A Giant Step: from Milli- to Micro-arcsecond Astrometry
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The distance to G59.7+0.1 and W3OH

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Abstract. We have measured the distance to the high-mass star-forming region G59.7+0.1 (IRAS 19410+2336) and W3OH. Their distances, 2.20 ± 0.11 kpc and 1.95 ± 0.04 kpc, respectively, were determined by triangulation using Very Long Baseline Array (VLBA) observations of 12.2 GHz methanol masers phase-referenced to compact extragalactic radio sources. In addition to the distances, we have also obtained their proper motions.

Keywords. ISM: molecules, astrometry, Galaxy: structure

1. Introduction

We are carrying out a large project to study the spiral structure and kinematics of the Milky Way. We will accomplish this by determining distances via trigonometric parallax and proper motions in star forming regions. The target sources are 12 GHz methanol masers. With accurate distance measurements we can locate spiral arms, and with absolute proper motions we can determine the 3-dimensional motions of these regions. Here we report results on G59.7+0.1 and W3OH.

2. Observations

We have conducted phase-referenced observations of G59.7+0.1 and W3OH with the VLBA in order to measure their relative position with respect to extragalactic radio sources. The observing sequence involved rapid switching between the extragalactic radio sources and the maser source. The time period between successive epochs was around three months. The background compact extragalactic sources were from ICRF or/and our VLA surveys (Xu *et al.* 2006a).

3. Results

In Fig. 1 we plot, for each source, the positions of one maser spot relative to the background reference radio sources. The parallax signature is fit by the five required parameters: one parameter for the parallax and two parameters for the proper motion in each of the coordinates. The distances of G59.7+0.1 and W3OH are measured to be 2.20 ± 0.11 kpc and 1.95 ± 0.04 kpc, respectively. The proper motions in the RA and Dec coordinates were -1.63 ± 0.04 and -5.12 ± 0.1 mas y^{-1} for G59.7+0.1 and -1.20 ± 0.02 and -0.15 ± 0.01 mas y^{-1} for W3OH, respectively.

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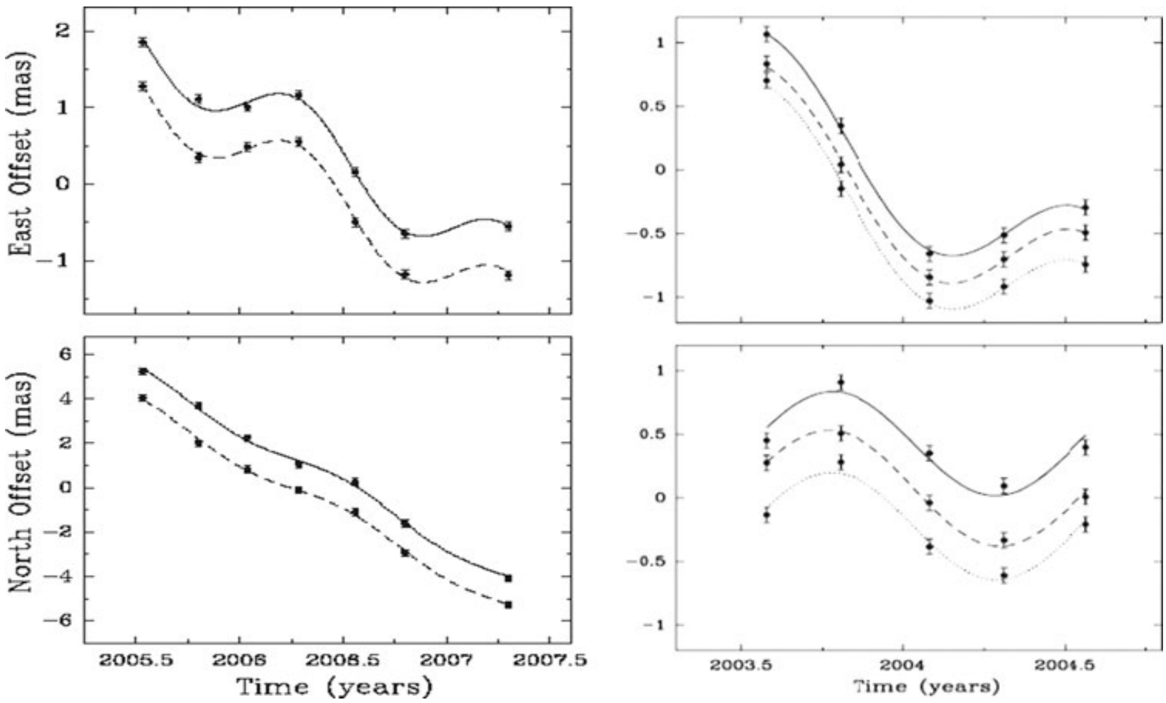

Figure 1. Position versus time for the reference maser spot relative to the background radio sources for G59.7+0.1 (left panel) and W3OH (right panel; Xu *et al.* 2006b, 2008). The top and bottom panels show the eastward and northward offsets, respectively. In both cases, the large difference in position between the maser and each background source has been removed, and the two curves have been offset for clarity.

