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DIAMETERS AND POSITIONS OF THREE SOURCES OF 18-cm OH EMISSION

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Observations of interstellar OH emission with single-dish antennas have given an upper limit of 5 min of arc to the angular size of the 18-cm line-emission regions.[1] This leads to very high values of brightness temperature. In addition, these objects show linewidths as narrow as 600 Hz, circular polarization as much as 100%, very surprising ratios of line strengths within a multiplet, and, in some cases, variations of flux with time.[2-6]

The purpose of this investigation is the determination of higher accuracy positions and a lower limit to the angular sizes. The instrument used was the pair of 90-ft steerable paraboloids at the Owens Valley Radio Observatory of the California Institute of Technology. The spacings between the antennas may be varied by moving them along tracks in east-west and north-south directions. They were operated at 1600 and 800 ft east-west and 1600 ft north-south in this investigation.

Each individual paraboloid has an equatorial mounting and can track most sources over an hour-angle range of 4 h before and after transit, giving a range of projected spacings as seen from the direction of the sources. The amplitude and phase of the interference fringes at each projected spacing represent two points in the complex two-dimensional Fourier transform of the angular distribution of brightness of the emitting region. A complete grid of projected spacings must be used to enable the reconstruction of the complete brightness distribution in the sky. To measure such a grid would be extremely time-consuming; for this preliminary investigation we chose spacings which we hoped would give significant information and guide further observations.

The horn feeds were parallel with the position angle of the E vector at 0°. Superheterodyne receivers were used with tunnel-diode preamplifiers and image-frequency rejection filters. The common local-oscillator signal was derived from a frequency synthesizer. The synthesizer settings were calculated in advance for all sources, dates, times, and velocities, using the program developed at the Radio Astronomy Laboratory of the University of California.

The intermediate-frequency section available had six channels each with a bandwidth of 6 kHz and each 30 kHz apart. Six local-oscillator settings 5 kHz apart covered a complete spectrum 180 kHz wide. Ten-minute integrations were made at each local-oscillator setting, giving noise fluctuations of 0.5°K antenna temperature.

Barrett and Rogers[6] have resolved line components as narrow as 600 Hz in W3C, with 1.5-kHz separation between features with different polarization. Possible variations of position or size over those ranges of frequency are smoothed out in our observations. On the other hand, we find little variation of position or size over larger ranges of frequency.

The instrumental parameters and locations of OH regions in the sky led us to choose observations of W3C, W49, and NGC 6334 at the strong components at 1665 and 1667 MHz. W3C is at the edge of the emission nebula IC 1795. W49 is associated with a postulated nebula which is completely hidden by intervening dust. Pho-

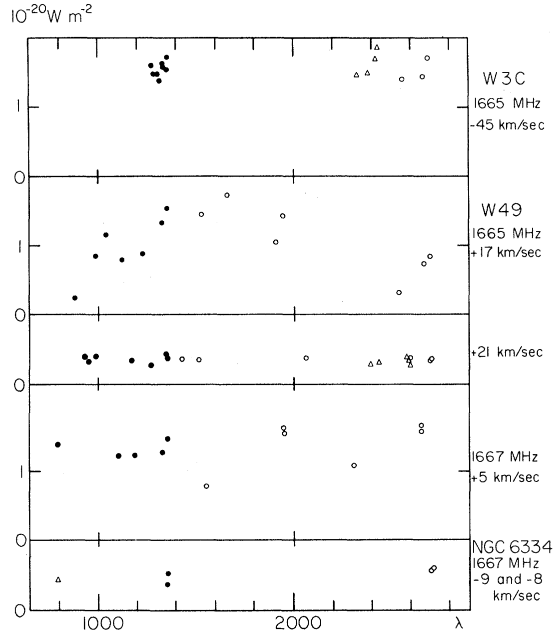

FIG. 1. Visibility curves. Solid circles are 800-ft, open circles 1600-ft east-west observations. 1600-ft north-south measurements are represented by triangles. Features W3C −45 km/sec and W49 +17 km/sec are the result of the addition of four channels. W49 +21 km/sec is one channel. In W49 +5 km/sec, five channels were added, while the points of NGC 6334 are the result of adding two channels.

tographs of EC 1795 and NGC 6334 show a complex mixture of ionized hydrogen and dust. W3C and W49 could be observed over the full hour-angle range. NGC 6334 could only be observed near transit.

