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First molecular cloud measurement with Irbene RT-32 radio telescope

A. Aberfelds[1,*], A. Vasyunin[1,2]

[1] *Engineering Research Institute "Ventspils International Radio Astronomy Center", Ventspils University of Applied Sciences, Inzenieru Str. 101, Ventspils, LV-3601, Latvia*

[2] *Ural Federal University, Ekaterinburg, Russia*

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This paper describes the efforts of the Ventspils International Radio Astronomy Center (VSRC) astrochemist and observation groups to study the formation of massive stars from chemical evaluation and radio emission point of view. By observing all four selected sources chemists group observations can provide important feedback to models, mainly an information for molecules with maser emission. Based on detection of masers in young stellar object (YSO) observations provide information that there are parts of molecular clouds where gas density and molecular abundances are higher by a few orders than in typical young star forming clouds.

Keywords: Molecular clouds, YSO, methanol

1 Introduction

Young stars form in collapsing massive molecular clouds, where after the fragmentation process individual young stellar objects (YSO) form. These YSO are deeply embedded in surrounding gas and dust and are heavily optically obscured. These aspects make longer than optical wavelengths observations preferable for studying YSO. In these environments complex organic molecules form and are the primary place where the molecular abundances and reactions are modelled [1].

In VIRAC of Ventspils University of Applied Sciences Astronomy department there are two groups of scientists: astrochemist and maser study group. This paper is the result of the first joint study of same objects by both teams. The research goals are: to observe selected sources in multiple molecular transitions, for detected lines to measure source brightness temperature and to provide gas parameters for sources based on line detection.

*Email: artis.aberfelds@venta.lv

The sources were selected from well known and in detail studied sources with the idea to have the possibility to compare results from publications of other authors. The astrochemist group decided to model chemical abundances of the following sources: W3(OH), S235, G34.24+0.13, L1544 and TW Hya. More information is presented in Table 1; the last source (TW Hya) in the list is not observable from Latvia.

Table 1 List of selected sources.

Source name	RA, J2000	DEC, J2000	Type
W3(OH)	02h27m03.82s	61d52m25.4s	YSO
S235	05h41m33.8s	35d48m27.0s	YSO
G34.24+0.13	18h53m21.44s	01d14m26.0s	YSO
L1544	05h04m16.6s	25d10m48.0s	Pre-stellar core
TW Hya	11h01m51.90s	–34d42m17.03155s	T Tau star

2 Observations

All observations were carried out using Irbene RT-32 radio telescope equipped with dual-channel broad band receiver 4.5–8.8 GHz. For all observations reported in this paper, the standard set-up with 1.5625 MHz band with configuration to use 4096 channels was used. The spectra were obtained in a frequency-switching mode by using 4 calibration stages each 15 seconds long with methods described in [2]. Data used in this paper has an on-source ingratiation time of approximately 60 min which gives three standard deviation amplitudes around 0.3–0.4 Jy. The data was obtained from 8 to 15 of June 2019.

The authors identified that in the frequency range covered by Irbene radio telescopes there are many transitions but only a few have good possibilities to detect:

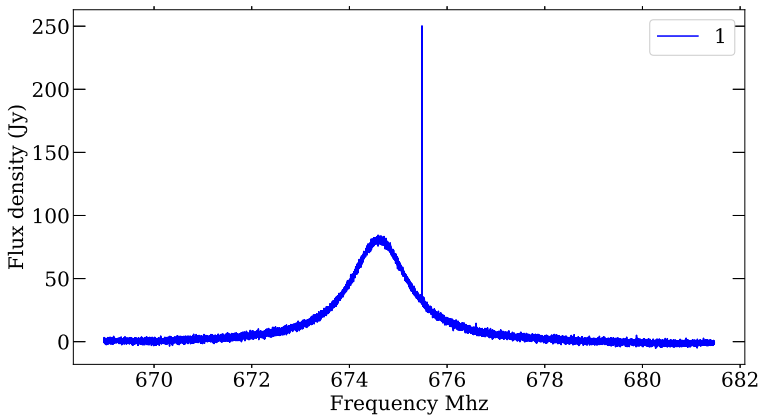


Figure 1 Illustration for the bad frequency range on RT-32 receiver. The resulting frequency (4829.659 MHz) is the sum of values visible in the plot plus an intermediate frequency (in this case 4100 MHz).

methanol $5_1 - 6_0$ A^+ 6668.519 MHz, ex-OH $^2\Pi_{3/2}$, $J = 5/2$, $F = 3^- - 3^+$ 6035 MHz, H_2CO $1_{10} - 1_{11}$ 4829.659 MHz and $H110\alpha$ 4874.157 MHz [3].

