PROPER MOTIONS OF H_2O MASERS IN W49(N) AND THE DISTANCE TO THE GALACTIC CENTER

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A distance of $R_0 = 7.6 \pm 1.6$ kpc for the galactic center is given by comparison of expansion parallax of a cluster of H_2O masers in W49(N) with the kinematic distance of that source. Data from additional epochs, now being calibrated, should further improve the accuracy of our determination of R_0.

1. INTRODUCTION

At high spatial and spectral resolution, H_2O masers are observed to consist of many bright, compact spots of H_2O maser emission at Doppler shifts ranging over tens or hundreds of km/s. Observations at several epochs show proper motions comparable to the Doppler shifts, which frequently delineate an outflow; quantitative comparison of the two, typically by means of a model fit, gives the distance of the cluster. W49(N) is the most populous cluster of masers in the galaxy. Its large number of maser features make it an excellent laboratory for studying the kinematics of maser outflow, from which an expansion parallax can be estimated. Its galactic longitude is 43° and its radial velocity, relative to the Local Standard of Rest, is about 6 km/s, so it lies near the solar circle. Assuming that its peculiar velocity is less than 10 km/s, and that the galactic rotation velocity is between 220 and 250 km/s near the solar circle, its distance from the earth is $(1.50 \pm 0.15) \times R_0$. Comparison of expansion and kinematic distances yields R_0.

2. OBSERVATIONS AND DATA REDUCTION

The data discussed here were obtained from 2 VLBI observations of H_2O masers in W49(N) 3 months apart, using antennas at Onsala, Haystack, Green Bank, the VLA and Owens Valley. We observed all low-velocity ($-20 < v_{\rm LSR} < 30$ km s^{-1}) and a sample of high-velocity features. Data were amplitude calibrated by scaling auto-correlation spectra from each station to a template and phase

M. Morris (ed.), The Center of the Galaxy, 47–49.

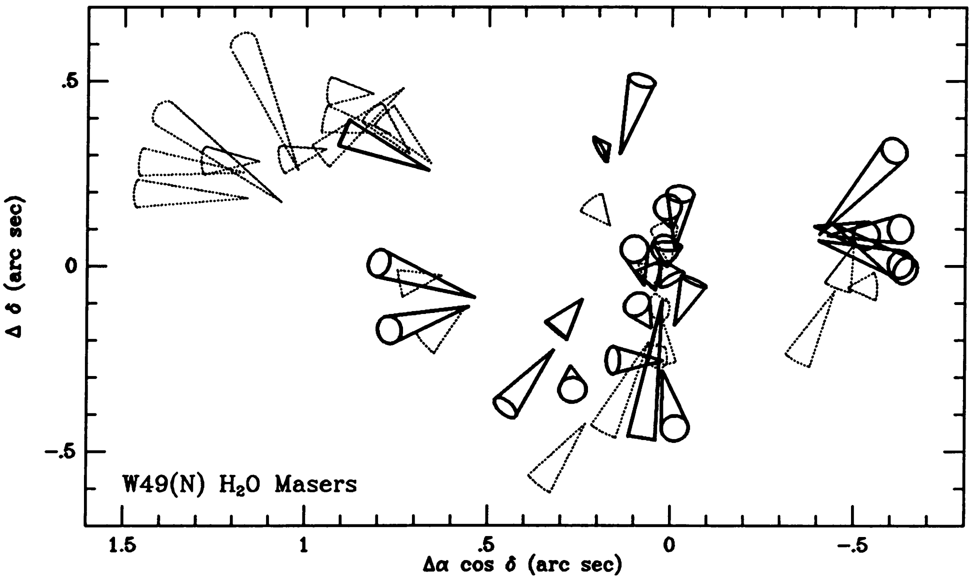

Fig. 1 Motions of H_2O maser spots in W49(N). Spots are at the apexes of the cones; lengths and inclinations show where they would travel in 150 years. Motions of nearby spots have been combined. Dotted cones show receding motions.

calibrated by subtracting the phases of a channel containing a bright, unresolved spot from all the data. We located the masers with fringe-rate mapping and determined more precise positions by fitting in the (u, v) plane. We then removed differential precession and nutation, and fitted proper motions to those spots that appeared at both epochs.

3. OUTFLOW AND MODEL FITTING

The general distribution of maser spots and many individual spots persisted from the 1978 one-epoch observation of Walker, Matsakis, and Garcia-Barreto to ours in 1982. Figure 1 shows motions for spots which we observed at both epochs.

