main) region were made with the 15 m JCMT in 1992 November. The continuum maps were obtained using the facility UKT-14 bolometer system with passbands centered at approximately 450 μm and 800 μm and beam sizes of 8″ and 14″, respectively. Our results are shown in Figure 1, along with maps of 20 μm[3)] and a 5 GHz radio continuum emission.[4)] The submillimeter continuum emission breaks up into three main emission centers—one in the east, and two in the west. We designate the sources SMS 1, 2, and 3 from E to W in order of decreasing right ascension.

SMS 1 is resolved and nearly circular at half power, with low flux level extensions to the east in the direction of IRS 3/W3B and north in the direction of IRS 1/W3A. The 450 μm and 800 μm centroid positions are consistent with the 20 μm position of IRS 5,[3)] several H_2O maser groupings,[5)] and the radio continuum source W3(M).[6)]

SMS 2 lies close to the 20 μm source IRS 4,[3)] and near to the compact HII region W3(C)[7)]. We find that the position of SMS 2 lies 7.5″ from the center of W3(C). The size of the positional discrepancy is sufficiently large that we are confident that SMS 2 is not associated with W3(C). IRS 4 lies 4″ from the centers of both W3(C) and SMS 2, nearly on a line between these two sources. Therefore we conclude that there are are least two distinct major sources of emission in this area (W3(C) and SMS 2), and quite likely an additional unrelated infrared source (IRS 4).

SMS 3 is more extended than the other two submillimeter sources. Cuts in right ascension and declination indicate that this source has a FWHM size of 30″ × 16″. No 20 μm emission was detected in this region to a point source detection threshold of 150 Jy,[3)] nor was radio continuum emission detected greater than 6 mJy/2″ beam.[6)]

Combining our data with infrared results,[3),8)] we have estimated the 20–800 μm luminosities for these three sources, as well as for IRS 1 (which was not detected as a distinct source in our submillimeter maps) and the entire region. The total luminosity for the region is estimated to be 5.2×10^5 $L_\odot$. IRS 1 and IRS 5 each account for about 30% of the total. SMS 1 and SMS 2 account for an additional 6% each. However, it should be noted that the luminosity of SMS 2 may contain some additional contribution from either IRS 4 or the source associated with W3(C), and therefore this luminosity should be regarded as an upper limit to the luminosity of SMS 2.

