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Mid-infrared images of compact and ultracompact HII regions: W51 and W75N.

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Abstract. A mid-infrared imaging survey at 8.7, 9.7 and 12.5 μm of a selected number of compact and ultracompact (UC HII) regions has been undertaken with the 2.1m telescope of the OAN at San Pedro Martir, Mexico. We present a detailed plane of the observations, and we discuss the preliminary results of two massive star-forming regions; W51 and W75N.

Key words. HII regions – Mid-IR images – Massive star-formation

1. Introduction

Massive stars deeply embedded in giant molecular clouds, produce compact and ultracompact HII regions (UC HII). Therefore these regions, very bright at radio wavelengths, tell us about the locations where massive stars form. Compact HII regions have diameters between 0.005 and 0.5 pc, electron densities $2\times10^3 \leq N_e \leq 3\times10^5$ cm^{-3} and emission measure $2\times10^6 \leq EM \leq 10^9$ pc cm^{-6}, and show a variety of morphologies (cometary, core-halo, shell structures, and spherical) (Wood & Churchwell 1989). The morphology and physical condition of the ionized gas depend on the complex interaction of massive hot stars and their natal molecular cloud. Different models have been proposed to explain these morphologies; from the *classical expansion* model in which the difference in pressure between the ionized gas and the surrounding neutral gas drives the expansion, to the *bow shocks* model supported by the stellar wind of an ionizing star that is moving supersonically through the ambient molecular cloud . The first model may explain the shell structures, while the second, the cometary morphologies observed in HII regions.

UC HII regions are small photoionized nebulae with sizes $\leq$0.05pc. Generally they are associated with water masers and could represent the earliest observable evolutionary phases of a massive star. Many compact and UC HII regions are often found in groups suggesting the presence of a recently formed association of O B stars. As the process of massive star formation is obscured

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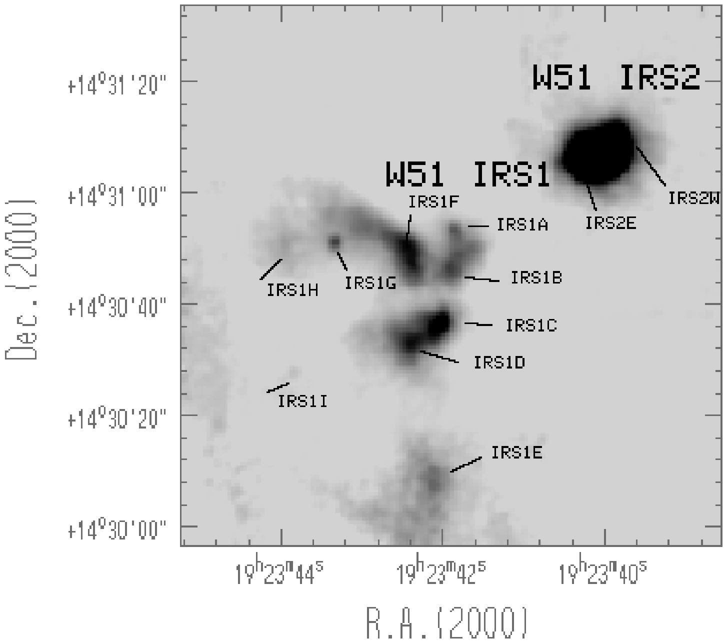

Fig. 1. The 12.5μm image of W51 with the identification of the mid-IR sources.

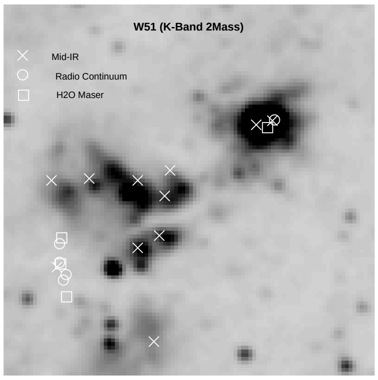

Fig. 2. 2MASS K-band images of W51 including the positions of the mid-IR sources, UC HII, and maser sources.

by the dust that surrounds newborn stars, it cannot be investigated at optical wavelengths. Mid-IR observations and in particular high spatial resolution images represent a powerful tool to study these very early phases of star formation.

For this purpose, we have undertaken a limited mid-IR imaging survey at arcsec spatial resolution of a selected sample of compact and ultracompact HII regions. In Section 2 we will show the observations and the relative sample, while preliminary results of the complex star forming regions, W51 and W75N are discussed in Sections 3 and 4.