Unfortunately, during observation data reduction for $H110\alpha$ line it was found that there was a receiver defect in that frequency range. It was also confirmed later by engineering tests (see Figure 1) with the conclusion that with frequency-switching technique this frequency range cannot be used for scientific measurements.

3 Line detection and results

For four observable sources with 3 targeted frequencies we detected a signal in 8 of 12 observations. All 3 transition lines were detected towards: W3(OH) and G34.24+0.13 methanol maser and formaldehyde absorption were detected towards S235 but there was no detection for L1544 (see Table 5).

Table 2 Measured values for W3(OH).

Transition	Peak flux density, Jy	Brightness temperature T_B, K
Methanol 6.7 GHz	3000	700000
Ex-OH 6.035 GHz	120	28000
H_2CO 4.829 GHz	–0.8	180

Towards W3(OH) a comparably very strong methanol and ex-OH maser (see Table 2 and Figure 2) were detected. Extremely high calculated brightness temperatures T_B [4] values suggest strong gain for masers. These aspects make line profiles less directly related to gas temperature, density and other factors which typically determine thermal line shapes and amplitude.

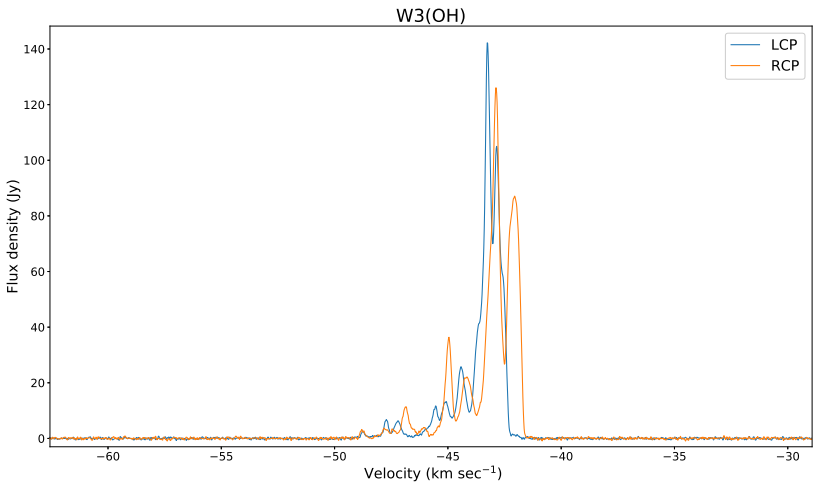


Figure 2 W3(OH) ex-OH maser spectrum.

Towards the source S235, RT-32 did manage to detect two of three targeted frequencies. In this case the obtained spectrum reveals low intensity lines (Table 3). Measured methanol $5_1 - 6_0$ A^+ 6668.519 MHz line amplitude is 1.6 Jy and estimated T_B is 360 K with the extra aspect that the S235 methanol line is narrow and we can assume that it is weak but still by stimulated emissions boosted maser. If there is ex-OH line it is very weak only $\leq$0.4 Jy and within the possible gas kinetic temperature range calculated T_B = 80 K.

Table 3 Measured values for S235.

Transition	Peak flux density, Jy	Brightness temperature T_B, K
Methanol 6.7 GHz	1.6	360
Ex-OH 6.035 GHz	$\leq$0.4	$\leq$80
H_2CO 4.829 GHz	–0.6	145

By observing G34.24+0.13 (see Figures 3 and 4) authors detected all three targeted transitions. Methanol line's flux is 20 Jy with T_B = 4800 K. Similarly, ex-OH was weak, only 0.9 Jy with T_B = 240 K (Table 4). Towards G34.24+0.13 measured H_2CO absorption was –3.1 Jy by far the strongest in our sample.

Table 4 Measured values for G34.24+0.13.

