A Multi-Wavelength Study of the S 151 Region

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Abstract. Preliminary results are presented of an extensive, multi-wavelength study we are currently undertaking of the S 151 region. We analyze the structure of the HII region, its interaction with molecular clouds, the clouds themselves, and the embedded objects within them.

1. Introduction

The isolated evolved HII region S 151 (l=108.6°, b=−2.7°) is located at a (kinematic) distance of 5.6 kpc. The angular size is about $20' \times 10'$ on the POSS E-print. It is weak, probably due to foreground extinction.

The infrared source IRAS23004+5642 (WB89-234) is about 6.′5 SW from the center of S 151. Wouterloot & Brand (1989) detected (IRAM 30-m) strong and narrow ^{12}CO(1–0) towards this source, which is exceptional for a star-forming region (see Wouterloot et al. 1995). The FIR luminosity of WB89-234, 9600 $L_\odot$, suggests it is a B0.5 star (in case of a single star on the ZAMS; Panagia 1973). At an angular distance of about $70''$ SW from the IRAS Point Source Catalog (IPSC) position an H_2O maser is situated, an additional sign of star formation currently taking place. Nearby (5.′5 S) is IRAS23004+5637 (WB89-235) which is at the same kinematic distance, and has L_{fir}=2800 $L_\odot$.

2. Observations

Observations have been carried out over a wide spectral range. The radio continuum structure was observed at 2.8 cm (Effelsberg). The large-scale molecular emission was mapped with the KOSMA 3-m [^{12}CO(2–1, 3–2)] while the clump associated with WB89-234 was mapped with the IRAM 30-m in the J=1–0 and 2–1 transitions of ^{12}CO, ^{13}CO, and C^{18}O; a small region around the water maser was observed in the J=2–1, 3–2, and 5–4 transitions of CS. The Effelsberg 100-m was used to detect NH_3(1,1), and (2,2) in a region around the maser, the H_2O emission of which has been monitored at irregular intervals between 1991-97 with the Medicina 32-m. From IPAC we obtained higher (30–90$''$) resolution maps in the 4 IRAS bands over a $2^\circ \times 2^\circ$ region, while with the TIRGO 1.5-m we observed a $4' \times 4'$ region around WB89-234 in J, H, K, H_2, and Brγ. With ISO we obtained, centered at the IPSC position: an LWS spectrum (43–197μm); a $6\farcm8\times6\farcm8$ ISOPHOT map at 60 and 200μm (not yet reduced); and a $4\farcm3\times4\farcm3$ ISOCAM (LW10) map.

3. Results

Figure 1 shows the distribution of the integrated intensity of ^{12}CO(2–1) (KOSMA data), superimposed on the HIRES map of the 25μm emission. The dashed contours represent the 6-cm continuum emission (Condon et al. 1989). While little molecular emission is found towards the central part of the HII region [near offset (5′,5′)], extended emission is detected to the NE and SW. The total molecular mass detected with KOSMA is $\sim 2.8\times10^4$ $M_\odot$. It is seen that on the whole the IR emission rather closely follows the CO distribution, but the details differ. Note in particular the IR peak at (5′,4′), which does not have a counterpart in CO emission. The extent of the emission region to the NE ($10' \leq \Delta\delta \leq 20'$) is smaller than that of CO in both the IR and optical, which might be caused by an ionization front which is visible on the Digital Sky Survey and in radio continuum. An interesting result from the HIRES maps is a displacement, from iteration 1 to iteration 20, of the maximum from the IPSC position to a position approximately corresponding with that of the H_2O maser (Fig. 2). Thus the IRAS source does not seem to coincide with the narrow-line, warm gas. In Fig. 2 one also sees a peak at $\sim 40''$ north of the IPSC position, in the map of iteration 20.

