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THE 1665 MHZ OH MASER LINE TOWARD A YOUNG PROTOSTELLAR OBJECT

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Abstract

We preset spectral line observations using MERLIN interferometer towards the massive star forming region IRAS 05137+3919. The Multi Element Radio Linked Interferometer Network (MERLIN) is an array of radio telescopes spread across Great Britain. The array has seven radio telescopes and is run by Jodrell Bank Observatory, the University of Manchester. MERLIN was used to observe the OH maser 1665 MHz line. MERLIN, with a 217 km diameter, gives a high angular resolution of 0.2 arcsecond at this 1665 MHz correspond to the 18-cm wavelength. The maser emission was detected and 13 OH maser spots at 1665-MHz line were drawn. There is one left hand circular polarization (LHC) and 12 right hand circular polarization (RHC) spots. We present the parameters of the OH maser components, namely the velocities, peak intensities and positions for each spot. We show the spatial distribution of the OH maser spots and show the distribution of their velocities of the left and right hand circular polarization components. It has been shown that the detected OH masers trace the central material of this star forming region close to the protostellar source.

1. Introduction

The formation of stars is one of most fundamental issues of astronomy. Understanding the nature of the protostellar period and the related processes is, at present, the major frontier of star formation research. Formation stars play a vital role in the dynamics and evolution of galaxy. Microwave amplification by stimulated emission of radiation (maser) originates from molecules which have been pumped to an excited state. Galactic maser emission originates from dense hot clumps of molecular gas. Masers are found in star forming regions (SFR), supernova remnants, and late-type stars. There are various very well-known maser species OH, H_2O, CH_3OH, SiO, and H_2CO to name some of the most common. The importance of using masers in studying star forming regions is that they enable us to study in great detail compact regions which can't be detected by other means.

OH masers observations towards star forming regions show that they are associated with different evolutionary stages of star forming process. It was believed that they are associated with HII regions only (e.g. Garay & Lizano 1999, and references therein). However observations which have been carried out towards a number of star forming regions show that OH masers are also associated with an earlier stage before the appearance of ionized HII regions (e.g. Cohen et al 1988; Braz et al. 1990; Edris, Fuller, & Cohen 2007). Many transition lines of OH masers have been detected, but the 1665 and 1667 MHz are the common lines associated with SFR. We have observed the 1665 MHz line to study one of the star forming regions.

IRAS 05137+3919 is one of the sample, drawn by Molinari et al. 1996, (named Mol 8, therein) from the Infrared Astronomical Satellite (IRAS) point source catalog to be a candidate of protostellar object. Mol 8(IRAS 05137+3919) is also called WB89 621 in the catalog of Wouterloot & Brand (1989), who detected (with the IRAM 30-m telescope) a strong CO (1−0) line emission at the IRAS position, and found evidence for wings of an outflow. Wings are also visible (^{13}CO, HCO^+, CS) spectra by Brand et al (2001). Casoli et al (1986) studied this source at the ^{13}CO and ^{12}CO gases. They detected emission in the ^{13}CO only. The Local standard of rest (LSR) velocity of the line ^{13}CO is -26 Km s^{-1}. Zhang et al. (2005) also detected a very powerful outflow from this source in CO. Varricatt et al (2010) said IRAS 05137+3919 was first identified as luminous Young Stellar Object (YSO) based on its IRAS colors. There are two IR-bright sources embedded in nebulosity in the center of his images. Molinari et al. (2002) detected HCO^+(1-0) emission from the central source, and from locations close to the NE and SW lobes of the H_2 jet, using the OVRO millimeter wave array. They derived a position angle of ~25° for the outflow.

Continuum emission at 3.4-mm was detected from the central object by Molinari et al. (2002). They also detected faint radio continuum emission from the central source at 3.6-cm (with flux density of 0.33 ± 0.03 mJy) using the VLA, but the VLA survey by Molinari et al. (1998) did not reveal any radio emission at 2 cm and 6 cm from IRAS 05137+3919.

