

## JVLA OVERVIEW OF THE BURSTING H<sub>2</sub>O MASER SOURCE G25.65+1.05

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### ABSTRACT

The source G25.65+1.05 (RAFGL7009S, IRAS 18316-0602) is the least studied of the three regions of massive star formation known to show exceptionally powerful H<sub>2</sub>O maser bursts. We report spectral line observations of the H<sub>2</sub>O maser at 22 GHz, the methanol maser transitions at 6.7, 12.2 and 44 GHz, and the continuum in these same frequency bands with The Karl G. Jansky Very Large Array (JVLA) at the post-burst epoch of 2017. For the first time, maps of 22 GHz H<sub>2</sub>O and 44 GHz CH<sub>3</sub>OH maser spots are obtained and the absolute position of the 22 GHz H<sub>2</sub>O bursting feature is determined with milliarcsecond precision. We detected four continuum components, three of which are closely spaced in a linear orientation, suggesting a physical link between them.

*Keywords:* ISM: evolution, masers

### 1. INTRODUCTION

Cosmic masers were discovered nearly 50 years ago, and although great strides have been made in understanding the nature of these intriguing objects, they continue to present behaviors that we cannot yet fully explain. One such phenomenon is the “super-bursts” of water maser emission. Water masers are known to be variable on a variety of time scales, but only three Galactic water masers are known to flare to the level of  $10^5$ – $10^6$  Jy ( $T_B \sim 10^{17}$  K): Orion KL, W49N, and the recently discovered G25.65+1.05.

Because unsaturated maser amplification is exponentially related to path length, the observed maser flux depends on the viewpoint of the observer. However, changes in maser flux also pertain to activity at, or in the vicinity of, the maser region. The super-burst phenomenon may be caused by an enhanced maser pumping mechanism due to a change to more favorable physical conditions; an increase in the incident seed photons entering the maser region; or due to an increase in maser path length on the line of sight to the observer. The latter case can be achieved by a chance overlap – when two masers of similar velocity move into superposition in the sky-plane, as described by Shimoikura et al. (2005). A comparison of flaring in different maser species and monitoring of free-free continuum levels can provide important clues to understand the nature of the flaring process.

G25.65+1.05 (associated with IRAS 18316–0602 and also known as RAFGL7009S) was included in the H<sub>2</sub>O maser surveys of Palla et al. (1991) and Brand et al. (1994) – both of which reported a powerful H<sub>2</sub>O maser with flux density  $>700$  Jy and  $V_{peak} = \sim 45$  km s<sup>−1</sup>. Long-term monitoring of H<sub>2</sub>O masers with the RT-22 of the Pushchino Radio Astronomy Observatory (Moscow region) showed flares in 2002, 2010, and 2016 with flux densities of 3400 ( $V_{peak} = 41.05$  km s<sup>−1</sup>), 19000 ( $V_{peak} = 41.29$  km s<sup>−1</sup>), and 46000 ( $V_{peak} = 41.80$  km s<sup>−1</sup>) Jy, respectively (Lekht et al.

2018). The next powerful burst of 65000 Jy ( $42.5 \text{ km s}^{-1}$ ) was detected in September 2017 (Volvach et al. 2017a, 2019) with the RT-22 of the Crimean Astrophysical Observatory. In October 2017, shortly after this burst, the source showed yet another increase of flux density – see Volvach et al. (2017b, 2019). The most recent burst was found to be short-lived: the peak flux density rose from  $\sim 20 \text{ kJy}$  to  $76 \text{ kJy}$  within half a day on November 20; the source then faded to  $\sim 20 \text{ kJy}$  on November 22 (Ashimbaeva et al. 2017). Although G25.65+1.05 is the target of intense monitoring, the transient nature of burst events may lead to some events going undetected. It is therefore likely that the super-burst phenomenon is more common than is currently thought.

The source is maser-rich, with both class I and II methanol<sup>1</sup>, OH, and H<sub>2</sub>O masers reported (e.g., Palla et al. (1991); Bayandina et al. (2019); Fontani et al. (2010)). The 6.7 GHz class II methanol maser in G25.65+1.05 has been extensively observed. At HartRAO, with the 26-m, it was detected with a peak of 113 Jy (van der Walt et al. 1995). Walsh et al. (1997) used the Parkes 64-m and found a 105 Jy flux with  $V_{\text{peak}} = +42 \text{ km s}^{-1}$ . The maser was detected with 181 Jy at  $V_{\text{peak}} = +41.8 \text{ km s}^{-1}$  with the Medicina 32-m (Slysh et al. 1999) and  $\sim 100 \text{ Jy}$  at  $V_{\text{peak}} = +42 \text{ km s}^{-1}$  with Effelsberg 100-m Fontani et al. (2010). The Torun 32-m observations showed a flux density of 200 Jy at  $V_{\text{peak}} = +42 \text{ km s}^{-1}$  (Szymczak et al. 2000). It was noted that the peak flux density of the 6.7 GHz maser reported by van der Walt et al. (1995) and Walsh et al. (1997) is less than half of the value reported by Slysh et al. (1999) and Szymczak et al. (2000); i.e., the maser is variable. The presence of a circumstellar disk was suggested in (Zavagno et al. 2002) and (Surcis et al. 2015) based on 6.7 GHz maser presence and structure.

It is interesting to note that Fontani et al. (2010) show three spectra of methanol: one of class II methanol at 6.7 GHz ( $\sim 100 \text{ Jy}$ , Effelsberg, 100-m) and two of class I methanol lines at 44 GHz ( $\sim 10 \text{ Jy}$ ) and at 95 GHz ( $\sim 2 \text{ Jy}$ ); both class I spectra were obtained with the Nobeyama 45-m telescope. The class I emission suggests the object is at a very early evolutionary stage, while the class II emission suggests a later stage, after the appearance of an ultracompact (UC) HII region. Established methanol maser classification (Bartl et al. 1987; Menten 1991) suggests that cIMM and ciIMM do not coexist because of distinct pumping conditions. One of the main cIMM properties is that they do not spatially coincide with ciIMM or with H<sub>2</sub>O and OH masers. OH maser lines in G25.65+1.05, according to recent JVLA data, show the strongest peak at 1665 MHz in the left polarization at  $V_{\text{LSR}} = +41.36 \text{ km s}^{-1}$  ( $\sim 9 \text{ Jy}$ ), 1 Jy at 1667 GHz, and no emission in satellite lines (Bayandina et al. 2019). Thus, a likely scenario is that this region hosts spatially separated molecular cores at different stages of evolution.

The 6.7 GHz class II methanol maser showed a  $>40\%$  flux increase several months in advance of the H<sub>2</sub>O maser burst (Sugiyama et al. 2017) possibly indicating an enhancement in the local IR radiation field. Maser flaring, albeit at lower levels, has been reported in other sources as well. For example, Hunter et al. (2017) report strong maser flaring in H<sub>2</sub>O, CH<sub>3</sub>OH, and OH in NGC6334I, accompanied by a 4-fold increase in the dust continuum emission. Correlated flaring of different maser species has been reported by several groups, for example, formaldehyde and methanol (Araya et al. 2010) and in water and methanol (Szymczak et al. 2016).

The distance to the source is an open question – VLBI measurements of the trigonometric parallax have never been performed for the source. Molecular line observations in most cases argue in favor of the near kinematic distance and yield values of 3.17 kpc (Molinari et al. 1996), 3.3 kpc (Walsh et al. 1997), and 2.7 kpc (Sunada et al. 2007). In contrast, HI self-absorption toward the source suggests a far kinematic distance of 12.5 kpc (Green & McClure-Griffiths 2011). A probability density function for source distance calculated on the basis of The Bar and Spiral Structure Legacy (BeSSeL, <http://bessel.vlbi-astrometry.org>) Survey data (Reid et al. 2016) indicates a distance of  $2.08 \pm 0.37 \text{ kpc}$  with a probability of 64%. In our calculations below we will use this value.

There is no optical identification with an HII region within  $2'$  (Molinari et al. 1996); i.e., this region is deeply embedded and/or is at a very early evolutionary state. The probable young stellar object of the region is a BIV star (Zavagno et al. 2002). According to McCutcheon et al. (1995), the source is weak in the radio continuum with  $2.7 \text{ mJy}$  flux density at 6 cm and classified as “probably pre-main-sequence”. Kurtz et al. (1994) presented 3.6 cm map and reported an “irregular” morphology for the UCHII region. The IRAS source is separated from the central continuum radio source by  $18''$  (a projected linear distance of 0.18 pc at 2.08 kpc). McCutcheon et al. (1995) also reported JCMT observations at 1100, 800 and 450 microns. They detected a dusty core, and using their data, along with the IRAS fluxes, they fit a two-component model to the spectrum. Their study suggests a larger, cooler core (0.3 pc and 35 K) and a smaller, hotter core (0.073 pc and 123 K). For the cold component they find a total dust mass of  $11.0 M_{\odot}$  with a molecular hydrogen column density of  $9.8 \times 10^{23} \text{ cm}^{-2}$ . Although the JCMT and IRAS spectra suggest

<sup>1</sup> Hereafter we will refer to CH<sub>3</sub>OH maser classes with the abbreviations proposed in (Menten 2012) cIMM and ciIMM, respectively.

a two-component model, the JCMT images of both [McCutcheon et al. \(1995\)](#) and [Thompson et al. \(2006\)](#) lack the angular resolution to distinguish internal structure.

Thermal lines, such as  $\text{NH}_3$  and  $\text{CS}$ , detected in the region show a peak at the velocity of  $V_{\text{LSR}} = +42.2 \text{ km s}^{-1}$  ([Molinari et al. 1996](#); [Bronfman et al. 1996](#)). Dense gas tracers such as  $\text{N}_2\text{H}^+$  and  $\text{C}_2\text{H}$  have similar LSR velocities of  $42.6$  and  $42.4 \text{ km s}^{-1}$ , respectively ([Sánchez-Monge et al. 2013](#)). A bipolar flow was detected in  $\text{CO}$  ([Shepherd & Churchwell 1996](#)) and  $\text{CH}_3\text{CN}$  ([Dartois et al. 2000](#)). The outflow was confirmed in the  $\text{SiO}$  (5-4) and  $\text{HCO}^+$  (1-0) lines, but not its bipolar structure ([López-Sepulcre et al. 2011](#); [Sánchez-Monge et al. 2013](#)). [Dartois et al. \(2000\)](#) report multiwavelength observations with the IRAM 30-m, the Plateau de Bure interferometer, UKIRT and ISO. Observations were carried out in  $\text{CH}_3\text{CCH}$  and  $\text{CH}_3\text{OH}$  lines, including deuterated species, and 3 mm continuum. Their maps can be interpreted as either a single, episodically driven outflow from a single source, or as multiple outflows from several distinct, but unresolved, sources. Observation of the  $\nu = 1-0 \text{ S}(1) \text{ H}_2$  line at  $2.166 \mu\text{m}$  did not allow to determine unambiguously whether there are single or multiple outflows and driving sources in the region ([Todd & Howat 2006](#)).

In response to the recent super-burst discovery, we initiated a multi-part investigation of G25.65+1.05 to study the burst mechanism in the context of massive star formation. This paper reports the first results of the investigation and aims to provide a brief overview of G25.65+1.05, in addition to introducing new data that impact our understanding of G25.65+1.05 and help establish a robust contextual basis for forthcoming work on this maser burst object.

## 2. OBSERVATIONS

Observations were carried out in two sessions on 2017 November 2 and December 9 with the Jansky Very Large Array (JVLA, NRAO) in the B-configuration as a Target of Opportunity program (project code 17B-408). The total observing time was 2 hours, comprising a first session of 45 minutes and a second of 75 minutes. Four frequency bands were used: C (6.0 GHz), Ku (15 GHz), K (22 GHz) and Q (45 GHz).

These JVLA observations of G25.65+1.05 were conducted during the post-burst period: Q-band observations were performed on 2017 November 2, i.e. after the powerful  $\text{H}_2\text{O}$  maser burst detected in September 2017 ([Volvach et al. 2017a, 2019](#)), but before the short-lived burst of November 20 ([Ashimbaeva et al. 2017](#)). C-, Ku-, and K-band observations were performed on 2017 December 9, i.e. after both recent bursts.

The pointing coordinates used were  $\text{RA}(\text{J2000}) = 18^{\text{h}}34^{\text{m}}21^{\text{s}}$ ,  $\text{DEC}(\text{J2000}) = -05^{\circ}59'42''$  and the central velocity was  $42 \text{ km s}^{-1}$ .

Table 1 reports the main observational parameters. 3C 48 was used as a flux density, bandpass, and delay calibrator; J1832-1035 as a complex gain calibrator (the angular separation from the target source is  $4.6^\circ$ ). About an hour was spent on J1832-1035 scans and  $\sim 20$  minutes on 3C 48.

Spectral lines were observed in windows of 1024 channels. The channel width was 0.98 kHz in C-band, 1.95 kHz in Ku-band, 7.81 kHz in K- and Q-bands. For the corresponding velocity resolutions, see Table 1.

For the continuum observations, 31 spectral windows were used in C-, K-, and Q-bands and 23 windows in Ku-band. In all cases, each spectral window contained 128 channels of 1 MHz width.

## 3. DATA REDUCTION

The data were reduced with the NRAO software package CASA (Common Astronomy Software Applications, <http://casa.nrao.edu>). The main stages of the data calibration were performed with the CASA package “VLA calibration pipeline”. Subsequent self-calibration was performed on the strongest maser channel for each frequency data set.

An unresolved issue in the calibration is the flux density scale for the maser emission. The flux densities of the 6.7 GHz, 22 GHz and 44 GHz masers, as detected with the VLA, are 2 to  $3\times$  higher than the corresponding single-dish fluxes. For the 6.7 GHz cIMM, data taken with the Torun 32-m (RT-32 of the Toruń Centre for Astronomy of Nicolaus Copernicus University) at about the same time reported 166 Jy while our VLA data showed 386 Jy (factor of 2.3). For the 22 GHz  $\text{H}_2\text{O}$  maser, nearly coeval data from the Torun 32-m and the Crimean 22-m telescope show  $\sim 9.8 \text{ kJy}$  while the VLA flux density was  $29.5 \text{ kJy}$  (factor of 3.0). For the 44 GHz cIMM, [Fontani et al. \(2010\)](#) reported 10 Jy, while our VLA data show 25 Jy (factor of 2.5). In what follows, we have scaled the VLA flux densities by the corresponding factors. We continue to investigate the nature of this discrepancy. Accordingly, the present work concentrates on astrometric results only, thus we note that it does not affect our analysis or conclusions, nor does the flux discrepancy occur for the continuum data.

Calibrated data were imaged using the Clark CLEAN algorithm ([Clark 1980](#)) with Robust weighting = 0. A two-dimensional Gaussian brightness distribution was fitted to the map in every channel with flux density above  $5\sigma$  level

(see Table 1 for  $\sigma$ -level at each frequency) to determine the position, flux density (integrated and peak) and LSR velocity of the maser spots. Here after the term “spot” refers to maser emission in a single channel map.

Spectra were obtained with the CASA Spectral Profile Tool. Detected flux densities of maser sources at each observed frequency differs in the right and left polarizations by less than 2%, ergo we present the Stokes I data.

## 4. RESULTS

### 4.1. Continuum Emission

Continuum emission above the  $5\sigma$  detection level was found in all four frequency bands. Four distinct continuum sources were detected in the G25.65+1.05 region, which we index as JVL A 1, 2, 3, and 4. Parameters of the detected continuum sources are listed in the Table 2 and the JVL A continuum images are shown in Figure 1.

Emission from the four sources is heavily blended at 6 GHz, appearing as a single region elongated in the NE-SW direction, with JVL A 4 seen as a protrusion to the SW. At 12 GHz, JVL A 4 is clearly separated from the other three sources, which remain heavily blended. At 22 GHz all four sources can be spatially distinguished and well-characterized using a 4-component Gaussian fit. At 44 GHz, only JVL A 1 and 2 are detected. The statistical errors of the Gaussian fit flux densities are listed in Table 2, while the error bars in Figure 2 represent a more realistic 5% error at 12 GHz, a 10% error at 22 GHz, and a 15% error at 44 GHz, which we adopted in our data analysis.

We show the flux density distributions for JVL A 1-4 in Figure 2. No values are shown for 6 GHz, owing to insufficient angular resolution to distinguish one source from another. JVL A 1 and 2 have the best-determined spectral indices, as they are detected (and reasonably well-resolved) at three distinct frequencies. Both sources have declining spectra, with  $\alpha$  equal to  $-0.49$  and  $-0.38$ , respectively, based on a linear least-squares fit to the 15, 22 and 45 GHz flux densities. JVL A 3 and 4 have less-robust spectral index measurements, owing to the relatively large uncertainties in their 45 GHz flux densities. Their spectral indices are  $+0.06$  and  $-0.78$ , respectively.

