Astronomy Letters, Vol. 24, No. 6, 1998, pp. 788–794. Translated from Pis'ma v Astronomicheskii Zhurnal, Vol. 24, Nos. 11–12, 1998, pp. 910–917.
Original Russian Text Copyright © 1998 by Val'tts.

The Unusual Methanol Maser 345.01+1.79

I. E. Val'tts

Astrospace Center, Lebedev Physical Institute, Russian Academy of Sciences, ul. Profsoyuznaya 84/32,
Moscow, 117810 Russia

Received April 20, 1998

Abstract—We analyze the spectra of G345.01+1.79 that were obtained during multi-frequency observations in class-I and class-II methanol lines at 44, 95, 107, 108, 133, 157, 165, and 229 GHz. We determine the relative positions of the condensations in which maser and thermal lines are formed. All strong class-II maser lines originate in the southern spot in the velocity interval –24 to –14 km s^{-1}. The thermal lines in class-II transitions are concentrated in the velocity interval of –14 to –11 km s^{-1}, which is closer to the velocity of the parent molecular cloud and the northern center of weak class-II maser emission. Although they have no peculiar velocity of the southern spot, the class-I masers spatially gravitate toward it. This is a unique source, the only one in which a maser has been detected at 108 GHz and one of a few in which a maser has been found at 157 GHz.

INTRODUCTION

Molecular clouds are observed in the Galaxy everywhere. They share many common properties; the main property among them is violent star formation inside such clouds. Young stars embedded in molecular clouds stir up the surrounding interstellar medium, triggering the formation of many peculiar objects, such as globules, Herbig–Haro objects, strong infrared and radio sources, extremely compact H II regions, bipolar outflows, and sources of molecular maser emission. These objects most likely characterize the various evolutionary phases of prestellar matter, but, at the same time, there is a clear relationship between them. Establishing the nature of this relationship would help in tracing the evolutionary processes in molecular clouds—from the stage of diffuse interstellar gas to the birth of protostellar and young stellar objects. In this case, multi-frequency studies of sources of line emission play a special role.

Observations of interstellar methanol lines are most informative in spectroscopic studies of molecular clouds. Methanol is very abundant in the interstellar medium and has a rich line spectrum. An analysis of its lines points to a great variety of physical conditions under which they are formed. Many methanol lines turned out to be maser lines. The methanol sources emitting maser lines can be divided into two classes. In general, class-I masers do not coincide with OH and H_2O masers, compact H II regions, and near-infrared sources. Class-II sources coincide with OH masers and compact H II regions, but do not coincide with H_2O masers (Batrla *et al.* 1987; Menten 1991a). At the same time, the accumulation of statistical data from observations of methanol maser sources leads us to conclude that this classification is not very strict and clear-cut. In many star-forming regions, class-I and class-II masers are observed toward the same objects at the same positions within the telescope beams; so far, it is not known whether these lines originate from the same clumps of matter in different evolutionary stages or whether these clumps are under different physical conditions and formed simultaneously, some as class-I masers and others as class-II masers. This problem can be resolved only by a more thorough study of the relative spatial positions of the emission sources, i.e., using interferometric observations. In this paper, we perform an analysis of the multi-frequency observations of methanol masers in combination with an analysis of their positions relative to OH and H_2O masers and infrared sources in the star-forming region G345.01+1.79, which is very rich in peculiar objects.

THE HISTORY OF THE STUDY OF G345.01+1.79

In 1980–1983, Caswell *et al.* (1980) and Caswell and Haynes (1983) published their surveys of the southern part of the Galactic plane from 326° to 2° through the Galactic Center in the main OH lines. The surveys were carried out with the 64-m radio telescope in Parkes (Australia), and the search was made toward HII regions, dust clouds, and various types of stars. There was the OH maser 345.01+1.79 among the OH masers discovered. Like most masers discovered in these surveys (a total of about 100), 345.01+1.79 turned out to be a class-I OH maser, i.e, with a stronger line at 1665 MHz than that at 1667 MHz. It stood out among the other OH masers neither in the line intensity, in the velocity interval of the full OH-line profile, nor in its position in the Galaxy. It lies at the edge of an extended H II region, which is slightly offset from the Galactic plane.

