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A new Sample of OH/IR Stars in the Galactic Center

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Abstract. We report on the preliminary results of an extensive search for OH/IR stars in the Galactic center region. The main goal is to use the larger sample of OH/IR stars to probe the gravitational potential in the Galactic center (see Lindqvist, Habing & Winnberg 1992b). The search in the 1612 MHz line of OH was performed by observations taken with the Australia Telescope Compact Array and by means of concatenating Very Large Array data sets used for a monitoring program (Van Langevelde et al. 1993). The volume surveyed is over 80 pc in diameter centered on Sgr A* and has a velocity coverage of -550 to $+600$ km s^{-1}. The 1σ noise is about 5 mJy, at least four times as deep as earlier surveys. So far we have found about 50 new OH/IR stars, almost as many as we expected. The newly found OH/IR stars seem to be similar in their observable properties to the OH/IR stars already known in the Galactic center. In our data we have found OH counterparts for two H_2O masers detected by Levine et al. (1995) and by Yusef-Zadeh & Mehringer (1995). These H_2O masers are not the argued clues for recent star formation: the objects are old OH/IR stars (Sjouwerman & Van Langevelde 1996).

1. Introduction

An OH/IR star is a far-evolved variable star, with a main-sequence mass of 1-8 $M_\odot$. It has reached the asymptotic giant branch (AGB) phase of its evolution. Due to heavy mass-loss, the star is obscured in the optical by a circumstellar envelope. These envelopes are environments in which masers can form, in par-

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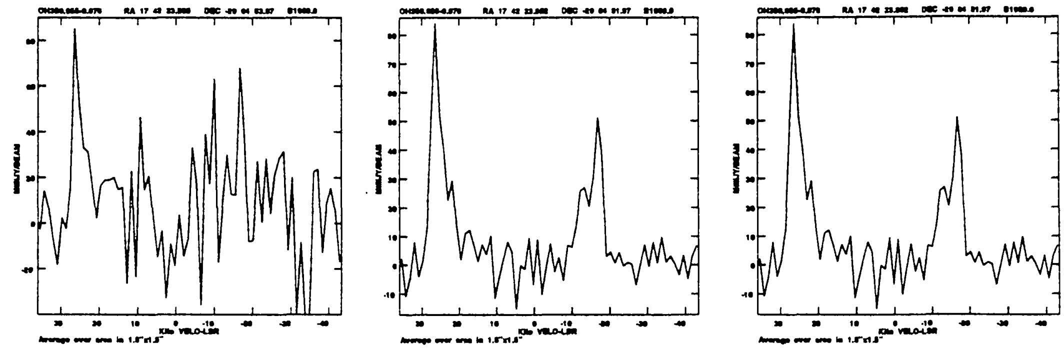

Figure 1. VLA concatenation for OH359.855-0.078 at different stages.

ticular the 1612 MHz satellite line of the hydroxyl (OH) molecule. The OH spectrum has a typical double peaked line profile, reflecting the red and blue shifted OH maser emission. The stellar radial (line-of-sight, LSR) velocity is taken as the mean of the red and blue shifted peaks. See Habing (1996) for a review.

Assuming that all normal stars will pass through this evolved evolution stage, OH/IR stars make very good objects to probe our Galaxy. The reason for this is that OH/IR stars are easy to detect. The Galaxy is mostly transparent at 1.6 GHz and the masers are relatively strong. Moreover, the stellar radial velocity can easily be determined from the spectrum. The population of OH/IR stars in the Galactic center (GC) is of special interest as it can provide clues to the gravitational potential in the very center of our Galaxy. Furthermore, the stars are located at the same distance, making studies of intrinsic physical properties of this stellar evolution stage possible.