The maser cluster is expanding from a common center. The outflow of the low-velocity features appears to be isotropic, while that of the high-velocity features is biconical with an opening angle of $\approx 60°$. The center of expansion lies near the prominent N-S "ridge" of spots, and coincides with a compact HII region (Dreher *et al.* 1988). The high-velocity spots are not at the center of the distribution, and cannot be simply low-velocity spots directed toward the observer. They must be either intermixed with the low-velocity spots or at the edges of the distribution. Spots with a range of velocities must be present.

Distance estimates from H_2O maser observations must relate the one measured linear degree of freedom, the Doppler shift (v_z), to the angular degrees of freedom: positions (x, y) and proper motions (μ_x, μ_y). Radial position (z) is not measured.

Models predict $\vec{v}$ as a function of position $\vec{r}$. In addition to the free parameters describing $\vec{v}(\vec{r})$, models include parameters for the position and velocity of the reference spot, and the unmeasured radial position z of each spot, relative to the center of expansion. The best-fitting model minimizes S, the summed, squared differences of observed and model velocities:

$$S = \sum_{spots} (d\mu_{ox} - v_{mx})^2 + (d\mu_{oy} - v_{my})^2 + (v_{oz} - v_{mz})^2$$

where d is the distance to the source.

With observations of H_2O masers in Orion, Genzel *et al.* (1981) made the most extensive previous study of maser outflow. The outflow velocity was assumed to take the form:

$$v_{mod} = V_0 \, r^{\alpha} \, \hat{r}$$

with $\hat{r}$ a radially directed unit vector and V_0 and α free parameters. A fit to low-velocity spots yielded $\alpha = 0.0 \pm 0.1$, while a fit to high-velocity spots yielded $\alpha = 0.3 \pm 0.1$ and a larger V_0. For masers in Sgr B2(N), in which only low-velocity features were observed, α was set to 0 (Reid *et al.* 1988).

Fits to the W49(N) maser motions favored $\alpha = 0$ for the low-velocity spots, and $\alpha = 1$, with large residuals, for all spots fit together. We tried a more complex model:

$$v_{mod} = V_0 \left(1 + \left(\frac{r}{R_e}\right)^{\alpha}\right) \hat{r},$$

where V_0, R_e and α are free parameters.

The best-fitting model gives a distance of $d = 10.6 \pm 1.4$ kpc, an outflow velocity of $V_0 = 57 \pm 6$ km/s, a characteristic radius of $R_e = 1.8 \pm 0.5$ arc sec and an index of $\alpha = 12 \pm 2$. The model radial velocity increases very rapidly indeed beyond about 1.8 arc sec. Some high-velocity spots have radii (estimated with the fitted parameter z) well within that radius, and the model fits them rather poorly. If the high-velocity spots are indeed at the edges of the distribution, they must either be accelerated there or become visible only there. From the fitted distance of $d = 10.6 \pm 1.4$ kpc and the kinematic distance of $d = 1.50 \pm 0.15\ R_0$ we obtain $R_0 = 7.6 \pm 1.6$. About half the uncertainty is from the model fit and half from that of the kinematic distance. This is consistent with 7.1 ± 1.5 kpc, as obtained from H_2O masers in Sgr B2(N) (Reid *et al.* 1988).

4. CONCLUSIONS

The maser cluster in W49(N) is an excellent laboratory for studying maser outflow, and has an accurate, unambiguous kinematic distance. A model fit to the outflow yields a distance of $R_0 = 7.6 \pm 1.6$ kpc for the galactic center. Further studies, including more proper motions from more epochs, should yield both a greater understanding of the outflow and a more accurate distance estimate.

5. REFERENCES

Dreher, J., *et al.* 1988, personal communication.
Genzel, R., Reid, M.J., Moran, J.M. and Downes, D. 1981, *Ap. J.*, **244**, 884.
Reid, M.J., Schneps, M.H., Moran, J.M., Gwinn, C.R., Genzel, R., Downes, D., and Rönnäng, B. 1988, *Ap. J.*, **330**, 809.
Walker, R.C., Matsakis, D.N., and Garcia-Barreto, J.A. 1982, *Ap. J.*, **255**, 128.

https://doi.org/10.1017/S0074180900186310 Published online by Cambridge University Press