

Observations of methanol masers at 95 GHz

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Abstract. — The Metsähovi 13.7-m radio telescope was used to search for emission in the 95 GHz $8_0 - 7_1A^+$ transition of methanol towards a number of star-forming regions. Eleven known 44 GHz ($7_0 - 6_1A^+$ transition) methanol masers were observed; 95 GHz emission was found towards nine sources, five of which are new detections. For two sources, S 140 and R 146, only upper limits were obtained. Most likely the 95 GHz line is masing in all cases with detected emission, except for W51 e1/e2 toward which a broad thermal emission line is observed. The integrated flux density is higher at 95 GHz than at 44 GHz. It is suggested that the 95 GHz methanol masers are as widespread as the 44 GHz masers.

Key words: methanol — masers — radio lines: interstellar

1. Introduction

Methanol masers are associated with almost all known regions of massive star formation. Most of the so-called Class I methanol masers (Menten 1991) emit in the transition $7_0 - 6_1A^+$ at 44 GHz. More than fifty 44 GHz masers have been found in the Galaxy (Morimoto et al. 1985; Forster et al. 1990; Haschick et al. 1990; Bachiller et al. 1990; Kalenskii et al. 1992). The methanol transition $8_0 - 7_1A^+$ at 95 GHz has its upper energy level 18.5 K higher than the upper level of the 44 GHz line. This transition may be inverted in the same manner as the transition $7_0 - 6_1A^+$, and may also show maser phenomenon.

Maser emission in the $8_0 - 7_1A^+$ transition was first detected by Ohishi et al. (1986) in the direction of Ori-KL, and by Nakano & Yoshida (1986) in the direction of S 235. Plambeck & Wright (1988) and Plambeck & Menten (1990) made interferometric observations of the star forming regions Ori-KL and DR 21 in this line, and determined a lower limit of 5000 K for the brightness temperature of the strongest maser component. Menten (1991) and Pratap & Menten (1993) have also reported 95 GHz observations of the star forming regions OMC-2, NGC 2264, W 51 and W 33. However, no systematic search for galactic methanol masers at 95 GHz has been carried out. To begin such a survey we have started a program of observations at 95 GHz towards known 44 GHz masers.

2. Observations

The observations were made during Oct. 29 – Nov. 1 1992 using the 13.7-m radio telescope at Metsähovi (Urpo 1975). The HPBW of the antenna is $60''$. The surface accuracy of the antenna is ca. 0.35 mm (rms), and at the frequency of 95 GHz the telescope has an aperture efficiency of about $16 \pm 2\%$ (Räsänen et al. 1983). The pointing accuracy is better than 10 arcsec (rms).

The observations were obtained with a spectral line receiver in frequency switching mode. The frequency of the $8_0 - 7_1A^+$ transition (95.169489 GHz) was taken from De Lucia et al. (1989). A cryogenically cooled low noise Schottky mixer (Dryagin et al. 1993) was used. The double sideband receiver noise temperature was 150 K. The back end was a 100 MHz wide AOS with 1728 channels and a frequency resolution of 120 kHz (corresponding to a velocity resolution of 0.4 km s^{-1} at 95 GHz). The system noise temperature, corrected for atmospheric absorption, rearward spillover and ohmic losses, varied during our observations from 900 K to 1800 K, depending on weather conditions and the elevation of the sources. The data were calibrated using the standard chopper-wheel method of Kutner & Ulich (1981). The antenna temperature, T_A^* , of 1K corresponded to 117 Jy. The variable weather conditions during the observations caused some 30% uncertainty in the antenna temperature.

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3. Results

The observations were made in the direction towards known 44 GHz maser sources (Haschick et al. 1990; Bachiller et al. 1990). The 95 GHz methanol line was detected towards nine sources out of eleven observed. Four of them – DR-21 West, NGC 2264, OMC-2, and W 51 e1/e2 – have been observed earlier (Plambeck & Menten 1990; Menten 1991; Pratap & Menten 1993).

Line parameters of the observed sources are given in Table 1. The first column gives the name of the source, the second and the third the equatorial coordinates. The fourth column presents the radial velocity of the line, the fifth the line width, corrected for the spectrometer resolution, the sixth the measured values (or upper limits) of the integrated flux. The seventh column gives the integrated flux densities of the $7_0-6_1A^+$ transition at 44 GHz (taken from Haschick et al. 1990 and Bachiller et al. 1990) and the last column gives the ratio ($R_{95/44}$) of the integrated flux densities at 95 GHz and 44 GHz. Figure 1 shows the 95 GHz spectra of the observed sources.