### 4.2. Spectral Maser Line Emission

Spectral line emission is detected in all frequency bands except the Ku-band (15 GHz). The position, velocity, integrated and peak flux density of each spot of 22 GHz  $\text{H}_2\text{O}$  maser and 6.7 and 44 GHz  $\text{CH}_3\text{OH}$  masers are listed in Tables 3, 4, 5, respectively. Spectra of these three maser species and their spatial distribution are presented in Figure 3. Even though the structures seen in the maser maps are small (about tens of mas) compared to the angular size of the synthesized beam ( $\sim 0.3''$  at 22 GHz) the high signal-to-noise achieved on the bright maser emission is such that the centroids of Gaussian fits to the data reliably trace the general structure of emission at these scales. An overview of maser activity in the source is presented in Figure 4; positions of all detected continuum and maser sources are combined in a single map.

#### 4.2.1. 22 GHz $\text{H}_2\text{O}$ Maser

22 GHz  $\text{H}_2\text{O}$  maser emission is detected in the velocity range  $\sim 35$ – $55 \text{ km s}^{-1}$  – the widest velocity range among all maser species detected in the region — with the peak at  $42.92 \text{ km s}^{-1}$  (Figure 3). There are four spectral components: the line at  $42.92 \text{ km s}^{-1}$  is associated with the burst of September 2017 (Volvach et al. 2017a, 2019) and is the closest to the systemic velocity of the source of  $V_{\text{LSR}} = +42.41$  (Sánchez-Monge et al. 2013). The bursting spectral line shows an asymmetric profile with the excess in the blue wing and a line width of  $\sim 1.5 \text{ km s}^{-1}$ . Three other lines – the blue line at  $\sim 37 \text{ km s}^{-1}$  and two red lines at  $\sim 51.5 \text{ km s}^{-1}$  and  $\sim 52.5 \text{ km s}^{-1}$  – have significantly lower flux densities and are separated from the systemic velocity by more than  $5 \text{ km s}^{-1}$ .

The morphological distribution of  $\text{H}_2\text{O}$  maser components can be divided into four groups. Three groups, which we denote as G1, G2 and G3, reside close to JVL A 1 and comprise the full range of maser velocities detected ( $35$  to  $55 \text{ km s}^{-1}$ ). Another group, G4, is close to JVL A 2 and only comprises masers blueshifted with respect to the systemic velocity. No water maser emission was found near JVL A 3 or 4 (see Table 3 and Figure 5).

Within the JVL A 1 maser groups, G2 masers reside  $\sim 150$  mas to the North of JVL A 1 and contain masers covering a wide range of velocities. Both the G1 and G3 groups exhibit simple elongated distributions, extending toward the G2 group, and only moderate deviations from the source systemic velocity. The G1-G2-G3 groups generally form a large ( $\sim 400$  mas) lateral V-shape, with G2 at its apex. The bursting maser is located within the G2 group, which exhibits the most complex spatial and velocity structure (see Figure 6) of all groups. Particularly notable are substructures which we denote (from East to West) as group G2 clusters I, II, III and IV. The continuous nature of clusters I-IV in position-velocity diagrams indicates that they are real physical structures.



Cluster II comprises maser spots with velocities of 49-51 km s<sup>-1</sup> and traces an ellipse-like structure with a size of  $\sim 20$  mas (Figure 7(b)). A least-squares fit of the cluster by an ellipse (see Figure 7(b)) yields a semi-major axis of 9.54 ( $\pm 0.52$ ) mas and a semi-minor axis of 5.42 ( $\pm 0.48$ ) mas, with an inclination angle of  $\sim 55^\circ$ . Clusters I and III are located symmetrically around cluster II (see Figure 7): the red (cluster I) consists of maser spots with velocities 52-55 km s<sup>-1</sup> and is located to the east, while the blue (cluster III) with velocities 41-46 km s<sup>-1</sup> is detected to the west. It is notable that both clusters show velocity ranges of about 6 km s<sup>-1</sup> (see Figures 7 (a) and (c)). Cluster III shows a small ( $\sim 40$  mas) V-shaped structure with the bursting maser located at its apex. Structures of similar morphology are reported in the literature, e.g. see Burns et al. (2016), and are proposed to be associated with the shocked gas at the interface between a jet and the ambient medium. The flux densities of maser components forming clusters I and III are about an order of magnitude higher than those of cluster II. Cluster IV exhibits blue velocities of 36-41 km s<sup>-1</sup> and is detected to the west of clusters I-III (see Figure 6). The cluster extent is  $\sim 0.06''$  and does not show a particularly ordered structure.

#### 4.2.2. CH<sub>3</sub>OH Masers

6.7 GHz CH<sub>3</sub>OH maser emission is detected in the velocity range  $\sim 38$ -44 km s<sup>-1</sup>, with the peak at 41.84 km s<sup>-1</sup> (Figure 3). Detected maser lines are blue-shifted from the source systemic velocity. Maser spots are distributed over an area of size  $\sim 0.4''$  (Figure 3) and spatially associated with the continuum source JVLA 2 (Figures 4 and 5).

There are three loci of 6.7 GHz CH<sub>3</sub>OH maser emission. The northern two loci are elongated in the NW-SE direction with a size  $\sim 500$  mas and located symmetrically around JVLA 2. Maser spots exhibit velocities of 40-43 km s<sup>-1</sup> and display the largest cIIMM flux densities in the region. The southern locus is compact, with a size of  $\sim 50$  mas (Figure 5) and formed by weak maser spots with velocity  $\sim 38.6$  km s<sup>-1</sup>. The northern and southern loci are separated from each other by  $\sim 200$  mas.

No 12 GHz class II CH<sub>3</sub>OH maser emission was found above the  $3\sigma$  level of 0.16 Jy of these observations. Their non-detection is relevant to the discussion in Section 5.

44 GHz CH<sub>3</sub>OH maser emission was detected in the velocity range  $\sim 41$ -44 km s<sup>-1</sup>, with the peak at 41.67 km s<sup>-1</sup> (Figure 3). Maser features are distributed along the NE-SW direction over a range  $\sim 8''$  (Figures 3 and 4). Four spatial clusters of 44 GHz cIIMM are present, with the NE-SW line located towards the NW of the continuum sources.

## 5. DISCUSSION

### 5.1. Nature of the Continuum Sources

In previous observations, made with lower angular resolution, continuum emission detected in the region was not resolved into separate sources. A single continuum peak at 3.6 cm (8.4 GHz) was detected in two different B-configuration VLA observations: Kurtz et al. (1994) and Jenness et al. (1995). Both studies reported a flux density of  $\sim 3.8$  mJy, although the peak emission coordinates were slightly different – Kurtz et al. (1994) places the peak closer to JVLA 2, while Jenness et al. (1995) locate it closer to JVLA 1. The higher resolution, multi-frequency observations reported here allow for more detailed analyses of the continuum sources in this region.

The negative spectral indices of JVLA 1 and 2 (and possibly of JVLA 4) suggest that these are all relatively young objects, which are not yet photo-ionizing their surroundings. Rather, the emission appears to be synchrotron radiation. Synchrotron jets are known to arise in young stellar objects (e.g., see the review by Anglada et al. (2018)). Such a mechanism appears to be at work in JVLA 1 and 2, possibly related to shocked gas near these embedded sources. Synchrotron emission can also arise near massive binary stars (e.g., Rodríguez et al. (2012)). The relatively flat spectrum of JVLA 3, and the detection of OH masers in its vicinity, suggest that it may be free-free emission from an optically thin HII region, in which case it is likely to be the oldest object of the four.

JVLA 1 and 2 appear to be in different evolutionary stages, based on their association with water and methanol masers (see Figures 4 and 5). ALMA archive data (Project Code 2012.1.00826.S) provide a 350 GHz image showing a point source at the position of JVLA 2. An unresolved bright IR source detected in K-band images (Zavagno et al. 2002; Varricatt et al. 2010) is also coincident with JVLA 2. Moreover, its association with cIIMM strongly suggests that this source is an embedded, accreting, massive young stellar object (MYSO).

The 6.7 GHz methanol masers in JVLA 2 seem to trace an edge-on disk. A least-squares ellipse fit to the data (Figure 9) gives a semi-major axis of  $\sim 240$  mas and semi-minor axis of  $\sim 25$  mas, with an inclination angle of  $\sim 68^\circ$ . Thus, assuming a kinematic distance of  $D = 2.08$  kpc (BeSSeL, <http://bessel.vlbi-astrometry.org>), the linear size of the putative disk is  $\sim 1000$  AU which is similar to the typical sizes of circumstellar disks traced by 6.7 GHz CH<sub>3</sub>OH

masers (e.g., Norris et al. (1998)). The position-velocity diagram for the NE and NW clusters (Figure 9) is in general agreement with the theoretical calculations for protostellar discs (Richer & Padman 1991). An alternative explanation is a bipolar outflow. Assuming a  $45^\circ$  orientation with respect to the sky, the  $4 \text{ km s}^{-1}$  velocity range over a distance of  $\sim 1000 \text{ AU}$  suggests a dynamic age of  $\sim 1000 \text{ yr}$  for such an outflow.

The 6.7 GHz class II  $\text{CH}_3\text{OH}$  maser is the only maser species for which we have pre-burst interferometric images. The ATCA 6.7 GHz image of the region showed the chain of four  $\text{CH}_3\text{OH}$  maser spots A, B, C, and D linearly distributed over  $\sim 1.5''$  in the NS direction (Walsh et al. 1998): spot A is undetected in the current JVL A observations, while our northern maser group and southern maser group can be associated with spots B and C/D, respectively. Comparison of the most recent compact array 6.7 GHz map (Hu et al. 2016) and our 6.7 GHz data does not show significant changes in the  $\text{CH}_3\text{OH}$  maser spot distribution, with only a shift by  $\sim 50 \text{ mas}$  ( $\sim 100 \text{ AU}$ ) of the southern maser cluster position. In VLBI observations of Fujisawa et al. (2014) only the NW maser cluster was detected, while in EVN observations of Surcis et al. (2015) positions of both the NE and NW maser clusters were determined. The southern cluster was not detected in either VLBI study, which may indicate extended structure.

The nature of JVL A 1 is less certain. Its lack of cIIMM emission, declining spectrum and exclusive association with water masers (Figures 4 and 5) may indicate that the continuum emission traces a shocked region of synchrotron emission, possibly a jet driven from the JVL A 2 MYSO. On the other hand, JVL A 1 may itself be a young stellar object with a jet. An accurate source distance would assist in distinguishing between these two scenarios by providing a distance for the presumed source-ejecta separation between JVL A 1 and 2.

Null detections of the 12.2 GHz maser line were reported by Gaylard et al. (1994) and Breen et al. (2010) with detection limits of  $\sim 10 \text{ Jy}$  and  $\sim 0.5 \text{ Jy}$ , respectively. Our observations also do not detect maser emission at a  $3\sigma$  level of  $0.16 \text{ Jy}$ . Breen et al. (2010) suggests that 12.2 GHz  $\text{CH}_3\text{OH}$  masers are associated with a later evolutionary phase of massive star formation. Therefore, the non-detection of this maser species in G25.65+1.05 may be indicative of an early evolutionary stage for the MYSO(s) in G25.65+1.05.

### 5.2. Outflows/Episodic Ejection Traced by Masers

No interferometric observation of the 44 GHz class I masers in G25.65+1.05 has previously been reported in the literature.

The two brighter 44 GHz cIIMM blue features at velocities  $41.4$  and  $41.7 \text{ km s}^{-1}$  (B1 and B2; hereafter cIIMM features are named in accordance with their velocity — see Table 5 and Figure 10) are separated by  $\sim 6''$  ( $\sim 0.06 \text{ pc}$ ) from the continuum source JVL A 1, associated with the bursting  $\text{H}_2\text{O}$  maser (see Figure 10). Weaker maser features G (green) at the velocity  $42.4 \text{ km s}^{-1}$ , and R (red) at the velocity  $43.7 \text{ km s}^{-1}$  are located almost symmetrically about JVL A 1 at  $\sim 2''$ , i.e.  $0.02 \text{ pc}$ , (Figure 10). Maser feature R spatially coincides with the peak of 1-0 S(1)  $\text{H}_2$  line emission (Figure 11), while no  $\text{H}_2$  emission was detected at the positions of the “green” and “blue” cIIMM features (Todd & Howat 2006). Figures 11 and 12 show that cIIMM features fall along a straight line perpendicular to the axis of NW-SE oriented large-scale bipolar outflow detected in 1-0 S(1)  $\text{H}_2$  (Todd & Howat 2006) and SiO (2-1), SiO (5-4),  $\text{HCO}^+$  (1-0) lines (Sánchez-Monge et al. 2013).

Various scenarios can be proposed to explain the locations of the 44 GHz cIIMM components. Given their roughly linear orientation, they might trace a compact bipolar outflow roughly aligned with the large-scale outflow revealed by molecular line observations described in Section 1. Another plausible explanation is episodic ejections from JVL A 1. As shown in Figure 13, the separation between JVL A 1 and the blue masers is about  $2\times$  larger than that between JVL A 1 and the red and green masers. In this scenario, the former (blue) masers would be older, with a  $5.2''$  ( $0.05 \text{ pc}$ ) separation from JVL A 1, while the latter (red and green) masers would be younger, with a  $0.2''$  ( $0.02 \text{ pc}$ ) separation from JVL A 1. Two, even earlier ejection events, may be traced by  $\text{H}_2$  emission (see Figure 14). The older ejection event, traced by  $\text{H}_2$  knots A – E, with a radius of  $\sim 0.3 \text{ pc}$ , while a younger event would be traced by the weaker  $\text{H}_2$  emission with a radius of  $\sim 0.13 \text{ pc}$ .

### 5.3. Possible Model of the Bursting Source

Maser bursts have recently been a topic of great interest for studies of accretion and ejection in the context of star formation. In particular, the recognition that massive stars may undergo episodic accretion bursts similar to low mass stars (for example the FUOrs and ExOrs, Audard et al. (2014)), has recently led to several important new insights on the topic (Hunter et al. 2017; Caratti o Garatti et al. 2016). Furthermore, the realization that such bursts are generally followed by ejection events has lead astronomers to look for the “smoking gun” of episodic accretion in evidence of

episodic ejections (Burns et al. 2016, 2017). However, direct evidence of such accretion and ejection events is scarce, partly due to the rarity of such events and also due to the difficulty in obtaining the required continuum mapping monitoring programs with highly-subscribed instruments. Masers, such as the 6.7 GHz methanol and 22 GHz water masers, trace regions near the sites of accretion and ejection, respectively (Menten 1996), and thus provide a viable method to search for new accretion or ejection activity in large sample of massive stars through maser monitoring observations.

In fact, examples of such rapid changes have already been reported in the literature. Following a 6.7 GHz maser flare in S255IR (Fujisawa et al. 2015; Caratti o Garatti et al. 2016) a  $\sim 3$  mag brightening in the  $H$  and  $Ks$  infrared bands was detected, which was attributed to a disk-mediated accretion burst onto a massive young stellar object. Similarly, the increased luminosity detected in NGC 6334 I and accompanied by strong maser flares was attributed to a sudden accretion event. Observations by Hunter et al. (2017) show that the free-free emission (at 1.5 cm) from NGC6334I has fallen by a factor of 4; such a decrease would arise quite naturally if the accretion event reduced the ionizing photon flux from the young stellar object. At the high densities of these massive star formation regions, the recombination timescale for the ionized gas can be of the order of a few weeks, hence the free-free continuum emission can track the same accretion events, but showing a decrease while the IR luminosity increases. Both these star forming regions showed significant changes in their maser emission during the aforementioned events. A byproduct of these findings was increased interest in the burst behavior of maser emission, interpreted in the context of star formation as described above. While single-dish monitoring results can imply such processes, imaging is required to associate spectral temporal changes to physical processes seen in star forming regions.

The current literature proposes three main routes for producing maser bursts; the increase of continuum emission entering the maser (S255, NGC6334, see above), changes in the pumping conditions (Honma et al. 2004), and the overlapping of maser clouds along the line of sight to the observer, as was reported by Shimoikura et al. (2005); Hirota et al. (2014) in Orion KL.

G25.65+1.05 has recently enjoyed intensive observational studies because of the repeated, intense 22 GHz water maser flares, similar in intensity to those of Orion KL and W49N. Our VLA observations were made about two months after the water maser outburst that occurred in September 2017 (Volvach et al. 2017a, 2019). The burst lasted for several days and reached a peak flux density of about 65 kJy, according to single-dish monitoring. At the time of the VLA observations, the correlated H<sub>2</sub>O maser flux density remained at about 10 kJy.

