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Interstellar scattering of OH/IR stars at the Galactic Centre

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SUMMARY

We present short VLBI observations, using the new VLBA antennas, of four OH/IR stars within 15 arcmin of SgrA*, and conclude that these OH masers are severely resolved due to interstellar scattering at the wavelength λ of 18 cm. This leaves no doubt that the λ^2 dependence of the image size of SgrA* is also due to interstellar scattering. We further conclude that an accurate distance to the Galactic Centre cannot be obtained from observations of OH/IR stars close to the Galactic Centre.

1 INTRODUCTION

In the past several years a large number of OH/IR stars in the Galactic Centre have been detected (Lindqvist *et al.* 1991). In five VLA primary beams (30 arcmin across), 136 OH/IR stars are known with a detection limit below 100 mJy.

These stars are good tools with which to study the dynamics of the inner Galaxy (Lindqvist *et al.* 1989) and the population characteristics of stars there. OH/IR stars also can provide independent distance measurements through the use of the so-called 'phase lag' technique (Jewell, Webber & Snyder 1980; Herman & Habing 1985; van Langevelde, van der Heiden & van Schooneveld 1990). In this method one obtains the distance by comparing the physical size with the apparent angular size. The physical size is obtained by accurately monitoring the variability of the blue- and red-shifted peaks in the spectrum, which gives the 'phase lag', i.e. the difference in arrival time between radio emission from the back of the masing circumstellar shell and the front. The angular size can be determined with radio interferometers. For the Galactic Centre one can estimate that a typical OH shell will be 500 mas across, implying that VLBI baselines will be needed to make an accurate measurement of the angular size. A resolution of ≈ 50 mas is required to obtain a 10 per cent accuracy for the distance to the Galactic Centre.

It has long been suggested (Davies, Walsh & Booth 1976) that the image of SgrA* is considerably broadened at 18 cm by interstellar scattering. Further investigations have established the λ^2 dependence and yielded good clues that the observed sizes are indeed due to interstellar scattering (Lo *et al.* 1981, 1985). If this is interstellar scattering, the question arises as to where to locate the scattering medium. One can argue that the observed pronounced scattering for the heart of our Galaxy cannot be coincidence and that the scattering medium must be part of the violent processes in the inner Galaxy. On the other hand, Cordes *et al.* (1988) argue that the scattering of SgrA* is not very extreme when compared to measurements of interstellar scattering on lines of sight to pulsars in the inner Galaxy.

The *a priori* knowledge is that SgrA* has an image size of ≈ 450 mas at 18 cm (Backer 1988). The nearest lines-of-sight for which data are available are towards SgrB2. Angular sizes of H_2O and OH masers in this complex are consistent with intersellar scattering, the OH masers having FWHM ≈ 100 mas (Gwinn *et al.* 1988). It is very important to obtain information on the angular sizes of other objects close to the line-of-sight to Sgr A*.

In this paper we describe short observations taken with the Very Large Array and the first finished antennas of the Very Long Baseline Array, both of the National Radio Astronomy Observatory.★ This MkII VLBI experiment shows clearly that interstellar scattering limits the seeing towards the Galactic Centre to several hundred mas, making the stars from the Lindqvist *et al.* (1991) sample unsuitable to determine the distance to the Galactic Centre by means of the 'phase lag' method. We will describe the observations, follow with the results and discuss some of the implications of these observations for our knowledge of interstellar scattering and the Galactic Centre.

2 THE OBSERVATIONS

The data were taken on 1990 Kuly 17 between 02 30 and 07 30 UT. The VLA was in B configuration and was used in phased-array mode. We also used VLBA antennas at Pie Town (PT), New Mexico, Los Alamos (LA), New Mexico, Fort Davis (FD), Texas and Kitt Peak (KP), Arizona. Data were recorded on MkII tapes and correlated on the MkII correlator at NRAO, Socorro, in the week after the observations. Very few technical problems were encountered while

