PROPER MOTIONS AND DISTANCES OF WATER MASER COMPLEXES +

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We report preliminary results of a long term spectral line VLBI experiment to observe internal proper motions of water maser sources in the vicinity of newly formed stars. This technique yields a picture of the three-dimensional kinematics of the region and a measure of the distance to the source. First results from the galactic center source SGR B2 are presented.

1. INTRODUCTION

Water masers have been observed to occur in diverse astrophysical settings ranging from the gaseous atmospheres of evolved stars to the turbulent environs of newly formed stars (cf. review of Reid and Moran 1981). Although the excitation mechanism is poorly understood, the maser′s tremendous intensity and point-like emission characteristics may be exploited to study the dynamics of the maser region. In regions of active star formation, the cloudlets of maser gas are swept along by the supersonic flows from a young star, and these motions may be traced by making successive VLBI images of the region over a period of one or two years.

A very important result of such observations is that a direct distance to the object can be obtained. The current precision of VLBI allows distances to be obtained for maser complexes lying at any distance within the galaxy. These maser complexes typically contain 50

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to 100 individual emission cloudlets. The distance is obtained from a statistical comparison of the angular motions with the radial velocities (obtained from doppler shifts of the maser line) of the maser spots. Since conditions in these complexes are highly turbulent, ordered flows are generally overwhelmed by random motions, and the distance determined is relatively insensitive to systematic motions within the complex. The uncertainty in the distance is inversely proportional to the square root of the number of proper motion vectors observed. Efforts are therefore made to detect as many maser cloudlets in any given source as possible.

In previous work for Orion KL (Genzel et al 1981a) a distance to the source of 480 +/- 80 pc was derived, respectively, in excellent agreement with optical determinations. A systematic outflow emanating from IRc2 was observed. For the sources W51 Main (Genzel et al 1981b) and W51 North (Schneps et al 1981), which are considerably more turbulent, distances of 7 +/- 1.5 kpc and 8 +/- 2.5 kpc, were obtained.

Encouraged by the early results, we undertook a new experiment covering sources of interest for galactic dynamics: Cepheus A, Orion KL, Sgr B2, W49 North, W3(OH), and G12.2+0.1. This second generation experiment employed improved software and observing procedures with the intent of maximizing the number of maser features detected. The observations, made at five epochs (1980 DEC, 1981 APR and DEC, 1982 MAR and JUN), were closely spaced in time in order to follow the motions of the masers during their one to two year lifetimes. Care was taken to maintain the same observing procedures among the recording sessions in order to reduce errors due to systematic instrumental effects. The observations involved six stations: Onsala, MPIFR, Haystack, NRAO, VLA, and OVRO. All epochs have been correlated, a task which required 50 percent of the NRAO Mk II correlator for two years, and calibration and mapping is underway.

2. PRELIMINARY RESULTS FOR SGR B2

A subset of the data for the maser complex in the galactic center, SGR B2, has been analyzed for the 1981 APR and 1982 MAR epochs. The northern and middle clusters (cf. Elmegreen et al 1980), separated by 44 arc seconds in a nearly north-south direction, were observed simultaneously in the telescope beams. Fringe rate maps (fig 1a: northern cluster) show the masers to be grouped in tight clusters, sparsely distributed over a three arc second region for each of the two clusters. Approximately 80 emission features were identified in these fields. Figure 1b shows a detail from fig. 1a with LSR velocities of the features indicated in km/sec.

Using the fringe rate maps as a guide, subfields containing emission features were imaged with synthesis techniques for each frequency channel. This showed that many of these maser emission spots to be small groups of masers distributed over several milliarcseconds, roughly doubling the number of maser features identified. Fig. 1c

Figure 1: Northern maser complex associated with the galactic center object SGR B2. The figure shows the tremendous range in size scale of the maser source. The top figure (c) is a schematic representation of synthesis maps, the other figures are the result of fringe rate mapping.