Our JVLA images reveal for the first time the location of the bursting maser in G25.65+1.05, with the additional context of the distributions of other maser species and investigation of the nature of the continuum sources (see Section 5.1). The bursting maser is found to reside at the periphery of a continuum source JVLA 1, which may be either a young protostellar object with a jet, or a region of shocked gas possibly ejected from the JVLA 2 MYSO. As such, the maser is probably associated with protostellar ejections rather than accretion events.

Our interpretation of the water masers associated with the burst feature in JVLA 1 is as follows. Two maser sheets propagating in a shock are delineated by the large V-shape formed by the G1-G2-G3 groups. At their intersect in G2, the fine scale distribution traces the intersect down to a smaller, similarly orientated v-shape that comprises G2 cluster III (Figure 7 (c)). Consequently, the bursting maser is observed at the exact point where the two maser sheets intersect in the sky-plane of the observer, i.e. where the path length of maser emission significantly increased along the line of sight.

Providing that the two sheets have a non-zero relative proper motion it can be expected that the intersect point will shift in location along the lengths of the maser sheets. This could explain the repeating nature of the bursts in G25.65+1.05. Measurements of the relative proper motions via VLBI observations would be required to test this scenario and could lead to the possibility to detect future burst events.

Considering the location and morphology of the water masers in G25.65+1.05, we consider the most likely burst scenario to be an increase of maser path length along the line of sight to the observer; i.e., a repeat of the Orion KL scenario (Shimoikura et al. 2005). The fast appearance and fast decay of the burst in G25.65+1.05 (Volvach et al. 2019) supports this view, since the other maser burst scenarios would require the presence of physical changes on intra-day timescales, to match and explain the same timescales of maser variability.

Further study of the burst process is being conducted by our group to clarify the case for G25.65+1.05, and to extend the sample to other bursting masers in current and future campaigns. In this effort we propose define a catalog of Bursting Maser Objects (further abbreviated as “BMO”) based on the format used for other transient astronomical

events, for example novae. For the burst event in G25.65+1.05 located in the Serpens constellation we suggest the name “BMO-Serp”.

## 6. CONCLUSIONS

This work may be summarized as follows:

1. Spectral line and continuum observations of G25.65+1.05 were conducted with JVLA B-configuration in C, Ku, K, and Q frequency bands during the post- H<sub>2</sub>O maser burst epoch of November-December 2017.
2. Continuum emission above a  $5\sigma$  detection level is found in all four frequency bands – positions of four continuum sources (JVLA 1, 2, 3, and 4) were determined.
3. Spectral line emission is detected in all frequency bands except Ku-band – no 12 GHz class II CH<sub>3</sub>OH maser emission was found.
4. Milliarcsecond accuracy J2000 coordinates, radial velocities, and flux densities were obtained for 22 GHz H<sub>2</sub>O and 6.7 and 44 GHz CH<sub>3</sub>OH masers. Spot maps and spectra for each maser are presented.
5. A map of 22 GHz H<sub>2</sub>O maser spots was obtained for the first time ever, and the absolute position of the 22 GHz H<sub>2</sub>O bursting feature was determined.
6. Three groups of 6.7 GHz class II CH<sub>3</sub>OH masers associated with continuum source JVLA 2 are detected. Comparison of pre- and post-burst maps of 6.7 GHz CH<sub>3</sub>OH maser emission didn’t reveal significant changes in maser spot distribution.
7. A map of 44 GHz class I CH<sub>3</sub>OH maser spots was obtained for the first time. We detected four 44 GHz maser features oriented in a linear structure that is roughly aligned with a large-scale bipolar outflow operating in the region.
8. Based on the presence of 6.7 GHz masers and the ALMA detection at 350 GHz, we propose that JVLA 2 is a massive, accreting protostar. JVLA 1 may be a marginally older object (because of the absence of cIIMM) but both objects appear to be relatively young, and likely host shocked gas, which is responsible for their cm-wave emission. A definitive interpretation of JVLA 3 and 4 must await multi-frequency observations at higher resolution and sensitivity.
9. We report the location and morphology of the 22 GHz H<sub>2</sub>O maser emission, and note the absence of change in other maser species in the field. This indicates that the H<sub>2</sub>O maser burst most likely was caused by the increase of maser path length along the line of sight to the observer due to intersection of two maser sheets.

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**Table 1.** Observation parameters

Band	Obs. Date	Integ. Time	Continuum			Spectral Line			
			Synth. Beam	PA	$\sigma$	Vel. res.	Synth. Beam	PA	$\sigma$
		(min)	(arcsec)	( $^{\circ}$ )	( $\mu$ Jy/beam)	(km s $^{-1}$ )	(arcsec)	( $^{\circ}$ )	(mJy/beam)
C (6.0 GHz)	2017-Dec-09	10	1.82 $\times$ 1.15	23.01	8	0.04	1.24 $\times$ 0.86	19.78	35
Ku (15 GHz)	2017-Dec-09	12	0.70 $\times$ 0.47	20.51	10	0.05	0.62 $\times$ 0.44	19.16	53
K (22 GHz)	2017-Dec-09	12	0.48 $\times$ 0.33	15.43	15	0.11	0.35 $\times$ 0.25	11.25	60
Q (45 GHz)	2017-Nov-02	10	0.33 $\times$ 0.19	44.27	41	0.05	0.24 $\times$ 0.14	33.08	36

**Table 2.** List of detected continuum sources

Freq.	RA(J2000)	DEC(J2000)	Integrated	Peak
(GHz)	( $^h$ $^m$ $^s$ )	( $^{\circ}$ $^{\prime}$ $^{\prime\prime}$ )	flux	flux
			(mJy)	(mJy/beam)
6 <sup>a</sup>	18:34:20.9000 $\pm$ 0.0003 <sup>b</sup>	-05:59:42.033 $\pm$ 0.009	3.94 $\pm$ 0.05	2.66 $\pm$ 0.02
JVLA 1				
15	18:34:20.9002 $\pm$ 0.0001	-05:59:41.698 $\pm$ 0.001	2.53 $\pm$ 0.01	1.97 $\pm$ 0.01
22	18:34:20.9003 $\pm$ 0.0001	-05:59:41.682 $\pm$ 0.003	2.52 $\pm$ 0.04	1.65 $\pm$ 0.02
45	18:34:20.8903 $\pm$ 0.0014	-05:59:41.739 $\pm$ 0.032	1.59 $\pm$ 0.26	0.47 $\pm$ 0.06
JVLA 2				
15	18:34:20.9133 $\pm$ 0.0001	-05:59:42.264 $\pm$ 0.002	0.79 $\pm$ 0.01	0.76 $\pm$ 0.01
22	18:34:20.9140 $\pm$ 0.0001	-05:59:42.266 $\pm$ 0.004	1.12 $\pm$ 0.03	0.95 $\pm$ 0.02
45	18:34:20.9078 $\pm$ 0.0008	-05:59:42.375 $\pm$ 0.012	0.60 $\pm$ 0.09	0.70 $\pm$ 0.05
JVLA 3				
15	18:34:20.9122 $\pm$ 0.0001	-05:59:42.876 $\pm$ 0.003	0.66 $\pm$ 0.01	0.54 $\pm$ 0.01
22	18:34:20.9113 $\pm$ 0.0004	-05:59:42.923 $\pm$ 0.007	0.71 $\pm$ 0.04	0.49 $\pm$ 0.02
45	18:34:20.8932 $\pm$ 0.0031	-05:59:42.892 $\pm$ 0.076	0.71 $\pm$ 0.26	0.21 $\pm$ 0.06
JVLA 4				
15	18:34:20.8244 $\pm$ 0.0002	-05:59:43.175 $\pm$ 0.004	0.43 $\pm$ 0.01	0.37 $\pm$ 0.01
22	18:34:20.8258 $\pm$ 0.0006	-05:59:43.151 $\pm$ 0.013	0.43 $\pm$ 0.03	0.31 $\pm$ 0.02

<sup>a</sup>Sources are unresolved at this frequency.

<sup>b</sup> Statistical errors of the fit are listed. A systematic error in the position of the sources could be of order 0.15'', due to position uncertainty of the phase reference source J1832-1035.

**Table 3.** 22 GHz H<sub>2</sub>O maser parameters

RA(J2000)	DEC(J2000)	Integrated	Peak	$V_{LSR}$	Group <sup>a</sup>	Cluster <sup>b</sup>
		flux	flux			
( <sup>h</sup> <sup>m</sup> <sup>s</sup> )	( <sup>°</sup> <sup>'</sup> <sup>''</sup> )	(Jy)	(Jy/beam)	(km s <sup>-1</sup> )		
18:34:20.9187±0.0005	-05:59:41.682±0.013	210±30	190±10	41.34	G1	
18:34:20.9173±0.0007	-05:59:41.668±0.013	440±50	310±20	41.45		
18:34:20.9188±0.0005	-05:59:41.682±0.011	490±50	440±30	41.55		
18:34:20.9158±0.0011	-05:59:41.660±0.017	780±110	460±40	41.66		
18:34:20.9018±0.0001	-05:59:41.557±0.002	230±10	220.47±1.97	51.03	G2	I
18:34:20.9018±0.0001	-05:59:41.557±0.002	280±10	260.73±2.23	51.14		
18:34:20.9018±0.0001	-05:59:41.557±0.001	320±10	299.10±2.47	51.24		
18:34:20.9018±0.0001	-05:59:41.557±0.001	340±10	323.80±2.63	51.35		
18:34:20.9018±0.0001	-05:59:41.557±0.001	350±10	327.50±2.67	51.45		
18:34:20.9018±0.0001	-05:59:41.557±0.001	330±10	314.57±2.57	51.56		
18:34:20.9018±0.0001	-05:59:41.557±0.001	320±10	301.37±2.50	51.66		
18:34:20.9018±0.0001	-05:59:41.557±0.001	330±10	306.87±2.53	51.77		
18:34:20.9018±0.0001	-05:59:41.557±0.001	370±10	350±10	51.88		
18:34:20.9018±0.0001	-05:59:41.557±0.001	460±10	430±10	51.98		
18:34:20.9018±0.0001	-05:59:41.557±0.001	580±10	540±10	52.09		
18:34:20.9019±0.0001	-05:59:41.557±0.001	690±10	650±10	52.19		
18:34:20.9018±0.0001	-05:59:41.557±0.001	760±10	710±10	52.30		
18:34:20.9019±0.0001	-05:59:41.557±0.001	730±10	690±10	52.40		
18:34:20.9019±0.0001	-05:59:41.557±0.001	630±10	590±10	52.51		
18:34:20.9019±0.0001	-05:59:41.557±0.001	470±10	440±10	52.61		
18:34:20.9019±0.0001	-05:59:41.558±0.002	310±10	293.07±2.43	52.72		
18:34:20.9020±0.0001	-05:59:41.558±0.002	188.50±3.03	176.90±1.67	52.82		
18:34:20.9021±0.0001	-05:59:41.559±0.002	108.53±1.90	101.77±1.03	52.93		
18:34:20.9023±0.0001	-05:59:41.560±0.002	63.37±1.17	59.57±0.63	53.03		
18:34:20.9024±0.0001	-05:59:41.561±0.002	39.67±0.80	37.47±0.43	53.14		
18:34:20.9025±0.0001	-05:59:41.563±0.002	28.60±0.67	27.23±0.37	53.24		
18:34:20.9026±0.0001	-05:59:41.563±0.002	24.67±0.60	23.57±0.33	53.35		
18:34:20.9027±0.0001	-05:59:41.564±0.002	25.60±0.60	24.53±0.33	53.46		
18:34:20.9029±0.0001	-05:59:41.565±0.002	30.27±0.67	28.80±0.37	53.56		
18:34:20.9030±0.0001	-05:59:41.566±0.002	38.13±0.77	36.20±0.43	53.67		
18:34:20.9032±0.0001	-05:59:41.566±0.002	49.37±0.93	46.73±0.50	53.77		
18:34:20.9033±0.0001	-05:59:41.567±0.002	63.50±1.13	59.90±0.63	53.88		
18:34:20.9034±0.0001	-05:59:41.568±0.002	78.87±1.37	74.37±0.73	53.98		
18:34:20.9035±0.0001	-05:59:41.568±0.002	92.17±1.57	86.93±0.87	54.09		
18:34:20.9035±0.0001	-05:59:41.568±0.002	99.80±1.70	94.07±0.93	54.19		
18:34:20.9035±0.0001	-05:59:41.568±0.002	98.47±1.67	92.70±0.90	54.30		
18:34:20.9035±0.0001	-05:59:41.568±0.002	86.47±1.47	81.67±0.80	54.40		

*Table 3 continued on next page*



Table 3 (continued)

RA(J2000)	DEC(J2000)	Integrated	Peak	$V_{LSR}$	Group <sup>a</sup>	Cluster <sup>b</sup>
		flux	flux			
( <sup>h</sup> <sup>m</sup> <sup>s</sup> )	( <sup>°</sup> <sup>'</sup> <sup>''</sup> )	(Jy)	(Jy/beam)	(km s <sup>-1</sup> )		
18:34:20.9035±0.0001	-05:59:41.568±0.002	67.00±1.17	63.27±0.63	54.51		
18:34:20.9035±0.0001	-05:59:41.568±0.002	44.97±0.83	42.63±0.47	54.61		
18:34:20.9034±0.0001	-05:59:41.568±0.002	25.97±0.60	24.90±0.33	54.72		
18:34:20.9034±0.0001	-05:59:41.568±0.004	13.07±0.50	12.84±0.27	54.82		
18:34:20.9032±0.0002	-05:59:41.567±0.006	5.93±0.40	6.06±0.23	54.93		
18:34:20.9014±0.0002	-05:59:41.560±0.005	7.73±0.43	7.42±0.24	49.03		II
18:34:20.9012±0.0003	-05:59:41.563±0.006	5.77±0.40	5.52±0.21	49.14		
18:34:20.9010±0.0003	-05:59:41.566±0.006	4.92±0.33	4.51±0.18	49.24		
18:34:20.9010±0.0003	-05:59:41.568±0.006	4.25±0.28	3.85±0.15	49.35		
18:34:20.9010±0.0003	-05:59:41.572±0.006	4.37±0.29	3.75±0.15	49.45		
18:34:20.9013±0.0003	-05:59:41.572±0.007	4.59±0.31	3.90±0.16	49.56		
18:34:20.9015±0.0003	-05:59:41.573±0.007	5.47±0.37	4.73±0.19	49.66		
18:34:20.9017±0.0003	-05:59:41.571±0.007	6.47±0.43	5.80±0.23	49.77		
18:34:20.9018±0.0002	-05:59:41.569±0.005	8.37±0.47	7.76±0.26	49.87		
18:34:20.9019±0.0002	-05:59:41.567±0.004	11.13±0.50	10.47±0.27	49.98		
18:34:20.9019±0.0001	-05:59:41.564±0.003	15.50±0.50	14.64±0.28	50.08		
18:34:20.9019±0.0001	-05:59:41.562±0.003	22.17±0.57	21.00±0.31	50.19		
18:34:20.9019±0.0001	-05:59:41.561±0.002	32.70±0.70	30.97±0.37	50.30		
18:34:20.9019±0.0001	-05:59:41.559±0.002	48.87±0.93	46.13±0.50	50.40		
18:34:20.9019±0.0001	-05:59:41.558±0.002	71.53±1.27	67.37±0.70	50.51		
18:34:20.9019±0.0001	-05:59:41.558±0.002	99.70±1.73	93.83±0.93	50.61		
18:34:20.9018±0.0001	-05:59:41.557±0.002	130.90±2.23	123.13±1.20	50.72		
18:34:20.9018±0.0001	-05:59:41.557±0.002	163.23±2.70	153.53±1.47	50.82		
18:34:20.9018±0.0001	-05:59:41.557±0.002	196.80±3.13	184.93±1.70	50.93		
18:34:20.8977±0.0001	-05:59:41.562±0.002	296.67±0.01	262.47±2.50	41.13		III
18:34:20.8980±0.0001	-05:59:41.563±0.002	460.00±6.67	386.67±3.33	41.24		
18:34:20.8985±0.0001	-05:59:41.566±0.002	716.67±13.33	536.67±6.67	41.34		
18:34:20.8994±0.0001	-05:59:41.571±0.002	1100.00±23.33	706.67±10.00	41.45		
18:34:20.8994±0.0001	-05:59:41.571±0.002	1500.00±30.00	966.67±13.33	41.55		
18:34:20.8986±0.0001	-05:59:41.566±0.002	1840.00±33.33	1370.00±16.67	41.66		
18:34:20.8982±0.0001	-05:59:41.563±0.002	2280.00±33.33	1866.67±16.67	41.76		
18:34:20.8981±0.0001	-05:59:41.562±0.001	2883.33±40.00	2443.33±20.00	41.87		
18:34:20.8981±0.0001	-05:59:41.562±0.001	3636.67±46.67	3073.33±23.33	41.97		
18:34:20.8981±0.0001	-05:59:41.563±0.001	4443.33±60.00	3743.33±30.00	42.08		
18:34:20.8980±0.0001	-05:59:41.563±0.001	5200.00±66.67	4436.67±33.33	42.19		
18:34:20.8979±0.0001	-05:59:41.562±0.001	5886.67±73.33	5173.33±36.67	42.29		
18:34:20.8977±0.0001	-05:59:41.561±0.001	6600.00±80.00	5976.67±43.33	42.40		
18:34:20.8976±0.0001	-05:59:41.561±0.001	7420.00±86.67	6853.33±46.67	42.50		
18:34:20.8976±0.00004	-05:59:41.561±0.001	8390.00±96.67	7823.33±53.33	42.61		