2. Observations

During two observing runs in September 2000 and November 2001 we have collected mid-IR images at 8.7, 9.7 and 12.5 μm of 24 compact and UC HII regions with the 2.1m telescope of the OAN at San Pedro Mańtir, Mexico, using the CID camera (Salas et al. 2002). The mid-IR camera is equipped with a Rockwell 128×128 Si:As blocked impurity band (BIB) detector array. The field of view of the array is $70'' \times 70''$ with an effective scale of $0.55''$/pix. The list of the observed regions is reported in Table 1. Preliminary results of W3 Main and

Table 1. List of compact and UC HII regions observed in the mid-IR

Source	α(1950)	δ(1950)	IRAS	Date
	h m s	° ′ ″		
GM24	17 17 02.3	-36 21 08		Sept.12 2000
G9.62+0.19	18 03 16.2	-20 32 00	18032-2032	Sept.13 2000
G19.61-0.23	18 24 50.3	-11 58 32	18248-1158	Sept.12 2000
G34.26+0.15	18 50 46.4	01 11 14	18507+0110	Sept.09 2000
G45.07+0.13	19 11 00.4	10 45 43	19110+1045	Sept.10 2000
G45.12+0.13	19 11 06.2	10 48 26	19111+1048	Sept.10 2000
W51d(IRS2)	19 21 22.3	14 25 15	19213+1424	Sept.08 2000
W51e(IRS1)	19 21 26.3	14 24 42		Sept.08 2000
G75.77+0.34	20 19 50.0	37 16 16	20198+3716	Sept.04 2000
G75.78-0.34	20 19 51.9	37 17 00		Sept.04 2000
W75N	20 36 50.1	42 26 59		Sept.12 2000
IRAS21306+5540	21 30 36.0	55 40 00		Sept.09 2000
NGC7538	23 11 36.5	61 11 50	23116+6111	Nov.06 2001
G111.612+0.374	23 13 21.2	60 50 51	23133+6050	Nov.06 2001
G111.282-0.663	23 13 52.7	59 45 38	23138+5945	Nov.07 2001
IRAS23139+5939	23 13 58.9	59 39 06		Sept.09 2000
W3Main	02 21 53.2	61 52 21	02219+6152	Sept.07 2000
W3OH	02 23 17.3	61 38 57	02232+6138	Sept.07 2000
BRC05	02 25 14.9	61 20 05	02252+6120	Nov.07 2001
AFGL5142	05 27 30.0	33 45 40	05274+3345	Nov.06 2001
AFGL5180	06 05 53.1	21 38 46	06058+2138	Nov.09 2001
GGD12-15	06 08 25.8	-06 10 50	06084-0611	Nov.09 2001
G192.384-0.041	06 12 53.6	18 00 26		Nov.08 2001
NGC2264(IRS1)	06 38 25.4	09 32 15	06384+0932	Nov.07 2001

W3(OH) are given in Persi et al. (2002a), the mid-IR image of G9.62+0.19 is discussed in Persi et al. (2002b), and a general view of the observations is reported by Tapia et al. (2002).

3. W51

W51 is a complex of HII regions located in the Sagittarius spiral arm at a distance of 7-8 Kpc, and is known as one of the most luminous and active region of massive star formation in the Galaxy. Three main centers of activity have been identified in the region. W51 IRS1 is a diffuse arclike HII region with a diffuse near-IR emission. W51 IRS2 also known as W51-North, is a cluster of point-like near-IR sources (Goldader & Wynn-Williams 1994), with three UC HII, W51d,d1 and d2, while W51 Main is a site of strong maser activity and several ultracompact HII regions (Zhang & Ho 1997).

For this complex region, we have obtained for each narrow-band filter,a mosaic of three images. We have found eight mid-IR sources in W51 IRS1 and at least two sources in W51 IRS2. A few sources appear diffuse in the mid-IR. Figure 1 illustrates the 12.5μm image with the identifications of the mid-IR sources. Our image is very similar to the 1.3cm and 2cm radio maps of Zhang & Ho (1997) and Gaume et al. (1993) respectively. This indicates that dust and ionized gas are well mixed within W51. In Figure 2 we report the positions of the mid-IR sources, compact and UC HII, and maser sources over the 2MASS K-band image. All the mid-IR sources within the positional accuracy have been identified with near-IR sources.

W51 IRS2 is enough complex in the mid-IR. At our spatial resolution, we identified at least two compact sources W51IRS2E and W51IRS2W surrounded by an envelope of emission that extends roughly 10-20″ (Figure 3). At the higher spatial resolution, Kraemer et al. (2001) resolved W51IRS2E in at least three components, while Okamoto, Y.K. et al. (2001) revealed in W51 IRS2 seven mid-IR sources with [NeII], [ArIII], [SIV] line emission, and silicate absorption.

Particulary interesting is the point-like mid-IR source IRS1G detected within W51 IRS1 (see Fig.1). Combining the near-IR observations from the 2MASS catalogue with our mid-IR flux densities, we have obtained in Figure 4, its spectral energy distribution (SED). This appears very steep with a infrared spectral index α(IR)=2.9. Integrating the SED, we obtained an infrared luminosity L_{IR}= 4.4 10^3 L_{Sun}.