4. Comments on individual sources

4.1. OMC-2

In the direction of OMC-2 (a complex of infrared sources) a narrow, probably masing line, was detected. The spectrum is very similar to that of Menten (1991): the line is at the same radial velocity and has the same width. Narrower maser lines have been detected earlier in this source in the transitions $7_0-6_1A^+$ (Haschick et al. 1990), $4_{-1}-3_0E$ (Haschick et al. 1989) and J_2-J_1E (Menten et al. 1988). The radial velocity of the line at 95 GHz coincides with radial velocities of other maser lines. The integrated flux density at 95 GHz is about the same as at 44 GHz.

4.2. S 231

This is a new detection at 95 GHz. A comparison with the corresponding maser at 44 GHz (Bachiller et al. 1990) shows that the line is a factor of 3 wider (but narrower by a factor of 2 than the thermal methanol line $1_0-0_0A^+$, observed by Slysh et al. 1993), and that the integrated flux is some 8 times higher.

4.3. S 255

This is also a new detection. The 95 GHz line is somewhat wider than the line at 44 GHz (Haschick et al. 1990). The integrated flux at 95 GHz is 5.7 times higher than at 44 GHz.

4.4. NGC 2264

The line is weaker and wider by a factor of two as compared to the spectrum of Menten (1991); however, the integrated fluxes are roughly the same. At 44 GHz there is a very narrow line at the same radial velocity with an integrated flux (Haschick et al. 1990) by a factor of 0.8 lower than the value at 95 GHz.

4.5. W 51 e1/e2

A wide, apparently thermal line was detected in the direction of the ultracompact HII-regions W 51 e1 and e2. This source has been mapped with the BIMA array by Pratap & Menten (1993) but they do not give any flux data. A narrow line was reported at 44 GHz by Haschick et al. (1990) at the radial velocity 48.9 km s^{-1} , but this was not seen at 95 GHz. The 95 GHz maser at the radial velocity of 56.5 km s^{-1} , mapped by Pratap & Menten (1993), is 1.3 arc minutes away from the ultracompact regions e1/e2 and outside the beam of the Metsähovi telescope.

4.6. W 75-North

This newly detected line at 95 GHz is at the same radial velocity as the 44 GHz line observed by Haschick et al. (1990), and is wider by factor of 4 (but narrower by a factor of 2 than the thermal methanol lines J_2-J_1E , measured by Menten et al. 1986). The integrated flux at 95 GHz is 4 times higher than at 44 GHz.

4.7. DR 21-West

We detected a strong narrow line in the direction of DR 21-West. Plambeck & Menten (1990) have observed with the BIMA array a still narrower line at the same radial velocity. At 44 GHz Haschick et al. (1990) observed a narrow line of the same width as Plambeck & Menten (1990) with the integrated flux by a factor of 0.43 lower than the value observed at 95 GHz in Metsähovi. Because an adjacent 95 GHz methanol maser, DR 21-C, is displaced $78''$ east of DR 21-West (Plambeck & Menten 1990), a possible pointing error of the telescope could produce a situation where lines from both sources would blend in the spectrum producing a larger line width.

4.8. W 75-S(3)

A new source at 95 GHz with a rather wide line. Figure 1 suggests that this line is a blend of two velocity components. At 44 GHz Bachiller et al. (1990) reported two lines within the velocity interval of the 95 GHz line. The ratio of the integrated fluxes at 95 GHz and 44 GHz is 1.8.

4.9. NGC 7538

This is the first observation of a line at 95 GHz from this source. The line is at the radial velocity of -57.55 km s^{-1} , the same as the radial velocity of the 44 GHz line observed by Bachiller et al. (1990). Haschick et al. (1990) report a wide line at 44 GHz at a slightly different radial velocity. Forster et al. (1990) observed at 44 GHz a line at -57.6 km s^{-1} with the line width 2.1 km s^{-1} but they do not give any integrated flux densities. The integrated flux at 95 GHz is some four times higher than at 44 GHz (Bachiller et al. 1990; Haschick et al. 1990).