Table 3 continued on next page

**Table 3** (*continued*)

RA(J2000)	DEC(J2000)	Integrated	Peak	$V_{LSR}$	Group <sup>a</sup>	Cluster <sup>b</sup>
		flux	flux			
( <sup>h</sup> <sup>m</sup> <sup>s</sup> )	( <sup>°</sup> <sup>'</sup> <sup>''</sup> )	(Jy)	(Jy/beam)	(km s <sup>-1</sup> )		
18:34:20.8976±0.00004	-05:59:41.561±0.001	9360.00±106.67	8756.67±56.67	42.71		
18:34:20.8976±0.00004	-05:59:41.561±0.001	10143.33±116.67	9490.00±63.33	42.82		
18:34:20.8976±0.00004	-05:59:41.561±0.001	10520.00±120.00	9843.33±63.33	42.92		
18:34:20.8976±0.00004	-05:59:41.561±0.001	10416.67±120.00	9743.33±63.33	43.03		
18:34:20.8976±0.00004	-05:59:41.561±0.001	9880.00±113.33	9243.33±60.00	43.13		
18:34:20.8976±0.00004	-05:59:41.561±0.001	9033.33±103.33	8453.33±56.67	43.24		
18:34:20.8976±0.00004	-05:59:41.561±0.001	8060.00±93.33	7536.67±50.00	43.34		
18:34:20.8976±0.00004	-05:59:41.561±0.001	7036.67±80.00	6576.67±43.33	43.45		
18:34:20.8977±0.00004	-05:59:41.561±0.001	5993.33±70.00	5600.00±36.67	43.55		
18:34:20.8977±0.00004	-05:59:41.561±0.001	4930.00±56.67	4603.33±30.00	43.66		
18:34:20.8977±0.00004	-05:59:41.561±0.001	3836.67±43.33	3580.00±23.33	43.76		
18:34:20.8977±0.0001	-05:59:41.561±0.001	2763.33±33.33	2576.67±16.67	43.87		
18:34:20.8978±0.0001	-05:59:41.561±0.001	1826.67±23.33	1700.00±13.33	43.98		
18:34:20.8978±0.0001	-05:59:41.560±0.001	1110.00±13.33	1033.33±6.67	44.08		
18:34:20.8979±0.0001	-05:59:41.560±0.001	633.33±6.67	586.67±3.33	44.19		
18:34:20.8980±0.0001	-05:59:41.559±0.001	346.67±0.01	322.27±2.67	44.29		
18:34:20.8982±0.0001	-05:59:41.558±0.002	188.17±3.07	174.63±1.67	44.40		
18:34:20.8983±0.0001	-05:59:41.558±0.002	104.77±1.83	96.70±1.00	44.50		
18:34:20.8985±0.0001	-05:59:41.558±0.002	62.50±1.17	57.33±0.63	44.61		
18:34:20.8989±0.0001	-05:59:41.559±0.002	42.57±0.83	38.43±0.43	44.71		
18:34:20.8995±0.0001	-05:59:41.561±0.002	34.63±0.73	30.93±0.40	44.82		
18:34:20.9001±0.0001	-05:59:41.560±0.002	34.20±0.73	30.30±0.37	44.92		
18:34:20.9004±0.0001	-05:59:41.560±0.002	38.27±0.80	33.80±0.40	45.03		
18:34:20.9005±0.0001	-05:59:41.560±0.002	45.47±0.90	39.63±0.47	45.13		
18:34:20.9004±0.0001	-05:59:41.560±0.002	54.57±1.07	46.67±0.53	45.24		
18:34:20.9001±0.0001	-05:59:41.560±0.002	63.67±1.20	52.97±0.60	45.34		
18:34:20.8998±0.0001	-05:59:41.561±0.002	71.13±1.33	57.93±0.67	45.45		
18:34:20.8997±0.0001	-05:59:41.561±0.002	72.53±1.37	58.83±0.67	45.56		
18:34:20.8957±0.0003	-05:59:41.539±0.009	4.73±0.43	4.61±0.23	36.29		IV
18:34:20.8954±0.0004	-05:59:41.540±0.011	5.83±0.63	5.60±0.33	36.39		
18:34:20.8948±0.0006	-05:59:41.536±0.015	7.10±1.07	6.73±0.60	36.50		
18:34:20.8949±0.0005	-05:59:41.543±0.012	4.30±0.53	4.20±0.31	37.34		
18:34:20.8951±0.0005	-05:59:41.544±0.010	3.67±0.40	3.53±0.22	37.44		
18:34:20.8954±0.0004	-05:59:41.547±0.010	3.37±0.37	3.23±0.20	37.55		
18:34:20.8957±0.0004	-05:59:41.548±0.009	2.95±0.27	2.85±0.15	37.66		
18:34:20.8961±0.0003	-05:59:41.551±0.009	2.83±0.25	2.69±0.14	37.76		
18:34:20.8960±0.0004	-05:59:41.560±0.010	2.81±0.26	2.58±0.14	37.87		
18:34:20.8957±0.0004	-05:59:41.570±0.011	3.02±0.32	2.68±0.17	37.97		
18:34:20.8954±0.0005	-05:59:41.577±0.014	3.23±0.40	2.69±0.20	38.08		

*Table 3 continued on next page*

**Table 3** (*continued*)

RA(J2000)	DEC(J2000)	Integrated	Peak	$V_{LSR}$	Group <sup>a</sup>	Cluster <sup>b</sup>
		flux	flux			
( <sup>h</sup> <sup>m</sup> <sup>s</sup> )	( <sup>°</sup> <sup>'</sup> <sup>''</sup> )	(Jy)	(Jy/beam)	(km s <sup>-1</sup> )		
18:34:20.8952±0.0006	-05:59:41.579±0.015	3.67±0.47	3.02±0.23	38.18		
18:34:20.8954±0.0005	-05:59:41.574±0.013	4.10±0.50	3.46±0.25	38.29		
18:34:20.8957±0.0004	-05:59:41.564±0.011	4.87±0.50	4.28±0.27	38.39		
18:34:20.8961±0.0004	-05:59:41.551±0.009	5.87±0.53	5.41±0.29	38.50		
18:34:20.8965±0.0003	-05:59:41.539±0.007	8.07±0.60	7.65±0.33	38.60		
18:34:20.8965±0.0003	-05:59:41.532±0.006	10.17±0.67	9.67±0.37	38.71		
18:34:20.8967±0.0002	-05:59:41.527±0.005	12.90±0.73	12.23±0.40	38.81		
18:34:20.8969±0.0002	-05:59:41.525±0.005	14.43±0.77	13.67±0.40	38.92		
18:34:20.8969±0.0002	-05:59:41.525±0.005	14.80±0.77	14.03±0.43	39.02		
18:34:20.8969±0.0002	-05:59:41.525±0.005	13.40±0.73	12.70±0.40	39.13		
18:34:20.8968±0.0003	-05:59:41.526±0.006	11.60±0.77	10.97±0.43	39.24		
18:34:20.8966±0.0004	-05:59:41.528±0.008	8.87±0.80	8.47±0.43	39.34		
18:34:20.8962±0.0005	-05:59:41.531±0.011	7.00±0.87	6.63±0.47	39.45		
18:34:20.8956±0.0006	-05:59:41.535±0.014	5.57±0.83	5.20±0.47	39.55		
18:34:20.8960±0.0005	-05:59:41.555±0.011	4.90±0.57	4.75±0.32	39.77		
18:34:20.8966±0.0003	-05:59:41.562±0.008	5.63±0.50	5.60±0.28	39.87		
18:34:20.8970±0.0003	-05:59:41.563±0.006	6.73±0.47	6.83±0.26	39.97		
18:34:20.8973±0.0002	-05:59:41.562±0.006	8.87±0.57	8.84±0.32	40.08		
18:34:20.8974±0.0002	-05:59:41.561±0.005	11.73±0.53	11.51±0.31	40.18		
18:34:20.8974±0.0001	-05:59:41.562±0.003	16.30±0.57	15.74±0.31	40.29		
18:34:20.8974±0.0001	-05:59:41.562±0.003	21.13±0.63	20.20±0.33	40.39		
18:34:20.8974±0.0001	-05:59:41.561±0.003	28.63±0.70	27.30±0.40	40.50		
18:34:20.8975±0.0001	-05:59:41.561±0.002	39.07±0.80	36.90±0.43	40.60		
18:34:20.8975±0.0001	-05:59:41.561±0.002	54.97±1.03	51.70±0.57	40.71		
18:34:20.8975±0.0001	-05:59:41.561±0.002	80.20±1.47	74.93±0.80	40.82		
18:34:20.8976±0.0001	-05:59:41.561±0.002	122.17±2.17	113.27±1.17	40.92		
18:34:20.8976±0.0001	-05:59:41.562±0.002	189.73±3.17	172.90±1.70	41.03		
18:34:20.8996±0.0001	-05:59:41.560±0.002	68.90±1.30	56.17±0.63	45.66	G3	
18:34:20.8996±0.0001	-05:59:41.560±0.002	61.03±1.17	50.40±0.60	45.77		
18:34:20.8996±0.0001	-05:59:41.560±0.002	52.10±1.03	43.97±0.53	45.87		
18:34:20.8996±0.0001	-05:59:41.560±0.002	43.27±0.87	37.30±0.47	45.98		
18:34:20.8996±0.0001	-05:59:41.560±0.002	36.30±0.73	31.97±0.40	46.08		
18:34:20.8995±0.0001	-05:59:41.560±0.002	30.53±0.67	27.30±0.37	46.19		
18:34:20.8995±0.0001	-05:59:41.561±0.002	25.77±0.63	23.27±0.33	46.29		
18:34:20.8995±0.0001	-05:59:41.562±0.003	21.00±0.57	19.06±0.30	46.40		
18:34:20.8996±0.0001	-05:59:41.562±0.003	16.83±0.53	15.29±0.28	46.50		
18:34:20.8998±0.0002	-05:59:41.562±0.004	13.03±0.50	11.87±0.27	46.61		
18:34:20.8999±0.0002	-05:59:41.565±0.004	10.57±0.50	9.47±0.26	46.71		
18:34:20.9000±0.0003	-05:59:41.570±0.006	8.93±0.50	7.50±0.25	46.82		

*Table 3 continued on next page*

**Table 3** (*continued*)

RA(J2000)	DEC(J2000)	Integrated	Peak	$V_{LSR}$	Group <sup>a</sup>	Cluster <sup>b</sup>
		flux	flux			
( <sup>h</sup> <sup>m</sup> <sup>s</sup> )	( <sup>°</sup> <sup>'</sup> <sup>''</sup> )	(Jy)	(Jy/beam)	(km s <sup>-1</sup> )		
18:34:20.9015±0.0004	-05:59:41.600±0.008	10.00±0.63	6.05±0.26	46.92		
18:34:20.9063±0.0006	-05:59:41.684±0.012	14.73±0.97	6.85±0.32	47.03		
18:34:20.9106±0.0002	-05:59:41.755±0.005	24.50±0.93	15.20±0.37	47.14		
18:34:20.9118±0.0001	-05:59:41.778±0.003	37.63±0.93	28.30±0.43	47.24		
18:34:20.9119±0.0001	-05:59:41.781±0.003	51.23±1.10	39.80±0.53	47.35		
18:34:20.9117±0.0001	-05:59:41.776±0.002	60.07±1.23	45.03±0.57	47.45		
18:34:20.9110±0.0001	-05:59:41.760±0.003	62.30±1.33	41.20±0.57	47.56		
18:34:20.9091±0.0002	-05:59:41.716±0.004	56.77±1.33	30.90±0.50	47.66		
18:34:20.9053±0.0002	-05:59:41.636±0.005	44.97±1.23	24.33±0.47	47.77		
18:34:20.9021±0.0001	-05:59:41.571±0.003	34.70±0.87	27.50±0.43	47.87		
18:34:20.9017±0.0001	-05:59:41.560±0.002	34.17±0.73	30.93±0.37	47.98		
18:34:20.9016±0.0001	-05:59:41.558±0.002	33.97±0.70	31.77±0.37	48.08		
18:34:20.9016±0.0001	-05:59:41.557±0.002	32.80±0.67	30.87±0.37	48.19		
18:34:20.9016±0.0001	-05:59:41.557±0.002	30.47±0.67	28.80±0.37	48.29		
18:34:20.9016±0.0001	-05:59:41.557±0.002	27.70±0.63	26.23±0.33	48.40		
18:34:20.9016±0.0001	-05:59:41.557±0.002	24.50±0.57	23.19±0.32	48.50		
18:34:20.9015±0.0001	-05:59:41.558±0.003	20.93±0.53	19.85±0.30	48.61		
18:34:20.9015±0.0001	-05:59:41.558±0.003	17.03±0.50	16.27±0.28	48.72		
18:34:20.9015±0.0001	-05:59:41.559±0.003	13.70±0.47	13.08±0.26	48.82		
18:34:20.9014±0.0002	-05:59:41.559±0.005	10.10±0.47	9.73±0.26	48.93		
18:34:20.9212±0.0006	-05:59:42.482±0.016	10.20±0.83	5.16±0.29	36.29	G4	
18:34:20.9232±0.0002	-05:59:42.540±0.006	23.93±1.13	16.53±0.50	36.39		
18:34:20.9236±0.0001	-05:59:42.556±0.004	52.57±1.77	41.97±0.87	36.50		
18:34:20.9237±0.0001	-05:59:42.561±0.003	94.83±2.70	79.90±1.37	36.60		
18:34:20.9238±0.0001	-05:59:42.564±0.003	0.14±0.01	117.13±1.83	36.71		
18:34:20.9238±0.0001	-05:59:42.565±0.003	0.16±0.01	138.63±2.10	36.81		
18:34:20.9238±0.0001	-05:59:42.566±0.003	0.16±0.01	136.70±2.03	36.92		
18:34:20.9238±0.0001	-05:59:42.567±0.003	126.87±3.17	112.20±1.67	37.02		
18:34:20.9237±0.0001	-05:59:42.567±0.003	85.03±2.17	74.90±1.13	37.13		
18:34:20.9236±0.0001	-05:59:42.567±0.003	46.70±1.33	40.37±0.67	37.23		
18:34:20.9232±0.0001	-05:59:42.565±0.004	22.93±0.80	19.23±0.40	37.34		
18:34:20.9229±0.0002	-05:59:42.562±0.006	11.93±0.60	9.67±0.29	37.44		
18:34:20.9227±0.0003	-05:59:42.549±0.009	7.20±0.53	5.42±0.25	37.55		
18:34:20.9226±0.0005	-05:59:42.522±0.012	5.87±0.47	3.65±0.19	37.66		
18:34:20.9215±0.0006	-05:59:42.480±0.015	5.63±0.47	2.92±0.16	37.76		
18:34:20.9200±0.0007	-05:59:42.441±0.016	6.63±0.50	3.15±0.17	37.87		
18:34:20.9193±0.0007	-05:59:42.423±0.015	8.40±0.63	4.02±0.21	37.97		
18:34:20.9187±0.0006	-05:59:42.413±0.014	10.77±0.77	5.11±0.25	38.08		
18:34:20.9185±0.0006	-05:59:42.412±0.014	12.93±0.90	6.19±0.30	38.18		

*Table 3 continued on next page*



**Table 3** (*continued*)

RA(J2000)	DEC(J2000)	Integrated	Peak	$V_{LSR}$	Group <sup>a</sup>	Cluster <sup>b</sup>
		flux	flux			
( <sup>h</sup> <sup>m</sup> <sup>s</sup> )	( <sup>°</sup> <sup>'</sup> <sup>''</sup> )	(Jy)	(Jy/beam)	(km s <sup>-1</sup> )		
18:34:20.9185±0.0006	-05:59:42.416±0.014	14.67±1.00	6.96±0.33	38.29		
18:34:20.9195±0.0005	-05:59:42.447±0.013	16.37±1.03	7.83±0.33	38.39		
18:34:20.9213±0.0004	-05:59:42.500±0.010	18.63±1.10	9.93±0.40	38.50		
18:34:20.9224±0.0002	-05:59:42.541±0.007	21.93±1.07	14.50±0.47	38.60		
18:34:20.9228±0.0002	-05:59:42.557±0.005	25.97±1.03	19.50±0.50	38.71		
18:34:20.9229±0.0002	-05:59:42.559±0.005	28.80±1.17	21.90±0.53	38.81		
18:34:20.9231±0.0002	-05:59:42.551±0.007	29.30±1.37	20.90±0.60	38.92		
18:34:20.9234±0.0003	-05:59:42.532±0.010	29.27±1.63	18.13±0.67	39.02		
18:34:20.9235±0.0003	-05:59:42.519±0.012	30.43±1.80	17.47±0.67	39.13		
18:34:20.9232±0.0003	-05:59:42.538±0.009	32.47±1.73	20.73±0.70	39.24		
18:34:20.9229±0.0002	-05:59:42.556±0.006	36.00±1.50	26.80±0.70	39.34		
18:34:20.9228±0.0001	-05:59:42.562±0.004	40.37±1.30	32.47±0.63	39.45		
18:34:20.9228±0.0001	-05:59:42.563±0.003	40.67±1.17	33.87±0.57	39.55		
18:34:20.9227±0.0001	-05:59:42.564±0.003	34.27±0.97	29.07±0.50	39.66		
18:34:20.9227±0.0001	-05:59:42.566±0.004	23.83±0.73	20.53±0.37	39.76		
18:34:20.9228±0.0002	-05:59:42.568±0.005	13.87±0.60	12.16±0.31	39.87		
18:34:20.9232±0.0003	-05:59:42.566±0.007	7.37±0.53	6.60±0.29	39.97		

<sup>a</sup>Conditional large-scale grouping of 22 GHz H<sub>2</sub>O maser spots detected in the field.