Virtually simultaneously with the OH survey of the Galactic plane, Caswell *et al.* (1983) conducted a similar H_2O survey with the same radio telescope. An H_2O maser, in general, only one, was found to be associated

1063-7737/98/2406-0788$15.00 © 1998 МАИК Наука /Interperiodica Publishing

with most OH masers. Only in a few most active star-forming regions were several H_2O masers associated with one OH maser; such was the OH maser 345.01+1.79. Two H_2O masers were detected near it: 345.01+1.79 (stronger) and 345.01+1.80 (weaker).

The study of the 345.01+1.79 region in methanol lines was initiated in 1987. Norris *et al.* (1987) surveyed 63 OH masers from the surveys of Caswell *et al.* (1980, 1983) and Caswell and Haynes (1983, 1987) in Parkes at 12 GHz in the 2_0–$3_{-1}E$ transition and discovered a strong maser toward OH 345.01+1.79 (a peak flux density of 426 Jy, the second brightest maser among the 16 detected masers).

In 1991, Menten (1991b) discovered a strong maser in the same direction at 6.7 GHz in the 5_1–6_0A^+ transition with the 45-m antenna at NRAO (United States) (a peak flux density of 544 Jy, the eighth brightest maser among the 88 masers detected). Both transitions belong to class-II masers.

Two more class-II maser transitions were detected in this source: at 157 GHz (the J_0–$J_{-1}E$ sequence) with the 12-m radio telescope at the Kitt Peak Observatory (United States) (Slysh *et al.* 1995) and at 108 GHz (the 0_0–$1_{-1}E$ transition) with the 30-m radio telescope at Pico Veleta (Spain) (Slysh *et al.* 1998a). It should be noted that masers at 157 and 108 GHz are very rare: only four masers from a sample of about 200 sources were discovered at 157 GHz and two of the 60 masers were detected at 108 GHz. In addition, another class-II maser transition (3_0–4_1A^+) has recently been discovered at 107 GHz in 345.01+1.79 with the 15-m SEST radio telescope in Chile (Booth *et al.* 1997) and with the 22-m Mopra radio telescope in Australia (Val'tts *et al.* 1998a).

Meanwhile, observations of 345.01+1.79 at frequencies typical of class-I methanol maser emission revealed class-I masers in this region as well. The observations were carried out in Parkes at 44 GHz in the 7_0–6_1A^+ transition (Slysh *et al.* 1994), in Mopra at 95 GHz in the 8_0–7_1A^+ transition (Val'tts *et al.* 1998b), and at Pico Veleta at 229 GHz in the 8_{-1}–7_0E transition (Slysh *et al.* 1998a).

Thermal methanol emission is also observed at 157 and 108 GHz. Thermal emission was also detected at 133 GHz (6_{-1}–5_0E transition) in a remote survey with the 12-m Kitt Peak radio telescope (Slysh *et al.* 1997) and at 165 GHz (4_1–4_0A^+ transition) in the Pico Veleta survey (Slysh *et al.* 1998a).

The region G345.01+1.79 was well studied in CS and CO lines (Juvela 1996) and in the infrared (Testi *et al.* 1994).

Thus, the problem lies in understanding the peculiar conditions of this region which allow the pumping of very strong masers at 12 and 6.7 GHz; rare masers at 157 and 108 GHz; a maser at 107 GHz; and the coexistence of class-I and class-II methanol masers, which are usually mutually exclusive.

