THE STRUCTURE OF OH MASER CLOUDS ASSOCIATED WITH LATE-TYPE STARS

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The absolute positions and the arcsec structure of OH maser clouds surrounding 20 Mira variables and late-type supergiant stars have been measured using the Very Large Array in a spectral line mode at 1612 MHz. The stars observed are listed in Table 1 which indicates that the angular radii θ of the maser clouds range up to 4". The linear radii R range from < 100 AU for the Mira variable U Ori to 10^4 AU for the supergiant IRC+10420 and are correlated with the stellar mass loss rates.

With the exception of VY CMa, for which there is evidence of a complex disk-like or ellipsoidal geometry, the stars in Table 1 appear to be surrounded by predominantly spherical, expanding envelopes. For nine stars the low and high velocity peak emission features are unresolved knots positionally coincident to within 0"1. For well resolved sources, gas at intermediate velocities is distributed in portions of ring-like structures whose sizes increase as the velocity approaches the stellar velocity; an outline of a complete circular shell is seen in some cases (OH 127.8-0.0, OH 26.5+0.6, and OH 32.8-0.3).

Nevertheless, there can be significant deviations from the idealized spherical case. 1) The emission distributions are clumpy at most velocities, indicating density/velocity perturbations. 2) Positional offsets between the low and high velocity peak emission features are observed for some stars whose underlying geometry is clearly spherical (e.g. OH 26.5+0.6). 3) The peak emission can be extended (OH 32.8-0.3). 4) There is often significant emission outside the peak velocities, not predicted for a spherical shell expanding at a constant velocity.

These effects are probably caused by a combination of density clumping ($\sim 10^{15}$-10^{16} cm) and streaming motions ($\sim$ 1-2 km/s) superposed on the radial expansion. Streaming motions are larger for stars located in close proximity to OB associations (VY CMa and NML Cyg), indicating that the interstellar ultraviolet radiation field is important in determining the observed OH distribution.

Most oxygen-rich, Mira-type stars appear to lose mass in a spherical outflow at a rate < 10^{-4} $M_{\odot}$/y, supporting radiation-driven or shock-driven mass loss models and suggesting these stars are responsible for the optical haloes surrounding some planetary nebulae. Non-spherical

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geometries and larger mass loss rates for related evolved objects (carbon stars, bipolar nebulae, non-spherical planetaries) may be the result of evolution in a close binary system. A more complete discussion is given by Bowers, Johnston, and Spencer (1983).

Table 1

PROGRAM STARS

Star	Position (±0"1) α(1950)	δ(1950)	Distance (kpc)	θ (")	R (10^3AU)	$\dot{M}$ ($10^{-6}M_\odot$/y)
IRC+10011	$01^h03^m48^s.09$	+12° 19' 51".4	0.5*	4.4	2.2	22
OH 127.8-0.0	01 30 27.63	+62 11 31.2	3.3	1.9	6.3	80†
OH 138.0+7.3	03 20 41.48	+65 21 32.8	2.4	≤0.8	≤1.9	≤ 7.6†
OH 141.7+3.5	03 29 23.65	+60 10 04.4	3.7	≤0.9	≤3.3	≤ 22†
IRC+50137	05 07 19.68	+52 48 53.9	0.8	3.0	2.4	11
U Ori	05 52 50.92	+20 10 06.0§	0.2	<0.6	<0.1	1.2
IRC+40156	06 29 45.03	+40 45 08.2	1.4	1.8	2.5	13†
VY CMa**	07 20 54.74	-25 40 12.4	1.5	2.1	3.2	230
IRC-20197	09 42 56.55	-21 47 54.4	0.7	≤1.4	≤1.0	4.1
WX Ser	15 25 31.98	+19 44 13.0	1.0	<1.1	<1.1	5
OH 17.7-2.0	18 27 39.77	-14 31 03.9	3.4*	0.9	3.1	20†
OH 26.5+0.6	18 34 52.47	-05 26 37.1	0.5*	3.5	1.6	5
OH 25.1-0.4	18 35 33.36	-07 12 35.2	9.1	<1.4	<12.7	<310†
OH 32.8-0.3	18 49 48.16	-00 17 53.5	3.2*	2.2	7.0	32
OH 39.7+1.5	18 56 03.88	+06 38 49.8	1.4*	2.0	2.8	28
OH 39.9+0.0	19 01 42.90	+06 08 44.2	7.7	0.9	7.2	29
R Aql	19 03 57.67	+08 09 07.7§	0.3	4.0	1.2	0.8
IRC+10420**	19 24 26.74	+11 15 10.9	3.4	3.0	10.2	200†
RR Aql	19 55 00.30	-02 01 17.1	0.9*	1.0	0.9	1.8†
NML Cyg**	20 44 33.84	+39 55 57.1	1.8	3.0	5.4	160

*Distance determined from angular radius and phase lag measurements.
†Mass loss rate derived from radius of maser region.
§Position precessed from epoch 1980.9 with no correction for known proper motion.
**Supergiant.

REFERENCE

Bowers, P. F., Johnston, K. J., and Spencer, J. H. 1983, Ap. J., in press.