<sup>b</sup> 22 GHz H<sub>2</sub>O maser clusters detected in the vicinity of G2 group.

**Table 4.** 6.7 GHz CH<sub>3</sub>OH maser parameters

RA(J2000)	DEC(J2000)	Integrated	Peak	$V_{LSR}$	Cluster <sup>a</sup>
		flux	flux		
( <sup>h</sup> <sup>m</sup> <sup>s</sup> )	( <sup>°</sup> <sup>'</sup> <sup>''</sup> )	(Jy)	(Jy/beam)	(km s <sup>-1</sup> )	
18:34:20.9090±0.0006	-05:59:42.476±0.014	0.79±0.03	0.90±0.02	38.42	S
18:34:20.9093±0.0004	-05:59:42.487±0.010	1.22±0.04	1.30±0.02	38.46	
18:34:20.9099±0.0003	-05:59:42.487±0.008	1.65±0.04	1.75±0.03	38.51	
18:34:20.9106±0.0003	-05:59:42.483±0.007	1.97±0.04	2.03±0.02	38.55	
18:34:20.9100±0.0003	-05:59:42.480±0.008	1.93±0.04	2.07±0.03	38.59	
18:34:20.9098±0.0003	-05:59:42.477±0.008	1.71±0.04	1.83±0.03	38.64	
18:34:20.9088±0.0004	-05:59:42.481±0.010	1.36±0.04	1.44±0.03	38.68	
18:34:20.9090±0.0005	-05:59:42.501±0.014	0.99±0.04	1.02±0.02	38.73	
18:34:20.9077±0.0007	-05:59:42.493±0.018	0.70±0.04	0.74±0.02	38.77	
18:34:20.9081±0.0009	-05:59:42.511±0.022	0.48±0.03	0.56±0.02	38.81	
18:34:20.9284±0.0007	-05:59:42.333±0.018	0.70±0.04	0.74±0.02	40.09	NE
18:34:20.9287±0.0004	-05:59:42.352±0.011	1.12±0.04	1.18±0.02	40.13	
18:34:20.9289±0.0003	-05:59:42.330±0.009	1.67±0.04	1.73±0.03	40.18	
18:34:20.9290±0.0002	-05:59:42.341±0.006	2.30±0.04	2.40±0.03	40.22	
18:34:20.9286±0.0002	-05:59:42.343±0.005	2.95±0.04	3.05±0.03	40.26	
18:34:20.9284±0.0002	-05:59:42.333±0.005	3.44±0.05	3.60±0.03	40.31	
18:34:20.9284±0.0002	-05:59:42.336±0.004	3.82±0.05	3.93±0.03	40.35	
18:34:20.9282±0.0002	-05:59:42.333±0.004	3.95±0.05	4.06±0.03	40.40	
18:34:20.9284±0.0002	-05:59:42.334±0.004	3.96±0.05	4.08±0.03	40.44	
18:34:20.9282±0.0002	-05:59:42.335±0.004	3.70±0.05	3.81±0.03	40.48	
18:34:20.9280±0.0002	-05:59:42.330±0.005	3.29±0.05	3.43±0.03	40.53	
18:34:20.9279±0.0002	-05:59:42.335±0.005	2.88±0.05	2.99±0.03	40.57	
18:34:20.9279±0.0002	-05:59:42.329±0.006	2.51±0.04	2.59±0.03	40.61	
18:34:20.9278±0.0003	-05:59:42.334±0.006	2.17±0.04	2.26±0.03	40.66	
18:34:20.9279±0.0003	-05:59:42.344±0.007	1.93±0.04	2.03±0.03	40.70	
18:34:20.9275±0.0003	-05:59:42.326±0.007	1.82±0.04	1.87±0.02	40.75	
18:34:20.9275±0.0003	-05:59:42.337±0.008	1.82±0.04	1.87±0.03	40.79	
18:34:20.9274±0.0003	-05:59:42.349±0.007	1.93±0.04	1.93±0.03	40.83	
18:34:20.9271±0.0003	-05:59:42.342±0.007	2.02±0.04	2.04±0.03	40.88	
18:34:20.9275±0.0003	-05:59:42.347±0.006	2.21±0.04	2.22±0.03	40.92	
18:34:20.9275±0.0003	-05:59:42.354±0.006	2.32±0.04	2.31±0.03	40.97	
18:34:20.9270±0.0003	-05:59:42.351±0.006	2.23±0.04	2.22±0.03	41.01	
18:34:20.9266±0.0003	-05:59:42.348±0.006	2.13±0.04	2.10±0.02	41.05	
18:34:20.9268±0.0003	-05:59:42.347±0.007	1.94±0.04	1.92±0.02	41.10	
18:34:20.9261±0.0004	-05:59:42.346±0.008	1.71±0.04	1.63±0.03	41.14	
18:34:20.9247±0.0004	-05:59:42.342±0.009	1.58±0.04	1.50±0.02	41.19	
18:34:20.9235±0.0004	-05:59:42.346±0.009	1.47±0.04	1.39±0.02	41.23	

*Table 4 continued on next page*

**Table 4** (*continued*)

RA(J2000)	DEC(J2000)	Integrated	Peak	$V_{LSR}$	Cluster <sup>a</sup>
		flux	flux		
( <sup>h</sup> <sup>m</sup> <sup>s</sup> )	( <sup>°</sup> <sup>'</sup> <sup>''</sup> )	(Jy)	(Jy/beam)	(km s <sup>-1</sup> )	
18:34:20.9218±0.0005	-05:59:42.320±0.010	1.48±0.04	1.33±0.03	41.27	
18:34:20.9148±0.0005	-05:59:42.297±0.009	1.64±0.05	1.47±0.03	41.32	
18:34:20.9069±0.0003	-05:59:42.209±0.006	2.54±0.05	2.27±0.03	41.36	NW
18:34:20.9027±0.0002	-05:59:42.190±0.004	4.83±0.06	4.71±0.03	41.40	
18:34:20.9015±0.0001	-05:59:42.174±0.003	9.21±0.08	9.29±0.04	41.45	
18:34:20.9010±0.0001	-05:59:42.173±0.003	15.86±0.12	16.08±0.07	41.49	
18:34:20.9010±0.0001	-05:59:42.174±0.002	25.23±0.18	25.64±0.10	41.54	
18:34:20.9012±0.0001	-05:59:42.177±0.002	39.20±0.25	39.90±0.14	41.58	
18:34:20.9014±0.0001	-05:59:42.179±0.002	60.23±0.36	61.20±0.20	41.62	
18:34:20.9015±0.0001	-05:59:42.180±0.002	87.39±0.48	88.81±0.29	41.67	
18:34:20.9016±0.0001	-05:59:42.181±0.002	114.70±0.65	116.55±0.36	41.71	
18:34:20.9017±0.0001	-05:59:42.183±0.002	138.91±0.74	141.15±0.43	41.76	
18:34:20.9017±0.0001	-05:59:42.183±0.002	156.96±0.87	159.48±0.48	41.80	
18:34:20.9018±0.0001	-05:59:42.184±0.002	165.22±0.87	168.00±0.52	41.84	
18:34:20.9019±0.0001	-05:59:42.183±0.002	155.22±0.83	157.65±0.48	41.89	
18:34:20.9020±0.0001	-05:59:42.184±0.002	127.43±0.70	129.46±0.40	41.93	
18:34:20.9020±0.0001	-05:59:42.183±0.002	93.00±0.52	94.53±0.30	41.98	
18:34:20.9019±0.0001	-05:59:42.182±0.002	61.29±0.37	62.40±0.21	42.02	
18:34:20.9019±0.0001	-05:59:42.183±0.002	36.60±0.24	37.30±0.14	42.06	
18:34:20.9017±0.0001	-05:59:42.181±0.003	20.26±0.16	20.72±0.09	42.11	
18:34:20.9015±0.0001	-05:59:42.183±0.003	11.29±0.09	11.57±0.05	42.15	
18:34:20.9016±0.0001	-05:59:42.177±0.003	6.40±0.06	6.60±0.03	42.19	
18:34:20.9015±0.0002	-05:59:42.185±0.005	3.72±0.05	3.84±0.03	42.24	
18:34:20.9019±0.0002	-05:59:42.176±0.006	2.34±0.04	2.41±0.03	42.28	
18:34:20.9020±0.0003	-05:59:42.188±0.007	1.77±0.04	1.88±0.03	42.33	
18:34:20.9026±0.0003	-05:59:42.190±0.008	1.71±0.04	1.75±0.02	42.37	
18:34:20.9024±0.0003	-05:59:42.200±0.007	1.92±0.04	2.02±0.03	42.41	
18:34:20.9032±0.0002	-05:59:42.193±0.006	2.21±0.04	2.32±0.02	42.46	
18:34:20.9036±0.0002	-05:59:42.195±0.006	2.54±0.04	2.66±0.03	42.50	
18:34:20.9025±0.0002	-05:59:42.196±0.005	2.73±0.04	2.83±0.03	42.55	
18:34:20.9034±0.0002	-05:59:42.195±0.006	2.81±0.05	2.93±0.03	42.59	
18:34:20.9040±0.0002	-05:59:42.189±0.006	2.68±0.04	2.77±0.03	42.63	
18:34:20.9035±0.0002	-05:59:42.197±0.006	2.30±0.04	2.45±0.03	42.68	
18:34:20.9034±0.0003	-05:59:42.203±0.008	1.91±0.04	1.98±0.03	42.72	
18:34:20.9043±0.0003	-05:59:42.195±0.009	1.52±0.04	1.60±0.02	42.77	
18:34:20.9041±0.0004	-05:59:42.203±0.010	1.22±0.03	1.28±0.02	42.81	
18:34:20.9043±0.0005	-05:59:42.224±0.012	0.97±0.04	1.04±0.02	42.85	
18:34:20.9057±0.0006	-05:59:42.217±0.014	0.84±0.04	0.87±0.02	42.90	
18:34:20.9044±0.0007	-05:59:42.216±0.017	0.70±0.04	0.75±0.02	42.94	

*Table 4 continued on next page*

**Table 4** (*continued*)

RA(J2000)	DEC(J2000)	Integrated	Peak	$V_{LSR}$	Cluster <sup>a</sup>
		flux	flux		
( <sup>h</sup> <sup>m</sup> <sup>s</sup> )	( <sup>°</sup> <sup>'</sup> <sup>''</sup> )	(Jy)	(Jy/beam)	(km s <sup>-1</sup> )	
18:34:20.9081±0.0008	-05:59:42.228±0.019	0.59±0.03	0.65±0.02	42.99	
18:34:20.9051±0.0010	-05:59:42.222±0.023	0.48±0.03	0.55±0.02	43.03	

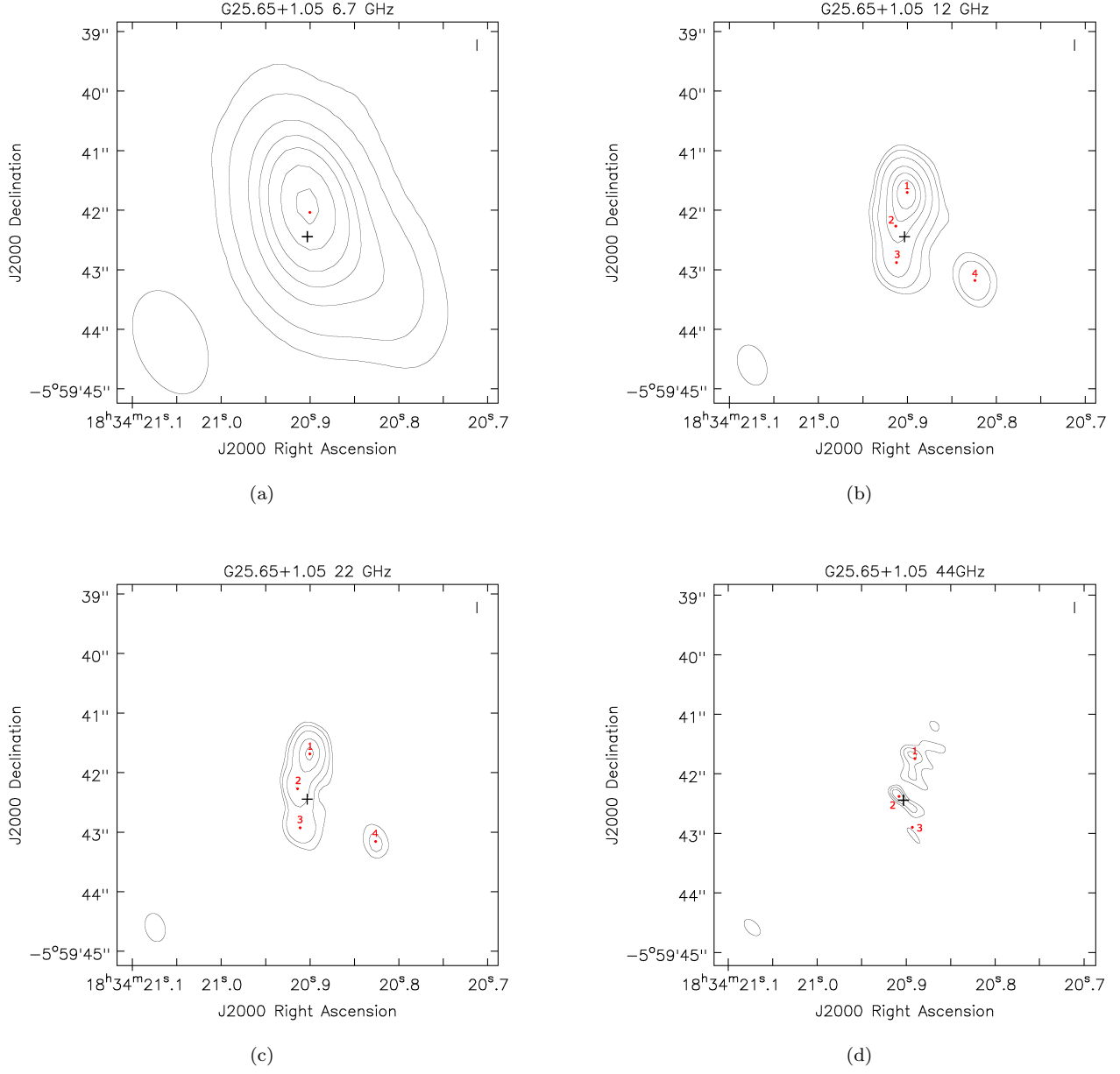
<sup>a</sup>Conditional large-scale grouping of 6.7 GHz CH<sub>3</sub>OH maser spots detected in the field.