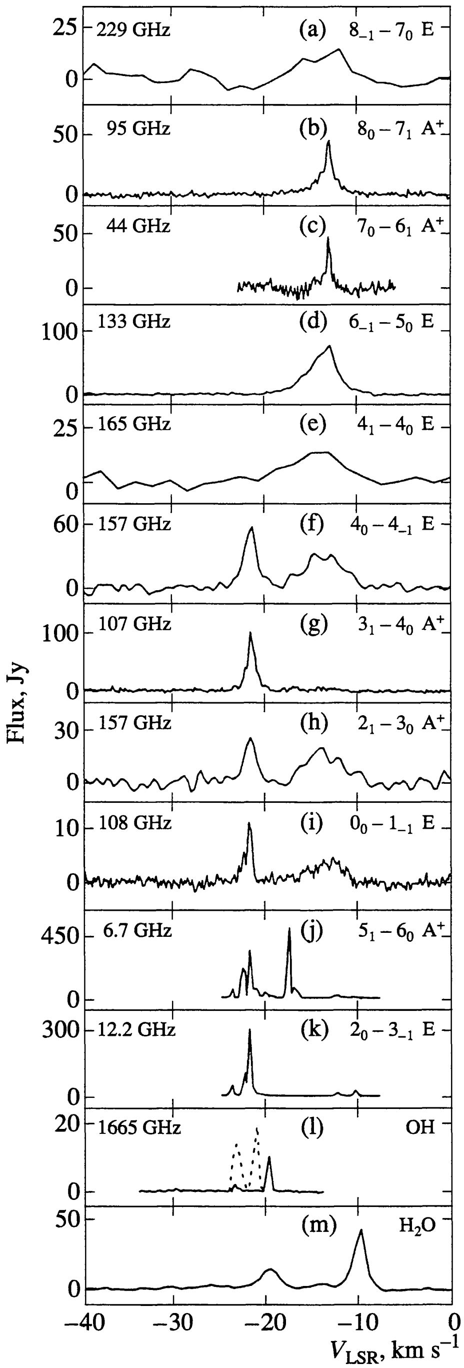

Fig. 1. The spectra of 345.01+1.79 at the following frequencies: (a) 229 GHz (Slysh *et al.* 1998a); (b) 95 GHz (Val'tts *et al.* 1998b); (c) 44 GHz (Slysh *et al.* 1994); (d) 133 GHz (Slysh *et al.* 1997); (e) 165 GHz (Slysh *et al.* 1998a); (f) 157 GHz (Slysh *et al.* 1995); (g) 107 GHz (Val'tts *et al.* 1998a); (h) 157 GHz (Slysh *et al.* 1995); (i) 108 GHz (Slysh 1998a); (j) 6.7 GHz (Norris *et al.* 1993); (k) 12 GHz (Norris *et al.* 1993); (l) OH (Caswell and Haynes 1983), the dotted and solid lines represent the left-hand and right-hand circular polarization, respectively; (m) H_2O (Caswell *et al.* 1983).

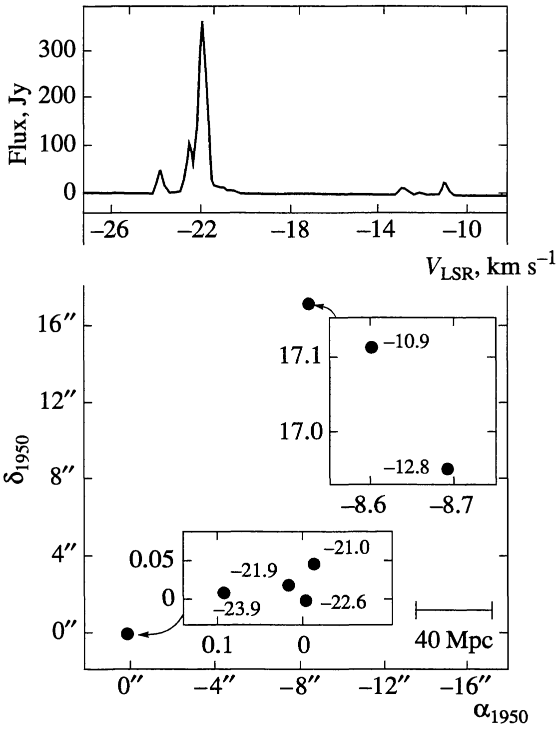

Fig. 2. The map of the maser 345.01+1.79 at 12 GHz from Norris *et al.* (1988).

ANALYSIS OF THE SPECTRA OF OH, H_2O, METHANOL, CO, AND CS

The spectra of maser and thermal features are all presented in Fig. 1. Figure 2 shows a map of the 12 GHz maser from Norris *et al.* (1988), and Fig. 3 shows the Mopra map of the 95-GHz maser. Table 1 lists the line parameters for various methanol transitions, Table 2 contains the parameters of the lines that were observed in the map at 95 GHz, and Table 3 gives the spatial parameters of the 95-GHz class-I maser that were obtained by analyzing the map. Let us first analyze the line positions in the spectra. The velocity of the main feature in the OH maser is –21 km s^{-1} (corrected for Zeeman line splitting). One (weaker) H_2O maser has the same velocity as the OH maser, and the other (stronger) maser has a velocity of about –10 km s^{-1}.

