

# MID-IR Images of HMSFRs associated with CH<sub>3</sub>OH and H<sub>2</sub>O masers

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Surveys of methanol (CH<sub>3</sub>OH) and water (H<sub>2</sub>O) masers in high-mass star forming regions (HMSFRs) have shown that both maser species trace the earliest evolutionary stages of the massive star formation processes. In order to derive the physical properties of the high-mass protostellar objects (HMPOs) associated with these regions, we have obtained mid-infrared images of 16 regions containing 6.7GHz CH<sub>3</sub>OH and H<sub>2</sub>O masers. The images at 8.9, 9.9, 12.7 and 18.7  $\mu$ m were taken between Nov. 6 -10, 2006 using the mid-IR camera CID (Salas et al. 2006, Rev.Mex.A.A. 42, 273) on the 2.1m telescope of the Observatorio Astronómico Nacional at San Pedro Mártir (Baja California, Mexico). The images were taken with a scale of 0.55"/pix and the mean PSF was 1.5-2.0 " (FWHM), close to the diffraction limit. The list of the observed regions is shown in Table 1:

Table 1: List of the observed CH<sub>3</sub>OH masers

IRAS	Methanol Maser	R.A.(J2000) h m s	Dec(J2000) ° ' "	ID
18434-0242	29.96-0.02	18 46 03.74	-02 39 21.4	
18556+0136	35.20-0.74	18 58 12.67	+01 40 36.5	G35.2N
18566+0408	37.54+0.21	18 59 10.00	+04 12 14.7	Mol 83
	45.47+0.13	19 14 07.80	+11 12 01.0	
20126+4104	78.10+3.64	20 14 26.00	+41 13 33.4	
	85.40-0.00	20 54 13.71	+44 54 07.9	CBJC8
22543+6145	109.86+2.10	22 56 18.09	+62 01 49.5	CepA
22566+5830	108.75-0.96	22 58 40.30	+58 46 46.0	
23139+5939	111.24-0.76	23 16 05.40	+59 55 22.0	
00338+6312	121.28+0.65	00 36 42.20	+63 28 30.0	L1287
02455+6034	136.84+1.12	02 49 23.10	+60 46 26.0	
05274+3345	174.19-0.09	05 30 42.00	+33 47 14.0	GLS142
05382+3547	173.69+2.87	05 41 33.80	+35 48 27.0	Mol 13
06056+2131	189.03+0.76	06 08 36.10	+21 30 28.0	AFGL6366S
06058+2138	188.95+0.89	06 08 53.35	+21 38 28.7	GLS180
06099+1800	192.60-0.05	06 12 54.02	+17 59 23.0	S255

We selected for discussion the results for four of the regions listed in Table 1. We have included in this paper also Spitzer/IRAC and 2MASS images.

## IRAS18556+0136 (G35.20-0.74)

This region, known as **G35.2N**, is characterized by the presence of an extended molecular outflow with a NE-SW axis (Birks et al. 2006 A&A 458, 181). VLA observations at 6 and 3.5 cm reveal several embedded YSOs. In addition, 3.5-mm continuum emission is detected very close to the radio source G35.2N (Gibb et al. 2003 MNRAS, 339, 1011). In this region, we have observed one source with an elongated N-S structure similar to that present in the Spitzer/IRAC images (see Fig.1 (left)).

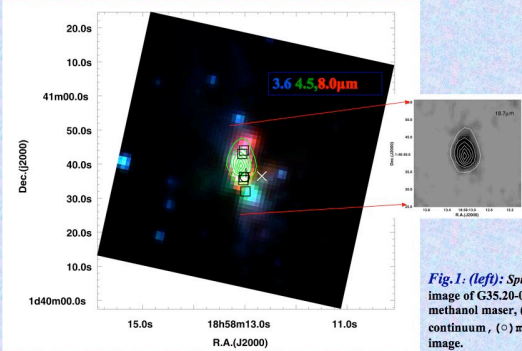
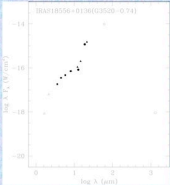


Fig.1: (left): Spitzer/IRAC colour-coded image of G35.20-0.74. Symbols: (X) 6.7 GHz methanol maser, (+) H<sub>2</sub>O maser, (•) radio continuum, (◻) mm source. (Right) 18.7μm image.