The dense core was detected in ammonia emission by Molinari et al. (1996). Molinari et al (2000) estimated the value of its mean dust temperature to be T_d=37K, and total circumstellar mass to be 210 $M_\odot$. Molinari et al. (2008) conducted a spectrum fitting to IRAS 05137+3919 from the mm/sub-mm wave continuum taken with SIMBA at SEST and SCUBA at JCMT to infrared, obtained from IRAS and MSX catalog, and reported that the exciting source is likely to be an O8 ZAMS star with $L=2.5x10^5 L_\odot$ and a distance of 11.5 kpc.

Maser emission was previously detected towards IRAS 05137+3919. Water maser emission has been detected by Palla et al. (1991) and Migenes et al. (1999), but no SiO emission was detected by Harju et al. (1998). Macleod et al (1998) and Szymczak et al. (2000) searched this source for 6.7 GHz methanol masers. They didn't find any of these maser emissions. However, Xu et al (2008) found two features towards our source that are separated by about 4.5 km s^{-1}. The 1665 MHz OH maser line was firstly detected in a survey by Slysh et al. (1997) with a flux density of 2.7 Jy and then by Edris, Fuller & Cohen (2007) with a flux density of 2.2Jy.

To determine the positions of the OH masers towards IRAS 05137+3919 in high accuracy and investigate how they are distributed and related to other tracers, we curried a high angular resolution observations using MERLIN. The details of the observations and reduction are given in Sec. 2 and the results are presented in Sec. 3. In Sec. 4 we discuss the interpretation while the conclusions are drawn in Sec. 5.

2. Observations and Data reduction

IRAS 05137+3919 was observed in the 1665-MHz OH maser transitions in March 2003 using the MERLIN seven working antenna telescopes. For the sake of correction other sources were observed during the observing run. The phase calibrator source (phase-Cal) 0520+411 was observed to retrieve the absolute position of the maser spots and therefore compare their locations from one line to another with high accuracy. A bandpass calibrator, 3C84, was observed to calibrate the variation of instrument gain and phase across the spectral bandpass. The source 3C286 was also observed, with the same correlator configuration and bandwidth. The velocity resolution was 0.21 km/s for a total of 0.256-MHz spectrum bandwidth corresponding to 45 km/s velocity range.

The data were initially reduced in Jodrell Bank observatory, the main site of MERLIN network, using the Astronomical Image Processing Software (AIPS). In Jodrell Bank, the MERLIN d-programs (see Diamond et al. 2003) were used to edit and correct the data for gain-elevation effects.

The flux density of the amplitude calibrator 3C84 was determined by comparing the visibility amplitudes on the shortest baselines with those of 3C286. Using flux densities of 13.605 Jy at 1665 MHz for 3C286 (Baars et al. 1977), the flux density of 3C84 at the time of observation was determined to be 22.53 Jy.

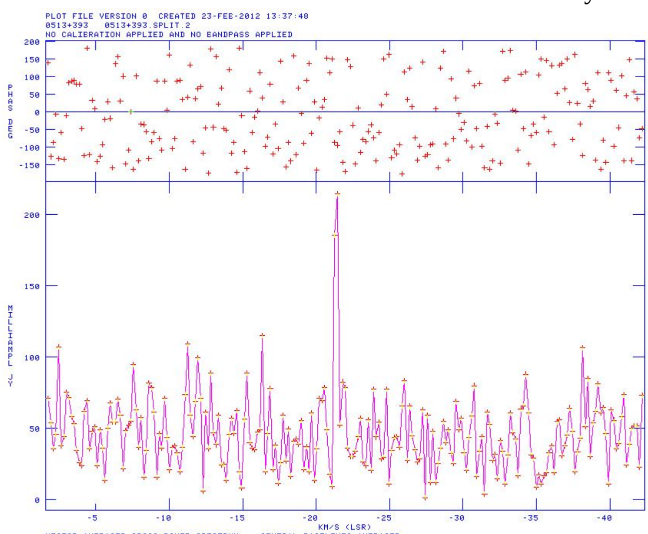

Fig. 2.1 The target spectrum between velocity and phase degree (top), velocity and flux (bottom)