Finally, in the southern part of W51 (W51 Main), we detected only a very weak source at 12.5μm (F=1.4±0.5 Jy) here named W51IRS1I(see Fig.1). This object not observed in the near-IR, may be the ultracompact HII region W51e3 found by Gaume et al. (1993). The lack of infrared sources in W51Main and the presence of several UC HII and maser sources, suggest that this is the youngest region of the complex.

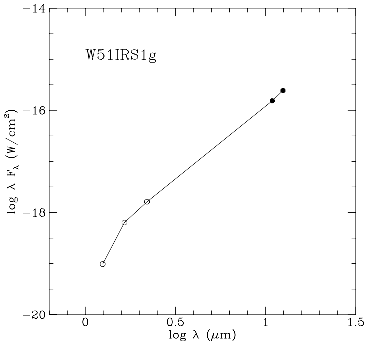

Fig. 4. Spectral energy distribution of the source IRS1G in W51 IRS1.

4. W75N

This region at a distance of 2 Kpc, is characterized by the presence of a massive molecular outflow with at its center a cluster of UC HII and maser sources (Torrelles et al. 1997). We have found three sources in our 12.5 μ image of Figure 5. Two mid-IR sources were identified with the near-IR sources W75N IRS1 and IRS2, both with IR excess, while the third source located at the north (VLA1 in Fig.5) is within the cluster of UC HII. This is a very red source detected only at 12.5 μ and could be the power source for the observed outflow. In particular this source was observed at 1.3 and 3mm (MM1 in Shepherd (2001)).

The spectral energy distributions of IRS1, and IRS2 obtained combining the

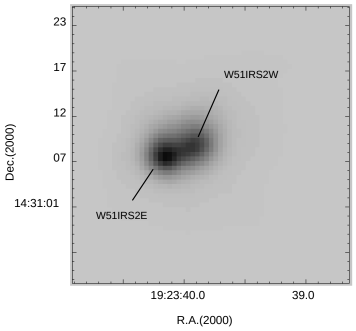

Fig. 3. 12.5μm image of W51 IRS2

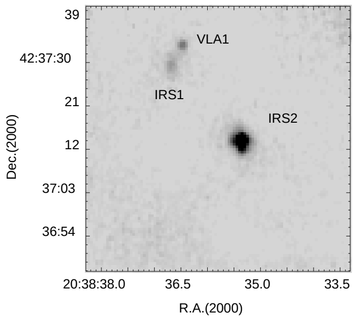

Fig. 5. 12.5μm image of W75N.

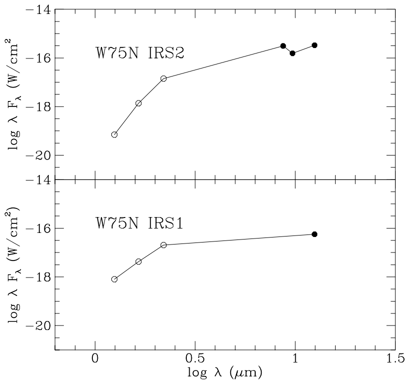

Fig. 6. Spectral energy distribution of W75N IRS1, and W75N IRS2.

near-IR photometry from 2MASS, and our observed mid-IR flux densities, are shown in Figure 6. The source IRS2 has a very steep energy distribution with the presence of silicate in absorption, while the SED of IRS1 is flatter indicating that probably the two sources are at different evolutionary stages.

5. Summary

We have undertaken a project of a mid-IR image survey of compact and ultracompact HII regions in giant molecular cloud in order to study the earliest evolutionary phases of massive stars, and to understand the dynamical processes that set the evolution of the molecular clouds. This can be made comparing infrared images and radio maps taken at similar spatial resolution. The preliminary results of the two complex star-forming regions, W51 and W75N, here reported, show the importance of high spatial resolution mid-IR images in studying the processes of high massive star formation.

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References

Gaume, R.A., Johnston, H.J., Wilson, T.L. 1993 ApJ, 417, 645
Goldader, J.D., Wynn-Williams, C.J. 1994, ApJ 433, 164
Kraemer, K.E., Jackson, J.M., Deutsch, L.K., et al. 2001 ApJ, 561, 282
Okamoto, Y.K., Kataza, H., Yamashita, T., et al. 2001 ApJ, 553, 254
Persi, P., Tapia, M., Bohigas, J. 2002 "Hot Star Workshop III" , ASP Conf.Ser. in press
Persi, P., Tapia, M., Roth, M., et al. 2002, A&A submitted
Salas, L., et al. 2002, to be submitted to Rev.Mex.Astr.Astrofis.
Shepherd, D.S. 2001, ApJ 546, 345
Tapia, M., Bohigas, J., Persi, P. 2002 "Hot Star Workshop III" , ASP Conf.Ser. in press
Torrelles, J.M., Gomez, J.F., Rodriguez, L.F., et al. 1997 ApJ, 489, 744
Wood, D.O.S., Churchwell, E. 1989, ApJS 69, 831
Zhang, Q., Ho, P.T.P. 1997, ApJ 488, 2411