Within the quoted positional errors, the detected mid-IR source is coincident with the water maser and probably with the Class II methanol maser. The spectral energy distribution (SED) of this source, obtained combining our mid-IR flux densities, 2MASS, Spitzer/IRAC, MSX and millimeter data, is illustrated in Fig.2. Integrating the SED we obtained  $L_{bol} = 6.1 \cdot 10^3 L_{sun}$  and an infrared spectral index  $\alpha(IR) = 2.4$ , computed between 2.2 and 18.7μm.

Fig.2 SED of IRAS18556+0136(G35.20-0.74). Symbols: (Δ) 2MASS, (•) Spitzer/IRAC, (◐) this work, (◐) MSX, (◻) IRAS, (◊) mm.

## IRAS18566+0408(G37.54+0.21)

IRAS18566+0408, known also as **Mol 83** (Molinari et al.1996 A&A 308, 573), is a massive star forming region located at a distance of 6.7 kpc. 22 GHz H<sub>2</sub>O and 6.7 GHz CH<sub>3</sub>OH masers and multiple molecular outflows were found in this region (Beuther et al. 2002a A&A 383, 892; Beuther et al. 2002b A&A 390, 289). A compact (< 6") and weak radio continuum source was detected towards the IRAS source by Carral et al. 1999 (RevMexAA, 35, 97) and Araya et al. 2005 (ApJ 618, 339). A near-IR object with H-K > 4.3 is coincident with the maser sources. At the position of this object we have detected a point-like mid-IR source. This source is also present in the Spitzer/IRAC images but it is saturated at 4.5, 5.8 and 8.0μm.

The very red source in IRAS18566+0408 is shown in the color-coded near-IR image and in the 18.7μm image of Fig.3

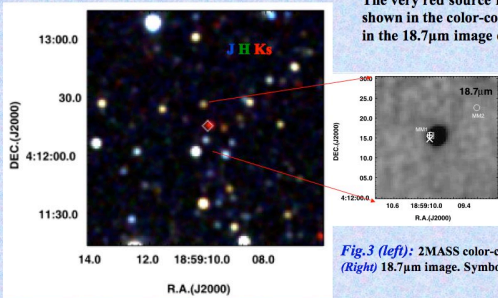
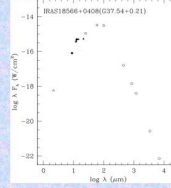


Fig.3 (left): 2MASS color-coded image of IRAS18566+0408. (Right) 18.7μm image. Symbols as in Fig.1



The complete SED of IRAS18566+0408 obtained combining observations from 2μm to 7mm is illustrated in Fig.4. This SED indicates the presence of a HMPO with  $L_{bol} = 1.3 \cdot 10^5 L_{sun}$  and  $\alpha(IR) = 2.5$ . This source could be responsible for driving the jet-like outflow observed by Zhang et al. 2007 (A&A 470, 267).

Fig.4 SED of IRAS18566+0408(G37.54+0.21). Symbols as in Fig. 2

## G85.40-0.0

Pestalozzi et al. 2005 (A&A 432, 737) give a very accurate position for the CH<sub>3</sub>OH maser in this region, while Cambresy et al. 2002 (AJ, 123,2559) identify a young cluster (CBJC8) analysing the 2MASS images. The distance of this region is very doubtful. G85.40-0.0 could be located in the Perseus spiral arm at a kinematical distance of 5-7 Kpc. Fig.5 shows the colour-coded Spitzer/IRAC (left) and the 2MASS colour-coded images (right) in which the presence of a young stellar cluster is evident.