Figure 3a shows T[C^{18}O(1–0)] contours superimposed on the T[^{12}CO(1–0)] in greyscale (IRAM data). The C^{18}O emission shows the presence of two clumps, connected by a ridge. The southernmost clump is near the H_2O maser, and the other is 60″ north of the IPSC position. The C^{18}O ridge has a discontinuity, near which there is a very small C^{18}O maximum, with linewidths of only 0.2–0.3 kms^{-1}. ^{12}CO and ^{13}CO maps show more extended strong emission towards both clumps, the ridge, and the IPSC position. The warmest gas is found in the ridge ($T_{kin} \approx$30–36 K). There is agreement between H_2 column densities derived from escape probability models and LTE calculations: $(1.5\pm0.4)\times10^{22}$ cm^{-2} and $(2.0\pm0.4)\times10^{22}$ cm^{-2} for the N and S clumps, respectively; in the ridge the peak is 1.2×10^{22} cm^{-2}, while near the IPSC position we find 2.0–5.0×10^{21} cm^{-2}. The total molecular mass associated with the region mapped at IRAM is 1.8×10^3 $M_\odot$, half of which is in the southern clump. For the latter clump we derive from the NH_3 data a T_{kin} of 23$\pm$5 K, while the CS data indicate an H_2 volume density of 2.5×10^5 cm^{-3}.

Figure 3b shows IRAM T[^{13}CO(1–0)] data as contours, and ^{13}CO linewidths as greyscale. ^{12}CO line profiles are narrow in and near the ridge (0.7–0.9 kms^{-1}; ^{13}CO linewidths reach values as low as 0.6 kms^{-1}), but are much broader towards the C^{18}O clumps: 2–3 kms^{-1} in the northern one (partially due to the presence of two velocity components), and 3–5 kms^{-1} in the southern one. The region near the maser exhibits strong outflow emission. The centers of the blue and red emission around the maser almost coincide, and are near the H_2O position. Under the assumption that the gas in the flow is optically thin and has

T_{ex}=10 K, we find the following parameters for the blue and red lobes, respectively: mass 1.0 and 4.1 $M_{\odot}$, momentum 4.6 and 16.6 $M_{\odot}kms^{-1}$, energy 2.5 and 8.3×10^{44} erg. The average radius of the outflow is 0.75 pc, and the dynamical age is 1.9×10^{5} yrs.

ISOCAM 12μm and deep optical images (Loiano 1.5-m) show emission around the northern clump, which might be due to PAHs (Bernard et al., this conference), ionized material, or reflected light, and at both clump centers ISOCAM finds a point source. The TIRGO observations reveal embedded (red) sources in both clumps, with associated diffuse emission, stronger at longer wavelengths, which is presumably due to dust emission around the embedded objects. In the southern clump there is a slightly extended NIR source, at which the outflow is centered. The emission is strongest in K and H_2, and while it's pointlike in J, it becomes elongated at longer wavelengths. The morphology of the emission differs between the K band and the shocked H_2 emission.

With a field-of-view of 80$''$ the LWS observation covers the ridge, but excludes both clumps. A reference position outside the molecular cloud was also observed. The resulting spectra are rather noisy, and show very few lines. Only [CII] at 157μm and [OI] at 63μm were detected at an appreciable level, with integrated fluxes (on–off) of resp. 5.0×10^{-19} Wcm^{-2} and 8.4×10^{-19} Wcm^{-2}. The [CII]/[OI] ratio of 0.6 is low compared to for instance S140 (Emery et al. 1996).

Initially we became interested in this region because of the association of a luminous IPSC source with very narrow and warm CO-emission. However, the HIRES data show that in reality the source detected by IRAS (WB89-234) nearly coincides with the H_2O maser, and not with the strong, narrow-line CO-emitting gas. The presence of this relatively low-density warm gas, the heating source of which is not yet known, indicates the absence of interaction with both S 151 and the embedded IR sources. Star formation in the S 151 area probably occurs in the whole region with strong FIR emission (as seen in the HIRES maps), from the edge of the large (20 pc) molecular cloud in the North, to WB89-235 in the South.