The 12-GHz maser has two activity centers. The velocity lies in the range –24 to –20 km s^{-1} for brighter lines, as that of the OH maser, and in the range –13 to –10 km s^{-1} for weaker lines. The lines of the 6.7-GHz maser have a similar distribution in the spectrum. The 157-, 108-, and 107-GHz masers also have a velocity of about –20 km s^{-1}, while the thermal features that are observed at these frequencies have a velocity closer to that of the weaker group of the 12- and 6.7-GHz masers. Judging by their velocity (–13 km s^{-1}), the class-I masers at 44 and 95 GHz also belong to the group of weak class-II masers and thermal features.

The thermal CS and CO lines (not shown in Fig. 1), which characterize the velocity of the quiet gas in the parent molecular cloud, have a peak intensity at –11 km s^{-1}, but also extend to the velocity range –24 to –22 km s^{-1} occupied by maser lines (Juvela 1996).

Thus, class-II methanol masers concentrate in one interval of radial velocities, while class-I methanol masers and thermal features concentrate in another. The velocity of class-I methanol masers matches the main velocity of the molecular cloud, while the velocity of the group of bright class-II methanol masers and OH maser differs from the velocity of class-I methanol masers by –8 km s^{-1}. The strong H_2O maser has a velocity close to that of the molecular cloud. It is logical to assume that these positions of spectral features reflect the spatial distribution of masers. In the next section, we verify this hypothesis.

ANALYSIS OF THE SPATIAL DISTRIBUTION OF MASER SPOTS

The positions of the OH and H_2O masers were measured by Australian researchers with the VLA back in 1983 immediately after the completion of the OH and H_2O surveys. They showed that the OH maser and the strong H_2O maser in the G345.01+1.79 complex are not related to each other (isolated) and are separated by ≥0.15 pc (Forster and Caswell 1989). The angular separation between the H_2O masers is ≈37″ (Caswell and Haynes 1983).

Based on the Parkes observations, Caswell *et al.* (1993) showed that the 12-GHz masers have two activity centers separated by 20″. One of these centers corresponds to strong spectral features with velocities –24 to –16 km s^{-1}, and the other corresponds to weak spectral features with velocities –13 to –11 km s^{-1}. The weak center is displaced in right ascension and to the north, toward the stronger H_2O maser. Having mapped the G345.01+1.79 region in the 12-GHz lines during previous observations with the Parkes–Tidbinbilla interferometer with a resolution of 20 ms, Norris *et al.* (1988) reached the same conclusion. Figure 2 shows the 12-GHz map of 345.01+1.79 from Norris *et al.* (1988).

The positions of the 6.7-GHz methanol masers coincide with those of the 12-GHz masers to within 0″.02, i.e., the masers at 6.7 GHz also have two activity centers—strong and weak [these observations were carried out with the ATCA interferometer in Narrabri (Australia) by Norris *et al.* (1993)].

In Narrabri, the coordinates of the methanol masers at 6.7 GHz and OH masers were measured simultaneously; the position of the strong 6.7-GHz maser was found to coincide with that of the OH maser to within ≤1″ (Caswell *et al.* 1995a).

Unfortunately, the class I 44-GHz maser was not mapped; we do not know whether it spatially belongs to the northern or southern spot. However, the 95-GHz

