The Australia Telescope campaign to study southern class I methanol masers

M.A.Voronkov (ATNF), K.J.Brooks, A.M.Sobolev, S.P.Ellingsen, A.B.Ostrovskii, J.L.Caswell

contact: Maxim.Voronkov@csiro.au

Introduction

Class I methanol masers (e.g. 9.9, 25, 104 GHz)

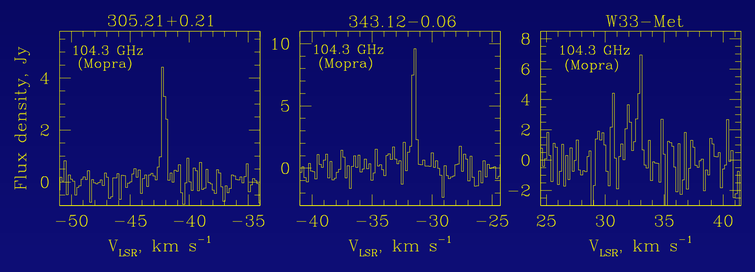
- Maser spots are spread around the protostar location
- Avoid strong infrared sources and ultra-compact HII regions
- Pumped by collisions with hydrogen and helium
- There is a lack of high resolution data to answer which phenomenon in star-forming regions these masers are associated with
- Need searches of various class I masers to develop a pumping model

Class II methanol masers (e.g. 6.7, 12 GHz)

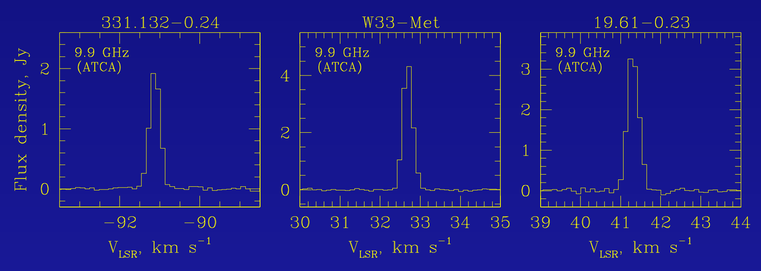
- Maser sites usually have established association with millimeter and infrared sources, and sometimes with ultra-compact HII regions
- Pumped by infrared radiation
- Are the main focus of studies since the discovery of the bright and widespread maser transition at 6.7 GHz

Mopra 104 GHz survey

- Observed 69 targets ⇒ two new masers, 5 marginal detections and 3 broad line sources
- Only one maser at this frequency was known prior to this work (W33-Met)



ATCA 9.9 GHz survey



- Observed 48 independent positions ⇒ 3 new masers, no broad line sources
- Only one maser at this frequency was known prior to this work (W33-Met)

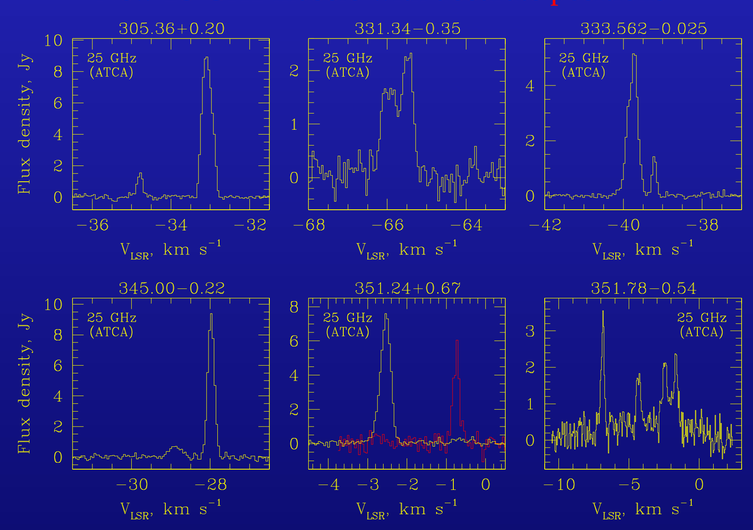
Source name	Absolute position (J2000) R.A.	Dec.	V_{LSR} (km s^{-1})	F (Jy)
331.132-0.24	16:10:59.47(1)	−51:50:23.9(2)	−91.16	1.9(1)
343.12-0.06	16:58:16.460(2)	−42:52:25.73(3)	−31.56	9.5(3)
W33-Met	18:14:10.897(3)	−17:55:58.42(8)	+32.72	4.3(1)
19.61-0.23	18:27:37.475(2)	−11:56:37.77(8)	+41.24	3.3(1)

- Positions and literature suggest a possible association with ionization shocks, except 343.12-0.06 where there is a clear association with an outflow

ATCA 25 GHz (J=5) search

- Observed 102 targets ⇒ 54 masers, 8 marginal, and 5 sources with just a broad line emission
- These masers were believed to be rare and only 4 masers were known prior to this work
- Most observations were done in the director's time ⇒ no position measurement for most sources
- Fluxes do not correlate with other class I masers