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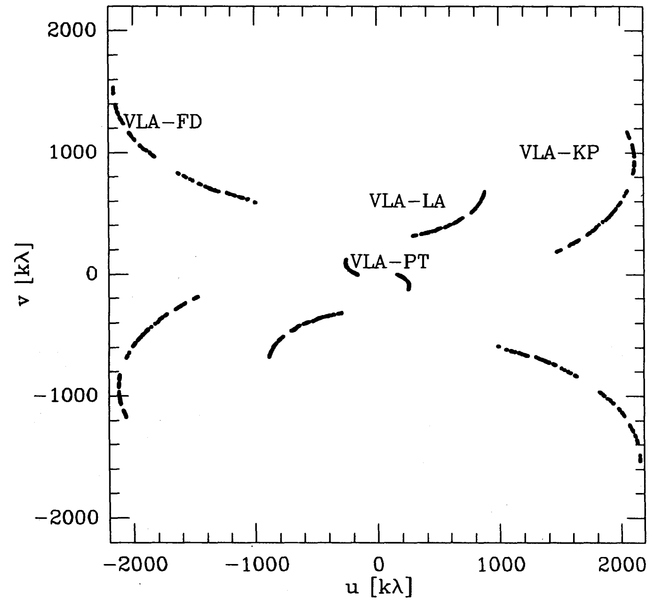

Figure 1. *uv*-coverage for the experiment. The tracks of baselines to the VLA are shown for the four sources at the Galactic Centre.

observing. For reasons of sensitivity we were mainly interested in baselines to the VLA, so not all low-sensitivity baselines were correlated. We show the *uv*-coverage of these four baselines in Fig. 1.

From the sample of OH/IR stars near the Galactic Centre, four sources were chosen as being the brightest ($S_{peak} > 2.0$ Jy) and as having different angular distances from SgrA*. We used a bandwidth of 500 kHz, which was centred on the known velocity of the OH/IR star. This band was divided into 96 channels in the NRAO MkII correlator, yielding a spectral resolution of 5.2 kHz (≈ 0.97 km s^{-1}).

We used NRAO530 as a fringe finder, both at the beginning and end of our run. Fringes on this source were detected on all processsed baselines. We used very short observations on 1748 − 253 to phase up the VLA every hour. This source turned out to be unresolved on most baselines as well, so we were able to check the coherence of the network every 30 min.

The data were processed in AIPS. We calibrated the telescopes with the monitored values of the system temperatures and estimated gains, as usually applied in continuum VLBI. In spectral line VLBI, a different calibration scheme is often used (Reid *et al.* 1980; Diamond 1989), in which it is assumed that all autocorrelation spectra contain the same profile and all sensitivities can be calibrated against one of the telescopes. However, this method cannot be used if one telescope is a phased interferometer looking at a crowded field like the Galactic Centre, since the method is based on the assumption that all telescopes will see the same autocorrelation spectra, which obviously does not hold in this case.

After calibration the data were corrected for the absence of Doppler tracking in the correlator. Next we determined the residual delay and fringe rate for our calibrators. We then attempted to find residual fringe rates for our OH sources.

3 RESULTS

We detected all four OH sources on the shortest baseline, VLA-PT. On the longer baselines we only detected fringes for OH0.190 + 0.036, on the VLA-LA baseline (see Fig. 2). With our coherence time we should have been able to detect any compact OH maser components brighter than ≈ 400 mJy (7σ).

We have modelled the data with a simple Gaussian profile without ellipticity. The poor sensitivity does not allow us to try different shapes. Because of the observed ellipticity in the scattered image of SgrA* (Lo *et al.* 1985) it would have been interesting to try this, but this is impossible with a single baseline. We were also unable to distinguish between alternative models of interstellar scattering, e.g. different power laws. In the fitting we have used only data from baselines