In AIPS (Astronomical Image Processing System) the data were calibrated for all remaining instrumental and atmospheric effects. Starting from a point source model, the phase calibrator source was mapped, with a total of three rounds of phase self-calibration and the resulting corrections applied to the source data. Fig 2.1 shows the target spectrum between velocity and phase degree (top), velocity and flux (bottom). The polarization leakage for each antenna was determined using 3C84 and the polarization position angle correction was performed using 3C286. Also AIPS was used to map the whole data set in Stokes I (see fig 2.2). The positions of the maser components were determined by fitting two-dimensional Gaussian components to the brightest peaks in each channel map. Components were considered as spectral features if they occurred in three or more consecutive channels. Using flux weighted means over those channels of each group, the positions and velocities of spectrum features were obtained. The uncertainties in relative positions are typically 10 mas.

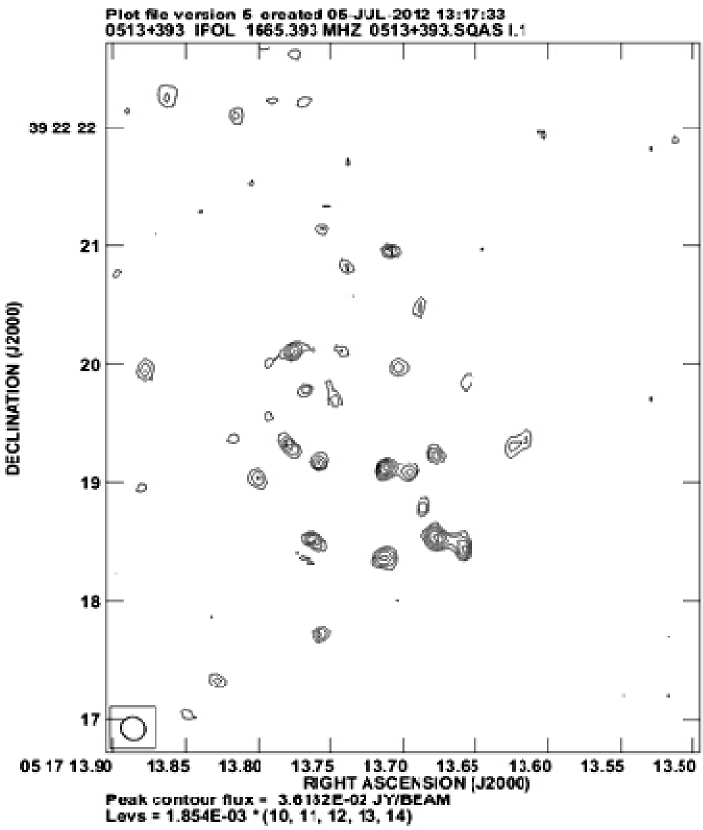

Fig 2.2 The contours image for 1665-MHz OH maser spots in stokes I

3. Results

The 1665-MHz OH maser line was detected with MERLIN towards IRAS 05137+3919. The absolute positions of brightest maser spot of the 1665 MHz OH line is RA $05^h\ 17^m\ 13.712^s$ and DEC 39° 22′ 18.360″ at velocity -21.4 km s^{-1}(see fig 2.1). A total of 13 OH maser spots at 1665-MHz line were detected. There is only one left hand circular polarization (LHC) spot and 12 right hand circular polarization (RHC) spots. Table 3.1 presents the parameters of the OH maser components detected namely the velocities, peak intensities and positions for each hand of circular polarization. The position angle for RHC spots is 35.997° and LHC spot is 36.253°. Figure 3.1 shows the spatial distribution of the OH maser spots and also shows their velocities.