For each antenna spacing on the ground, the orientation of the line joining the antennas was determined from observations of some strong point sources. Interspersed with the OH observations were calibrations of fringe amplitude and phase, using measurements of known small-diameter sources about once an hour. These sources were 3C 119, 3C 390, 3C 409, and 1827-36. The fluxes and positions of these sources were kindly provided by E. B. Fomalont. The position calibration is traceable to optical identifications. The calibration procedures above needed a 4-MHz bandwidth, giving a very good signal-to-noise ratio with 5 min of integration.

The plot of amplitude of the interference fringes as a function of projected antenna spacing is known as a visibility curve. With one exception, all of the OH regions studied had close to constant visibility, indicating angular diameters less than 20 sec of arc. In order to improve the accuracy of this determination, we added the visibility curves from all adjoining frequency channels covering a particular feature in the line. This was done after inspection of the curves from individual channels to insure that no information was lost. Since this inspection showed that the sources were probably unresolved, the antenna spacings were taken without regard to position angle. The added visibility curves are shown in Fig. 1.

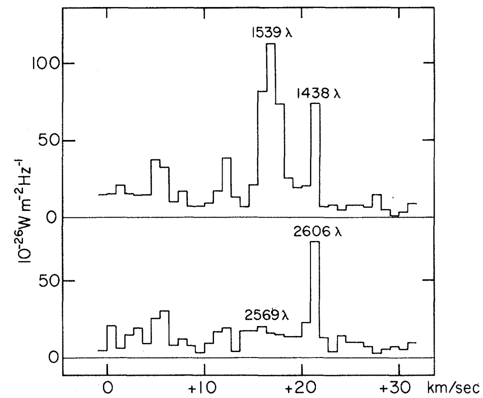

FIG. 2. W49, line profiles of the 1665-MHz line at different hour angles. The four numbers are the projected spacings in wavelengths during the observation. They are slightly different in each profile because not all the intensities were recorded at the same time.

A remarkable exception is the feature in W49, 1665 MHz, at +17 km/sec. Narrow band observations by Davies, de Jager, and Verschuur[7] show at least three features, which our resolution smooths into one broad feature. Figure 2 shows spectra compiled from our observations. All indicated spacings come from the same day, but at different hour angles. The +17-km/sec feature changes markedly, while the one at +21 km/sec is unchanged. This change of amplitude is apparent on four adjacent channels, which are added in Fig. 1. In this case the fringe position angle is important. This angle does not vary significantly over the east-west observations, but it is very different at the north-south observations. The latter cannot be represented in the two-dimensional curve here.

From the calibrated phases as a function of hour angle the positions of the sources were calculated. There is an ambiguity of how many fringes should be added or subtracted to these phases. By observing at various base lines and over a sufficiently large hour-angle range, it is possible to solve this ambiguity.

Table I. Measured positions of OH emission features.

Source	Line	Velocity feature (km/sec)	Base-line spacing (ft) and orientation	Date 1966	Right ascension (1950)	Declination (1950)	Remarks
W3C	1665	−45	800 E-W	6, 7 April	$2^h23^m15^s.8$	61°38′54″	
(IC 1795)			1600 E-W	30, 31 March	2 23 17 .1	61 38 51	Position less accurate than at 800 ft E-W due to smaller range in hour angle
W49	1665	+21	800 E-W	6, 7 April	19 17 50 .0	All	Declination uncertain
			1600 E-W	30, 31 March		approximately	because of low
	1665	+17	800 E-W	6, 7 April	19 07 49 .4	9°2′	declination
			1600 E-W	30, 31 March	19 07 49 .1		
	1667	+5	800 E-W	8, 9 April	19 07 50 .1		
			1600 E-W	1, 2 April	19 07 50 .3		
	1665	+17	1600 N-S	13-15 April	19 07 48 .6	8 59 48 ± 5	Fringe ambiguity
	1667	+5				or 9 1 16 ± 5	
						or 9 2 44 ± 5	
	1665	All	...	...	19 07 49 .6	...	
	1667				±0.3 (±5″)		

Because of the high declination of W3C (about 62°) both right ascension and declination could be easily determined, even by using only the 800-ft east-west spacing. As only hour angles between +1 and +4 h were measured at the 1600-ft east-west spacing, the position as given in Table I is less accurate than the one at 800 ft, although the values are not very different. There were insufficient phase measurements to determine a position at 1600-ft north-south.