From previous surveys already about 150 OH/IR stars are known within ~100 pc of Sgr A*, the radio source that is believed to be (close to) the dynamical center of our Galaxy (Baud et al. 1981, Habing et al. 1983, Lindqvist et al. 1992a, Van Langevelde et al. 1992). Unfortunately, this sample suffers from small number statistics when used as test particles in the Galactic potential. With an extended sample of OH/IR stars we hope a better analysis can be performed with smaller statistical errors, both on dynamics and physical properties (Lindqvist, Habing & Winnberg 1992b, Lindqvist et al. 1996). An increased number of OH/IR stars within 50 pc of Sgr A*, and in particular the role of high velocity stars, will further constrain future modeling of the GC: with or without a massive black hole.

2. Observations

In order to determine the phase-lag for the most luminous OH/IR stars close to the GC, Van Langevelde et al. (1993) monitored OH/IR stars in one Very Large Array (VLA) primary beam (which contains Sgr A*). In the period from February 1988 till January 1991, this field was observed at 19 different epochs for two hours each. Due to interference, the noise in a single map varies from 13 to 60 mJy, with an average of 20 mJy. By adding these data sets, that only differ in date, VLA configuration (resolution) and noise level, theoretically one would obtain a data set with an rms noise per channel of about 5 mJy. Although the VLA data sets are not centered at the GC (in sky coordinates and radial velocity), one should be able to use these data sets to find an additional number of 'weak' OH/IR stars close to the GC. We have concatenated 17 usable data sets and analyzed the maps. We have searched for emission stronger than 40 mJy, made spectra for these 5σ detections and listed them in a table (Sjouwerman et al. 1996).

To overcome the asymmetry problems, and additionally to look for high velocity OH/IR stars (over ±200 km s^{-1}, which is the VLA velocity coverage) we used the Australia Telescope Compact Array (ATCA) in July 1994. The maps were searched for double peaks down to about 25 mJy (Sjouwerman et al. 1996). The total area searched is out to 40 pc from Sgr A* with LSR velocities between -550 and $+600$ km s^{-1}, completely overlapping the VLA observations. Typical noise levels (1σ) reach 5 mJy, four times less than the Lindqvist et al. (1992a) survey. Following Lindqvist et al. (1996), a reasonable estimate of the increase in the number of OH/IR stars, adopting a derived luminosity function, would yield about 60 new OH/IR stars within 30 pc from Sgr A*.

3. Preliminary results

Figure 1 concerns the OH source 359.855-0.078, a typical weak (ie. low flux density) OH masering OH/IR star in the direction of the GC. We use it to demonstrate and justify the concatenation process in order to find weak and yet unknown OH/IR stars in the VLA data sets.

On the left, a spectrum of an ordinary VLA monitor data set is given. This source is too weak to be monitored by Van Langevelde et al. (1993) as the signal hardly can be distinguished from the noise. This data set is as sensitive as the original OH/IR star survey of Lindqvist et al. (1992a) and one might only suspect that there is an OH/IR star to be found here. Second, an intermediate result of the concatenation project is shown. This spectrum is taken from the concatenation of six VLA B-array monitor data sets. From this spectrum it becomes clear that this star has a second peak at a velocity of -18 km s^{-1}. The right panel shows a spectrum of this source in the final data set. Apart from an increase in signal to noise, the spectrum looks more like a genuine OH/IR star spectrum than the former ones. This is also caused by averaging the variable flux density of the source over the 17 epochs. The rms noise is 8 mJy.

The ATCA data were reduced in a standard way. Searching the cube was done by creating a map containing the maximum intensity of all velocity channels at each pixel representing the sky. This map was searched for pixels with more