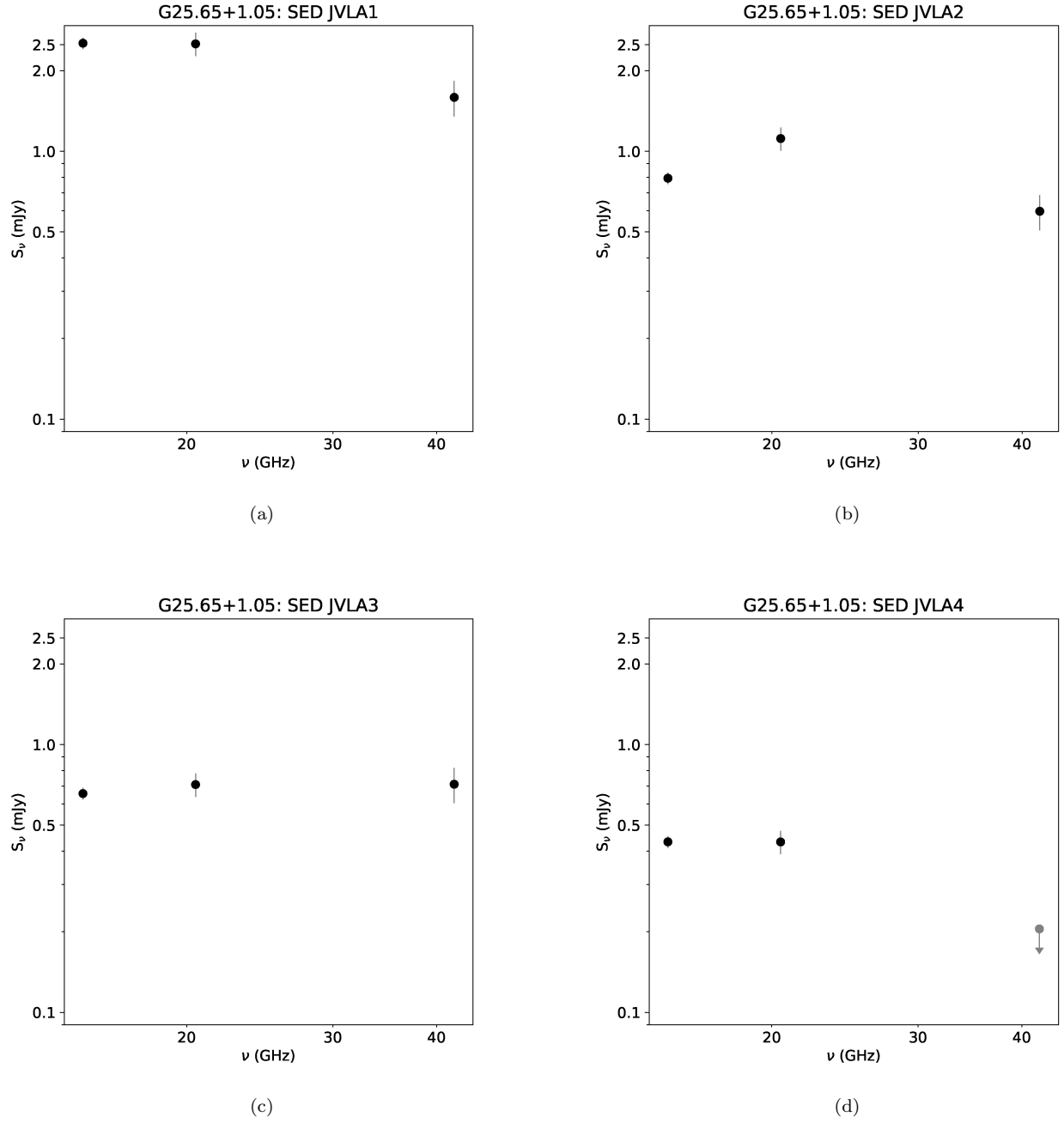
**Table 5.** 44 GHz CH<sub>3</sub>OH maser parameters

RA(J2000)	DEC(J2000)	Integrated	Peak	$V_{LSR}$	Cluster <sup>a</sup>
		flux	flux		
( <sup>h</sup> <sup>m</sup> <sup>s</sup> )	( <sup>°</sup> <sup>'</sup> <sup>''</sup> )	(Jy)	(Jy/beam)	(km s <sup>-1</sup> )	
18:34:20.7684±0.0003	-05:59:42.132±0.007	1.03±0.11	0.97±0.06	43.90	R
18:34:20.7680±0.0003	-05:59:42.131±0.007	1.12±0.12	1.08±0.07	43.85	
18:34:20.7676±0.0003	-05:59:42.131±0.006	1.34±0.13	1.29±0.07	43.80	
18:34:20.7672±0.0003	-05:59:42.125±0.007	1.38±0.14	1.30±0.08	43.75	
18:34:20.7670±0.0003	-05:59:42.128±0.007	1.36±0.14	1.32±0.08	43.69	
18:34:20.7667±0.0003	-05:59:42.129±0.006	1.28±0.13	1.27±0.07	43.64	
18:34:20.7665±0.0003	-05:59:42.127±0.007	1.22±0.12	1.15±0.07	43.59	
18:34:20.7665±0.0003	-05:59:42.129±0.007	0.98±0.11	0.94±0.06	43.53	
18:34:20.7667±0.0004	-05:59:42.127±0.007	0.70±0.08	0.71±0.05	43.48	
18:34:21.0018±0.0005	-05:59:39.942±0.009	0.42±0.06	0.40±0.03	42.58	G
18:34:21.0015±0.0004	-05:59:39.937±0.008	0.52±0.07	0.50±0.04	42.52	
18:34:21.0017±0.0004	-05:59:39.921±0.009	0.70±0.09	0.63±0.04	42.47	
18:34:21.0018±0.0003	-05:59:39.922±0.007	0.91±0.10	0.87±0.06	42.42	
18:34:21.0015±0.0003	-05:59:39.929±0.007	1.14±0.12	1.07±0.06	42.36	
18:34:21.0017±0.0003	-05:59:39.923±0.006	1.08±0.10	1.05±0.06	42.31	
18:34:21.0017±0.0003	-05:59:39.925±0.007	0.72±0.08	0.72±0.04	42.26	
18:34:20.5784±0.0002	-05:59:43.310±0.004	6.64±0.40	5.77±0.22	41.73	B2
18:34:20.5782±0.0002	-05:59:43.300±0.004	10.8±0.60	9.76±0.32	41.67	
18:34:20.5785±0.0004	-05:59:43.295±0.007	8.76±1.04	8.32±0.56	41.62	
18:34:20.5789±0.0005	-05:59:43.283±0.009	4.52±0.72	4.27±0.38	41.57	
18:34:20.5377±0.0007	-05:59:42.857±0.015	4.32±0.96	3.72±0.48	41.57	B1
18:34:20.5374±0.0005	-05:59:42.859±0.009	5.64±0.84	4.72±0.40	41.51	
18:34:20.5367±0.0007	-05:59:42.856±0.011	7.96±1.20	4.52±0.48	41.46	
18:34:20.5358±0.0009	-05:59:42.851±0.011	9.36±1.40	4.44±0.48	41.41	
18:34:20.5334±0.0008	-05:59:42.838±0.010	8.28±1.12	3.83±0.37	41.36	
18:34:20.5312±0.0007	-05:59:42.827±0.010	6.04±0.84	3.05±0.30	41.30	
18:34:20.5304±0.0006	-05:59:42.824±0.009	3.80±0.52	2.54±0.22	41.25	

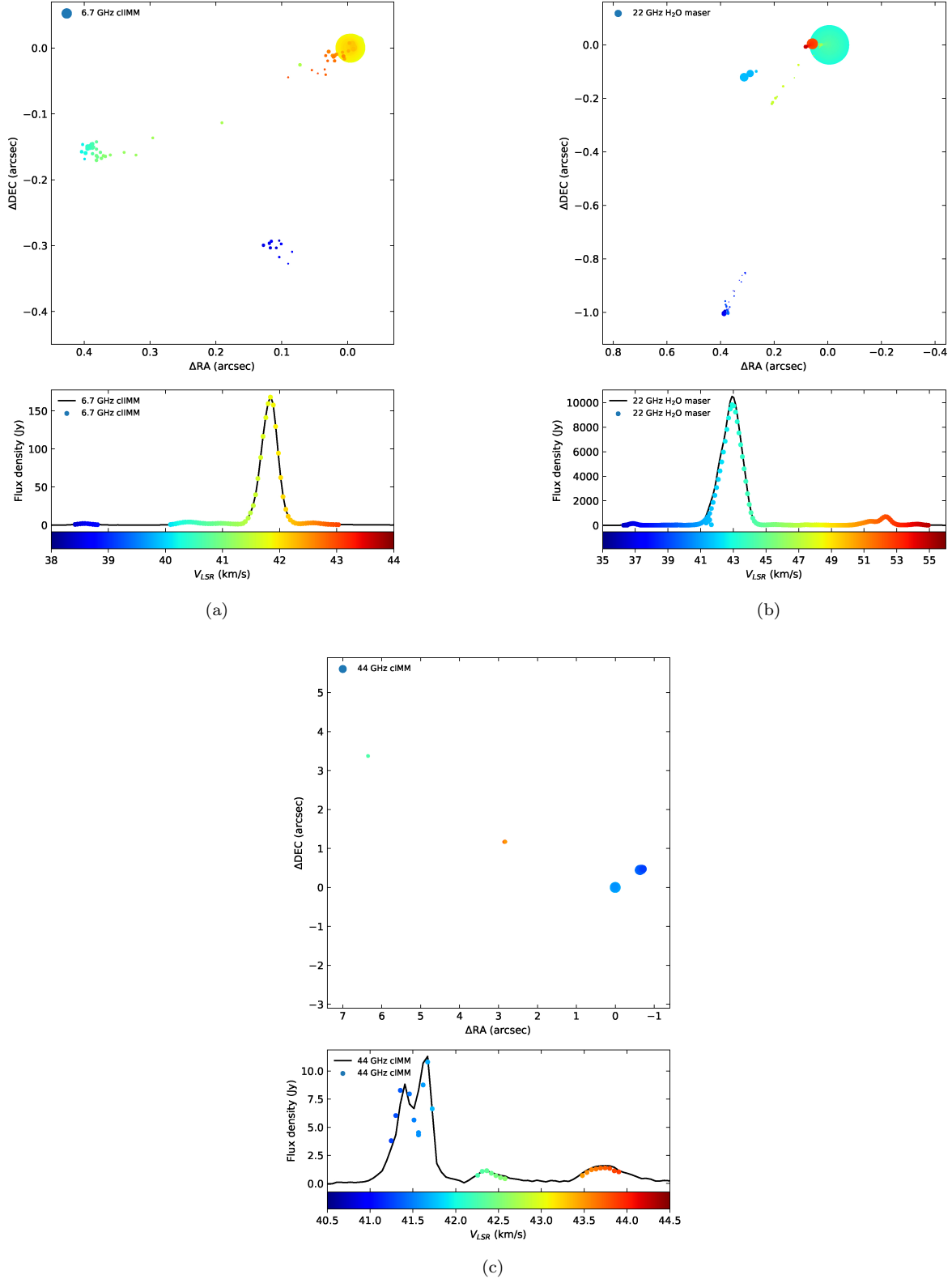
<sup>a</sup>Conditional large-scale grouping of 44 GHz CH<sub>3</sub>OH maser spots detected in the field, spots are labeled according to their velocity: “B1” and “B2” – blue spots, “G” – green, and “R” – red.



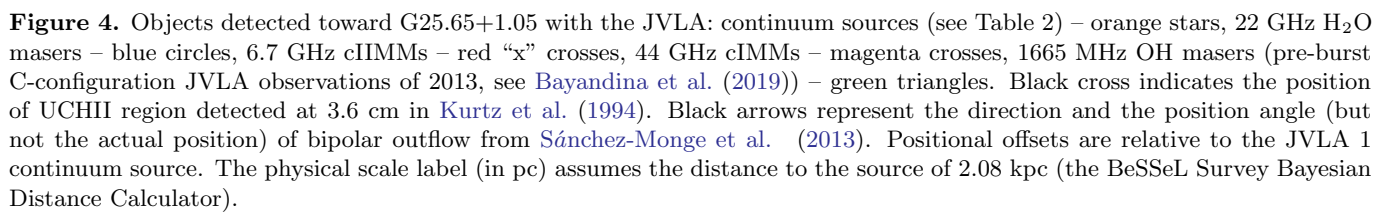
**Figure 1.** Continuum images of G25.65+1.05 at (a) 6.7 GHz (levels [3, 10, 30, 50, 70, 100, 130]  $\times$  20  $\mu$ Jy/beam), (b) 12 GHz (levels [3, 5, 10, 20, 30, 40]  $\times$  40  $\mu$ Jy/beam), (c) 22 GHz (levels [3, 5, 10, 20, 30]  $\times$  50  $\mu$ Jy/beam), and (d) 44 GHz (levels [3, 5, 7, 10]  $\times$  70  $\mu$ Jy/beam). Red points indicate detected peaks of continuum emission at a certain frequency – see Table 2. Indices correspond to source labeling from Table 2. The black cross marks the position of the UCHII region from (Kurtz et al. 1994).

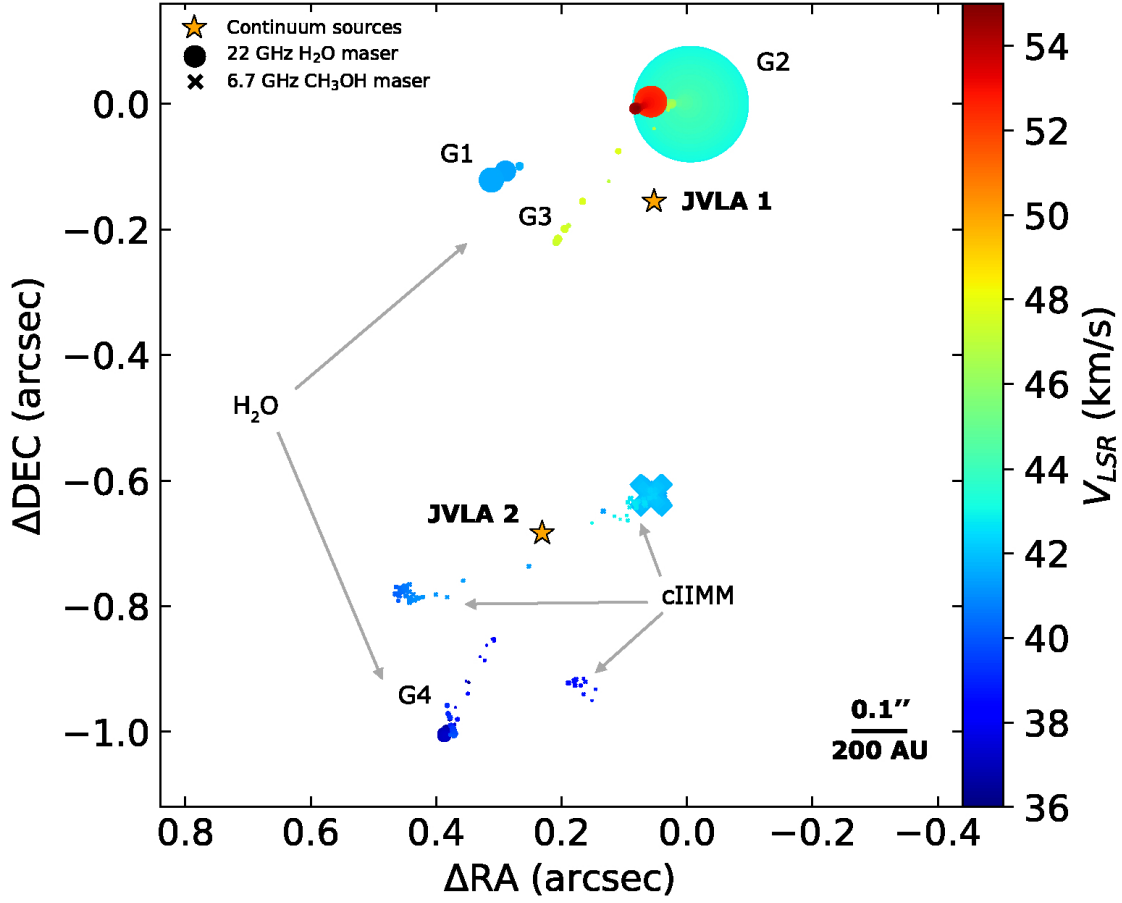


**Figure 2.** Spectral energy distribution (SED) of the detected in G25.65+1.05 continuum sources (a) JVL A1, (b) JVL A2, (c) JVL A3, and (d) JVL A4. Filled circles represent the integrated flux densities with error bars. The error bars indicate adopted in our data analysis a 5% error at 12 GHz, a 10% error at 22 GHz, and a 15% error at 45 GHz. Grey filled circle on JVL A4 SED is an upper limit ( $3\sigma$  level) at 45 GHz.