Transition	Peak flux density, Jy	Brightness temperature T_B, K
Methanol 6.7 GHz	20	4800
Ex-OH 6.035 GHz	0.9	240
H_2CO 4.829 GHz	–3.1	140

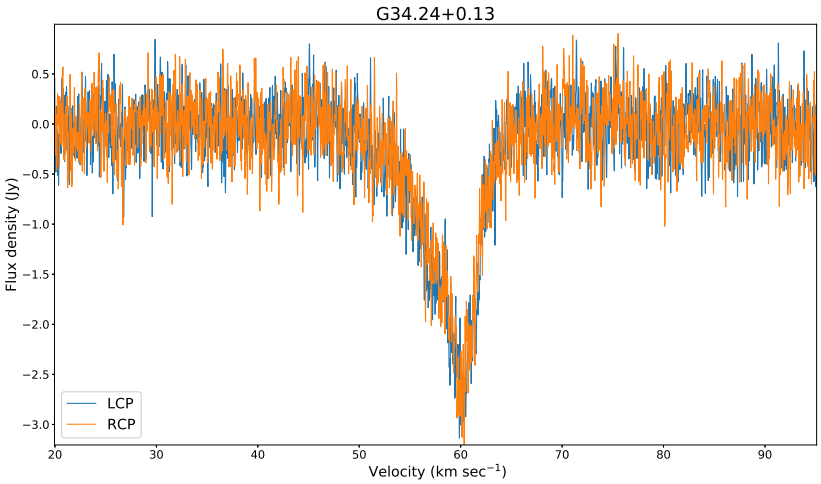


Figure 3 G33.24+0.13 H_2CO absorption.

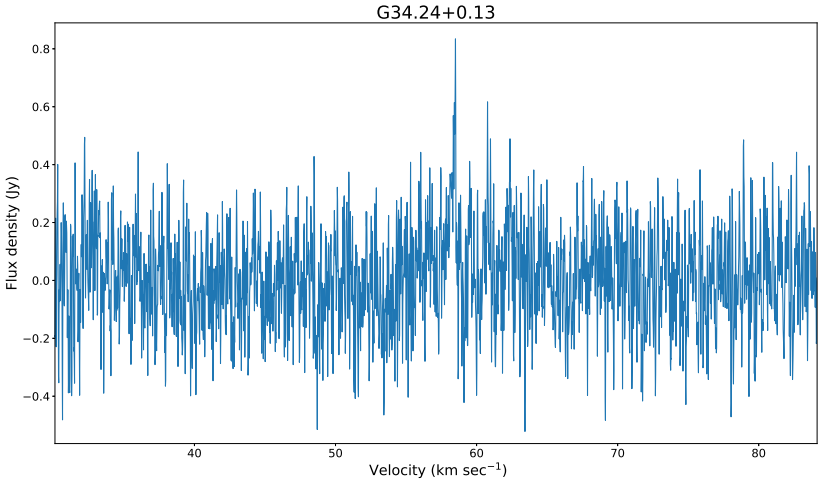


Figure 4 G33.24+0.13 ex-OH two polarization average spectrum.

Table 5 Measured values for L1544.

Transition	Peak flux density, Jy	Brightness temperature T_B, K
Methanol 6.7 GHz	≤0.3	≤70
Ex-OH 6.035 GHz	≤0.3	≤70
H_2CO 4.829 GHz	≤0.31	≤70

4 Conclusions

Using the RT-32 radio telescope located in Irbene, for the first time, the authors have demonstrated estimation of YSO parameters from locally obtained observation data. Taking into consideration that methanol and ex-OH masers are active only in a narrow range of gas physical properties it is possible to conclude that in three molecular clouds towards which methanol maser was detected are areas where H_2 concentration is above 10^7 molecules per cm^{-3}, methanol relative to hydrogen abundance is larger than 7×10^{-7} molecules and gas kinetic temperature is in the range from 10 to 200 K. Analogically for ex-OH masers environmental parameters are similar: H_2 concentration is above 10^7 molecules per cm^{-3}, OH relative abundance is larger than 2×10^{-7} molecules with respect to H_2 and gas kinetic temperature is in the range from 30 to 100 K; also dust temperature is estimated to be about 70 K [1]. It is important to remember that even though these two maser species can be found in the same YSO they can be separated by several hundreds of astronomical units.

No detections towards L1544 are surpassing because this source is classified as pre-stellar core and at this early stage of star forming evaluation the proto-star is not typically bright enough to provide necessary energy amount for maser pumping.

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