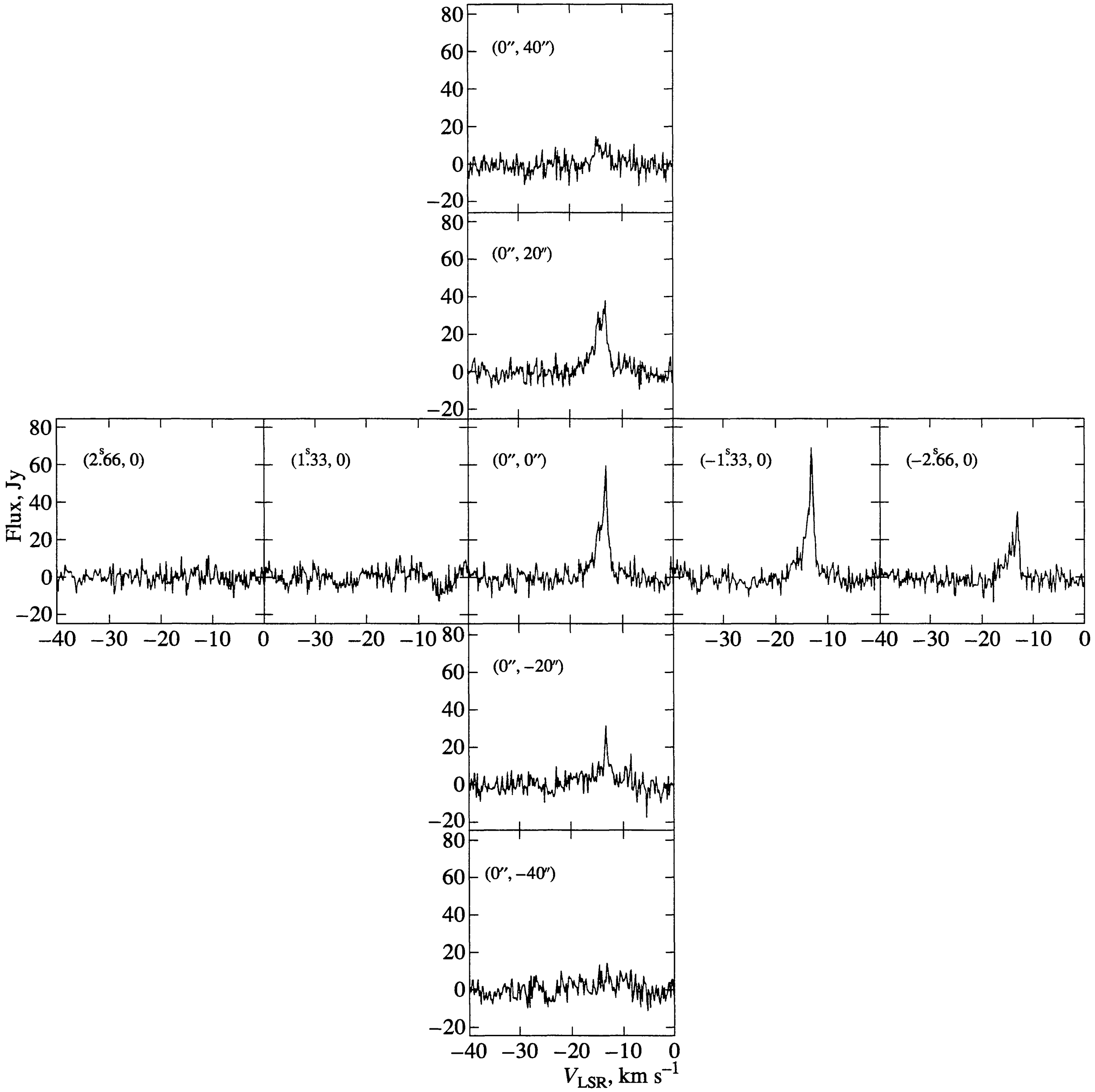

Fig. 3. The map of the maser 345.01+1.79 at 95 GHz obtained with the 22-m radio telescope in Mopra.

Mopra map shows [Fig. 3, see Val'tts *et al.* (1988b) for details on the 95-GHz Mopra observations] that the emission from the class-I 95-GHz maser is observed precisely in the southern activity center. The Mopra absolute coordinates of the maser at 95 GHz ($\alpha_{1950} = 16^h53^m19\overset{s}{.}8 \pm 3\overset{s}{.}8$, $\delta_{1950} = -40°09'42\overset{''}{.}0 \pm 1\overset{''}{.}7$) differ by a mere $3\overset{''}{.}9$ in right ascension from the coordinates of the strong class-II maser determined by Norris *et al.* (1993). The pointing error of the Mopra telescope is 10″; i.e., within the error limits, the 95-GHz maser coincides in position with the southern source with velocities −24 to −16 km s^{-1}. At the same time, the radial velocity of the 95-GHz maser is closer to that of the northern source with velocities −13 to −11 km s^{-1}. The 95-GHz line consists of two components at velocities of −14.5 and −13.1 km s^{-1} (note that the stronger feature at 44 GHz has a velocity of −13.2 km s^{-1}); the weaker component at −14.5 km s^{-1} is displaced to the north from the stronger component by $-6\overset{''}{.}6 \pm 7\overset{''}{.}9$ in right ascension and by $14\overset{''}{.}2 \pm 5\overset{''}{.}3$ in declination; i.e.,