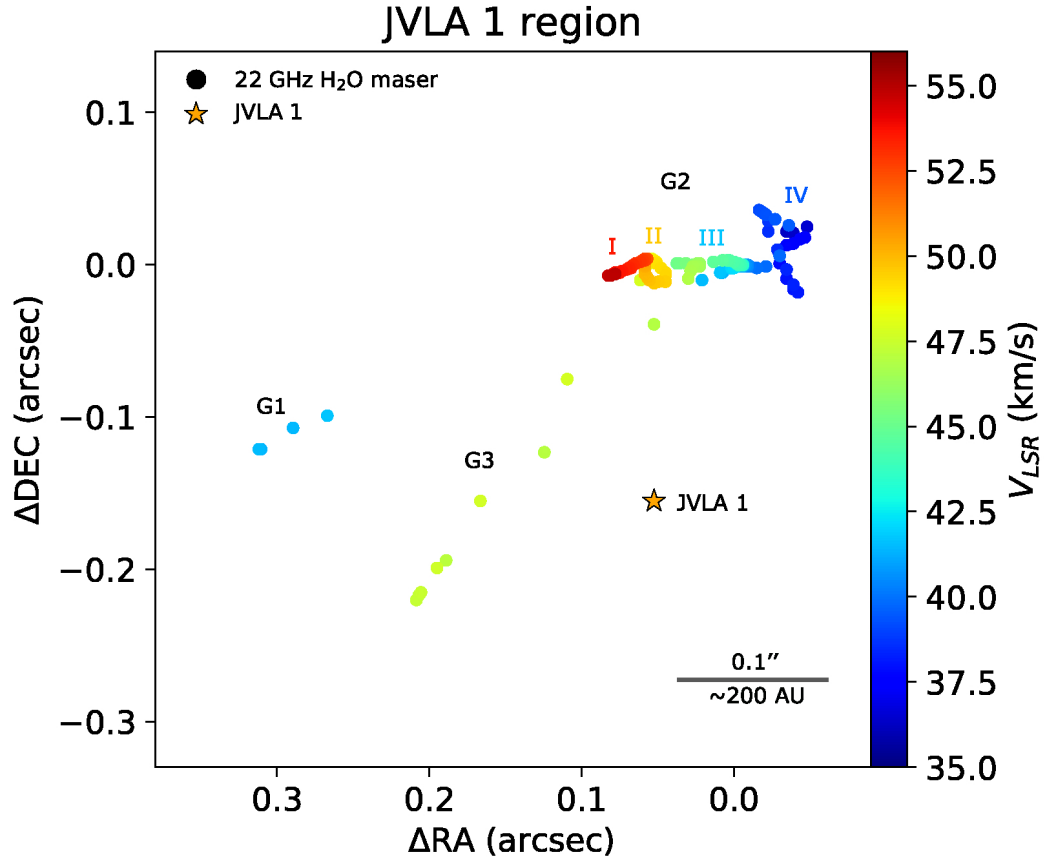


**Figure 3.** Maser data at (a) 6.7 GHz, (b) 22 GHz, and (c) 44 GHz for G25.65+1.05: the upper panel – a map of the maser spots and the lower panel – the maser source spectrum. Plots are color-coded by radial velocity (see colorbar for color scale). The diameter of each spot is proportional to the flux. Positional offsets are relative to the strongest maser spot at each frequency.

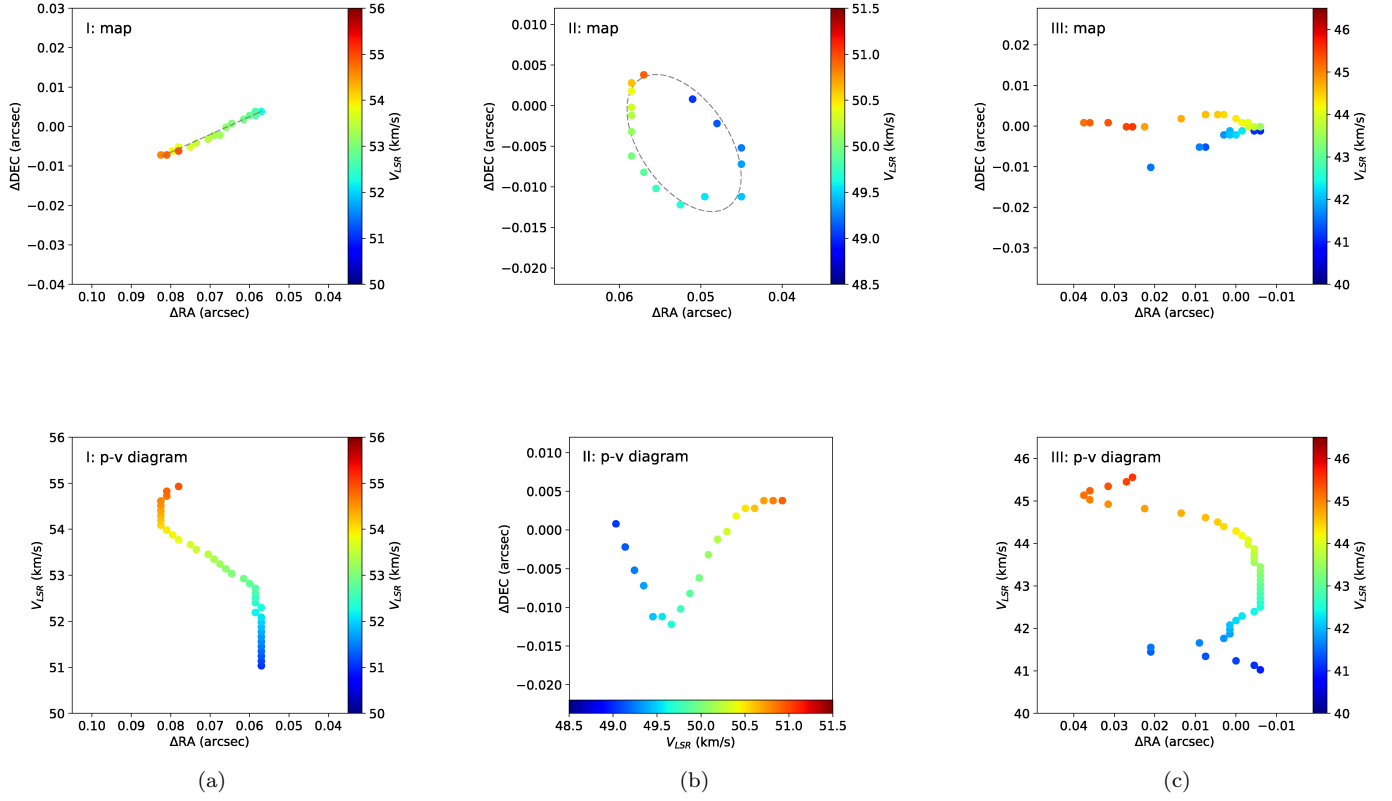




**Figure 5.** Distribution of 22 GHz  $H_2O$  (marked by circles) and 6.7 GHz  $CH_3OH$  (marked by “x” crosses) maser spots detected in vicinity of JVLAs 1 and 2 sources. The diameter of each spot is proportional to the flux. For 22 GHz  $H_2O$  maser groups labeling see Table 3. Plot is color-coded by radial velocity (see colorbar for color scale). Positional offsets are relative to the strongest 22 GHz  $H_2O$  maser spot. The physical scale label (in AU) assumes the distance to the source of 2.08 kpc (the BeSSeL Survey Bayesian Distance Calculator).

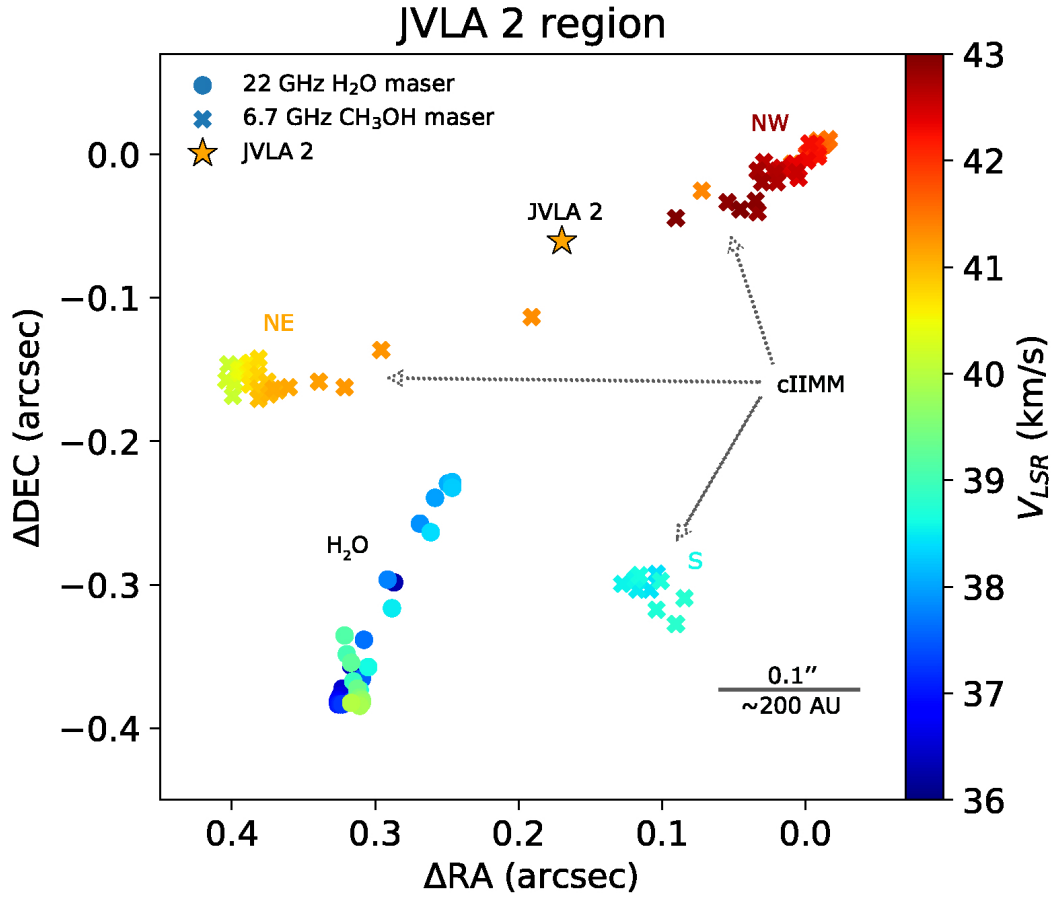


**Figure 6.** Distribution of 22 GHz  $H_2O$  maser spots detected in JVLA 1 region. For 22 GHz  $H_2O$  maser groups and clusters labeling see Table 3. Plot is color-coded by radial velocity (see colorbar for color scale). Positional offsets are relative to the strongest 22 GHz  $H_2O$  maser spot. The physical scale label (in AU) assumes the distance to the source of 2.08 kpc (the BeSSeL Survey Bayesian Distance Calculator).

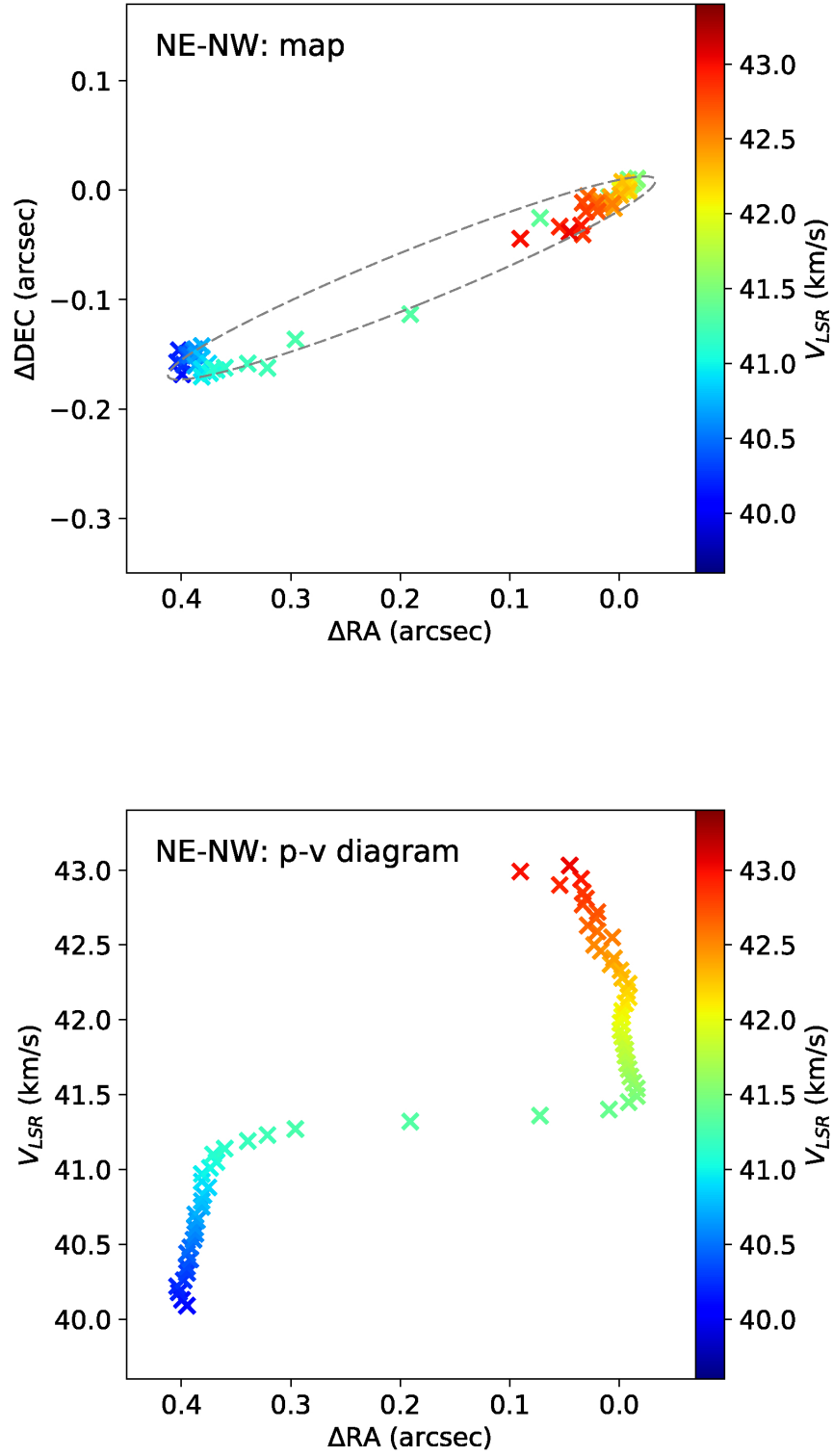


**Figure 7.** Close-up of H<sub>2</sub>O maser group G2 in the JVL A 1 region: (a) cluster I, (b) cluster II, (c) cluster III containing bursting maser feature (position (0,0)). Plot is color-coded by radial velocity (see colorbars for color scale). Positional offsets are relative to the strongest 22 GHz H<sub>2</sub>O maser spot.