FIG 1 c

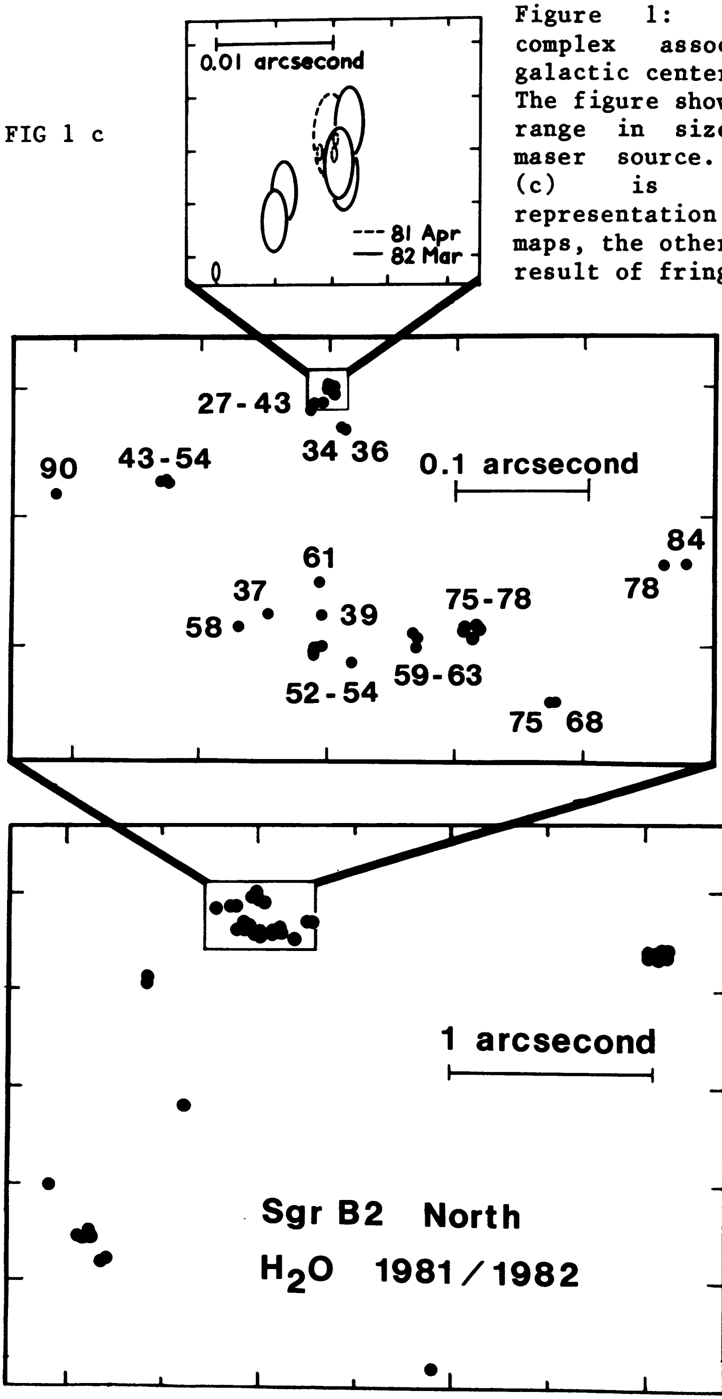

FIG 1 b

FIG 1 a

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schematically summarizes 20 synthesis maps, cover a 5 km/s velocity range, for a subfield of fig. 1b. The size of the features in the figure indicate the relative intensities.

3. EXPECTED PRECISION OF GALACTIC DISTANCES

Unlike previous experiments, the measurement errors in maser positions should be a negligible contribution to the distance uncertainty. The resolution of the synthesized beam is approximately 0.4 millarcsecond. The measurement precision of the position of the emission centroid is limited by the dynamic range (about 100:1) for strong features, and by the signal-to-noise ratio for weak features. We thus expect that for the majority of maser features, the position of the emission centroid can be determined to about 10 microarcseconds. We anticipate that systematic errors due to baseline uncertainties, etc., will be less than this. The latter source of error will be further reduced (to second order) when observations of one epoch are compared against another in a differential measurement of the proper motion. The magnitude of the position shifts typically exceed 100 microarcseconds, which is an order of magnitude greater than the position uncertainties.

The statistical errors in the distance depends primarily on the number of maser features we can identify between any two epochs. If motions of all the features found in SGR B2 can be traced over several epochs, the distance to the galactic center could be determined to perhaps 10 percent. However, if only the motions of maser clusters are traced, the uncertainty will be closer to 20 percent.

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