Table 1. Line parameters for various methanol transitions in the source 345.01+1.79

Transition (frequency, GHz)	Flux, Jy	Line width, km s^{-1}	Flux, Jy	Line width, km s^{-1}	Reference
	velocities –24÷–16 km s^{-1}		velocities –14÷–10 km s^{-1}		
8_{-1}–7_0E(229)	–	–	12.0	5.0	Slysh *et al.* (1998a)
8_0–7_1A^+(95)	–	–	29.9	0.5	Val'tts *et al.* (1998b)
	–	–	16.3	3.4	
7_0–6_1A^+(44)	–	–	13.7	0.4	Slysh *et al.* (1994)
	–	–	10.5	1.3	
6_{-1}–5_0E(133)	–	–	66.2	3.8	Slysh *et al.* (1998b)
5_1–6_0A^+(6.7)	508	–	31.0	–	Norris *et al.* (1993)
4_1–4_0E(165)	–	–	10.6	5.8	Slysh *et al.* (1998a)
4_0–$4_{-1}E$(157)	54.9	1.6	26.9	5.0	Slysh *et al.* (1995)
3_1–4_0A^+(107)	85.5	1.1	–	–	Val'tts *et al.* (1998a)
	6.2	1.0	–	–	
2_1–3_0A^+(157)	21.4	1.9	18.4	4.2	Slysh *et al.* (1995)
2_0–$3_{-1}E$(12)	310	–	14.0	–	Norris *et al.* (1993)
0_0–$1_{-1}E$(108)	9.5	1.0	3.8	6.0	Slysh *et al.* (1998a)

Table 2. Gaussian parameters of the two components of the 8_0–7_1A^+ methanol line at 95 GHz as derived from the Mopra map

Spectrum number on map in Fig. 3	Line component	Flux, Jy	Line velocity, km s^{-1}	Line width, km s^{-1}	Spectrum number on map in Fig. 3	Line component	Flux, Jy	Line velocity, km s^{-1}	Line width, km s^{-1}
3	1	39.6 ± 3.0	–13.2 ± 0.1	1.2 ± 0.2	7	1	15.7 ± 3.9	–13.2 ± 0.1	0.7 ± 0.2
	2	17.3 ± 3.0	–14.5 ± 0.2	1.1 ± 0.4		2	25.4 ± 2.2	–14.1 ± 0.1	3.1 ± 0.2
4	1	41.5 ± 8.0	–13.1 ± 0.1	0.8 ± 0.1	8	1	48.1 ± 2.9	–13.2 ± 0.1	1.2 ± 0.1
	2	25.2 ± 3.0	–13.9 ± 0.3	2.7 ± 0.5		2	24.0 ± 2.9	–14.6 ± 0.1	1.3 ± 0.3
5	1	18.6 ± 6.5	–13.1 ± 0.0	0.5 ± 0.1	9	1	24.1 ± 3.4	–13.1 ± 0.1	1.0 ± 0.2
	2	16.5 ± 2.2	–13.9 ± 0.3	3.2 ± 0.6		2	9.0 ± 3.2	–14.5 ± 0.3	1.0 ± 0.6
6	1	8.5 ± 2.2	–12.9 ± 0.4	1.6 ± 0.9					
	2	12.3 ± 2.8	–14.7 ± 0.2	1.3 ± 0.4					

Note: The spectrum numbers are given in order of offset on the map: right ascension (from + to –)—declination (from + to –).

Table 3. Positions and sizes of the source 345.01+1.79 as derived from the 95-GHz map in the 8_0–7_1A^+ line for the two line components; the position at which the 95-GHz maser was discovered in Mopra (Val'tts *et al.* 1998b) is the reference position: $\alpha_{1950} = 16^h53^m21\overset{s}{.}0$, $\delta_{1950} = -40°09'40''.0$

Velocity of line component, km s^{-1}	$\Delta\alpha$	$\Delta\delta$	θ_x	θ_y
–13.1	–13″.7 ± 3″.8	–2″.0 ± 1″.7	40″.6 ± 9″.4	35″.7 ± 3″.5
–14.3	–20″.3 ± 6″.9	–12″.2 ± 5″.0	45″.9 ± 17″.9	50″.3 ± 12″.5

within the error limits, only the weaker feature coincides with the northern source.

