SURVEY OF INTERMEDIATE/HIGH–MASS STAR–FORMING REGIONS AT CENTIMETER AND MILLIMETER WAVELENGTHS

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ABSTRACT

We present the results of millimeter and centimeter continuum observations toward ***10 intermediate/high-mass young stellar objects*** *(YSOs), selected fom the lists compiled by Molinari et al. (1996) and Mueller et al. (2002), with distances < 3.5 kpc and bolometric luminosities >* $10^3\ L_\odot$*, not previously mapped in the cm and mm range.*

The 1.2 mm emission is detected toward all the IRAS sources. In some cases the emission shows a clear peak surrounded by some substructure, while in other cases the emission is very extended and weak. The 1.2 mm is likely tracing the dust core in which the YSO is forming, for which we estimated masses from 10 to 140 $M_\odot$*. For all the sources , but one, we detected centimeter emission associated with the IRAS source, being compact or ultracompact HII region candidates, with early B-type stars as the ionizing stars. The 7 mm emission is partially resolved for the four sources observed at this wavelength, with contribution of dust emission at 7 mm ranging from 0% to 60%.*

By combining our data with infrared surveys, we built and fitted the spectral energy distribution (SED) of the sources. In addition, we found a correlation between the degree of disruption of the natal cloud and the size of the centimeter source. Finally, an evolutionary sequence is proposed.

OBSERVATIONS

The 1.2 mm observations were carried out on 2004 January 23 to 25 with the **IRAM 30m Telescope**. Nine regions were observed at 1.2 mm. Data reduction was performed with the MOPSIC software package. The centimeter observations were carried out on 2004 July 10 and 13 using the **Very Large Array** (VLA) in the D configuration. Ten regions were observed at 3.6 and 1.3 cm. Four sources were aditionally observed at 7 mm with the VLA in the D configuration during the first months of 2007. Cleaned maps were made using the AIPS software of NRAO.

MAIN RESULTS

Millimeter emission

4 regions → show a intense peak with some substructure
4 regions → show very extended and weak emission
1 region → no detection
We derived the mass of gas and dust at 1.2 mm, finding values from 10 to 140 $M_\odot$

Centimeter emission

37 new centimeter sources detected at 3.6 and/or 1.3 cm
30 of them lying within the central 50" (~ 0.5 pc) around the IRAS source
13 sources with $\alpha < -0.1$ → possibly extragalactic sources
17 sources with $\alpha > -0.1$ → HII regions, radiojets, externally ionized globules

The HII regions have sizes from < 0.01 to 0.3 pc, being compact or UC HII regions, with early B-type stars as the ionizing stars
4 sources have morphologies and properties characterisc of thermal radiojets

In Fig. 1 we show the centimeter and millimeter maps for three of the sources. The rest of the maps and more information can be found in Sánchez-Monge et al. (in press).

Spectral Energy Distributions (SEDs)

By combining our data with the infrared surveys of 2MASS, MSX, and IRAS, we built the SED and fitted the millimeter and centimeter emission with a modified blackbody law taking into account the contribution of a free-free optically thin law (see Fig. 2). We found median values of 30 $M_\odot$ for the mass, 29 K for the dust temperature, and 1.9 for the dust emissivity index.

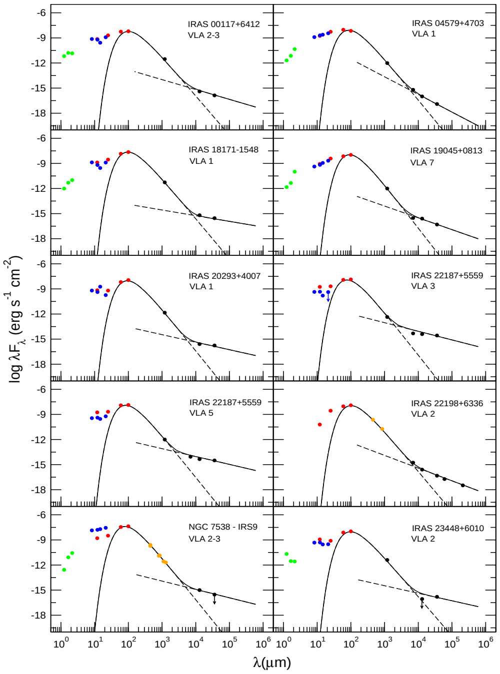

Figure 2.- Spectral Energy Distributions. Green dots: 2MASS data. Blue dots: MSX data. Red dots: IRAS data. Orange dots: millimeter and submillimeter data from literature. Black dots: Sánchez-Monge et al. Dashed lines: modified blackbody and free-free optically thin fits to the cm and mm emission. Black lines: sum of the modified blackbody and the free-free optically thin laws.