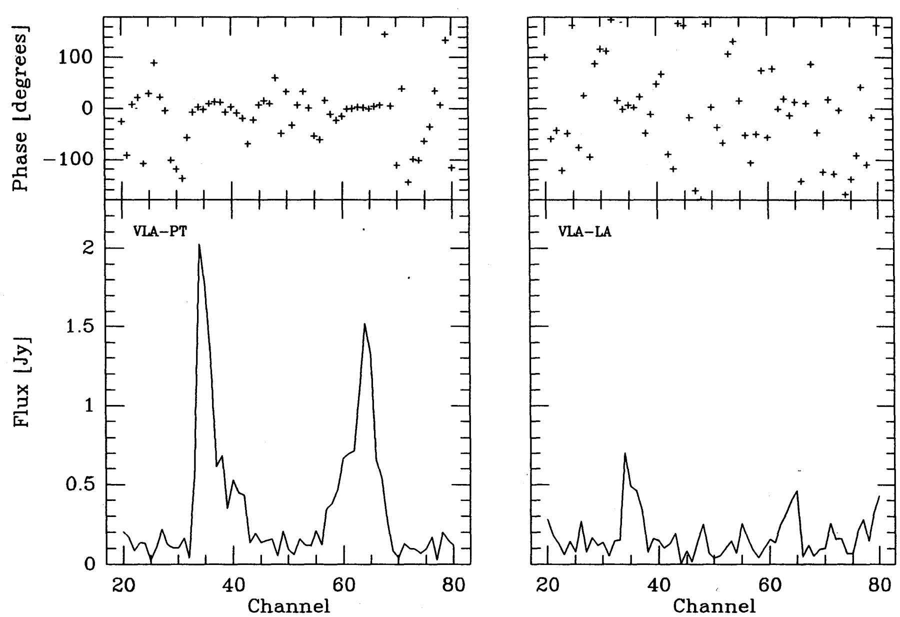

Figure 2. Spectra for OH0.190 + 0.036 on the baseline VLA-LA and VLA-PT.

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Table 1. Scattering sizes for our OH/IR stars at the Galactic Centre. The values were obtained by fitting symmetric profiles to the brightest spectral line data. The last column gives the distance to SrA* in arcmin.

Name	RA	Dec	θ mas	Δ_{SgrA*} arcmin
OH0.190+0.036	17 42 45.47	-28 44 09.7	103 ± 14	15.6
OH359.763-0.121	17 41 24.14	-29 03 20.5	531 ± 44	14.5
OH359.938-0.077	17 42 35.69	-29 00 36.4	571 ± 50	1.9
OH359.954-0.041	17 42 29.46	-28 58 37.5	591 ±230	0.7

where a full solution was obtained, so no upper limits were used where no detection was found, but the non-detections were always consistent with the measured sizes.

The inferred angular sizes depend strongly on the measured zero-baseline flux. This was determined from a measurement of the unresolved flux from an ongoing VLA monitor program of OH/IR stars towards the Galactic Centre. We used VLA data from 1990 July 26, 9 d after our VLBA experiment. These sources are variable on a typical time-scale of 300 d. We used these observations instead of the autocorrelation spectra obtained with the VLA during our run because of the higher accuracy. The results of the model fits are given in Table 1. We show the data and the fit for OH0.190 + 0.036 in Fig. 3.

4 IMPLICATIONS

We argue that the measured sizes are due to interstellar scattering. Since calibrators were found on all baselines, we are convinced that the experiment was technically a success. In general there is the possibility that the measured size is intrinsic to the source. But many OH/IR stars throughout the Galaxy have been observed with VLBI and in all cases much compact emission has been found. In fact there is evidence that in these cases the smallest scales detected are set by scattering (Kent & Mutel 1982; Diamond *et al.* 1988; Kemball, Diamond & Montovani 1988). We therefore conclude that the results here are due to interstellar scattering.

This then indicates that the observed angular size of SgrA* is also caused by interstellar scattering. The fact that the angular sizes for both SgrA* and the OH masers are comparable seems to indicate that the scattering medium is the same for both OH/IR stars and SgrA*. One can also conclude that SgrA* and the OH/IR stars are at approximately the same distance, which of course is no surprise.

From the measurements of SgrB2 (Gwinn *et al.* 1988), and the fact that our data seem to reveal a trend of decreasing angular size with distance from SgrA*, we conclude that, at a distance of 8 kpc, the size of the scattering medium is 100–200 pc across. If one assumes that the scattering is spherical, one can estimate the degree of turbulence within the medium. Our observations suggest that the OH/IR sources lie just behind the scattering screen, so their emission must be scattered through a large angle, implies a high degree of turbulence. Following the notation of Cordes, Weisberg & Boriakoff (1989), we derive a value for $C_N^2 \approx 10^6\ \mathrm{M}^{-20/3}$, which indicates that this must be one of the most turbulent regions known.

5 CONCLUSIONS

We have been able to do some interesting science with the first telescopes of the VLBA. One of the important advantages of the VLBA was already noticeable, in that we were able to prepare, observe, correlate and calibrate this VLBI experiment within several weeks.

From the results it is clear that the line-of-sight to the inner 100 pc of the Galaxy intersects with a region of heavy interstellar scattering. This implies that the observed angular size dependence on wavelength of SgrA* is indeed due to interstellar scattering. This also makes it impossible to use OH/IR stars close to SgrA* to determine the distance to the Galactic Centre by the 'phase lag' method.

These measurements on OH/IR stars provide a powerful tool to study interstellar scattering in the inner Galaxy. We are currently working on more observations on different lines-of-sight.