The class-I quasi-maser at 229 GHz is <10″ in size and, like the class-I 95-GHz maser within the position errors (5″–10″), coincides with the southern source (Slysh *et al.* 1998a). The radial velocity of this maser, –13.5 km s^{-1} (a linewidth of 4.7 km s^{-1}), matches that of the brighter component at 95 GHz (see Fig. 1).

Let us summarize the results of our analysis of the spectra and the spatial distribution of maser spots in the G345.01+1.79 region.

DISCUSSION

One would think that the class-I masers, as implied by their velocity (which is close to that of the quiet gas, weaker class-II masers, and thermal methanol emission), are associated with the northern maser spot. In this scheme, the observed line separation would be naturally explained. The southern activity center contains a young massive star (most likely of spectral type O) immersed in dust and surrounded by a extremely compact H II region, whose presence is suggested by the existence of an OH maser in this center. The class-II methanol masers form around this star. This is a classical star-forming region at the W3(OH)-type evolutionary stage. In this case, according to the classical scheme, the class-I masers would be observed from another, cooler and denser part of the molecular cloud and would be associated with an object at an earlier, prestellar evolutionary stage. An analog of such an object can be the class-I maser in the source M8E.

However, this simple and attractive scheme is in conflict with the results of our analysis of the spatial positions of the 95- and 229-GHz masers, according to which the class-I masers are observed in the southern spot, but do not have the peculiar velocities that the class-II masers and the OH maser have.

The class-I maser lines cluster in velocity in a narrow spectral interval with a small scatter of velocities around –14 km s^{-1}. In contrast, the class-II masers exhibit a large spread in velocity, though they spatially concentrate only in the southern spot. The young star in the southern spot appears to have a low peculiar velocity relative to the bulk of the parent molecular cloud. The same star entrains the extremely compact H II region, the OH maser, the class-II methanol masers, and a small part of neutral molecular gas. This explains the cloud CS line emission, which is observed up to a velocity of –24 km s^{-1}. Meanwhile, Caswell *et al.* (1995b) specially draw attention to the similarity between the intensity distributions in the strong masers at 6.7 and 12 GHz in the southern spot and in the weak masers at 6.7 and 12 GHz in the northern spot, i.e., some similar characteristic features in the physical conditions are preserved in the two fairly widely separated regions; these features allow precisely these intensity distributions of class-II masers to be formed.

Let us now discuss the main peculiarity of the spectra of 345.01+1.79, namely, the presence of rare maser features at 157 GHz (transitions of the J_0–$J_{-1}E$ sequence) and at 108 GHz (the 0_0–$1_{-1}E$ transition). As was noted above, we detected the 157-GHz maser only in four classical class-II masers: W3(OH), 345.01+1.79, W48, and Cep A. The 108-GHz maser is an even rarer phenomenon, which was detected only in 345.01+1.79 and, possibly, in M8E (very weak). In all the other sources we studied, the 108-GHz line is observed as a thermal line. The presence of maser emission in 345.01+1.79 can be explained, for example, by the fact that more molecules are collected in this source along the line of sight than those in other sources of 108-GHz emission. The rare 157-GHz maser lines are most intense precisely in 345.01+1.79, which lends support to our assumption that the optical depth in methanol lines in this source is very large. Since the line intensity in nonsaturated masers is proportional to $e^{|\tau|}$ (τ is the optical depth in the line), the emergence of a maser is of a threshold nature: when the negative optical depth slightly increases, the line intensity can sharply increase. For this reason, the optical depth in other sources, such as W3(OH), W48, and Cep A, can be close to the optical depth that is necessary for the emergence of a 108-GHz maser but enough for masers to form only at 157 GHz. In 345.01+1.79, the optical depth turned out to be large enough for the 157- and 108-GHz masers to be formed.

CONCLUSIONS

In summary, there is a molecular cloud in the star-forming region G345.01+1.79, from which CO, CS, and thermal methanol lines are observed. This region contains two centers of methanol activity (southern and northern) with an angular separation of 20″. All the class-II methanol masers and the OH maser concentrate in the southern activity center. The class-I masers also gravitate toward it, although they have no peculiar velocity. However, this fact does not mean that the class-I and class-II masers are physically related to each other: the distance to 345.01+1.79 is 3 kpc (Forster and Caswell 1989); an angular distance of 5″ (the accuracy with which the position coincidence of the class-I and class-II masers can be guaranteed) corresponds to a linear separation of 15000 AU, and these may well be distinctly different objects. For the nature of G345.01+1.79 to be elucidated, we must first make even more accurate position measurements for the OH, H_2O, and methanol masers using VLBI to determine their relative positions and to map each maser in order to analyze its internal structure. Such studies will allow us, on the one hand, to draw conclusions about the pumping conditions in the masers (for example, to determine whether they have the same excitation source, which is possible in the case of partial or complete coincidence of the high-precision positions) and, on the other hand, to determine the evolutionary status of each maser in this star-forming complex and of the entire complex.