New 25 GHz masers with accurate positions

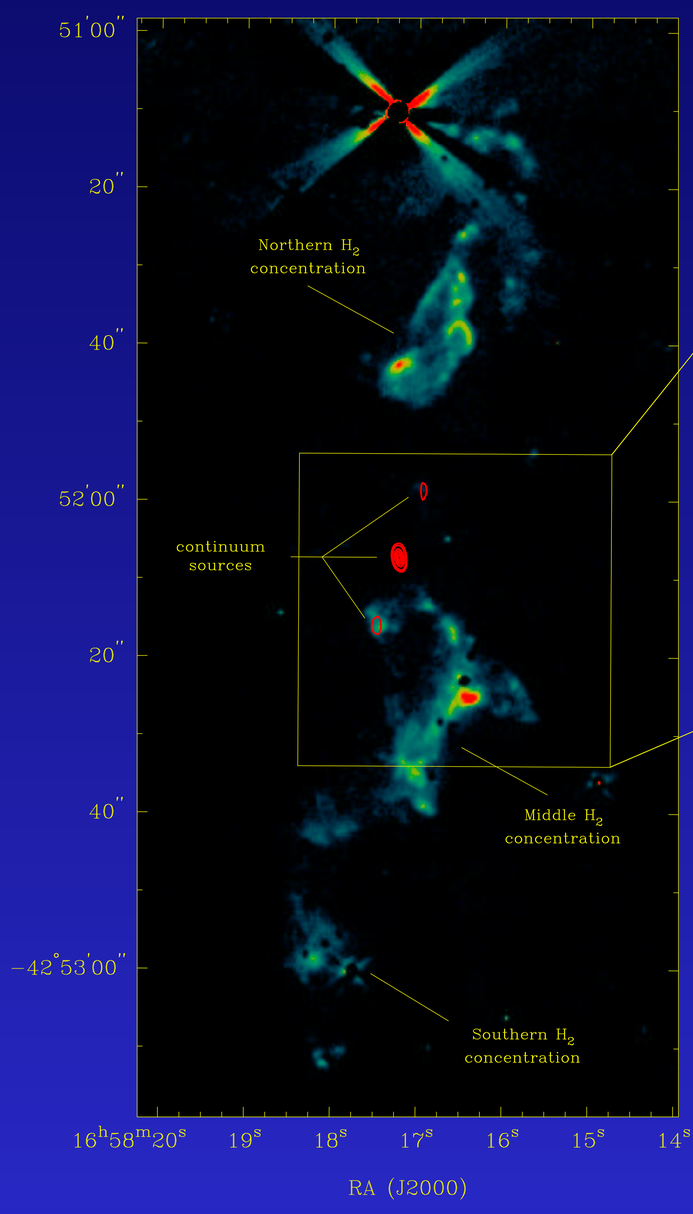


Source name	Absolute position (J2000) R.A.	Dec.	V_{LSR} (km s^{-1})	F (Jy)
305.36+0.20	13:12:36.921(4)	−62:33:35.46(4)	−33.08	8.9(1)
	13:12:36.772(4)	−62:33:37.00(4)	−34.77	1.5(1)
331.34-0.35	16:12:26.413(2)	−51:46:20.57(3)	−65.40	2.3(2)
	16:12:26.413(3)	−51:46:20.57(5)	−65.92	1.7(2)
333.562-0.025	16:21:08.803(1)	−49:59:47.89(3)	−39.70	5.0(1)
	16:21:08.748(2)	−49:59:48.81(3)	−39.88	1.8(1)
	16:21:08.814(1)	−49:59:48.17(3)	−39.23	1.4(1)
345.00-0.22	17:05:11.114(1)	−41:29:19.83(2)	−27.97	9.4(1)
	17:05:11.110(3)	−41:29:20.4(1)	−28.87	0.7(1)
351.24+0.67	17:20:18.325(1)	−35:54:41.26(2)	−2.54	7.6(1)
	17:20:23.643(1)	−35:55:02.59(4)	−0.73	6.0(4) *
351.78-0.54	17:26:42.862(1)	−36:09:03.35(3)	−6.84	3.5(2)
	17:26:42.451(2)	−36:09:17.37(9)	−4.26	1.7(2)
	17:26:42.481(3)	−36:09:17.4(1)	−2.33	2.2(2)
	17:26:42.448(2)	−36:09:15.8(1)	−1.72	2.5(2)