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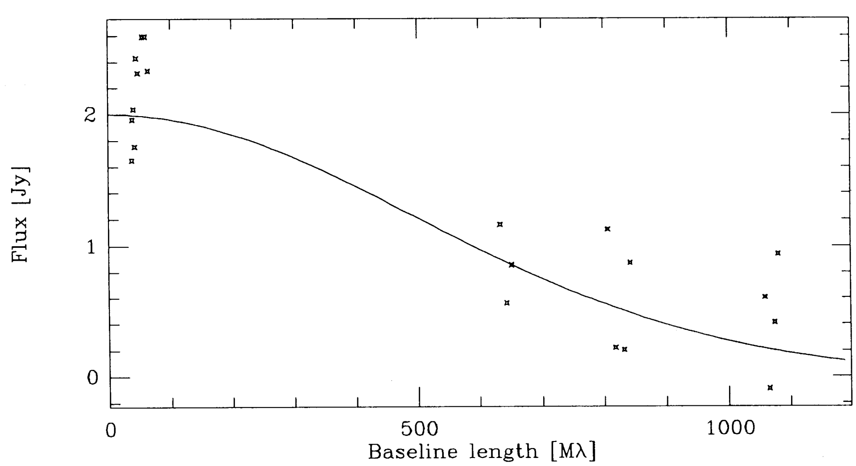

Figure 3. The observed flux density of the brightest spectral feature of OH0.190 + 0.036 as a function of baseline length.

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REFERENCES

Backer, D. C., 1988. In: *Radio wave scattering in the interstellar medium,* p. 111, eds Cordes, J. M., Rickett, B. J. & Backer, D. C., American Institute of Physics, New York.

Cordes, J. M., Spangler, S. R., Weisberg, J. M. & Clifton, T. R., 1988. In: *Radio wave scattering in the interstellar medium,* p. 180, eds Cordes, J. M., Rickett, B. J. & Backer, D. C., American Institute of Physics, New York.

Cordes, J. M., Weisberg, J. M. & Boriakoff, V., 1985. *Astrophys. J.,* **288,** 221.

Davies, R. D., Walsh, D. & Booth, R., 1976. *Mon. Not. R. astr. Soc.,* **177,** 319.

Diamond, P. J., Martinson, A., Dennison, B., Booth, R. S. & Winnberg, A., 1988. In: *Radio wave scattering in the interstellar medium,* p. 195, eds Cordes, J. M., Rickett, B. J. & Backer, D. C., American Institute of Physics, New York.

Diamond, P. J., 1989. In: *Very Long Baseline Interferometry, Techniques and Applications,* p. 231, eds Felli, M. & Spencer, R. E., NATO ASI series, Kluwer, Dordrecht.

Gwinn, C. R., Moran, J. M., Reid, M. J. & Schneps, M. H., 1988. *Astrophys. J.,* **330,** 817.

Herman, J. & Habing, H. J., 1985. *Phys. Rep.,* **124,** 255.

Jewell, P. R., Webber, J. C. & Snyder, L. E., 1980. *Astrophys. J.,* **242,** L29.

Kemball, A., Diamond, P. J. & Montovani, F., 1988. *Mon. Not. R. astr. Soc.,* **234,** 713.

Kent, S. R. & Mutel, R. L., 1982. *Astrophys. J.,* **263,** 145.

Lindqvist, M., Winnberg, A., Habing, H. J., Matthews, H. E. & Olnon, F. M., 1989. In: *The Center of the Galaxy, Proc. IAU Symp. No. 136,* p. 503, ed Morris, M., Kluwer, Dordrecht.

Lindqvist, M., Winnberg, A., Habing, H. J. & Matthews, H. E., 1991. *Astr. Astrophys. Suppl.,* submitted.

Lo, K. Y., Cohen, M. H., Readhead, A. C. S. & Backer, D. C., 1981. *Astrophys. J.,* **249,** 504.

Lo, K. Y., Backer, D. C., Ekers, R. D., Kellermann, K. I., Reid, M. & Moran, J. M., 1985. *Nature,* **315,** 124.

Reid, M. J., Haschick, A. D., Burke, B. F., Moran, J. M., Johnston, K. J. & Swenson, G. W., 1980. *Astrophys. J.,* **239,** 89.

van Langevelde, H. J., van der Heiden, R. & van Schooneveld, C., 1990. *Astr. Astrophys.,* **239,** 193.

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