ACKNOWLEDGMENTS

I wish to thank Simon Ellingsen for help in the observations of the maser at 95 GHz in Mopra. I also thank V.I. Slysh, S.V. Kalenskii, and M. A. Voronkov for a helpful discussion. This study was supported by the Russian Foundation for Basic Research (project no. 95-02-05826) and the Science and Technology Program “Astronomy” (project no. 1.3.4.2).

REFERENCES

Batrla, W., Matthews, H.E., Menten, K., and Walmsley, C.M., *Nature,* 1987, vol. 326, p. 49.

Booth, R.S., private communication, 1997.

Caswell, J.L. and Haynes, R.F., *Aust. J. Phys.*, 1983, vol. 36, p. 361.

Caswell, J.L. and Haynes, R.F., *Aust. J. Phys.*, 1987, vol. 40, p. 215.

Caswell, J.L., Batchelor, R.A., Forster, J.R., and Wellington, K.J., *Aust. J. Phys.*, 1983, vol. 36, p. 401.

Caswell, J.L., Haynes, R.F., and Goss, W.M., *Aust. J. Phys.*, 1980, vol. 33, p. 639.

Caswell, J.L., Vaile, R.A., and Forster, J.R., *Mon. Not. R. Astron. Soc.*, 1995a, vol. 277, p. 210.

Caswell, J.L., Vaile, R.A., Ellingsen, S.P., and Norris, R.P., *Mon. Not. R. Astron. Soc.*, 1995b, vol. 274, p. 1126.

Forster, J.R. and Caswell, J.L., *Astron. Astrophys.*, 1989, vol. 213, p. 339.

Juvela, M., *Astron. Astrophys., Suppl. Ser.*, 1996, vol. 118, p. 191.

Menten, K.M., *Astrophys. J.*, 1991b, vol. 380, p. L75.

Menten, K.M., *Proc. of the Third Haystack Observatory Conference on Atoms, Ions and Molecules, ASP Conf. Ser.*, Haschick, A.D. and Ho, P.T.P., Eds., 1991a, p. 119.

Norris, R.P., Caswell, J.L., Gardner, F.F., and Wellington, K.J., *Astrophys. J.*, 1987, vol. 321, p. L159.

Norris, R.P., McCutcheon, W.H., Caswell, J.L., *et al., Nature,* 1988, vol. 335, p. 149.

Norris, R.P., Whiteoak, J.B., Caswell, J.L., *et al., Astrophys. J.*, 1993, vol. 412, p. 222.

Slysh, V.I., Kalenskii, S.V., and Val'tts, I.E., *Astrophys. J.*, 1995, vol. 442, p. 668.

Slysh, V.I., Kalenskii, S.V., Val'tts, I.E., *et al., Astrophys. J.*, 1998b (in preparation).

Slysh, V.I., Kalenskii, S.V., Val'tts, I.E., and Golubev, V.V., *Astrophys. J.*, 1997, vol. 478, p. L37.

Slysh, V.I., Kalenskii, S.V., Val'tts, I.E., and Otrupcek, R., *Mon. Not. R. Astron. Soc.*, 1994, vol. 268, p. 464.

Slysh, V.I., Kalenskii, S.V., Val'tts, I.E., and Voronkov, M.A., *Astron. Astrophys.*, 1998a (in preparation).

Testi, L., Felli, M., Persi, P., and Roth, M., *Astron. Astrophys.*, 1994, vol. 194, p. 634.

Val'tts, I.E., Slysh, V.I., Ellingsen, S., *et al., Mon. Not. R. Astron. Soc.*, 1998a (in press).

Val'tts, I.E., Slysh, V.I., Ellingsen, S., *et al., Mon. Not. R. Astron. Soc.*, 1998b (in press).

Translated by G. Rudnitskii