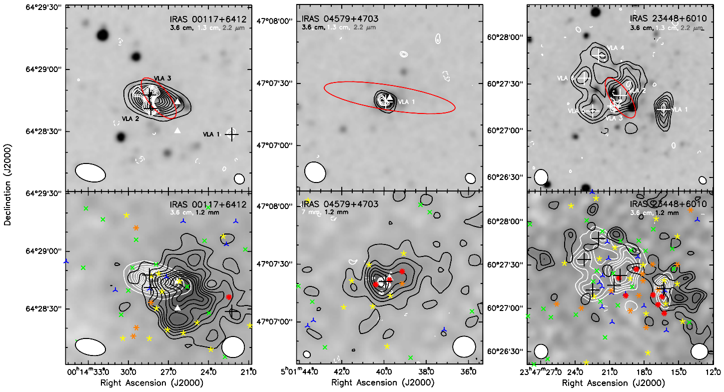

Figure 1.- *Top panels*: Black contours: VLA 3.6 cm continuum emission. White contours: 1.3 cm continuum emission. Grey scale: K-band 2MASS image. The red ellipse indicates the error ellipse of the IRAS source. *Bottom panels*: Grey scale and black contours: IRAM 30m continuum emission at 1.2 mm. White contours: VLA 3.6 cm continuum emission, except for IRAS 04579+4703, where white contours correspond to VLA 7 mm continuum emission. Stars indicate 2MASS sources, with its infrared excess codified as follows: from high to less infrared excess, red, orange, yellow, green, and blue stars. In all panels, white filled triangles indicate H_2O masers.

EVOLUTIONARY CLASSIFICATION

By combining the morphology of the cm and mm emission, together with the separation of both emission peaks, we found a **correlation** between the fraction of millimeter flux picked up within ~ 0.2 pc at the position of the centimeter peak, and the size of the centimeter source (see Fig. 3). This correlation allowed us to define an **evolutionary classification** taking into account the degree of expansion of the HII region, and the degree of disruption of the natal cloud.

Furthermore, from our data and the infrared properties of each source, complemented with dense gas, outflow, and maser emission from literature, we classified each massive YSO in an evolutionary stage, consistent with the correlation previously found (see Sánchez-Monge et al., for details).

The **youngest source** in our sample (IRAS 22198+6336), with no near- neither mid-infrared emission, has compact dust emission associated with a compact centimeter source.
More evolved sources (as IRAS 23448+6010), have an extended centimeter source, with the millimeter emission weak and dispersed around the centimeter source.

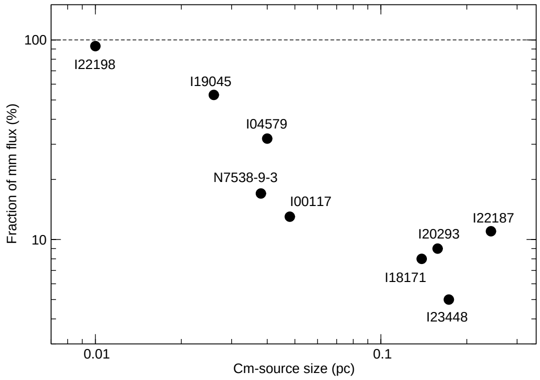

Figure 3.- Fraction of the millimeter flux picked up within ~ 0.2 pc (the size of the IRAM 30m beam at the distance of the farthest source of this survey, 3.4 kpc) at the position of the centimeter peak, versus the size of the centimeter source.

REFERENCES

Molinari, S., Brand, J., Cesaroni, R. & Palla, F. 1996, A&A, 308, 573
Mueller, K.E., Shirley, Y.L., Evans II, N.J. & Jacobson, H.R. 2002, ApJS, 143, 469
Sánchez-Monge, Á., Palau, A., Estalella R., Beltrán, M.T., & Girart, J.M. (submitted)