References

Condon J.J., Broderick J.J., Seielstad G.A., 1989, AJ97, 106

Emery R., Aannestad P., Minchin N., et al., 1996, A&A315, L285

Panagia N., 1973, AJ78, 929

Wouterloot J.G.A., Brand J., 1989, A&AS80, 149

Wouterloot J.G.A., Fiegle K., Brand J., Winnewisser G., 1995, A&A301, 235 (Erratum: 1997, A&A319, 360)

Fig. 1

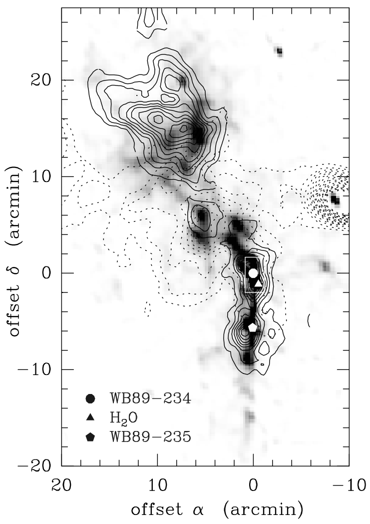

Fig. 2

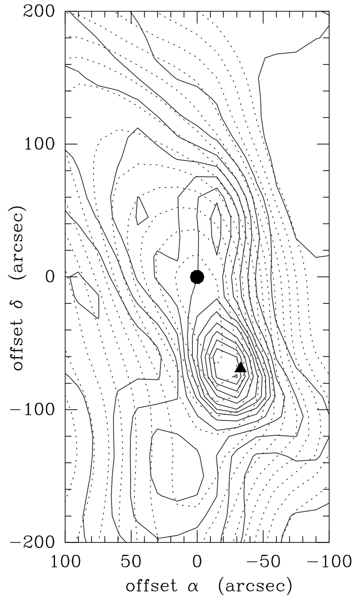

Fig. 3

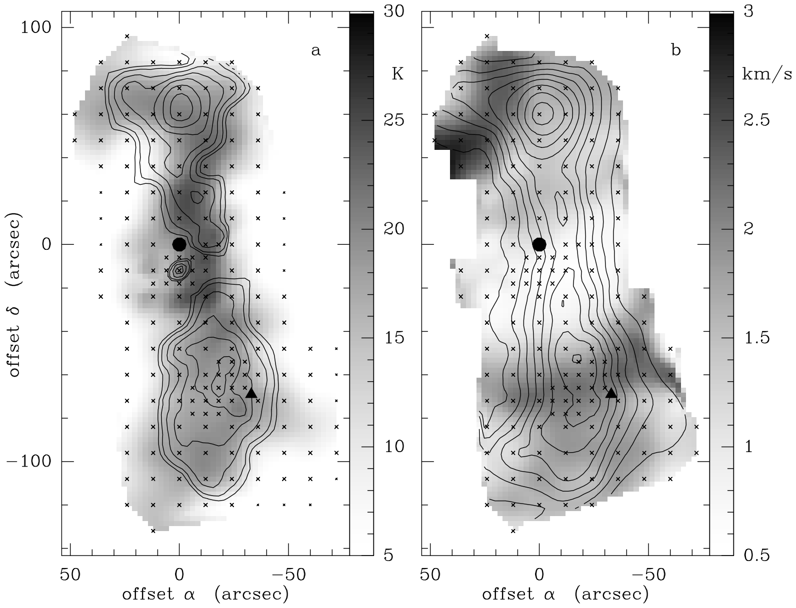

Figure 1. KOSMA CO(2–1) [drawn: 2(2)20 Kkms^{-1}], 6-cm cont. [dashed: 10(10) mJy/beam] and HIRES 25μm [greyscale]; the box indicates the region mapped with the IRAM 30-m.
Figure 2. HIRES 12μm after 1 iteration [dashed]; after 20 iterations [drawn]
Figure 3. a: contours are for IRAM C^{18}O(1–0) (0.1, 0.2(0.2)1.2 K); greyscale is ^{12}CO(1–0); b: contours are for ^{13}CO temperature (1(1)9 K), greyscale for linewidth.