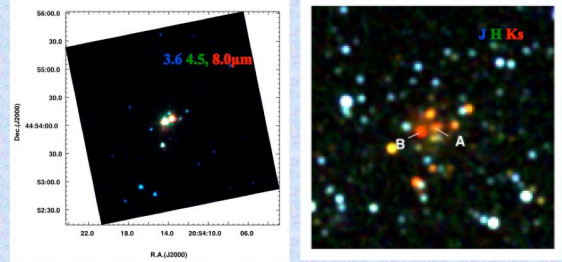
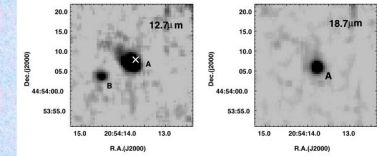


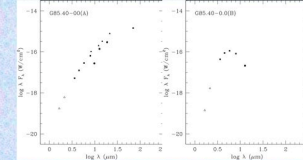
Fig.5(left): Spitzer/IRAC colour-coded image of G85.40-0.0. (Right) 2MASS color-coded image

The two very red near-IR sources (A and B in Fig.5(right)) have been detected also at 12.7μm. Source A is coincident with the Class II Methanol maser as indicated in Fig.6 (left). Their spectral energy distributions are illustrated in Fig.7.



Source A has been also detected at 70μm by Spitzer/MIPS. Integrating its SED we derive  $L_{bol} = 1.2 \cdot 10^4 L_{sun}$  and  $\alpha(IR) = 2.8$ .

Fig.6: 12.7 and 18.7μm images of G85.40-0.0



These values and the coincidence with the methanol maser indicate the source A as an high mass protostellar object.

Fig.7: SEDs of sources A and B in G85.40-0.0

## IRAS23139+5939(G111.24-0.76)

This HMSFR is located near S157 at a distance of 4.8 Kpc. H<sub>2</sub>O maser, radio continuum, and millimeter source have been found associated with the IRAS source (Tofani et al. 1995, A&AS 112, 299; Beuther et al.2002, A&A 383, 892; Trinidad et al. 2006 AJ,132,1918). A very red source (H-Ks=2.8) is observed at the position of IRAS23139+5939 (see Fig.8) in which we have detected a mid-IR source. The methanol maser reported by Pestalozzi et al (2005) is distant about 30" W from this position. The symbol (X) in Fig.7 (left) indicates the position of the 6.7 GHz methanol maser. The association of the methanol maser with this region is unclear.

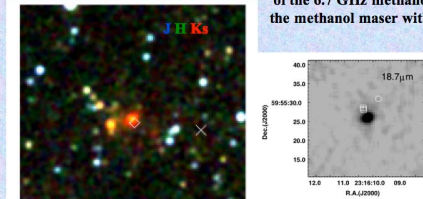
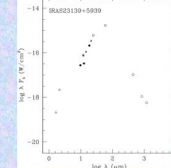


Fig.8 (left): 2MASS colour-coded image of IRAS23139+5939. (Right) 18.7μm image. Symbols as in Fig.1



The spectral energy distribution of IRAS23139+5939 obtained combining our mid-IR observations with 2MASS, MSX, IRAS and mm continuum observation is shown in Fig.9. The SED appears very steep with  $\alpha(IR) = 2.1$  and a computed bolometric luminosity  $L_{bol} = 1.0 \cdot 10^4 L_{sun}$

Fig.9 SED of IRAS23139+5939. Symbols as in Fig.2

In conclusion, we confirm in these regions the presence of HMPOs which characteristics are given in Table 2

Region	$L_{bol}$ ( $L_{sun}$ )	$\alpha(IR)$
IRAS18556+0136	$6.1 \cdot 10^3$	2.4
IRAS18566+0408	$1.3 \cdot 10^5$	2.5
G85.40-0.0(A)	$1.2 \cdot 10^4$	2.8
IRAS23139+5939	$1.0 \cdot 10^4$	2.1