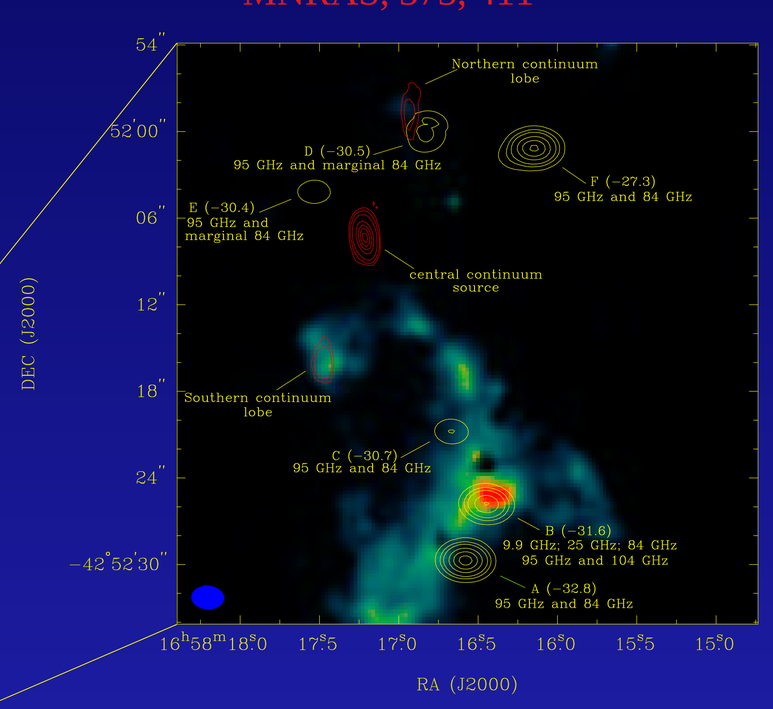
* the spectrum of this offset component is plotted in red

343.12-0.06 (IRAS 16547-4247)

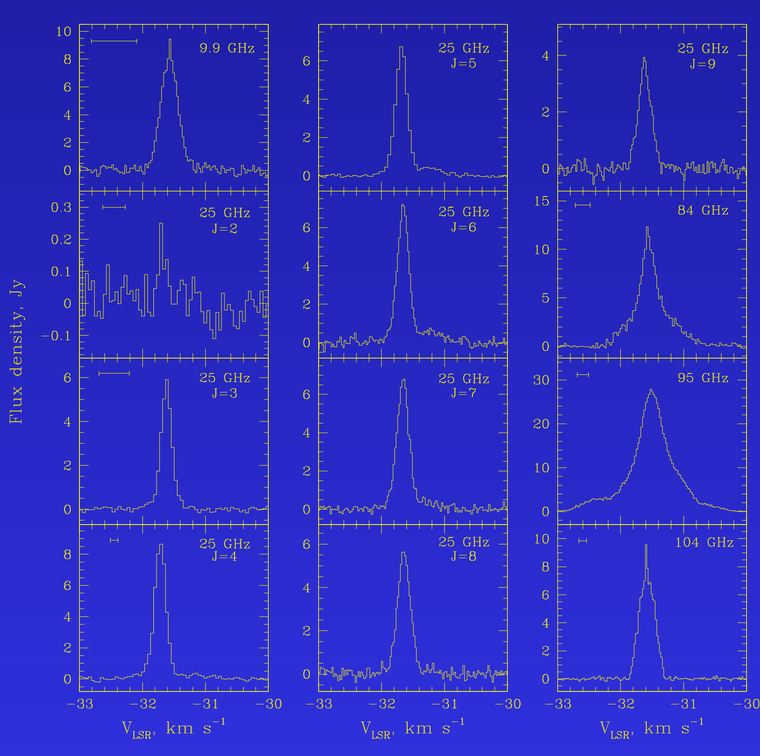
A molecular hydrogen image of the source obtained by Brooks et al. (2003, ApJ, 594, L131):



- Masers detected in all class I transitions observed so far
- The source harbours a highly collimated jet-driven molecular outflow
- ATCA has been used to observe 12 class I maser transitions at 9.9, 25 (a series from J=2 to J=9), 84, 95, 104 GHz in a short period of time
- One spot (B) is active in all observed transitions, while 5 others are active at 84 and 95 GHz only (spots E and D are marginal detections at 84 GHz)



Spectra of Spot B:



- Spots A-C clearly trace the shocked gas delineated by the H_2 2.12 μm emission and their velocities are close to that of the molecular core ⇒ they are associated with the interface region

Conclusions

- The 9.9- and 104-GHz masers brighter than 0.1 and 0.5 Jy, respectively, are rare. Models suggest that they require more energetic conditions (higher temperatures and densities)
- The 25-GHz masers are found in a large number of sources
- In 343.12-0.06, these masers were detected in one spot (B) only and showed association with the brightest knot of H_2 emission
- We were unable to reproduce the relative intensities of all observed transitions in a single model. Parameter gradients in the shocked gas? If yes, the length scale is less than 300 AU
- Three southern spots in this source (two are active at 84 and 95 GHz only) show clear association with a jet-driven molecular outflow Their velocities are close to that of the molecular core within which the jet is embedded. This fact supports the idea that some class I masers reside in the interface regions of outflows. There are indications that other 9.9-GHz masers found in the project could be associated with the ionization shocks
- The 9.9- and 104-GHz spectra of 343.12-0.06 contain a very narrow spike (<0.03 km s^{-1}) which has a brightness temperature greater than 5.3×10^7 and 2.0×10^4 K at 9.9 and 104 GHz, respectively

For more details see Voronkov et al., 2006, MNRAS, 373, 411