4.10. S 140 and R 146

No line was detected at 95 GHz, but our upper limits of the integrated flux are higher than the integrated fluxes at 44 GHz (Haschick et al. 1990, Bachiller et al. 1990). Since the integrated flux ratio between 95 GHz and 44 GHz is typically 1.5-3 (see above), one might expect a detection of the 95 GHz line from these sources when a better sensitivity is available.

5. Summary and conclusions

As a result of this pilot survey it has been found that 9 out of a sample of 11 maser sources were detected also at 95 GHz. It is suggested that the 95 GHz masers are as widespread as the 44 GHz masers (of which some 50 have been observed). The integrated flux at 95 GHz is typically 1.5-3 times higher than at 44 GHz. However, for the very symmetrical line profiles in our sample (OMC-2 and NGC 2264), for which $\Delta V < 0.9 \text{ km s}^{-1}$, the integrated fluxes at 95 GHz and 44 GHz are roughly the same. The line width in the present 95 GHz observations is almost always larger than observed at 44 GHz. The 95 GHz and 44 GHz lines may differ because the emission may be coming from spatially different regions at the two frequencies. Most likely the 95 GHz line is masing in all cases with detected emission, except for W51 e1/e2 toward which a broad thermal line is observed.

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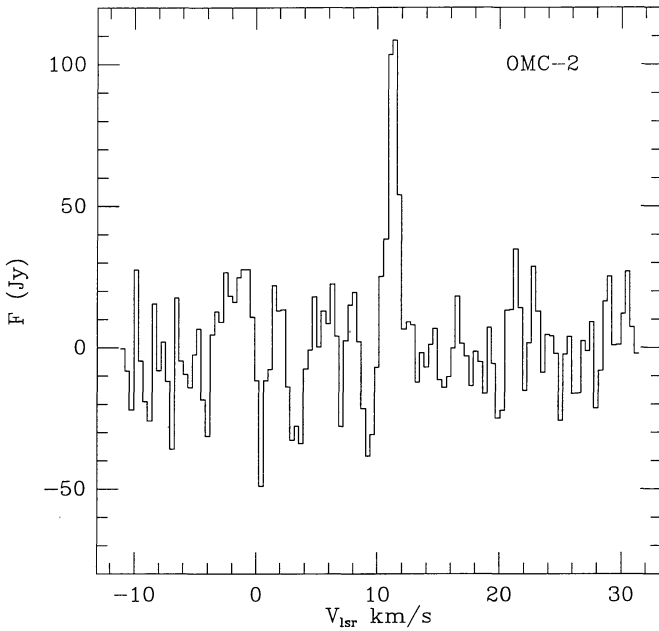
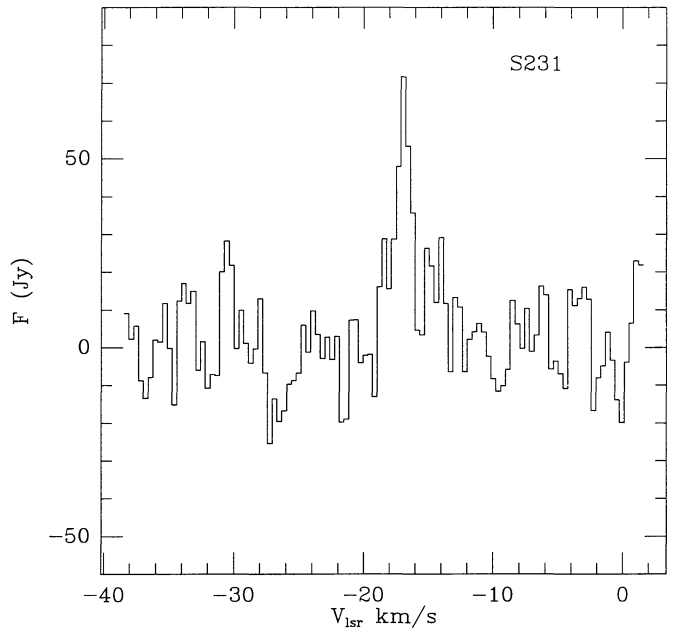
Table 1. CH₃OH (8₀ – 7₁) A⁺ line parameters with their 1σ statistical errors