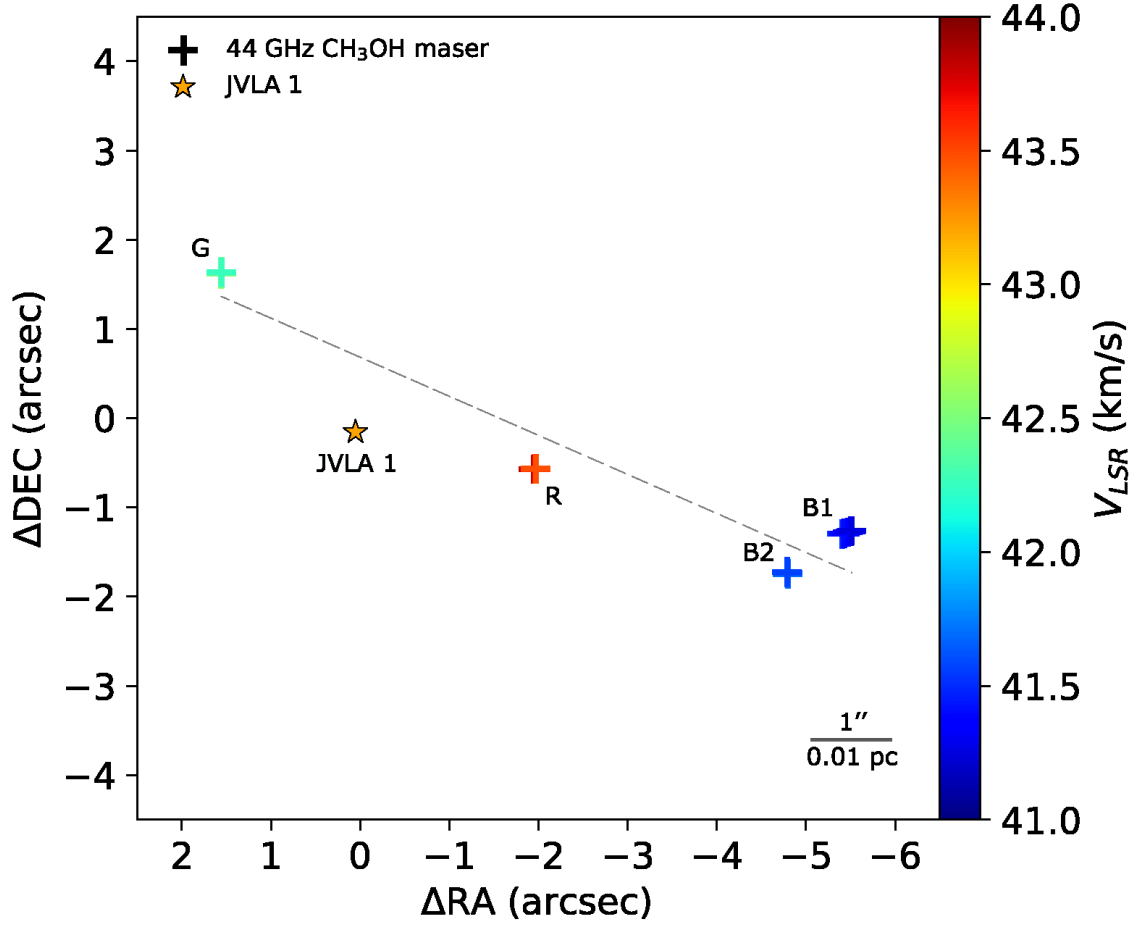




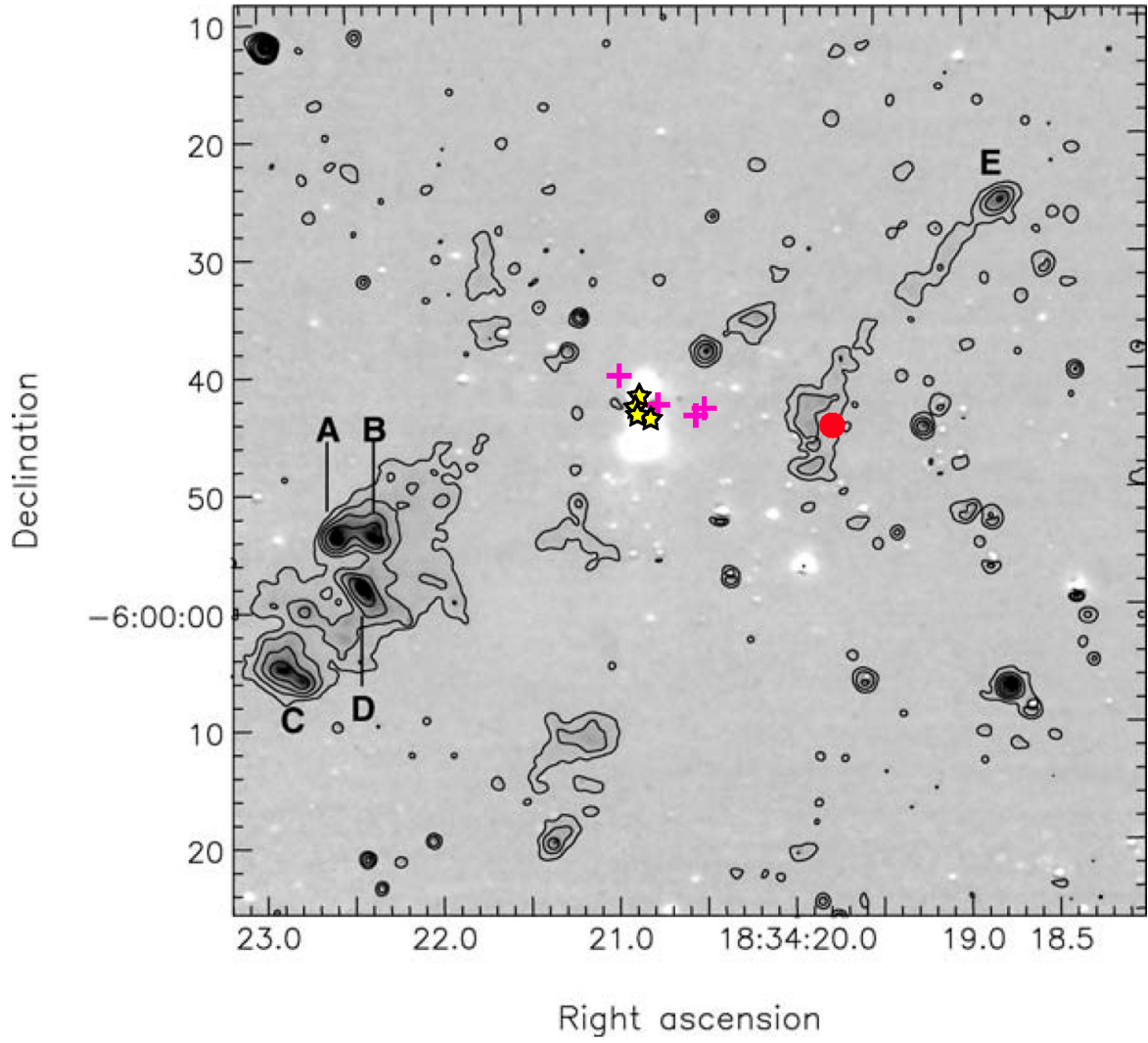
**Figure 8.** Distribution of 6.7 GHz  $CH_3OH$  and 22 GHz  $H_2O$  maser spots detected in JVLA 2 region. For 6.7 GHz  $CH_3OH$  maser clusters labeling see Table 4. Plot is color-coded by radial velocity (see colorbar for color scale). Positional offsets are relative to the strongest 6.7 GHz  $CH_3OH$  maser spot. The physical scale label (in AU) assumes the distance to the source of 2.08 kpc (the BeSSeL Survey Bayesian Distance Calculator).



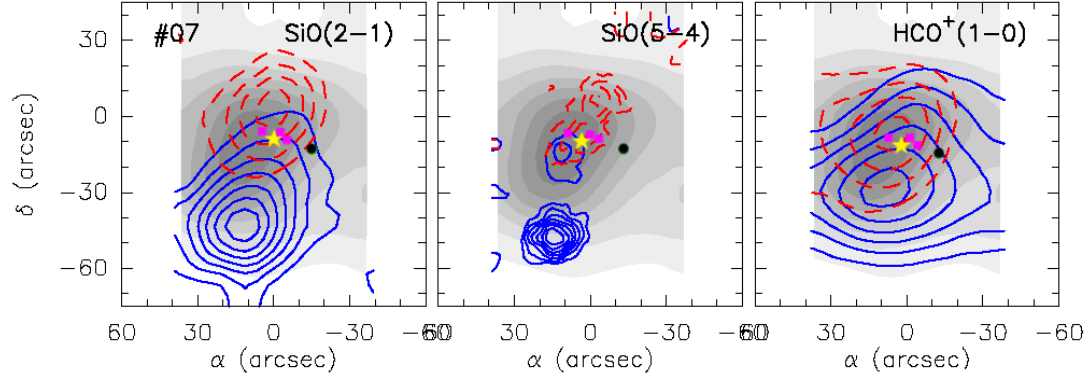
**Figure 9.** 6.7 GHz  $\text{CH}_3\text{OH}$  maser clusters NE and NW: upper panel – map and a least squares fitting of ellipse, bottom panel – p-v diagram. Plot is color-coded by radial velocity (see colorbar for color scale).



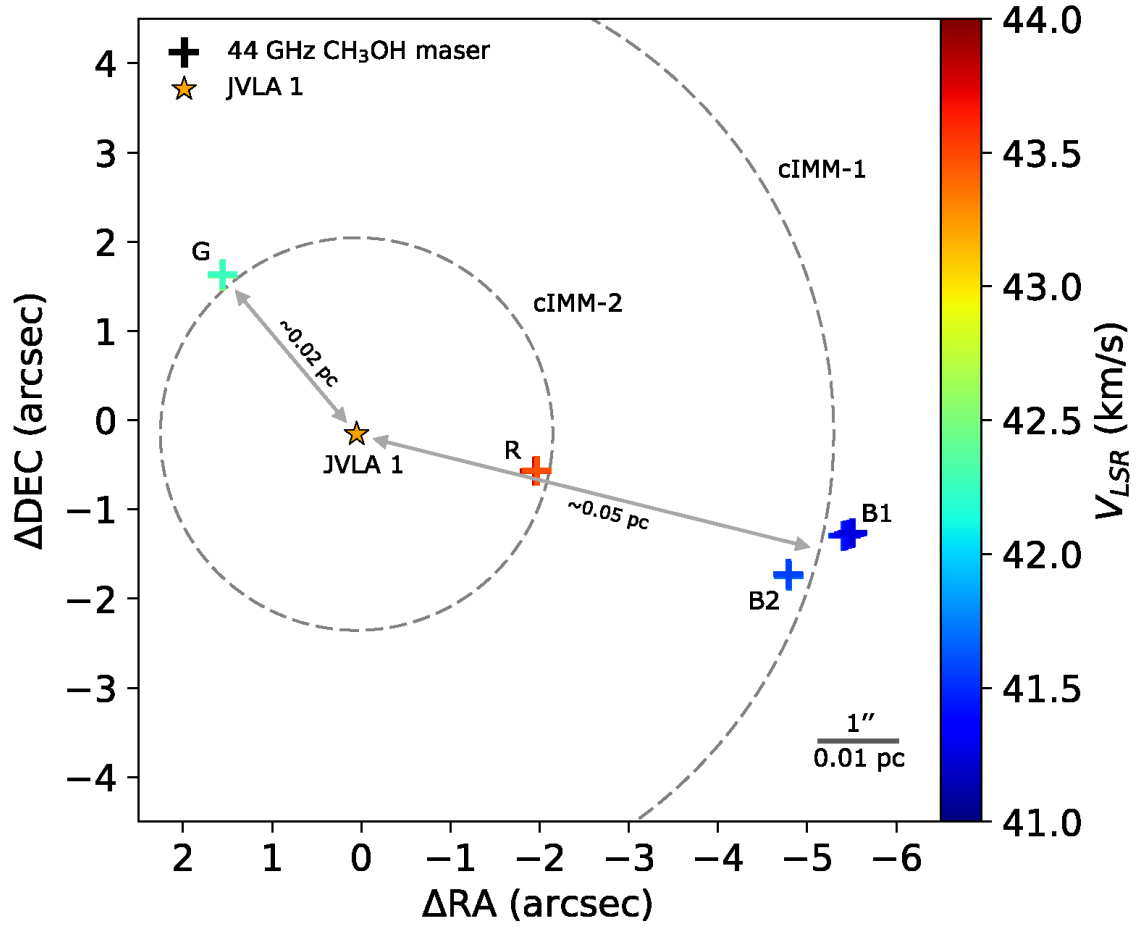
**Figure 10.** Distribution of 44 GHz CH<sub>3</sub>OH maser spots. For 44 GHz CH<sub>3</sub>OH maser groups labeling see Table 5. The dashed line represents the least squares fit of maser positions. Plot is color-coded by radial velocity (see colorbar for color scale). Positional offsets are relative to the JVL 1 continuum source. The physical scale label (in pc) assumes the distance to the source of 2.08 kpc (the BeSSeL Survey Bayesian Distance Calculator).



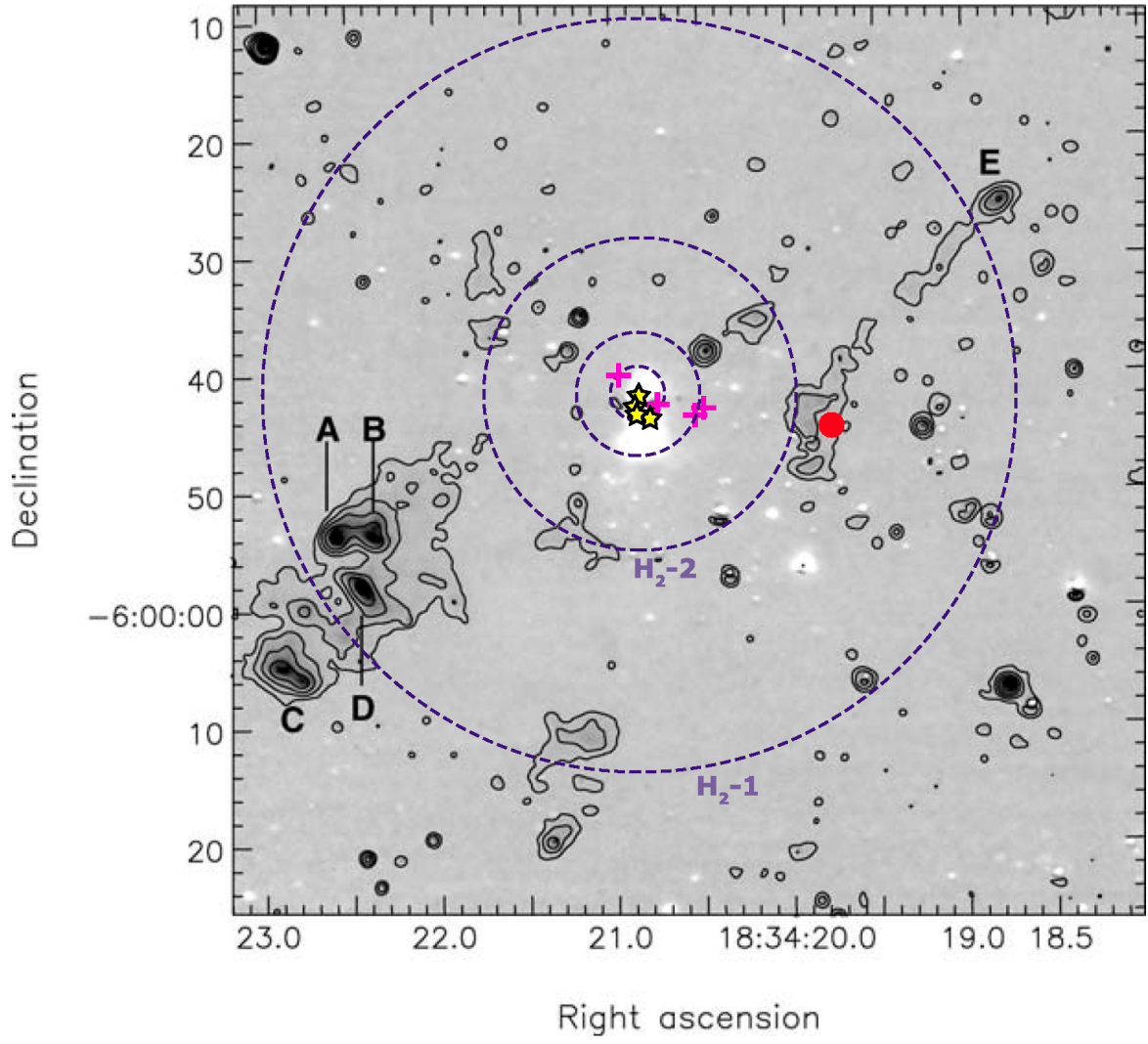
**Figure 11.** Objects detected toward G25.65+1.05 with the JVLA are overplotted on continuum-subtracted  $\nu = 1-0$  S(1)  $\text{H}_2$  image from Fig.2 in [Todd & Howat \(2006\)](#): continuum sources (see Table 2) – yellow stars, 44 GHz cIMMs – magenta crosses. Position of IRAS 18316-0602 is indicated by red circle. For the levels see [Todd & Howat \(2006\)](#).



**Figure 12.** Objects detected toward G25.65+1.05 with the JVLA are overplotted on SiO (2-1), SiO (5-4), and  $\text{HCO}^+$  (1-0) outflow maps from Fig.2 in [Sánchez-Monge et al. \(2013\)](#): average position of continuum sources (see Table 2) – yellow star, 44 GHz cIMMs – magenta squares. Position of IRAS 18316-0602 is indicated by black circle. The gray scale corresponds to the  $\text{N}_2\text{H}^+$  (10) integrated emission. Blue-solid and red-dashed contours represent blue- and red-shifted integrated wing emission, respectively. For the levels see Table 2 in [Sánchez-Monge et al. \(2013\)](#).



**Figure 13.** Possible model: episodic ejection traced by cIMMs. Two episodes of possible ejection: 1) cIMM-1: traced by B1 and B2 features, radius is  $\sim 0.05$  pc; 2) cIMM-2: traced by G and R features, radius is  $\sim 0.02$  pc. Plot is color-coded by radial velocity (see colorbar for color scale). Positional offsets are relative to the JVL A 1 continuum source. The physical scale label (in pc) assumes the distance to the source of 2.08 kpc (the BeSSeL Survey Bayesian Distance Calculator).



**Figure 14.** Possible model: episodic ejection traced by  $\text{H}_2$  emission. Possibly two more episodes of ejection are traced by  $\text{H}_2$  emission: 1)  $\text{H}_2$ -1: traced by  $\text{H}_2$  knots A, B, C, D, E – radius is  $\sim 0.3$  pc; 2)  $\text{H}_2$ -2: traced by weak  $\text{H}_2$  knots – radius is  $\sim 0.13$  pc.