G59.7+0.1 is not associated with any known arms and is located between the Perseus and the Sagittarius arms (Fig. 2). The distance of 2.2 kpc is close to its near kinematic distance (2.1 kpc). It may be a spur of the Sagittarius arm because it is closer to that arm than to the Perseus arm. Such structures have been observed for many galaxies (La Vigne *et al.* 2006). The spurs may form as a consequence of gravitational instabilities inside spiral arms or/and effects of magnetic fields (Kim & Ostriker 2002). On the other hand, it may be a tail of the Local arm because it looks associated with sources in the Local arm, such as Orion, Cep A and the Sun.

Sources in the Perseus arm (near W3OH) have kinematic distances of about 4.2 kpc, while the luminosity distance of neighboring O-type stars is 2.2 kpc (Humphreys 1978). This discrepancy has fueled debate over whether the Perseus arm is indeed kinematically anomalous or the distances to O-star are inaccurate. We have now resolved this significant discrepancy, showing that the luminosity distance is approximately correct, and W3OH has a large kinematic anomaly.

In order to study the 3-D motion of G59.7+0.1 and W3OH at their positions in the Galaxy, we adopt the IAU standard constants $R_0 = 8.5$ kpc and $\Theta_0 = 220$ km s^{-1}. We also adopt the solar motion values $U = 10.0 \pm 0.40$, $V = 5.25 \pm 0.60$, and $W = 7.17 \pm 0.40$ km s^{-1} from Dehnen & Binney (1998).

For G59.7+0.1, using $V_{LSR} = 22.4$ km s^{-1} from the CS velocity, we have
In the direction of Galactic rotation: 210 ± 10 km s^{-1};
Radial toward the Galactic Center: $+7 \pm 3$ km s^{-1}
Toward North Galactic Pole: -5 ± 1 km s^{-1}.

For W3OH, using $V_{LSR} = 44.2$ km s^{-1} from the maser velocity, we have
In the direction of Galactic rotation: 206 ± 10 km s^{-1};
Radial toward the Galactic Center: $+17 \pm 1$ km s^{-1}
Toward North Galactic Pole: -0.8 ± 0.5 km s^{-1}.

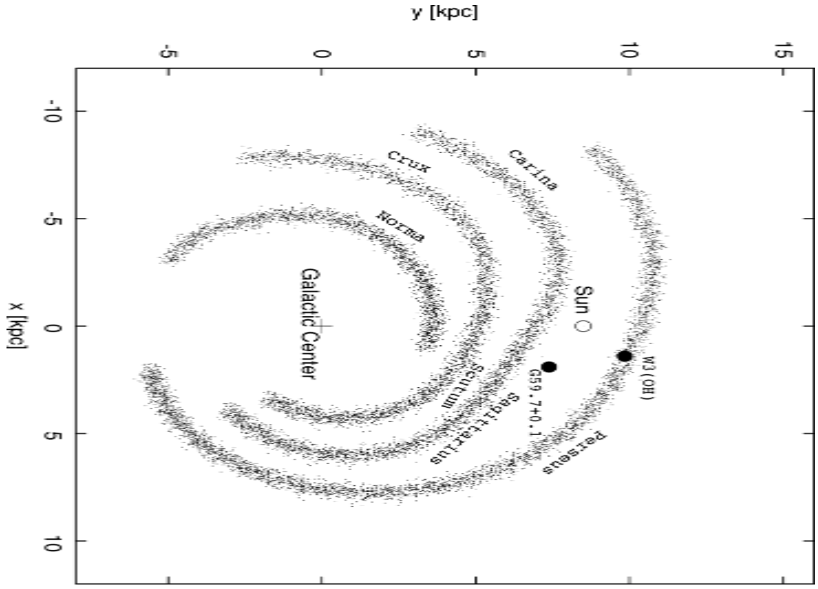

Figure 2. Positions of G59.7+0.1 and W3OH in the Galactic plane. The positions of the spiral arms are taken from Taylor & Cordes (1993). G59.7+0.1 may be located at the tail of Local arm or a spur of the Sagittarius arm. The portion of the Perseus arm traced by W3OH exhibits strong kinematic anomalies.

The errors are mainly caused by large uncertainty in solar motion, galactocentric distance of Sun, and rotation velocity at Sun. The 3-D motion indicates that their peculiar motion, more than 10 km s^{-1} in the galactic plane is quite large, about 3 - 4 times of the velocity dispersion of star-forming clouds. This peculiar motion is in qualitative agreement with spiral density wave theory (Roberts 1972).

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