Source	Coordinates		V _{LSR} (kms ⁻¹)	ΔV(FWHM) (kms ⁻¹)	∫S _{95dV} (Jykms ⁻¹)	∫S _{44dV} (Jykms ⁻¹)	R _{95/44}
	α ₁₉₅₀	δ ₁₉₅₀					
OMC-2	05 ^h 32 ^m 59.8 ^s	-05°11'29"	11.26 (0.03)	0.86 (0.07)	100 (14)	96 (2) ^{a)}	1.1 (0.1)
S 231	05 35 51.3	35 44 16	-17.00 (0.05)	1.57 (0.10)	110 (15)	14 (2) ^{b)}	7.9 (2.1)
S 255	06 10 01.0	18 00 44	10.75 (0.10)	2.12 (0.20)	97 (14)	17 (2) ^{a)}	5.7 (1.3)
NGC 2264	06 38 24.9	09 32 28	7.24 (0.03)	0.83 (0.06)	130 (12)	107 (4) ^{a)}	1.2 (0.1)
W 51 e1/e2	19 21 26.2	14 24 43	55.67 (0.12)	5.58 (0.23)	300 (17)	221 (9) ^{a)}	1.4 (0.1)
W 75-North	20 36 50.4	42 27 23	9.05 (0.06)	1.98 (0.12)	90 (09)	23.1 (1.4) ^{b)}	4.0 (0.5)
DR 21-West	20 37 07.6	42 08 46	- 2.54 (0.03)	1.06 (0.05)	290 (12)	125 (3) ^{a)}	2.3 (0.1)
W 75-S(3)	20 37 16.7	42 15 15	- 4.47 (0.09)	2.38 (0.15)	90 (09)	53 (3) ^{b)}	1.8 (0.2)
R 146	21 42 40.0	65 52 57	- 6.4 (0.10) ^{b)}	1.1 (0.3) ^{b)}	< 75 ^{c)}	16 (4) ^{b)}	< 4.7
S 140	22 17 41.2	63 03 43	- 8.22 (0.07) ^{a)}	0.7 (0.2) ^{a)}	< 81 ^{c)}	12 (3) ^{a)}	< 6.8
NGC 7538	23 11 37.7	61 11 12	-57.55 (0.04)	1.31 (0.07)	220 (14)	63 (5) ^{a)} or 52 (3) ^{b)}	3.5 (0.4) or 4.2 (0.4)

a) Haschick et al. (1990)

b) Bachiller et al. (1990)

c) assuming a line width as measured at 44 GHz

**Fig. 1a.****Fig. 1b.****Fig. 1.** Spectra of the 8₀ – 7₁A⁺ (95 GHz) transition of methanol observed towards 7₀ – 6₁A⁺ (44 GHz) maser sources. The velocity resolution is 0.4 km s⁻¹

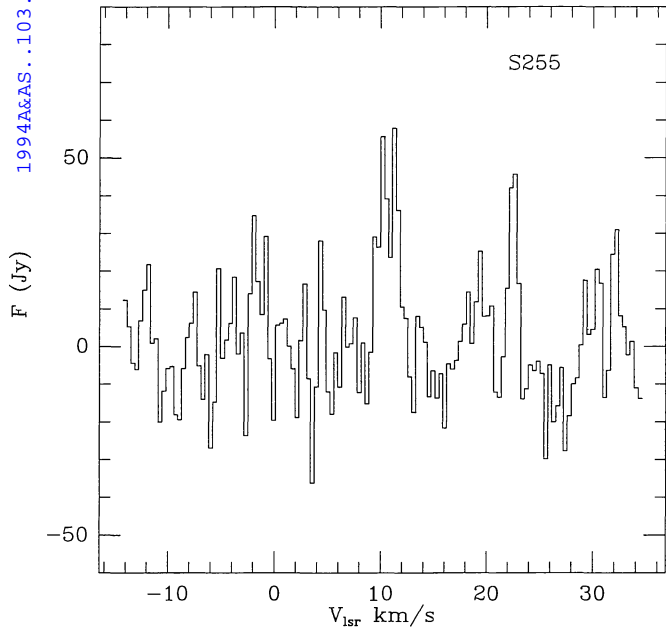


Fig. 1c.