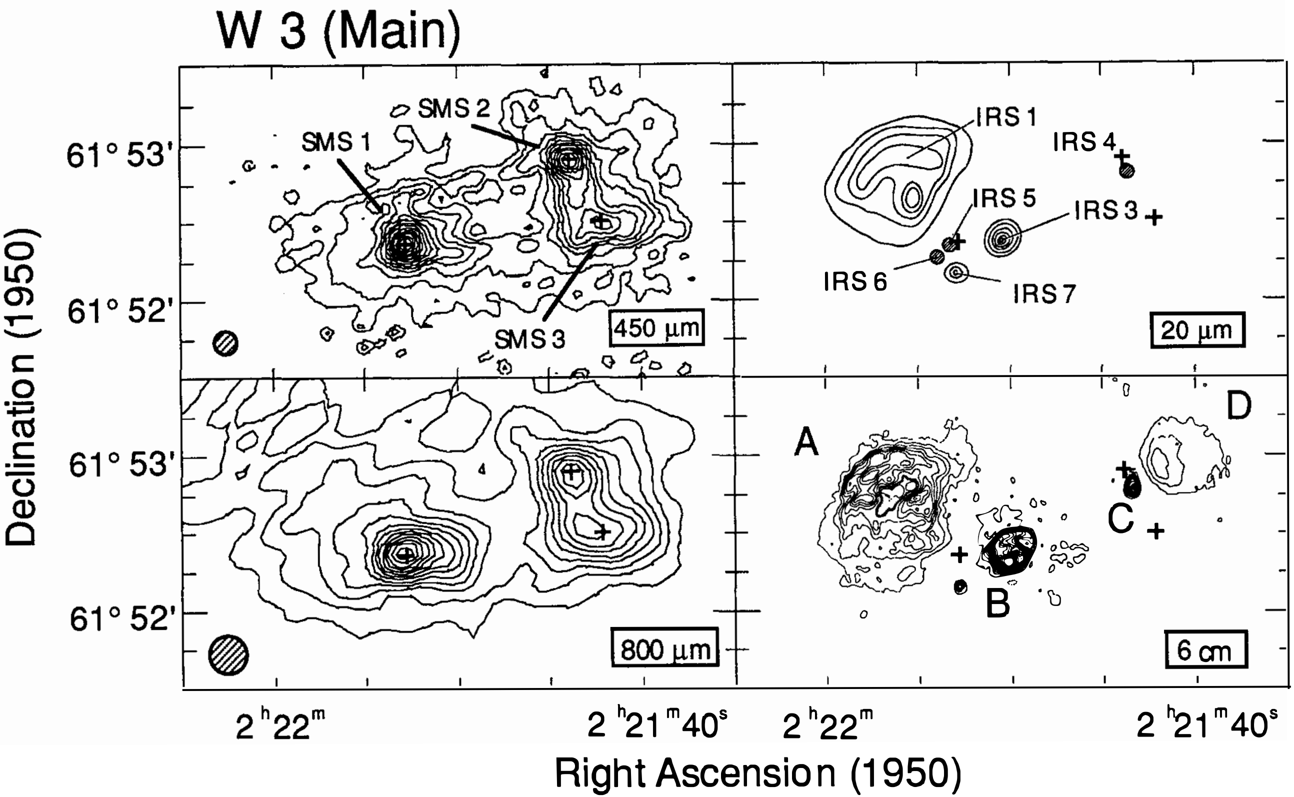

Fig. 1 Submillimeter images of the W3(Main) region at 450 μm (**top left**) and 800 μm (**bottom left**) compared with the 20 μm map from Wynn-Williams et al. (1972; **top right**) and the 5 GHz contours from Harris & Wynn-Williams (1976; **bottom right**). The submillimeter beam sizes are shown in the lower left of each relevant panel. Contours for the 450 μm map begin at 15 Jy/8″ beam and increment by 15 Jy/8″ beam. Contours for the 800 μm map begin at 1 Jy/14″ beam and increment by 1 Jy/14″ beam.

IRS 5 has long been recognized as a candidate high-mass protostar, based on its high luminosity, infrared energy distribution, and relatively weak radio continuum emission (see, e.g., [3),8),9),10)] We have found two more sources in the W3(Main) cloud that exhibit behavior similar to that of IRS 5. While both have luminosities about a factor of 5 lower than that of IRS 5, they are not associated with detected radio continuum emission.

These radio-quiet sources account for at least 35% (SMS 1/IRS 5 + SMS 3) and up to 50% (SMS 1/IRS 5 + SMS 2 + SMS 3) of the total luminosity generated in the W3(Main) core. With the addition of extended emission probably generated by lower-luminosity, non-ionizing sources, the luminosity from W3(Main) could be roughly equally divided between sources associated with HII regions and sources which have little or no ionized environs.

Based on these results, we suggest that the submillimeter continuum emission is a better tracer of the spatial distribution of luminosity in high mass star formation region than is the radio continuum emission.

On galactic scales, several authors have tried to determine the fraction of our galaxy's total luminosity that is generated by HII region stars. Sodrowski *et al.* found that roughly half of the total infrared luminosity in the galaxy is generated in or near HII regions,[11)] while Scoville & Good claim stars that ionize hydrogen can account for 25% of the total.[12)] However, these investigations used data with large beam sizes and therefore could not distinguish between luminosity generated by HII region sources and luminosity generated by nearby companions such as the sources examined in this work. With the large beams used in these surveys, all of the luminosity from the W3(Main) core would appear to be coincident with all of the radio continuum flux. If our result for W3(Main) can be generalized to all embedded HII regions, then the total galactic luminosity due radio-quiet and non-ionizing sources may be greater than that found by these authors.

1) Wynn-Williams, C. G., & Becklin, E. E. 1974, PASP, 86,5
2) Chini, R., Krugel, E., & Wargau, W. 1987, A&A, 181,378
3) Wynn-Williams, C. G., Becklin, E. E., & Neugebauer, G. 1972, MNRAS, 160,1
4) Harris, S., & Wynn-Williams, C. G. 1976, MNRAS, 174,649
5) Genzel, R. Downes, D., Moran, J. M., Johnston, K. J., Spencer, J. H., Walker, R. C., Haschick, A., Matveyenko, L. I., Kogan, L. R., Kostenko, V. I., Rönnäng, B., Rydbeck, O. E. H., & Moiseev, I. G. 1978, A&A, 66,13
6) Colley, D. 1980, MNRAS, 193,495
7) Wynn-Williams, C. G. 1971, MNRAS, 151,397
8) Werner, M. W., Becklin, E. E., Gatley, I., Neugebauer, G., Sellgren, K., Thronson, H. A., Harper, D. A., Loewenstein, R., & Moseley, S. H. 1980, ApJ, 242,601
9) Hackwell, J. A., Gehrz, R. D., Smith, J. R., & Briotta, D. A. 1978, ApJ, 221,797
10) Wynn-Williams, C. G. 1982, ARA&A, 20,587
11) Sodrowski, T. J., Dwek, E., Hauser, M. G., & Kerr, F. J. 1987, ApJ, 322,101
12) Scoville, N. Z., & Good, J. C. 1989, ApJ, 339,149