Table 3.1 The parameters of the left and right hand circular polarization components of 1665-MHz OH masers detected towards IRAS 05137+3919.The leading terms of the positions are RA(J2000)= 05h 17m and DEC(J2000)= 39° 22'.

stokes	Vel. kms^{-1}	Beak Jy/beam	RA s	RA err s	Dec ″	Dec err ″
RHC comp.						
1	-21.365	0.322 ± 0.050	13.694	0.001	19.108	0.018
2	-21.377	0.159 ± 0.050	13.712	0.003	19.111	0.035
3	-23.755	0.053 ± 0.023	13.702	0.004	19.089	0.047
4	-21.399	0.144 ± 0.049	13.680	0.004	18.509	0.043
5	-21.397	0.291 ± 0.055	13.659	0.002	18.600	0.020
6	-21.364	0.165 ± 0.051	13.660	0.003	18.448	0.033
7	-23.890	0.088 ± 0.022	13.659	0.002	18.615	0.028
8	-21.375	0.428 ± 0.050	13.712	0.001	18.360	0.012
9	-23.704	0.100 ± 0.024	13.714	0.003	18.332	0.031
10	-21.400	0.326± 0.057	13.762	0.002	18.541	0.027
11	-23.822	0.048 ± 0.022	13.765	0.004	18.536	0.049
12	-21.347	0.214 ± 0.055	13.681	0.003	19.306	0.032
LHC comp.						
1	-21.464	0.115 ± 0.017	13.769	0.002	19.088	0.019

4. Discussion

IRAS05137+3919 was previously detected for the 1665-MHz OH maser by Slysh et al. (1997) and Edris, Fuller &Cohen (2007). The flux density changes from 2.7 Jy (Slysh et al. 1997), to 2.2 Jy (Edris, Fuller & Cohen 2007) to be ~0.4 Jy in the present work. These changes in the flux density mean that the source of OH maser is variable. The peak velocity did not change from Slysh et al (1997) and Edris, Fuller &Cohen (2007) and in this study to be at ~ -21.4 km s^{-1}.

Xu et al. (2008) detected the first methanol masers at the 6.7 GHz and found two peaks that are separated by about 4.5 km s^{-1}. The detected 6.7 GHz CH_3OH masers are at equatorial coordinates (J2000) 05 17 13.3 +39 22 14 and the radial velocity range -21.1, -16.0 km s^{-1}. The weaker peak of these two methanol maser components is consistent with the detected 1665-MHz OH maser in its flux density, 0.35 Jy, and radial velocity -21.1 km s^{-1} which indicates that the emission of these two maser species are coming from the same material. On the other hand, the stronger peak is 1.5 Jy and its radial velocity is -16.2 km s^{-1} which indicates that it is not coming from the same material. Also The position of this stronger methanol maser component at 05 17 13.3 +39 22 14 confirm that it is offset from the central material.

The water maser study of Honma et al. (2011) shows a bipolar outflow/jet from an exciting source (a proto-star in IRAS 05137+3919) forms two shock regions, where the water maser emissions are observed. The offset between our 1665-MHz OH positions and the central position for H_2O outflow/jet in declination is ~0.7" and the velocities of H_2O spots at -29.64 and 27.95 Km s^{-1} are shifted from the velocities of OH masers spots by ~ 7 km s^{-1}.This indicates that while the H_2O masers emission trace the outflow/jet process, the OH masers emission trace the central region of the circumstellar material.