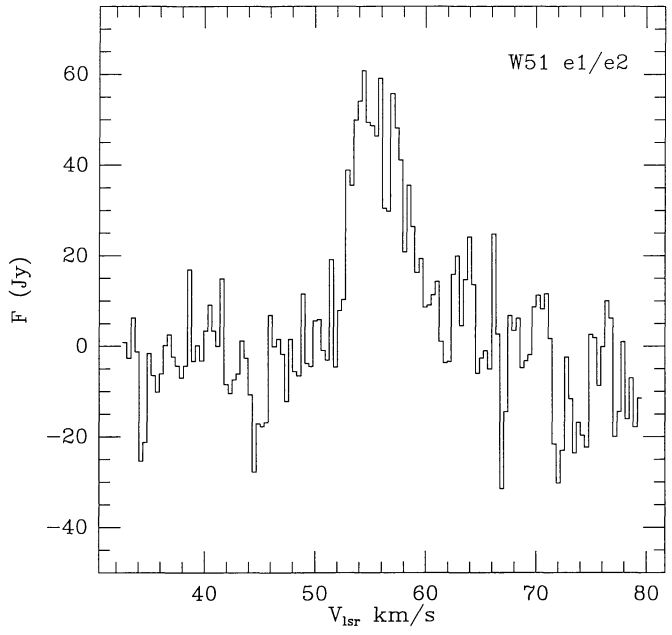


Fig. 1e.

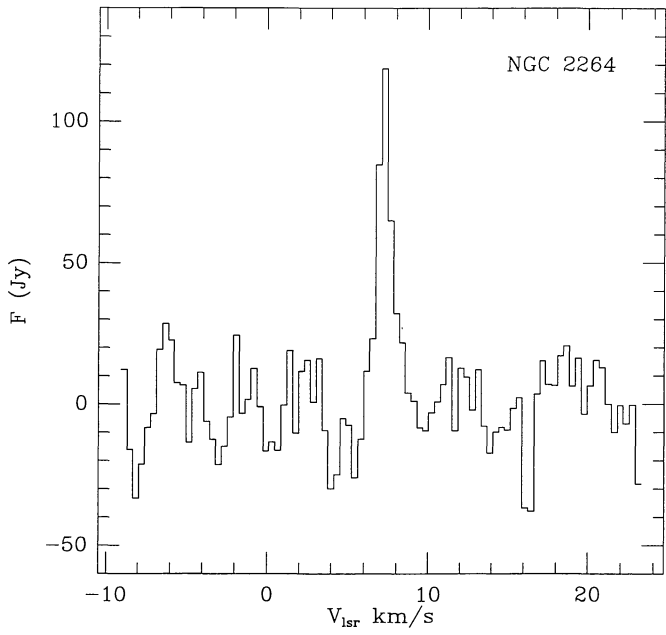


Fig. 1d.

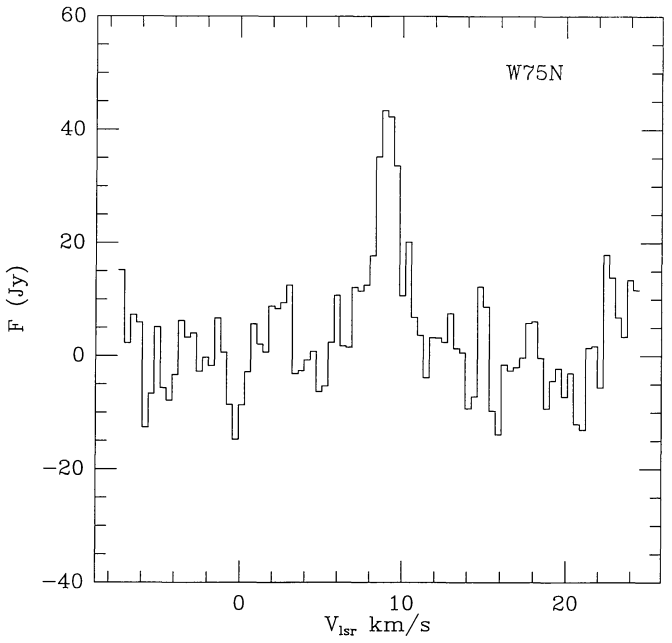


Fig. 1f.