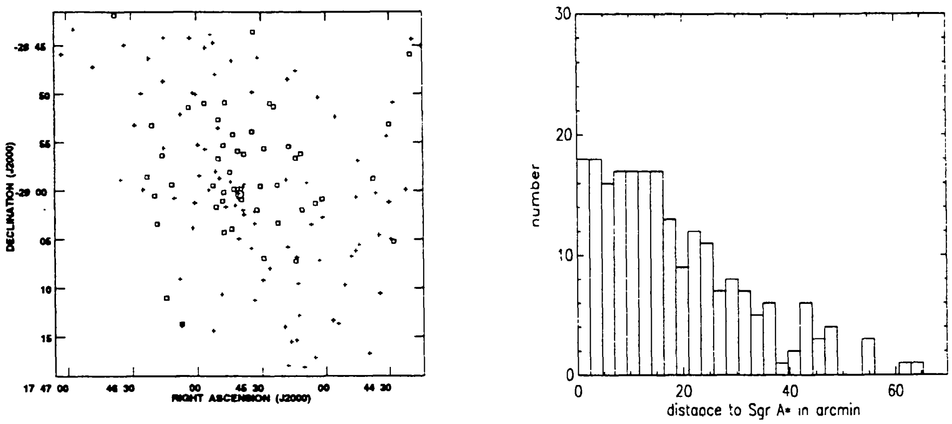

Figure 2. OH/IR stars in the Galactic center. Left: squares are new detections, crosses are previously known OH/IR stars and the circle in the middle shows the position of Sgr A*. Right: number of OH/IR stars versus distance to Sgr A* in arcminutes.

flux than a certain level and the pixel and its flux was stored. Later, we grouped adjacent pixels in 'islands' and made spectra at the maximum intensity of each island. Plausible double peaked spectra were regarded as detections of OH/IR stars. We listed about 50 detections, the squares in the left hand panel of figure 2. Crosses are previously known OH/IR stars; the circle in the middle shows the position of Sgr A*. Most of the newly found double peaks can be found both in the concatenated VLA data as well as in the ATCA observations. A number of new detections are corresponding to K-band variables found by Glass et al. (1996). Two previously unknown OH/IR stars have radial velocities over ± 200 km s^{-1}.

As the space and velocity distributions and the expansion velocity distribution for the newly found double peaked OH masers compare very well with the known OH/IR stars, we expect to have found similar objects, though with a less luminous OH maser (in our direction). Adopting the same metallicity as for the previously known, strong OH masering OH/IR stars, we derive a similar bolometric luminosity distribution and hence main sequence masses for these stars. We found almost as many OH/IR stars as expected: about 50 instead of 60. This probably means that the cut-off at the low luminosity side of the luminosity distribution is caused by the sensitivity limit; we have not reached the low luminosity cut-off of the real OH maser luminosity distribution. The right hand panel of figure 2 shows the number of stars versus the distance to Sgr A*. The numbers have not been corrected for completeness yet.

Finally, we found OH/IR stars where Levine et al. (1995) as well as Yusef-Zadeh & Mehringer (1995) claim to have found H_2O masers associated with young stars or star forming regions (Sjouwerman & Van Langevelde 1996). The table focuses on detections in H_2O of Levine et al. (1995) and Yusef-Zadeh &

TABLE 1
H_2O AND OH DETECTIONS

survey	Right Ascension & Declination (1950)		($''$)	Radial Velocity (km s^{-1} wrt. LSR) low	mean	high	(km s^{-1}) resolution	Line flux (mJy km s^{-1})
the LFMM source: OH 359.956–0.050								
H_2O LFMM	17 42 32.00	−28 58 47.8	(±0.2)	...	45.3	55.8	(5.0)	...
H_2O Y-ZM	17 42 31.87	−28 58 46.8	...	...	44.7	...	(2.6)	603
OH VLA	17 42 31.95	−28 58 47.9	(±1.9)	34.3	48.5	62.7	(1.2)	610
OH ATCA	17 42 31.96	−28 58 50.0	(±3.3)	34.2	50.2	66.2	(1.5)	190

Mehringer (1995) combined with our OH counterparts for this source. Looking at the data in the table, we claim the maser emission is from one source only; from the double peaked OH maser spectra we conclude the source is an evolved intermediate mass AGB star with an age of about one Gyr.

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