For W49 the three different velocity features were taken separately at the east-west spacings. At the 1600-ft north-south spacing, the +17 and +5-km/sec components were taken together. For all spacings a good right ascension could be obtained and indeed there is no obvious difference in right ascension between various velocity features. If we combine all the values of the right ascension for all the features and spacings, we get $19^h 7^m 49^s.6 \pm 0^s.3$ (±5″). At the east-west spacings an approximate declination of 9° 2′ was measured. However, this value is very uncertain due to the low declination of the source. That is also the reason that we could not decide what the fringe ambiguity was for the 1600-ft north-south observations. Each of the three values in Table I has a small error (±5″). The value 8°59′48″ is within the accuracy of the single-dish position as measured at the Hat Creek Observatory of the University of California.[8] As all of our other positions are well within the errors (±1′) of the position determinations with the same single dish, our first quoted value for the declination is probably the most likely.

It is surprising that the feature at +17 km/sec in W49 which has the complicated visibility curve has still a right ascension which is equal to the one of the other features within the error. Except for this feature, none of the visibility curves show clear resolution effects. The +21-km/sec component in W49 shows some tendency of decreasing at higher spacing. This would correspond to an angular size of 20 sec of arc. This seems to us a good value for the upper limit of the sizes. The solid angle in the sky is a factor of 200 smaller than earlier published values. The lower limit of the brightness temperature must then be of the order of 5×10^5°K.

The visibility curve of the feature at +17 km/sec has the characteristics of the visibility curve of a double source. If this is the case, the distance between the two components is 100″. However, too few spacings are available to decide about a model as the structure can be much more complicated.

The OH emission in NGC 6334 is known to occur all over the nebula.[5] Our visibility curve indicates that the individual components of the 1667-MHz line have a very small diameter.

The source W49 could not be identified with anything on the Palomar-Schmidt Sky Survey prints. The region is very heavily obscured

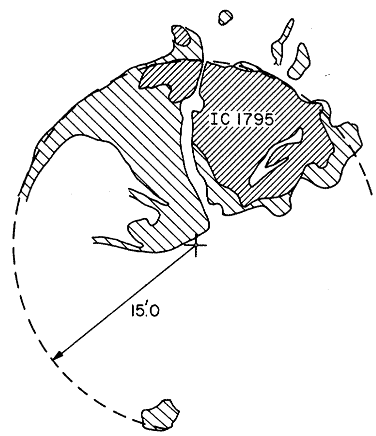

FIG. 3. Sketch of the optical field in the vicinity of the source W3C. The position of the radio source is at the cross.

and there is no sign of any emission nebula.

The source W3C is south of the emission nebula IC 1795 as already found by earlier investigations. At the actual position there is nothing visible on the Schmidt prints. This region is heavily obscured too, and it is not surprising that no identification can be made. In Fig. 3 it is shown that there might well be a relation between the OH source and a very regular arc forming the border of the most intense part of IC 1795 and continuing along fainter nebulosity. The radius of the circle with the OH source as center is 15 min of arc or 4.4 pc at a distance of 1 kpc. The true nature of this region could be obtained by mapping it in the radio continuum with a sufficiently small beam and by measuring the radial velocities of both the optical emission and the neutral hydrogen at 21-cm wavelength.

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RADIO PROPAGATION IN THE SOLAR GRAVITATIONAL FIELD

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It has been proposed by Muhleman and Reichley[1,2] and Shapiro[3] to test the general theory of relativity by measuring an additional time delay on a radar signal propagating between the earth and a target planet due to the solar gravitational field. This effect was predicted by the above authors from the Schwarzschild exterior metric and is of sufficient size to be measured with presently available planetary radar systems. However, the solar-corona electron plasma will also cause a signal delay at radio frequencies, and the question of separating the two effects is a serious one.

In this note we derive a relationship for computing the combined effect on propagation in a simple plasma in the presence of a weak gravitational field.

Møller[4] shows that Maxwell's equations in a vacuum in the presence of a static gravitational field are, in standard form,

$$\mathrm{Curl}\,\vec{E} = -\frac{1}{c}\frac{\partial\vec{B}}{\partial t},\quad \mathrm{div}\,\vec{B} = 0,$$

$$\mathrm{Curl}\,\vec{H} = \frac{1}{c}\frac{\partial\vec{D}}{\partial t},\quad \mathrm{div}\,\vec{D} = 4\pi\rho, \tag{1}$$

where

$$\vec{D} = \epsilon\vec{E},\quad \vec{B} = \mu\vec{H}, \tag{2}$$