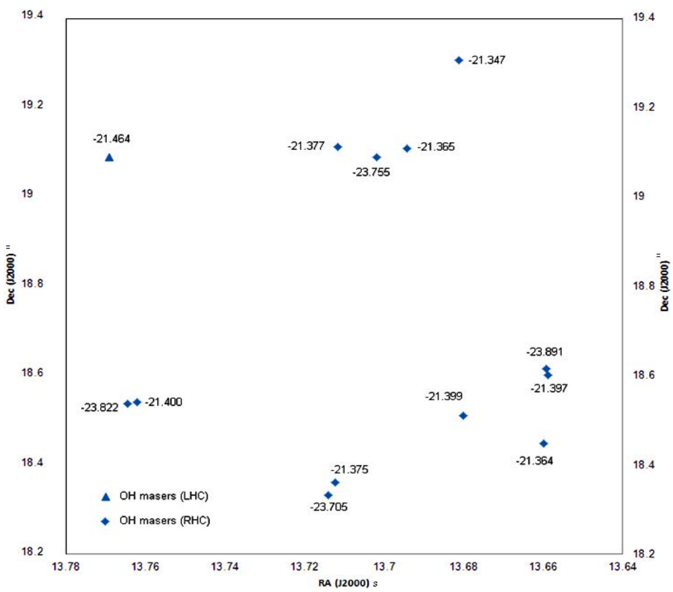

Fig 3.1 The position and velocities of the left and right hand circular polarization components of 1665-MHz OH masers detected towards IRAS 05137+3919. The leading terms of the positions are RA(J2000)= 05^h 17^m and DEC(J2000)= 39° 22'.

The position of the detected 1665-MHz OH maser spots are located in the center of the outflows region detected by Varricatt et al. (2010) and Zhang et al.(2005) which indicates that the OH masers comes from the central core close to the protostar as shown in fig. (4.1) by the over drawn black square, in the right plot. The positions of OH masers are also in consistent with the central region of the 3.4-mm and 3.6 cm continuum emission detected by Molinari et al. (2002).

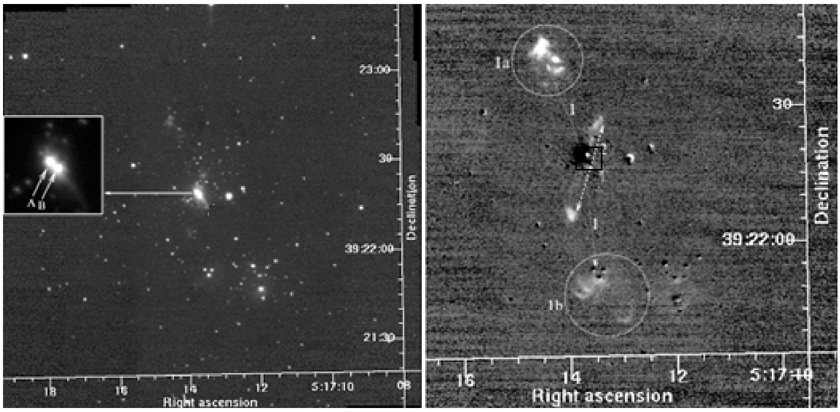

Fig 4.1 Left: K-band image of IRAS 05137+3919. The inset displays a magnified view of the central region to show the "A, B" pair resolved. Right: the central part of the continuum-subtracted H_2 image. Black square is the position of OH masers at fig 3.1.

5. Conclusion

A total of 13 OH maser spots at the 1665-MHz line were detected towards the SFR, IRAS 05137+3919. There is one left hand circular polarization (LHC) and 12 right hand circular polarization (RHC) components. The absolute positions of brightest maser spot of the 1665 MHz OH line is located at RA 05^{h} 17^{m} 13.712^{s} and DEC 39° 22′ 18.360^{s}, and at velocity -21.4 Km s^{-1}.

The source of OH maser is variable because the flux density changes from study to another. The detected 1665-MHz OH maser is consistent with The 6.7 GHz methanol maser component in its flux density, 0.35 Jy, and radial velocity -21.1 km s^{-1} which indicates that the emission of these two maser species are coming from the same material. The OH masers seem to come from the central material close to the protostar and close to continuum emission from the central source at 3.6 cm and in the center of a bipolar outflow.

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