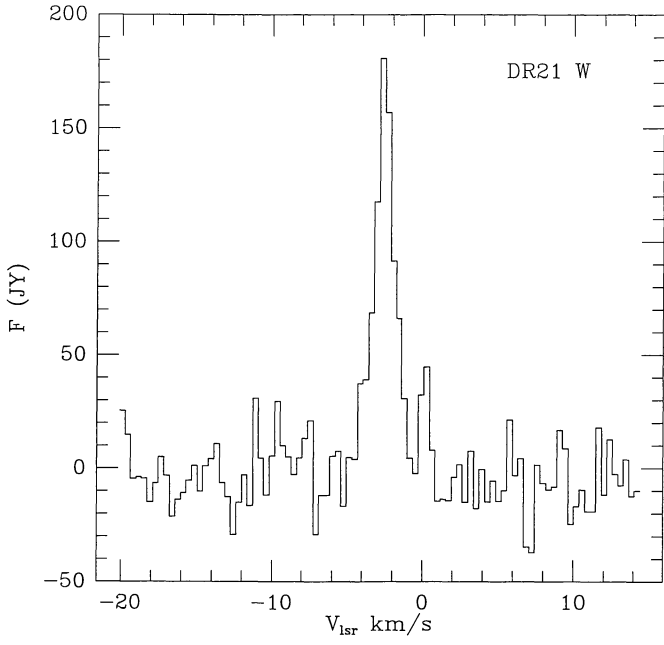


Fig. 1g.

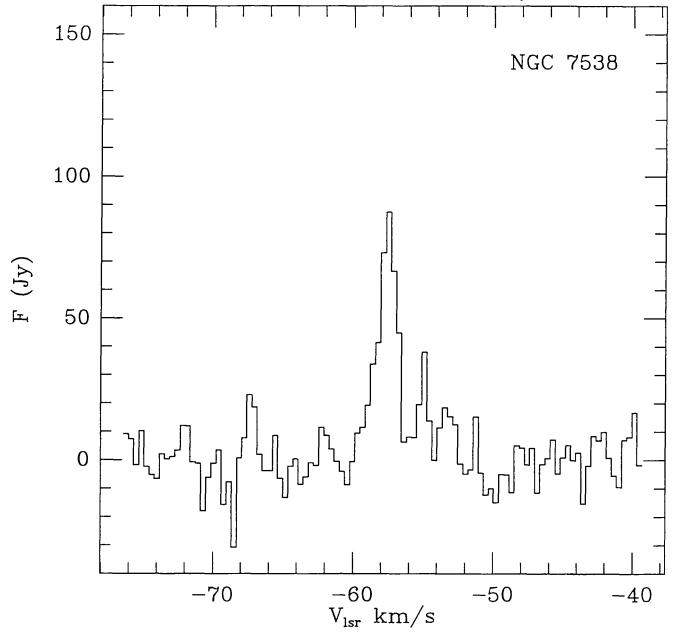


Fig. 1i.

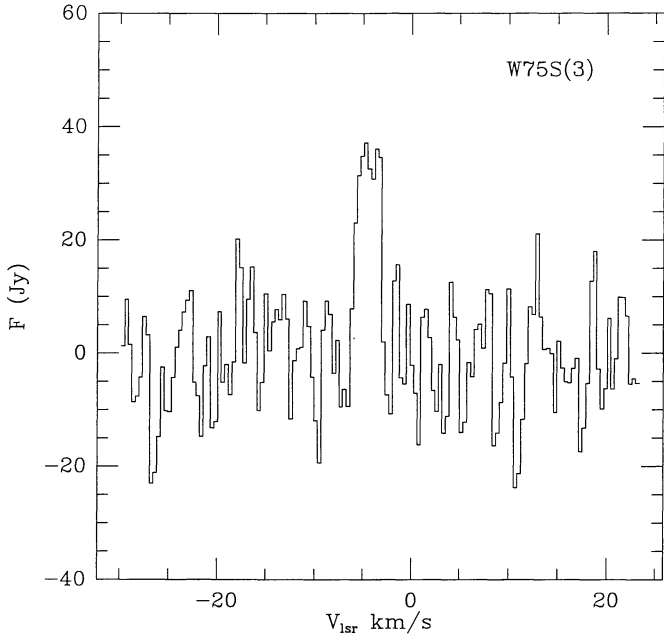


Fig. 1h.